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Evaluation of the impact of different policy options for managing to water quality limits

Final Report – Main Report

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Landcare Research
Manaaki Whenua

Evaluation of the impact of different policy options for managing to water quality limits

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Contents

List of Figures

List of Tables

Executive Summary

New Zealand has a diverse range of aquatic environments from mountain springs to coastal estuaries, connected by an intricate network of rivers, lakes, wetlands, estuaries and groundwater systems. Its freshwater bodies are of good quality by global standards and are a pivotal resource for agriculture, recreation, tourism, energy and industry. It is a source of life and food, and it is a central part of everyday life. Water has a strong cultural and spiritual presence in New Zealand, and Maori value water highly because it is central to their identity.

Despite being relatively clean and abundant at the national scale, deteriorating water quality is a pressing issue for a number of catchments around New Zealand. Diffuse discharges, including nutrient discharges, are a significant factor in this deterioration (Ministry for the Environment 2007; Land and Water Forum 2010). The Land and Water Forum was established to develop a common direction for freshwater management in New Zealand, and provided its first set of recommendations to the Government in early 2011. In response, the Government announced a package of initiatives, including the National Policy Statement (NPS) for Freshwater Management that sets out objectives and policies that direct local government to manage water in an integrated and sustainable way, while providing for economic growth within set water quantity and quality limits. The Land and Water Forum was subsequently asked by the Government to develop further recommendations on how to manage within quality limits, and is due to report in September 2012. The Ministry for Primary Industries commissioned this research to support the Forum process and to assist in the evaluation of cost-effective policy options for managing to targets.

This report focuses primarily on the costs and benefits of policies designed to manage nutrients from rural diffuse or non-point sources, specifically total nitrogen (N) and total phosphorus (P). The bulk of the report is dedicated to estimating the impacts on rural landowners of various policy approaches to reducing nutrient discharges in three important New Zealand catchments: the Hurunui and Waiau Rivers, the Manawatu River, and Lake Rotorua. The policy impacts are assessed using a combination of quantitative analysis and qualitative discussion. A majority of the costs and benefits are estimated using two catchment-level, agri-environmental, partial equilibrium economic models – the New Zealand Forest and Agricultural Regional Model (NZFARM) and NManager. These models allow for detailed representation of practices, economics and environmental impacts for two key primary industries, agriculture and forestry. Each model has a unique structure and parameterisation and thus its own set of strengths and weaknesses. An overview of the key components of the models is shown in Table 1.

Table 1 Overview of economic modelling for water quality policy case studies

Catchment	Economic Model	Scale	Key Land Uses	Key Environmental Outputs
Hurunui and Waiau	NZFARM	Spatial: 6 sub-catchment zones Temporal: Annual	Dairy, sheep and beef, deer, pigs, forestry, arable, horticulture, scrub, conservation land	N leaching P loss GHG emissions
Manawatu	NZFARM	Spatial: 4 sub-catchment zones Temporal: Annual	Dairy, sheep and beef, deer, forestry, arable, horticulture, scrub, conservation land	N leaching P loss GHG emissions
Rotorua	NManager	Spatial: 1 catchment Temporal: Annual	Dairy, sheep and beef, forestry	N leaching GHG emissions

The economic models used for this analysis include several practices for managing nutrients at the farm-level, such as reducing nitrogen fertiliser application, applying nitrification inhibitors (DCD), or wintering off dairy cows. At least two other important management options tracked in this analysis, stream fencing and riparian planting, are not currently included in either of the economic models. As a result, we also investigate the potential costs and benefits of adopting these measures outside of the model simulations.

The management practices that can contribute to reductions in nutrients tracked in this analysis are listed in Table 2, and does not cover all feasible options to reduce N and P. First, we do not include all possible nutrient sources or options to mitigate nutrient leaching from diffuse sources into waterways. Second, we do not track or account for nutrient mitigation from point sources within the catchment. Including additional management options and sources of mitigation would potentially reduce the estimated costs of each of the policies assessed in this report.

Table 2 Management practices used in this analysis for reducing N and P

Management Practice	NZFARM	NManager	Outside Models
Stock Exclusion via Fencing Streams			√
Reduced N Fertiliser	√	√	
Apply Nitrification Inhibitors (DCD)	√	√	
Wintering Off Dairy Cows	√	√	
Construct Dairy Feed Pad	√		
Riparian Planting			√
Change Stocking Rate	√	√	
Using High Fertility Ewes		√	
Use Imported Feed	√	√	
Feasible Combinations of Above	√	√	√

We consider a number of policies that could improve water quality, primarily through the maintenance or reduction in nutrient loads from land-based operations. The first option we consider is having landowners implement the set of 'good management practices' (GMP) listed in Table 2 that would result in a lower level of nutrient leaching. We consider both voluntary adoption of GMP and adoption in response to regulatory requirements. The second set of policies we consider is a nutrient cap-and-trade programme. This places a regulatory limit on total nutrient leaching from all major sources in the form of nutrient discharge permits but allows for the trading of permits between the regulated sources. We assess the cap-and-trade policy under several allocation options[1] and spatial restrictions for trading to estimate the range of likely costs and changes in land use and land management. The final option we consider is a direct tax on nutrient discharges.

For each policy scenario, we report the mitigation costs of achieving the nutrient reduction target to improve water quality and the resulting changes in farm profit,[2] represented by net revenues in the catchment. Where appropriate, the predicted land-use change resulting from each scenario is also reported. We do not quantify all the costs and benefits of each policy in monetary terms, rather we report the relative changes in the catchment's nutrient discharges and revenue streams resulting from each policy scenario.

There are several other important factors and metrics to consider for a policy assessment beyond estimating the economic impacts of reducing N and P from diffuse sources. These are outside the scope of this report. Sediment and faecal coliform, for example, can have a strong influence on water quality. The economic and biophysical models used for this analysis are currently not able to assess the impacts of these factors from changes in land use and/or land management. However, the on-farm land management practices and options to mitigate N leaching and P losses often improve micro-organism and sediment contamination as well. The models used in this analysis also estimate changes in greenhouse gas emissions (GHG), thereby highlighting some of the other "co-benefits" that could arise from implementing policies that promote the reduction of nutrient discharges from diffuse sources. Acknowledging this concept of co-benefits is important as there are often multiple pollutants and policies being discussed simultaneously at the central government and regional council level.

This analysis also does not account for the broader impacts of changes in land use and land management beyond the farm gate. The flow on effects from some of the policies investigated in this report could produce a significant change in regional employment and GDP. There could also be social and cultural impacts as well. The estimates presented in this report provide just a subset of possible metrics that could be used to determine the best policy to manage nutrients at the catchment-level.

Many other important aspects of reducing nutrients from rural diffuse sources not covered by the economic models are addressed through additional quantitative analysis and supplemented by qualitative discussion. This additional analysis includes assessing the likely

[1] Allocation options are how the regulatory limit is translated into individual discharge permits for each source.

[2] Farm profit is measured as annual earnings before interest and taxes, or the net revenue earned from output sales less fixed and variable farm expenses.

changes in water quality from implementing (or not) a particular nutrient reduction target, the likely administrative and transaction costs of a policy, and how the costs and benefits could impact different stakeholders in the community. A list of key caveats, assumptions, and limitations for this analysis is included in Box 1.

Box 1: Key caveats, assumptions, and limitations of this analysis

- We define a 'cost-effective policy' as a modelled policy that achieves the nutrient target in the catchment at the least cost to the landowners, given the specified management options.
- Our economic analyses depend on the datasets and estimates provided by biophysical models like OVERSEER and SPASMO, and farm budgeting models such as FARMAX. Estimates derived from other data sources may provide different results for the same catchment. Thus, the tools and analysis presented here should be used in conjunction with other information during the decision making process.
- Data and model limitations prevent this analysis from including all possible N and P mitigation strategies that could be implemented in a given catchment. Some mitigation options not explicitly included are some farm-level mitigation options (e.g. optimum soil test P) and catchment-wide solutions (e.g. series of constructed wetlands). Tracking additional mitigation options could lower both the overall cost of the policy and the cost to individual landowners.
- The economic models do not track or account for nutrient mitigation from point sources. Incorporating the costs of mitigating point sources may change the relative cost-effectiveness of the policies. The Hurunui-Waiau and Manawatu case studies assume a constant nutrient attenuation rate across the entire catchment area and that nutrients from diffuse sources will all reach the waterway of concern within 10 years. The Rotorua case study assumes that there are several groundwater lag zones within the catchment, and that nutrients exported from some farms can take up to 200 years to reach the lake.
- The economic models do not explicitly account for all administrative and transaction costs of the various policies. Doing so could alter the estimates for the distributional impacts to farmers, land use change, and overall cost of the different policies.
- The models are static and assume that technology, climate, input costs, and output are all constant for the duration of the policy. However, the aim of the models is to compare a range of policy options at a given point in time.
- NZFARM tracks both N and P while NManager only tracks changes in N. We acknowledge that there are other important factors and metrics to consider beyond N and P for assessing changes in water quality, such as sediment and faecal coliform.
- With the exception of the voluntary GMP scenarios, the analysis assumes full compliance for each nutrient reduction policy. Actual outcomes will differ if individuals do not understand the policy or choose not to comply.
- Each case study uses catchment-specific economic data, biophysical data, options for land management, and policy assumptions. In addition the Hurunui-Waiau and Manawatu catchment studies use the same economic model but the Rotorua case study uses a different model. Thus, the estimates from one case study are not directly comparable with another, although limited comparisons can legitimately be made between the Hurunui-Waiau and Manawatu cases because they use the same economic model.

The three catchments investigated in detail are:

1. The Hurunui-Waiau catchment, Canterbury. This is a South Island river catchment with predominant land uses being hill country grazing, lowland irrigated pastures and plantation forests. Water quality is currently acceptable to the community, but is an increasing concern in the catchment, particularly given the on-going expansion of irrigation in the Hurunui Plains. This catchment has shallow stony soils with high nitrogen leaching rates, and has a large irrigation scheme proposal under development. The water quality and water quantity limits for the catchment have been developed by the local zone committee.

2. The Manawatu catchment. This is a North Island river catchment with longstanding extensive and intensive land uses. Intensive pastoral systems are predominantly rain-fed with a mix of dairy and sheep and beef farming. Significant water quality problems already exist in the catchment due to point and non-point source discharges. Water quantity and quality limits are specified in the Horizons Regional Council's (HRC) Proposed One Plan.[3]

3. Lake Rotorua. This is a North Island lake catchment with a mix of pastoral and forestry land uses on volcanic soils. Water quality is poor (BoPRC 2012) and is likely to deteriorate further as there are long lag times between nutrient discharges and impacts on the lake. There are also large tracts of Maori land within the catchment. This catchment has extensive information on groundwater flows and a limit-setting policy is in place through Bay of Plenty Regional Council's (BoPRC) Regional Land and Water Plan.

A discussion of the important findings for each catchment is included below, and a summary of the key impacts on N for each policy scenario is listed in Table 3. The main report provides more detail on these findings, while the appendices include additional policy scenarios that demonstrate the range of impacts from several different nutrient targets and tax levels.

Hurunui-Waiau Catchment

The water quality limits being discussed for the Hurunui-Waiau catchment are intended to maintain nutrient loads at 2010 levels (Environment Canterbury 2011a). There is also an irrigation scheme being proposed for the Hurunui Plains area of the catchment that could more than double the area of irrigable land in the catchment (Environment Canterbury 2012). The policy scenarios are all compared to a baseline where there is no additional irrigation scheme. Our modelling indicated the following:

- At the catchment level, adding a large irrigation scheme would raise net catchment revenue by 10% through increased production, but would also increase N leaching by 24%, P loss by 4% and GHG emissions by 72% in the catchment, in the absence of any additional policies to manage water quality and GHG impacts. For the Hurunui Plains,

[3] Schedule D (December 2010 version). The One Plan was appealed to the Environment Court, and at the time of writing this report, the Environment Court decision had not been released.

where the irrigation scheme will operate, there would be productivity benefits and increased profits for dairy, sheep and beef, and arable crop farmers that increase their access to water, but N leaching and P loss could both increase by nearly 60%.

- If landowners in the catchment maintained their current land use and adopted GMPs such as applying nitrification inhibitors (DCD), riparian planting, and installing dairy feed pads, it is unlikely that the 2010 catchment nutrient loads would be maintained if a large irrigation scheme were implemented (policy #1a–b). The estimated average costs of implementing GMPs are around $50/tN, primarily because of the relatively high cost of these practices for sheep and beef farmers in the catchment.
- Of the policy options modelled, a catchment-wide trading programme with a grandparenting allocation proved to be the most cost-effective[4] for landowners to maintain 2010 catchment nutrient loads with the irrigation scheme implemented. Compared with the baseline, a cap-and-trade programme that allocates permits to landowners based on their 2010 N leaching and P loss levels (i.e. grandparenting) increases net catchment income by 5% (policy #2a). With catchment-wide trading there may still be water quality issues (e.g. localized 'hotspots') in the Hurunui Plains because N leaching is estimated to increase by 16% and P loss by 44% for over baseline levels in that area.
- Restricting trading of discharge permits to a specific area of the catchment may reduce the likelihood of 'hotspots', but net revenues only increase by 4% over the baseline (policy #2b).
- We modelled a modified equal allocation approach (policy #2c) where an average permit level per hectare was established and then adjusted for the productive capacity of the land. This generated similar results as a grandfathering allocation with area-restricted trading (policy #2b). Allowing farmers in the more productive Hurunui Plains to purchase permits from landowners in the lower productivity areas (i.e. foothills) would provide flexibility for landowners to increase their own level of nutrient discharges while still meeting 2010 nutrient loads.
- Theoretically, an optimally implemented nutrient tax (policy #3) would produce similar impacts to a catchment-wide cap-and-trade programme (policy #2a, #2c). The N and P tax could, if desired, be varied across different parts of a catchment to meet different water quality limits (policy #2b).
- The optimal N tax rate to maintain nutrients at 2010 levels was to charge all landowners in the catchment $23/kg N and $119/kg P (policy #3). Although this is an 'optimal' solution from a catchment-wide perspective, there could be distributional impacts as not all landowners who would be required to pay the tax would benefit from the new irrigation scheme.
- The marginal costs of abatement for taxes are non-linear making it difficult to establish an optimal tax ex–ante. Providing flexibility to adjust the tax over time would better ensure that nutrient load limits are maintained over the long run. If policy makers have

[4] In this report, a 'cost-effective policy' is defined as a modelled policy that achieves the nutrient target in the catchment at the least cost to the landowners. It does not necessarily account for administrative and transaction costs that could make the policy more costly in reality.

to frequently adjust the tax rate, then this could generate more economic and social disruption in the transition than a cap-and-trade approach.

Manawatu Catchment

The water quality limits modelled for the Manawatu catchment would require a reduction of N leaching by 53% and P losses by 49%, similar to those specified by Horizons Regional Council (Ausseil & Clark 2007). We assume that the entire limit would have to be achieved through mitigation from the land-use sector based on the fact that 90% of nitrogen in the Manawatu River is from two main types of non-point sources – dairy, and sheep and beef farming (Clothier et al. 2007). Part of the policy outlined in the December 2010 version (the Decisions Version) of the proposed Horizons One Plan required that new dairy farms demonstrate compliance with cumulative nitrogen leaching maxima that vary with Land Use Capability (LUC) classification (i.e. natural capital approach). For the model scenarios, we evaluate a policy option slightly different from the One Plan where *all* dairy farms must comply with LUC based nitrogen leaching caps,[5] plus other options such as implementing GMPs, various cap-and-trade schemes, and a nutrient discharge tax. The baseline scenario modelled assumed that the proposed water quality policy had yet to be implemented. As a result of the policy assumptions presented in this report, the estimates are *not* directly comparable with analyses of the One Plan. The key findings from the policies modelled for the Manawatu catchment are:

- A GMP approach that assumed the most effective voluntary practices (i.e. DCD and riparian planting) would be implemented on 50% of the eligible land in the catchment could reduce N leaching by 7%, and P losses by 14% relative to the baseline (policy #1a). This would not achieve the specified nutrient reductions.
- If all pastoral landowners were required by regulation to implement the GMPs of applying DCDs and undertaking riparian planting, and all dairy farmers also had to implement the GMP of wintering their cows off the farm, then N leaching and P loss is estimated to decrease by 15% and 27%, respectively (policy #1b). This would be done at a low average cost ($2/kgN) to the landowner, primarily because applying DCDs could improve productivity, but would not achieve the water quality limits specified by the Regional Council.
- A catchment-wide cap-and-trade programme with a grandparenting-based allocation (policy #2a) proved to be one of the most cost-effective policies of those options modelled to meet the water quality limits at the catchment-level. Net revenue for landowners in the catchment declined by 17% and adding administration and transaction costs further reduced revenues to 22% below 2007 baseline revenues.
- Allocating discharge permits based on LUC is intended to intensify the use of high productivity land while simultaneously reducing nutrient loads. This is referred to as a natural capital allocation approach. Only requiring existing dairy enterprises in each LUC to meet specified nutrients discharge levels results in a 6% reduction in total N compared to the modelled baseline (policy #2c), and less than a 1% reduction in net

[5] This policy option is not the same as the policies for diffuse discharges in the notified version, neither is it the same as that in the decisions version of the Proposed One Plan.

revenue. This is because (1) most dairy farms are already located on the LUCs with permitted discharges of 18 kgN/ha/yr or more and thus required little change to meet the specified leaching rates stated in the December 2010 version of the Horizons One Plan, and (2) dairy farms comprise less than 20% of the catchment, and therefore dairying does not have a large enough share of the land mass to achieve a 53% reduction in N discharges on its own.

- A natural capital approach could still be a feasible policy to meet nutrient reduction targets if (1) discharge permits based on LUC are allocated to *all* pastoral, arable and horticultural land uses (not just dairy) and (2) *all* landowners are required to collectively meet the HRC's nutrient targets of reducing N by 53%, and P by 49% through a catchment-wide trading scheme (similar to policy #2a). In this case, net revenue for landowners in the catchment was estimated to decline by 17% and adding administration and transaction costs further reduced revenues to 22% below baseline revenues.
- The grandparenting (policy #2a) and natural capital approaches (policy #2d) for allocating nutrient discharges have similar estimated impacts at the catchment level when all landowners are covered, given that the policies are designed to (1) cover nutrient losses from all landowners and (2) cap nutrients at the levels necessary to meet the HRC water quality limits. However, impacts would vary at the farm-level between grandparenting and natural capital based approaches because some landowners would receive different amounts of permits, depending on allocation criteria used.
- Restricting trades to smaller areas within the Manawatu catchment would reduce the possibility of localized water quality 'hotspots'. However, spatially restricting trades resulted in a modelled decline in revenue of about 43% when accounting for changes in farm profit, administration and transaction costs (policy #2b). This is because farmers in the 'flats' area of the catchment must reduce nutrients in their own area of the catchment rather than purchasing discharge permits from farmers in the 'hills' that may be able to reduce their N and P discharges at a lower cost.
- The cap-and-trade programme and nutrient discharge tax policies assessed could result in significant changes in land use in the Manawatu catchment with land converting from pasture to arable, forests, scrub, or fallow.
- Theoretically, a nutrient tax (policy #3), implemented optimally, will provide similar impacts as a catchment-wide cap-and-trade programme (policy #2a). We estimate that charging landowners a tax of $36/kgN that leaches from their land should achieve the desired nutrient loads set at the catchment-level. The average cost of reducing N was estimated to be $23/kgN, which is significantly lower than the tax rate because many landowners can implement changes in land management that reduce N at costs lower than the specified tax.
- In all likelihood there would be no need to tax P as the land use and land management changes implemented in response to the N tax will also achieve the required P loss reductions in the catchment.
- Varying the N and P tax across different parts of the catchment to meet different nutrient reduction goals has similar outcomes as policy #2b. Estimates reveal that the N tax could range from $18.70/kgN in the Manawatu Hills to $89.70/kgN in the Tararua Flats.

- The marginal costs of abatement for a tax are non-linear, which could make it difficult to establish the optimal tax ex ante. Providing flexibility to adjust the tax over time would better ensure that nutrient reduction goals are achieved over the long run but could generate more economic and social disruption in the transition than a cap-and-trade approach if policy makers have frequently to adjust the tax rate.

Rotorua Catchment

The provisional water quality target proposed for the Rotorua catchment is to reduce the annual N load to the lake from 755 tN to 435 tN in the long run, with agricultural N loss to fall by approximately 60% by 2022. The agricultural sector is expected to reduce 270 tN of the desired 320 tN. The remainder will come from non-agricultural sources. The water quality target for total N in the Rotorua catchment is significantly lower than the two river catchments modelled because it is a much smaller catchment. The baseline assumes there is no additional water quality policy over and above current settings. The key findings from the policy options modelled for the Rotorua catchment are:

- Implementing a mix of GMPs on pastoral land such as applying DCDs, reducing N fertiliser, importing feed, and adjusting the mix and level of stock would decrease the N loads arriving at Lake Rotorua relative to baseline, but by less than the 270 t reduction required to achieve the regional council's long run environmental goal of 435 tN/yr (policy #1a & b). In over-allocated catchments such as Lake Rotorua land use change as well as management changes may be required to meet environmental goals.
- Even when nutrient exports decrease by 270 tN in 10 years, the loads of N reaching the lake do not achieve the long run sustainable load goal of 435 tN per year until approximately 2100 due to unmanageable legacy loads. These long delays between costly N export cuts and N load outcomes could be an issue in any catchment where some N travels through groundwater and the groundwater lags are long.
- Reducing N discharges by 270 tN by 2022 was estimated to cost $3.2 million per year (policy #2a). A large amount of this cost would be spent on mitigation efforts on dairy land, relative to the land area occupied by dairy farms. If agriculture had to meet all the required N leaching reductions (i.e. 320 tN) it will cost an additional $1million per year (policy #2b). This equates to a 30% increase in costs for only an additional 18% decrease in nutrients.
- A reduction of 270 tN could also be achieved by a $30/kg N tax. Setting the tax at $27/kg N only achieves a reduction of 240 tN, while a $33/kg N tax gave a reduction of 303 tN (policy #3a, b & c).
- The distribution of costs in a cap-and-trade programme is determined by the choice of allocation scheme. Allocating permits based on current discharges (i.e. grandparenting) and then buying sufficient permits back to achieve the N reduction target would cost the regulatory agency a modelled $5.4 million/year with farm profits increasing by more than 10%. Conversely, auctioning all permits would net the regulatory agency $5.3million and farm profits would fall by 39–70%.

Generalized Findings

While the impacts of water quality policies will differ between catchments there are some findings that we can generalize from the three case studies. These include:

- The policy scope and stringency of the nutrient reduction goals affects the economic impact of the policy. If nutrient limits are established prior to major declines in water quality occurring then the economic burden of reaching the specified limits is significantly lower. This is illustrated in the difference in estimates of the total costs of policies #2 and #3 for the Hurunui-Waiau and Manawatu catchments. The proposed policy to maintain current water quality in the Hurunui-Waiau allowed the flexibility to increase their intensity and net revenues by about 5%, while the large reductions in nutrients proposed for the Manawatu meant that landowners had a reduction in profit by 22% or more.
- The economic impact of large reductions in nutrients, while large, was less in percentage terms than the required nutrient reduction, e.g. achieving a 53% reduction of N in the Manawatu catchment would reduce catchment net revenue by 22% (under optimal policy settings that enable a dynamically efficient adjustment to limits; and assuming well-informed economically-rational decision making by land users). This, of course, depends on mitigation technologies available and the willingness and ability to invest in the adoption of GMPs, change land use, or participate in a trading programmes.
- In catchments where the nutrient load is significantly above the limit (e.g. Manawatu or Rotorua), it is unlikely that a policy to voluntarily or mandatorily implement GMP will achieve the necessary reduction in discharges. Our simulations suggest that additional policy instruments may be required and it is likely that some level of land use change will be needed, though this will depend on the severity of the problem and individual catchment characteristics.
- The average cost of nutrient reductions can vary both within and across modelled catchments. Key reasons include current land use and land management, feasible mitigation options, and biophysical aspects such as soil type and topography.
- The modelled costs of reducing P loss are significantly larger than N leaching on a per unit basis. This is likely due to the small amount of P in the catchment relative to N, and hence that the value of output per unit of P is also higher to mitigate than the same unit of N. There are also limited management practices included in the model that are specific for controlling P loss.
- The marginal abatement costs (i.e. the cost of reducing an additional unit of N or P at the limit) are also different between the three catchments. This also indicates that there is likely to be a high level of variation in mitigation potential across catchments in New Zealand.
- Economic theory shows that a pollution tax and cap-and-trade programmes should result in equally efficient nutrient reductions provided there is perfect information about the pollution sources and how landowners would react to alternative instruments that put a price on nutrient outputs. We find this in the three catchments assessed for this report. The cost savings may be somewhat undercut though by the administration and setup costs of establishing a tax or nutrient trading programme. Additional transitional costs are likely in a tax regime if policy makers cannot set the optimal tax rate ex ante, and adjust the tax rate frequently.
- Although tax and trading scheme can theoretically achieve the same level of nutrient reductions at the same cost at the catchment-scale, the two approaches can have different distributional implications. Some landowners would face lower costs from a

cap-and-trade programme from selling excess nutrient reduction permits. In the tax case, the government receives tax revenue from the landowners and has the ultimate decision on how to utilise the funds, such as by decreasing other taxes or investing in research, education, or alternative mitigation options to assist with the policy.

- If all the revenue collected from the nutrient tax were recycled back to landowners in the form of a dividend or reduction of other taxes, then the changes in net catchment revenue would be similar to the grandparented cap-and-trade policy. This is the assumption that we use in when presenting catchment-wide estimates for the tax policies in this report. If not all of the taxes collected were recycled back to the landowner, however, the total costs to farmers would be higher under this policy approach. Furthermore, landowners that might not have the ability to implement more cost-effective management practices on their farm could face a potentially high price of maintaining their current operation.
- How discharge permits are allocated does not have large economic impacts at the catchment level. However, different allocation systems can lead to significantly different distributional impacts. For instance, in the Manawatu catchment, the natural capital allocation approach would reduce the cost of meeting the nutrient limit for those located in high-productive land by 11% compared with a grandparenting allocation. At the same time, those located in less productive areas would face 16–17% higher costs to meet the limit with a natural capital allocation. If landowners were able to trade permits, the equilibrium result at the catchment level will be similar regardless of how the permits were distributed (i.e. natural capital, grandparenting, etc.). These findings are based on the assumption that an efficient trading market exists and all landowners are profit maximisers. Impacts may differ where there are high transaction costs, spatially restricted trading, or there is an unwillingness to buy and sell permits even if it is economically efficient to do so.
- The larger the geographical area for trading, the more cost-efficient the programme is likely to be. This results from a more diverse set of land-uses, landowners, and tradable permits. However, there may be a greater possibility of localised water quality ‘hotspots’ with catchment-wide trading than where trades are restricted to smaller areas.
- Land-use change in response to changes in market conditions is typically a slow process. Evidence suggests that adjusting land use quickly will be costly, and may justify slower transition pathways to minimize cost.

Table 3 Estimated Impacts of Nutrient Reduction Policies

Catchment[a]	Scenario	N Target (tonnes)[b]	Total N in 2022 (tonnes)	% N Target Achieved by 2022[c]	% N Target Achieved by 2100[c]	Average Mitigation Cost ($/kg N)	Time to Achieve (years)	Total Annual Cost ($ million)[d]	Profit[e] Change from Baseline (%)
Hurunui-Waiau	Baseline without Waitohi Irrigation Scheme	2930	2930	100%	100%	n/a	0	n/a	0%
	Baseline with Voluntary GMP (Policy #1a)	2930	2710	108%	108%	$52	10	$11.2	-5%
	Baseline with Regulatory GMP (Policy #1b)	2930	2300	127%	127%	$46	10	$29.3	- 12%
	Waitohi Irrigation- No Water Quality Policy	2930	3620	76%	76%	n/a	Not	-$24.4	+10%
	Waitohi-Catchment-wide Trading (Policy #2a)	2930	2930	100%	100%	n/a	10	-$11.0	+5%
	Waitohi-Region-restricted Trading (Policy #2b)	2930	2930	100%	100%	n/a	10	-$9.3	+4%
	Waitohi-Equal Allocation Trading (Policy #2c)	2930	2930	100%	100%	n/a	10	-$9.8	+4%
	Waitohi-N Tax at $23/kgN and P Tax at $119/kgP (Policy #3)	2930	2930	100%	100%	n/a	10	-$11.0	+5%
Manawatu	Baseline	2536	5400	0%	0%	n/a	0	n/a	0%
	Voluntary GMP (Policy #1a)	2536	5019	13%	13%	$2	Not	$0.8	0%
	Regulatory GMP (Policy #1b)	2536	4591	28%	28%	$2	Not	$1.8	-1%
	Catchment-wide Trading (Policy #2a)	2536	2536	100%	100%	$23	10	$64.7	-22%
	Region-restricted Trading (Policy #2b)	2536	2520	101%	101%	$45	10	$129.4	-43%
	Natural Capital Allocation Trading – Dairy Only (Policy #2c)	2536	5076	11%	11%	$4	10	$1.2	-0.4%
	Natural Capital Allocation Trading – Pasture and Arable (Policy #2d)	2536	2536	100%	100%	$23	10	$66.2	-22%
	Tax at $36/kgN (Policy #3)	2536	2536	100%	100%	$23	10	$66.2	-22%
Rotorua	Baseline	435	755	100%	100%	n/a	0	n/a	0%
	BoPRC GMP (Policy #1a)	435	539	68%	58%	$7	Not	$0.8	-5%
	Stringent GMP (Policy #1b)	435	472	88%	91%	$11	Not	$2.6	-18%
	Catchment-wide Trading - 270tN reduction (Policy #2a)	435	454	94%	100%	$9	92	$3.2	-22%
	Catchment-wide Trading - 320tN reduction (Policy #2b)	435	479	86%	100%	$5	147	$4.2	-29%
	Tax at $30/kgN (Policy #3a)	435	454	94%	100%	$4	92	$3.2	-22%
	Tax at $27/kgN (Policy #3b)	435	472	88%	91%	$9	Not	$2.6	-18%
	Tax at $33/kgN (Policy #3c)	435	436	100%	109%	$11	16	$3.9	-27%

n/a: not applicable

[a] Each case study catchment uses different economic data, biophysical data, options for land management, and policy assumptions. The Hurunui-Waiau and Manawatu catchment scenarios were modelled using NZFARM while Rotorua was modelled NManager. Thus, the estimates from each case study are not directly comparable.

[b] Nutrient reduction targets are set simultaneously for N and P for Hurunui-Waiau and Manawatu. Rotorua targets are only for reductions in N leaching.

[c] Values greater than 100% indicate that additional nutrient reductions beyond the target have been achieved. In the case when the policy requires a simultaneous reduction in N and P, the economically optimal solution could be to change land use or land management in a manner that reduces one nutrient beyond the target level.

[d] Negative costs in the Hurunui-Waiau catchment imply that there is an increase in net revenue from increase in intensity due to implementation of Waitohi Irrigation Scheme

[e] Farm profit is measured as annual earnings before interest and taxes, or the net revenue earned from output sales less fixed and variable farm expenses.

1 Introduction

New Zealand has a diverse range of aquatic environments from mountain springs to coastal estuaries, connected by an intricate network of rivers, lakes, wetlands, estuaries and groundwater systems. Its freshwater bodies are of good quality by global standards and water is important to everyone in New Zealand, regardless of whether one is Māori or Pakeha. It is a pivotal resource for recreation, tourism, energy and industry. It is a source of life and food, and it is a central part of everyday life.

The value of water is particularly high for iwi. Māori consider all natural resources as living taonga (treasures) that are intimately connected both physically and spiritually, and an important role of tangata whenua is that of kaitiaki – guardians – of the natural world and all the living things in their area of responsibility. This connection means that the natural world is central to their worldview, and individual and cultural identity. As such, Māori have a distinctive role in water catchments as tangata whenua. Māori also operate with other, potentially conflicting, roles: they are small and large pastoral landowners, forest owners, and water users. Their large landholdings, particularly of underdeveloped farming land, leave Māori particularly exposed to land-use intensification restrictions and allowance allocation decisions (Kerr & Lock 2009).

Despite being relatively clean and abundant at the national scale, deteriorating water quality is a pressing issue for a number of catchments around New Zealand. Diffuse discharges, including nutrient discharges, are a significant factor in this deterioration (Ministry for the Environment 2007; Land and Water Forum 2010). The Land and Water Forum was established to develop a common direction for freshwater management in New Zealand, and provided its first set of recommendations to the Government in early 2011. In response, the Government announced a package of initiatives, including the National Policy Statement (NPS) for Freshwater Management that sets out objectives and policies that direct local government to manage water in an integrated and sustainable way, while providing for economic growth within set water quantity and quality limits (NZ Government, 2011).

The National Policy Statement (NPS) for Freshwater Management was written to drive national consistency in local RMA planning and decision-making while allowing for an appropriate level of regional flexibility. Policy A of the NPS essentially directs regional councils to use the Resource Management Act to establish water quality targets and set enforceable limits[6] to maintain or improve water quality in their rivers, lakes, and streams. Once limits are set, policies need to be put in place to efficiently allocate freshwater resources to users in an efficient and straightforward way that provides the ability to maximise its value while not putting any additional strain on the environment. For example, Policy A2 of the NPS explicitly states that "where water bodies do not meet the freshwater objectives made pursuant to Policy A1 [establish freshwater objectives and set freshwater quality limits], every regional council is to specify targets and implement methods (either or both regulatory and non-regulatory) to assist the improvement of water quality in the water bodies, to meet those targets, and within a defined timeframe." The Land and Water Forum was subsequently

[6] The NPS defines a limit as 'the maximum amount of resource use available, which allows a freshwater objective to be met', and a target as 'a limit which must be met at a defined time in the future'.

asked by the Government to develop further recommendations on how to manage within quality limits, and is due to report in September 2012. The Ministry for Primary Industries commissioned this research to support the Forum process and to assist in the evaluation of cost-effective policy options for managing to targets.

This report focuses primarily on the costs and benefits of policies designed to manage nutrients from rural diffuse or non-point sources, specifically total nitrogen (N) and total phosphorus (P). A bulk of the report is dedicated to estimating the impacts on rural landowners of various policy approaches to reducing nutrient discharges in three important New Zealand catchments: the Hurunui and Waiau Rivers, the Manawatu River, and Lake Rotorua. The policy impacts are assessed using a combination of quantitative analysis and qualitative discussion. A majority of the costs and benefits are estimated using two catchment-level agri-environmental partial equilibrium economic models, the New Zealand Forest and Agricultural Regional Model (NZFARM) and NManager. These models allow for detailed representation of practices, economics and environmental impacts for two key primary industries, agriculture and forestry. Each model has a unique structure and parameterisation and thus its own set of strengths and weaknesses.

The economic models used for this analysis include several practices for managing nutrients at the farm-level, such as reducing nitrogen fertiliser application, applying nitrification inhibitors (DCD), or wintering off dairy cows. At least two other important management options tracked in this analysis, stream fencing and riparian planting, are not currently included in either of the economic models. As a result, we also investigate the potential costs and benefits of adopting these measures outside of the model simulations.

This analysis tracks several management practices that can contribute to reductions in nutrients, but it does not cover all feasible options to reduce N and P. First, we do not include all possible nutrient sources or options to mitigate nutrient losses from diffuse sources into waterways. Second, we do not track or account for nutrient mitigation from point sources within the catchment. Including additional management options and sources of mitigation would potentially reduce the estimated costs of each of the policies assessed in this report.

We consider a number of policies that could improve water quality, primarily through the maintenance or reduction in nutrient loads from land-based operations. The first option we consider is having landowners implement the set of ‘good management practices’ (GMP) that would result in a lower level of nutrient leaching. We consider both voluntary adoption of GMP and adoption in response to regulatory requirements. The second set of policies we consider is a nutrient cap-and-trade programme. This places a regulatory limit on total nutrient leaching from all major sources in the form of nutrient discharge permits but allows for the trading of permits between the regulated sources. We assess the cap-and-trade policy under several allocation options[7] and spatial restrictions for trading to estimate the range of likely costs and changes in land use and land management. The final option we consider is a direct tax on nutrient discharges.

[7] Allocation options are how the regulatory limit is translated into individual discharge permits for each source.

For each policy scenario, we report the mitigation costs of achieving the nutrient reduction target to improve water quality and the resulting changes in farm profit,[8] represented by net revenues in the catchment. Where appropriate, the predicted land-use change resulting from each scenario is also reported. We do not quantify all the costs and benefits of each policy in monetary terms, rather we report the relative changes in the catchment's nutrient discharges and revenue streams resulting from each policy scenario.

There are several other important factors and metrics to consider for a policy assessment beyond estimating the economic impacts of reducing N and P from diffuse sources. These are outside the scope of this report. Sediment and faecal coliform, for example, can have a strong influence on water quality. The economic and biophysical models used for this analysis are currently not able to assess the impacts of these factors from changes in land use and/or land management. However, the on-farm land management practices and options to mitigate N leaching and P losses often improve micro-organism and sediment contamination as well. The models used in this analysis also estimate changes in greenhouse gas emissions (GHG), thereby highlighting some of the other "co-benefits" that could arise from implementing policies that promote the reduction of nutrient discharges from diffuse sources. Acknowledging this concept of co-benefits is important as there are often multiple pollutants and policies being discussed simultaneously at the central government and regional council level.

This analysis also does not account for the broader impacts of changes in land use and land management beyond the farm gate. The flow-on effects from some of the policies investigated in this report could produce a significant change in regional employment and GDP. There could also be social and cultural impacts as well. Thus, the estimates presented in this report provide just a subset of possible metrics that could be used to determine the best policy to manage nutrients at the catchment-level.

Many other important aspects of reducing nutrients from rural diffuse sources not covered by the economic models are addressed through additional quantitative analysis and supplemented by qualitative discussion. This additional analysis includes assessing the likely changes in water quality from implementing (or not) a particular nutrient reduction target, the likely administrative and transaction costs of a policy, and how the costs and benefits could impact different stakeholders in the community. A list of key caveats, assumptions, and limitations for this analysis is included in Box 1.

The three catchments investigated in detail are:

1. The Hurunui-Waiau catchment, Canterbury. This is a South Island river catchment with predominant land uses being hill country grazing, lowland irrigated pastures and plantation forests. Water quality is currently acceptable to the community, but is an increasing concern in the catchment, particularly given the on-going expansion of irrigation in the Hurunui Plains. This catchment has shallow stony soils with high nitrogen leaching rates, and has a large irrigation scheme proposal under

[8] Farm profit is measured as annual earnings before interest and taxes, or the net revenue earned from output sales less fixed and variable farm expenses.

development. The water quality and water quantity limits for the catchment have been developed by the local zone committee.

2. The Manawatu catchment. This is a North Island river catchment with longstanding extensive and intensive land uses. Intensive pastoral systems are predominantly rain-fed with a mix of dairy and sheep and beef farming. Significant water quality problems already exist in the catchment due to point and non-point source discharges. Water quantity and quality limits are specified in the Horizons Regional Council's (HRC) Proposed One Plan.[9]

3. Lake Rotorua. This is a North Island lake catchment with a mix of pastoral and forestry land uses on volcanic soils. Water quality is poor (BoPRC 2012) and is likely to deteriorate further as there are long lag times between nutrient discharges and impacts on the lake. There are also large tracts of Maori land within the catchment. This catchment has extensive information on groundwater flows and a limit-setting policy is in place through Bay of Plenty Regional Council's (BoPRC) Regional Land and Water Plan.

The report is organised as follows. First we discuss the methodology behind the agri-environmental economic models, how we define and model changes in water quality based on biophysical modelling and assumptions, and introduce the various policies that are considered. Second, we present the water quality policy assessments for the three catchment case studies and resulting impacts on economic and environmental output. Finally, we summarise our findings and present some conclusions. The main report is accompanied by a series of appendices contain greater details on the economic models, data, and detailed results that support our policy analysis.

[9] Schedule D (December 2010 version). The One Plan was appealed to the Environment Court, and at the time of writing this report, the Environment Court decision had not been released.

2 Methodology

This report assesses the economic and environmental impacts of various water quality policies for three catchments in New Zealand: Hurunui-Waiau, Manawatu, and Rotorua. The geographical location of each catchment is shown in Figure 1.

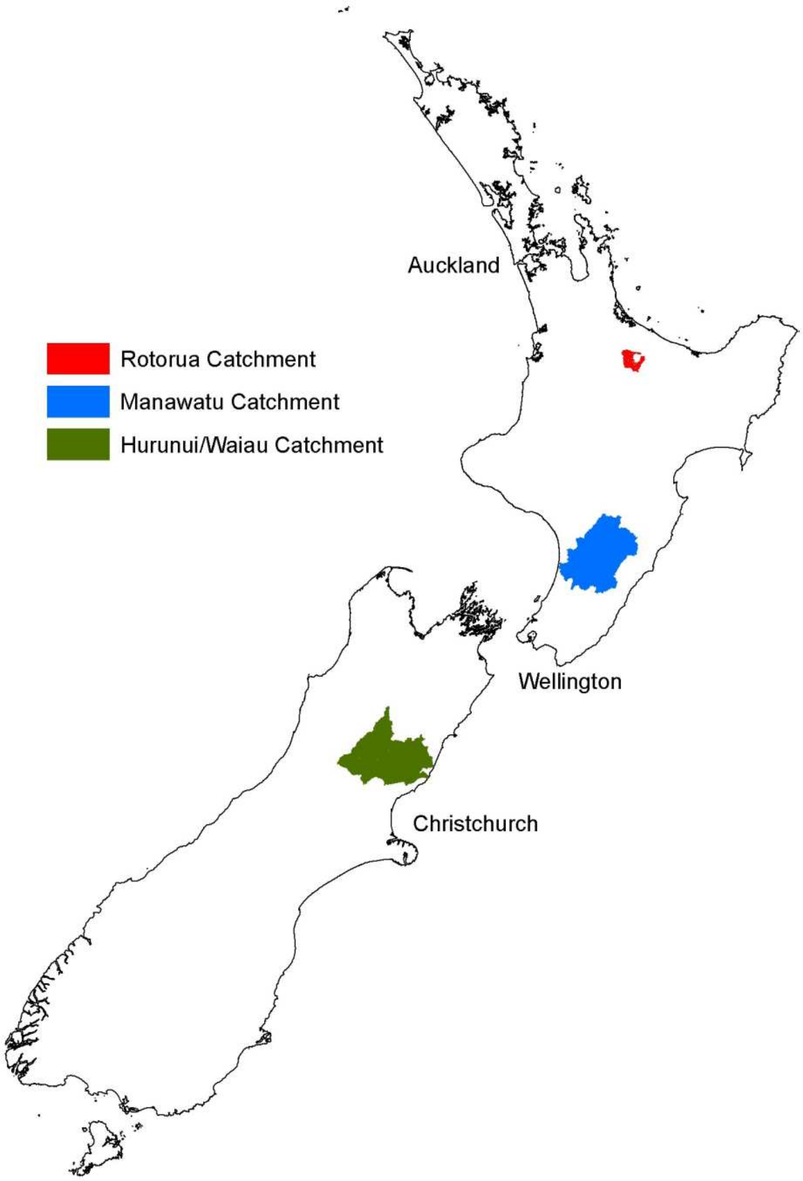

Figure 1 Location of case study catchments

The analysis of the proposed policies for the case studies will be primarily conducted using two catchment-based economic models – the New Zealand Forest and Agriculture Regional Model (NZFARM) and NManager. Each model has a unique structure and parameterisation and thus its own set of strengths and weaknesses. An overview of the key components of the models is show in Table 4. Additional policy insight is provided by a mix of quantitative analysis and qualitative discussion. A more detailed description of the models is discussed below.

Table 4 Overview of economic modelling for water quality policy case studies

Catchment	Economic Model	Scale	Key Land Uses	Environmental Outputs
Hurunui and Waiau	NZFARM	Spatial: 6 sub-catchment zones Temporal: Annual	Dairy, sheep and beef, deer, pigs, forestry, arable, horticulture, natural	N leaching P loss GHG emissions
Manawatu	NZFARM	Spatial: 4 sub-catchment zones Temporal: Annual	Dairy, sheep and beef, deer, forestry, arable, horticulture, natural	N leaching P loss GHG emissions
Rotorua	NManager	Spatial: 1 catchment Temporal: Annual	Dairy, sheep and beef, forestry	N leaching GHG emissions

2.1 New Zealand Forest and Agriculture Regional Model (NZFARM)

The New Zealand Forest and Agriculture Regional Model (NZFARM) is a comparative-static, non-linear, partial equilibrium mathematical programming model of New Zealand land use operating at the catchment scale developed by Landcare Research (Daigneault et al. 2012; Greenhalgh et al. 2012). Its primary use is to provide decision-makers with information on the economic impacts of environmental policy as well as how a policy aimed at one environmental issue could affect other environmental factors. It can be used to assess how changes in technology, commodity supply or demand, resource constraints, or farm, resource, or environmental policy could affect a host of economic or environmental performance indicators that are important to decisions-makers and rural landowners. The model can track changes in land use, land management, N leaching, and P leaching by imposing a variety of policy options that range from establishing a catchment-level cap-and-trade programme to imposing nutrient leaching constraints at the enterprise-level. Although the model is static, it is parameterised such that responses to policy are not instantaneous but instead track a medium- to long-term response that landowners are likely to take over a 5–10-year period. A detailed schematic of components of NZFARM is shown in Figure 2.

The model's objective function is to determine the level of production outputs that maximize the net revenue[10] (π) of production across the entire catchment area, subject to land use and land management options, agricultural production costs and output prices, and environmental factors such as soil type, water available for irrigation, and any regulated environmental outputs (e.g. nutrient leaching limits) imposed on the region. Regions (i.e. sub-catchment

[10] Net revenue (farm profit) is measured as annual earnings before interest and taxes, or the net revenue earned from output sales less fixed and variable farm expenses.

zones) within a catchment are differentiated by land use capability, such that all land in the same region will yield similar levels of productivity for a given enterprise and land management scheme.

In addition to estimating economic output from the agriculture and forest sectors, NZFARM also tracks a series of environmental factors including N and P leaching and GHG emissions (carbon, methane and nitrous oxides). Simulating endogenous land management is an integral part of the model, which can differentiate between ‘business as usual’ (BAU) farm practices and less-typical options that can change levels of agricultural output, nutrient leaching, and GHG emissions, among other things. Key land management options include changing fertilizer regimes and stocking rates, adding an irrigation system or implementing mitigation technologies such as the installation of a dairy feed pad or the application of nitrogen inhibitors. Including a range of management options allows us to assess what levels of regulation might be needed to bring new technologies into general practice. Landowner responses to N leaching and P loss restrictions in NZFARM are parameterised using estimates from biophysical models such as OVERSEER, SPASMO and FARMAX. Details on the specific land management, economic, and environmental factors tracked in this report are described in Appendix A. The costs tracked within NZFARM are land-use conversion costs, cost of implementing a mitigation option and changes in input costs. It does not track transaction costs such as administrative costs or any resultant changes in land value.

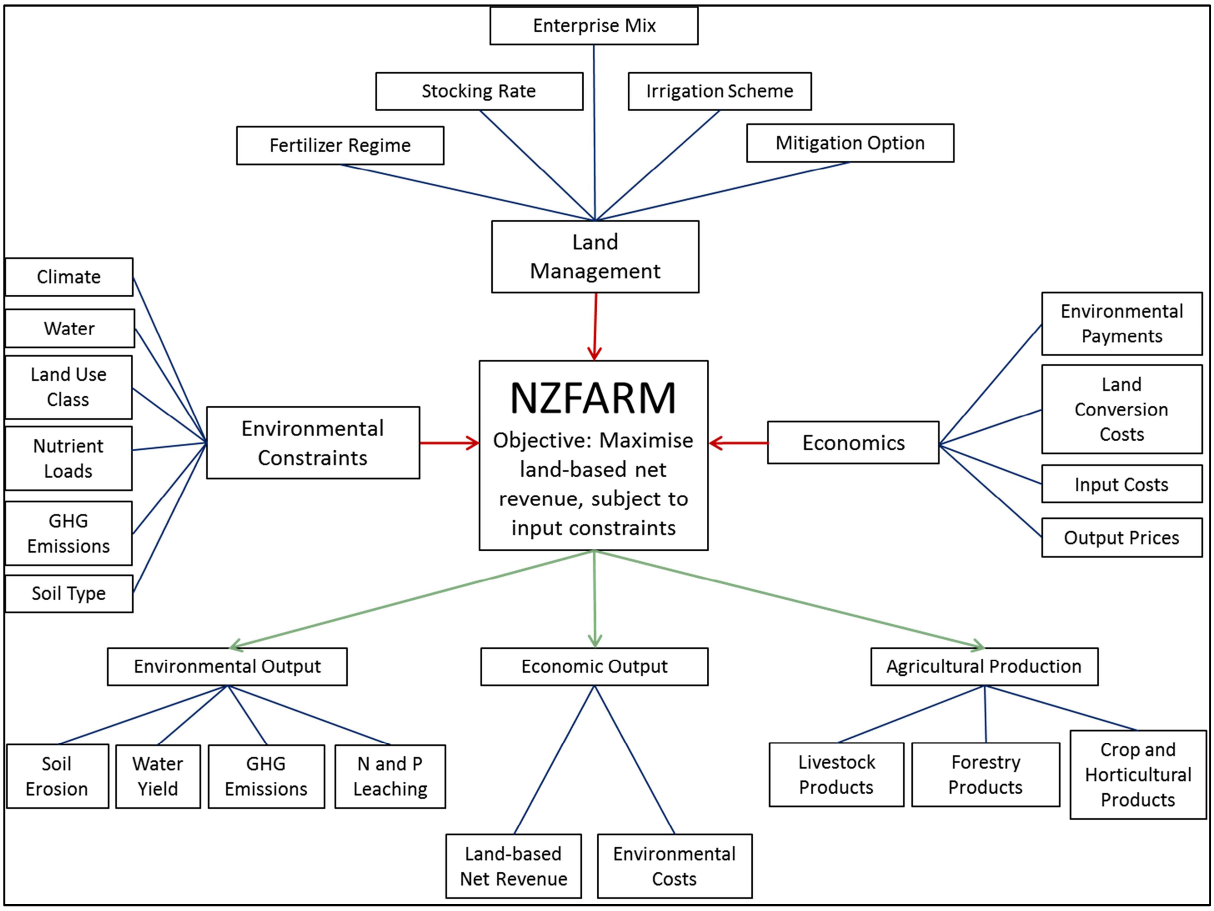

Figure 2 Schematic of NZFARM inputs and outputs

2.2 NManager

Motu Economic and Public Policy Research have developed NManager, a partial-equilibrium simulation model that combines biophysical properties of the Lake Rotorua catchment with a model of farmer N mitigation responses to regulation. Full information on the NManager model can be found in Anastasiadis et al. (2011), but we summarise key points of the model here for convenience, with a more detailed explanation of changes to the model, and the model's strengths and key assumptions in Appendix H.

NManager uses biophysical maps of groundwater and surface water nutrient flows to model the environmental outcomes of farm N discharges. Farmer responses to N leaching regulation are simulated using OVERSEER and FARMAX to estimate mitigation costs for a representative dairy and a representative sheep/beef farm under different N mitigation management. NManager uses these inputs to estimate farmer mitigation and land use change over time. Outputs of the model include costs and environmental impacts of different policies. A key strength of NManager is the linkage to hydrologic data to predict the water quality outcomes of policies over time.

Because the model estimates costs over many time periods, the costs of a given policy are calculated as the net present value of meeting the environmental target using the BOPRC standard discount rate of 7%. These costs are then translated into annual annuities. This cost is the discounted sum of all mitigation costs required to meet the environmental target, where mitigation costs are calculated using the profit-mitigation curves outlined in Anastasiadis et al. (2011). As a result, estimated costs of policies do not include the costs of set-up and administration of policies. They also do not include the impact of regulation on land values. Therefore, the derived costs are likely to be underestimates as the simulations assume that farmers adjust instantly and optimally to changes in costs; in reality these adjustments are likely to be slower and less optimal. However, as the current version of the NManager is static we do not allow for any technology change, which would result in overestimates of cost.

2.3 Estimating Water Quality and Nutrient Reduction Targets

Regulatory agencies are increasingly setting water quality load limits as part of land and water management. Generally, the limit setting process starts with establishing water quality objectives and associated concentration limits (or targets where the current quality exceeds the limits). For example, in Lake Rotorua, a target of reaching a tropic lake index (TLI) representative of conditions in the 1960s has been established. For managing land use activities and point source discharges, the concentration limits are then often converted to load (e.g. kg) limits, as loads represent a convenient measure for resource allocation, and because models of nutrient losses from farms are often expressed as annual loadings.

In this section, we review the factors that come into play when linking loads to concentration limits, and the range of approaches that have been used by land/water managers to establish load limits in the three case-study catchments.

We also summarise how load limits have been established for the economic modelling for the three case studies. The economic models used in this study rely on outputs from biophysical models such as OVERSEER and SPASMO that present nutrients as total N leached and total P loss at the point of discharge (i.e. paddock or forest plot) on an annual average basis, so it is important to consider how loadings of total nutrients at the source can be related to concentration limits or load limits at the point of interest. Additional details on these nutrient budgeting models are provided in Appendix A.

Nitrogen leaching in the form of nitrate is a complex process and is affected by a number of soil, environmental and management conditions (Di & Cameron 2000). N leaching loss is the amount of N that has moved down through the soil to the ground water below the plant rooting depth or is lost as runoff (OVERSEER 2012). N leaching from agricultural land and the subsequent contamination of water resources are recognized as an important environmental issue because high concentrations of nitrate in drinking water are deemed to be harmful to human health (Di & Cameron 2002). Nitrates leached from agricultural land that drain into surface water bodies may also cause deterioration in quality though algal blooms. The actual loss to receiving water (e.g. aquifers, rivers, etc.) depends on the degree of attenuation that occurs during the passage of N from the ground water just below rooting depth to the receiving water, including that which may be attenuated in wetlands.

Phosphorus (P) loss to waterways in New Zealand mainly occurs through surface run-off, and, to a much lesser degree, by subsurface flow. The range of P leaching from agricultural systems is generally much less than N leaching (e.g. on average 0.11–1.6 versus 21–177 kg/ha/yr, respectively). Based on this comparison, it can appear that P loss may only have a minor impact on waterways (Menneer et al. 2004). However, aquatic primary producers such as freshwater algae can be extremely sensitive to even small increases in P. This is especially so in waterways where P is limited (McDowell et al. 2004). Soil properties have a significant influence on the amount of P that reaches a given waterway. This is because of the high proportion of P loss that occurs as P bound to soil particles. About 80% in of P runoff is particle bound (i.e. bound to sediment or organic material) and about 20% is dissolved (Menneer et al. 2004).

Relating nutrient loads to concentration limits involves a number of factors that have been addressed directly or indirectly in the various case studies included in this report. Some of these factors include:

- Conversion of concentration limits to nutrient loads at the point of interest in the stream or lake. This may entail consideration of:
  - variations in concentrations with season or flow rate. For example, storm flows may be less important for stream periphyton because they occur only over small time periods and periphyton growths tend to accumulate during prolonged stable flows. Summer loadings of nutrients may be more important than winter loadings because in winter the growth of periphyton will be limited by sunlight, temperature and flows.
  - the form of nutrients. Concentration limits in streams are often expressed in terms of soluble nutrients whereas nutrient loading models are often in terms of total nutrients.
- Conversion of loads at the point of generation to loads at the point of interest. This may entail consideration of :
  - loss/attenuation processes which remove (or store long-term) nutrients between the point of discharge and the point of impact. A complication in this regard is that

sources from different parts of the catchment may have different attenuation between the source and the impact location.

- transport and transformation processes that alter the form of nutrients or timing of their delivery. Examples are groundwater lags, settling and remobilisation from the stream bed, and exchanges between streams and groundwater.
- timing and form of the sources. For example, reducing wipe-off flows from border-dyke irrigation might reduce overall phosphorus loadings by, say, 20% but reduce summer low-flow loadings of dissolved reactive phosphorus (DRP) by 50%.

Previous modelling that has underpinned the setting of water quality targets has not accounted for changes in flow and in flow regimes as a result of changes in water storage, irrigation or land use. Alteration of flow regimes affects the relationship between concentrations and ecological endpoints such as periphyton biomass, as well as altering the dilution, thereby affecting the load limits. This is especially relevant for the Hurunui/Waiau catchments, where water storage and substantially increased irrigation are currently under active consideration and may lead to changes to the proposed load limits during the plan hearing process.

Substantial changes in any or all of the above factors are likely to alter the relationship between catchment nutrient losses, nutrient loads in the stream or to a lake, and concentrations and other water quality objectives (notably, periphyton extent). Significant changes in the nature and location of activities within a catchment may also alter the relationship between total catchment nutrient losses and total stream loadings, for example, by changing the predominant form of nutrients, timing of nutrient delivery, and amount and spatial patterns of nutrient attenuation to and within the stream.

Time lags and attenuation factors are also an issue for translating nutrient loads from non-point sources to changes in water quality in a receiving water-body over time. For Hurunui and Manawatu, we define targets for annual nutrient losses based on annual stream loading, on the grounds that groundwater flows, and on other factors will largely smooth out seasonal effects. Estimates by GNS (Appendix I) reveal that it is acceptable to assume lag of times of 2–7 years in the Hurunui-Waiau and Manawatu catchments. While not directly embedded in NZFARM, we do account for them the policy assessment of this report. For Rotorua, lags range from a few years to many decades, and are accounted for in NManager (Anastasiadis 2011). Additional detail on the methods applied to estimate lag times used in this Hurunui-Waiau and Manawatu catchments study is provided in Appendix I.

Table 5 Key issues and metrics for measuring water quality in case study catchments

Component	Hurunui-Waiau	Rotorua	Manawatu
Receiving water(s) concerned	Groundwater Main stem of streams (2 locations) and tributaries. Estuary (Hapua)	Lake	Streams Lake Coast
Objectives relating to nutrients	Drinking water quality (groundwater) Limit nitrate toxicity	Return to1960s conditions	Control periphyton biomass Nitrate toxicity Phytoplankton control in

Component	Hurunui-Waiau	Rotorua	Manawatu
	Limit periphyton cover		lakes
Concentration limit(s)	Half maximum acceptable value (MAV) value for drinking water nitrate in groundwater; nitrate toxicity 95% protection value; No change in concentration of dissolved inorganic nitrogen (DIN) and DRP at SH1 (post-2017) and Mandamus (below and above area of land development, respectively) from 2005 to 2010 average	Concentrations circa 1960s	Soluble inorganic nitrogen (SIN) and DRP concentrations specified for each Water Management Zone (WMZ). Total P (TP) and total N (TN) targets in lake (very low) Note that upstream targets can impact downstream loads in connected catchments.
Derived load limits in the water-body of interest.	Current (2005–2010) measured loads of DIN & DRP at SH1 and Mandamus. No load limit for tributaries or groundwater (concentrations only). Limits were derived assuming current flow regime.	435 tonnes of TN/year from catchment based on 1960s estimates. TP load similar to present.	Derived for SIN from concentration limits and measured flows, excluding top 10% of flows. No load limits in the Proposed One Plan for P. Load limits to protect lakes have not been established.
Linkage from sources in the catchment to limits in the water body of interest.	Load limits for losses at source have not yet been established in the relevant plans. A range of models were used including CLUES, a simplified groundwater model, and spreadsheet models of nutrient loading. Point sources controlled separately but negligible loads associated with these.	For N, the ROTAN model was used to relate losses from the land to loading to the lake. This was calibrated to measurements. For P, CLUES was used to estimate the percentage reduction in loads to the lake achievable by mitigation, but not absolute loadings (which were determined by measurements). Point sources are controlled exogenously via resource consents. Some geothermal sources (e.g. Tikitere) may be treated to remove N.	Point sources were subtracted from measured load to give the contribution of non-point sources to the measured load. N loss rates from the land are determined from loss models such as OVERSEER and SPASMO. These should not exceed limits prescribed for each LUC class. 50% attenuation of non-point sources. Point sources controlled separately via resource consents.

Component	Hurunui-Waiau	Rotorua	Manawatu
Attenuation	Included in CLUES predictions. Not dealt with explicitly in groundwater contribution to stream predictions or spreadsheet models.	A small amount of attenuation was included in catchment model for N by calibration. Default attenuation rates in CLUES used.	No attenuation for point sources. 50% reduction for non-point sources.
Forms of nutrients	Spreadsheet models and groundwater model assumed all losses in soluble form. CLUES results for total nutrient loads converted to soluble fractions based on currently measured proportions.	ROTAN models TN and CLUES models TP, which is consistent with the loading limits.	Losses assumed to be all soluble.
Lags	Not used to derive the long-term limits.	Included in ROTAN model for N. Important because of N emissions from past land use stored in groundwater. This had limited impact on the optimal mitigation, because most dairy farms are in a similar lag zone. Not included for P. Pathway from surface to lake via deep groundwater is not considered to be important for P.	Not considered to be important in studies to date.
Groundwater-surface water interactions	A groundwater model was used for N.	ROTAN N model includes groundwater explicitly	Not considered to be important in studies to date.
Storm flows	Loading limits and models include storm flows.	Loading limits and models include storm flows.	Models are for total loading. Limits exclude high flows.
Seasonality of nutrient loads	Seasonality of nutrient losses at source considered to be smoothed for in-river effects by groundwater time lags. Thus only annual (not seasonal) load limits set.	Considered to be unimportant as target concerns annual loading into lake	Seasonality not considered important.

2.4 Incorporating Nutrient Reduction Targets into Economic Models

The previous section outlined some of the factors that are involved in setting load limits and linking source loads in the catchment to limits in the stream, and how this has been addressed in previous studies. Clearly there are a multitude of potential factors, and some simplification is required to make the problem tractable for linking with economic models. Several assumptions had to be made for the economic models to account for the initial (baseline) amount nutrients in each catchment as well as the changes in nutrient loads that may result from a policy. A summary of the major assumptions is listed in Table 6, and additional details are provided in the individual case studies.

Table 6 Key assumptions for Modelling Nutrients in NZFARM and NManager

Catchment	Nutrient Leaching Estimates	Time Lags from Source to Water	Catchment Load Measurement	Load Targets for Policy Scenarios	Estimating Nutrient Reductions
Hurunui-Waiau	Total N and Total P from OVERSEER, SPASMO and other literature	Assume lags <7 years, so accounted for in long-term economic response of model	Hurunui and Waiau River Regional Plan loads based on DRP and DIN	Current measured loads at SH1 and Mandamus recorders	Set % change in total N and total P equal to % change in load to meet limit at catchment scale
Manawatu	Total N and Total P from OVERSEER, SPASMO and other literature	Assume lags <7 years, so accounted for in long-term economic response of model	One Plan concentrations for SIN and DRP	Catchment-wide cap is reduction of 53% N and 49% P from baseline estimate Regional targets varies by Water Management Zone	Set % change in total N and total P equal to % change in concentration to meet limit for each zone
Rotorua	Total N from OVERSEER	8 zones account for lags up to 200 years	Total N	435 tonnes total N	Set load limit at total N

2.5 Nutrient Reduction Policies

Nearly all the water quality policies investigated in this report can be assessed with the two agri-environmental economic models. We assess the economic incentives to reduce nutrient output at the least cost. Core policies include (1) requiring specific targets to meet regional water quality standards, (2) imposing an environmental tax on farming outputs (e.g. $/kgN leached), or (3) mandating the use of specific 'good' management practices.

Most of the policies are analysed to use the nutrient reduction targets currently being proposed by the regional council that governs each catchment (see Section 2.3). For the policies that look at a specific farm management practice, we assess how large the potential change in nutrient loads could be given the likely adoption of a given practice if it were promoted as a voluntary practice as well as the potential costs and benefits if all landowners adopted that practice under a regulatory scheme.

We discuss the general structure for each of the policies and why they are typically considered in the case of water quality protection or improvement below. A summary of the key features, advantages, and disadvantages of these policies is listed in Table 7.

Promote good management practices

One approach for regulating agriculture is to require all farms adopt a good management practice(s). In this case, mitigation is typically carried out using the least cost combination of on-farm mitigation methods, but not land use change. Adoption of a GMP can be done through regulatory (e.g. mandate fencing of streams) or voluntary or industry-backed measures (e.g. Dairying and Clean Streams Accord). Management practices that can contribute to reductions in nutrients tracked in NZFARM include:

- altering stocking rate
- changing N fertiliser application rates
- applying the nitrification inhibitor dicyandiamide (DCD)
- constructing dairy feed pad
- wintering cows on the dairy farm or not
- some combinations of these

Practices that are tracked in NManager include:

- altering stocking rate
- changing N fertiliser application rates
- applying DCD to dairy farms
- wintering cows on the dairy farm or not
- using imported feed
- altering the mix of stock classes (sheep and beef)
- using very high fertility ewes (sheep)
- some combinations of these

Two other important management options – stream fencing and riparian planting – and are not currently included in either of the economic models. We also investigate the potential costs and benefits of adopting these measures, as both are currently viable and well-promoted measures for reducing nutrients. The level that some of these GMPs would be voluntarily adopted by landowners – a key assumption for estimating whether a nutrient reduction target could be met – is discussed in Section 2.6. Additional estimates for the costs and relative effectiveness of various mitigation options from other published studies focusing on nutrient reductions in New Zealand catchments are listed Appendix G.

Nutrient cap-and-trade policy

A cap-and-trade programme is often proposed for reducing nutrients in a catchment because they are typically more flexible and cost effective than requiring that all landowners meet individual targets or implement certain land management practices (i.e. command and control). This approach provides some degree of environmental certainty for the regulatory agency as it sets the nutrient cap or target that must be achieved; thereby ensuring landowners adapt their land use or land management to meet the target. This option has been proposed for nutrient trading programmes in New Zealand and is currently being implemented in the Lake Taupo catchment (Environment Waikato 2009).

Nutrient cap-and-trade markets typically do not place individual restrictions on dischargers. Instead, nutrient trading markets limit (or cap) the total annual nutrient leaching permitted in a catchment to a level that will achieve a specified environmental goal. This cap is then allocated between the relevant nutrient sources (e.g. farmers) in the catchment, often as nutrient discharge permits or allowances. Sources are then required to hold sufficient permits to cover their total nutrient losses (or discharge). Those sources that do not hold enough permits to cover their discharges must either reduce their discharges or buy additional permits from other participants who have surplus permits.

Nutrient trading markets are attractive for a number of reasons. As the regulation targets the cumulative total discharge rather than individual discharges in a catchment, sources have flexibility around their discharge level: they can increase, maintain, or decrease their discharge, as long as they hold sufficient permits to cover their N leaching. They also have flexibility in how they mitigate their leaching levels, including land-use change. This flexibility encourages profit maximizing landowners to mitigate as long as their cost of mitigation is less than the market price of a permit; those with low mitigation costs will mitigate and profit by selling permits to those with higher mitigation costs. Theoretically, this will equalize marginal mitigation costs around the catchment and ensure that that mitigation is carried out by those who can do so most cheaply.

A cap-and-trade programme involves costs around the setting of the regulation (command and control policies would face the same costs) and then some additional cost around the trading component of the programme. The costs for the trading component of the programme will be any costs associated with the transferring permits (e.g. to modify a consent, updating nutrient budgets) and any initial start-up costs (e.g. developing a marketplace). The costs borne by both a command and control and a cap-and-trade policy include the setting of the limit and the allocation of the cap between sources. Allocating permits can be a time-consuming and politically contentious process, as the allocation will result in a redistribution of current or future landowner wealth. We model a series of possible allocation options for each case study and estimate the potential cost to the landowners and the community in the catchment that results from each of these options. Some of the likely administration and transaction costs associated with the policy are further discussed in Section 2.5.

"Grandparenting" allocation, catchment-wide cap-and-trade programme

Grandparenting is where each source is allocated a permit based on their existing (or reference year) nutrient discharge and is a common allocation option. Therefore, for this scenario, each landowner is allocated nutrient discharge permits based on a reference year's enterprise mix and nutrient loss. For the agricultural sector, this allocation option allows existing land uses to continue at the owners discretion, but only within a farm's total discharge permit. If farmers wish to increase their land–use intensity, they must acquire permits from other landowners in the regulated area to meet the cumulative nutrient leaching targets for the catchment. Some landowners might find it more advantageous (i.e. profitable) to reduce their nutrient losses and sell excess permits to others. The nutrient policies evaluated in this report vary by catchment, but each case study assesses a catchment-wide cap-and-trade programme where landowners are allocated permits based on their nutrient leaching levels for a reference year.

"Grandparenting" allocation, region-restricted cap-and-trade programme

This policy is similar to the catchment-wide cap-and-trade programme above, except that permits can only be traded within a given region (e.g. Foothills) in the catchment instead of anywhere within the greater catchment. Landowners are allocated permits based on their reference year leaching losses, but they can only buy or sell permits within a smaller area or region within the catchment. This policy is more restrictive than trading across the whole catchment as there are fewer permits to trade in a regional market, which could result in higher costs. It may also be more costly to administer because the regulatory agency would have to oversee several trading markets instead of one catchment-wide market. However, there could be an advantage from a water quality perspective as it may reduce potential 'hotspot' issues where there are localised areas of lower water quality resulting from trading increased downstream discharges with lower upstream discharges. This allocation scheme is evaluated for Hurunui-Waiau and Manawatu catchments, but not the Rotorua catchment.

Nutrient Discharge Permit Auction

Under this allocation scheme all farmers must purchase an allowance for every unit of nutrient that they discharge above a benchmark level that is considered unmanageable or cannot be mitigated (e.g. 4 kgN/ha/yr, which is the lowest rate of N discharging that can be achieved on pastoral land in the Rotorua catchment). Allowances end up in the hands of those who value them the most through an auction where farmers will theoretically bid up to their marginal cost of mitigation for an allowance. This allocation scheme is evaluated for the Rotorua catchment.

Cap-and-trade with other allocation options

This policy considers a cap-and-trade programme with other allocation options that have been considered in regional policy, including:

1) Hurunui-Waiau: Environment Canterbury's equal allocation approach allocates the same number of nutrient discharge permits (e.g. a 'benchmark' rate of 10 kgN/ha/yr) on an aerial basis to all eligible landowners in a given nutrient management zone (NMZ) in the catchment (Lilburne & Webb 2012). The approach is loosely based on valuing the natural capital of land, and acknowledges that there will be greater costs for high-leaching farms to achieve their permitted discharge level than lower leaching landowners. This was aimed to provide an economic incentive and the flexibility to encourage landowners of good quality land to increase their level of intensification and penalise owners of land that is prone to high leaching, thus reducing their land use intensity.

2) Manawatu: The natural capital approach in another benchmark-type scheme that allocates nutrient discharge permits based on the physical characteristics of the land or soil type. This typically reflects either the land's productive potential or vulnerability to nutrient leaching, and is independent of existing land use. The approach supports the sustainable use of both land and water resources by favouring land areas that have good productive potential and/or low leaching rates. Horizons Regional Council's most recent version of the One Plan proposes to set cumulative nitrogen leaching rates (kgN/ha) for dairy farms based on the productivity potential of eight land use capability classes (LUC). For example, the Plan specifies that all dairy farmers in LUC III are permitted to discharge up to 24 kgN/ha/yr from their land. We go beyond the One Plan Specification by requiring all landowners to meet these per hectare (ha) leaching rate targets *and* to meet the N and P reduction targets for the catchment as a whole.

3) Rotorua: The BOPRC best management practice allocation is motivated by a BOPRC cost-sharing proposal in their proposed regional plan (2012). The council proposes a cost-sharing arrangement where farmers are responsible for shifting their farm to best practice while the rest of the costs of achieving the environmental target will be covered by local, regional, and central government.

Pricing nutrient discharges (tax)

The final policy we consider is a discharge tax, which is intended to incentivise landowners to decrease their nutrient leaching if the benefit of leaching another unit of N or P is less than the tax rate of discharging an additional unit of the nutrient. If the tax rate is set correctly, it will result in the same level of mitigation across the catchment as a cap-and-trade policy. The key difference between the two financial mechanisms is that with a tax, the price is established ex ante and the quantity of nutrient reductions are then determined by the response of the landowners. In the case of a cap-and-trade programme, the nutrient cap or target is set ex ante, and the nutrient reductions are then priced based on the cost of mitigation.

There are benefits and costs of implementing an environmental tax on nutrients relative to other policies. A tax provides a certain price for landowners and is easy to understand. It allows participants to plan ahead and invest with confidence. The tax collected can be used by the council to decrease other taxes (a so-called 'double dividend'), or can be invested in research and innovation and education to further address the environmental problem. Administering a discharge tax is often simpler than a cap-and-trade programme, and therefore less expensive to administer. In either case, however, regulatory agencies will still need to collect data to estimate nutrient losses. This approach might therefore be more costly relative to command and control type regulation or the promotion of voluntary adoption of GMPs where the regulatory agency has to spend most of their effort ensuring and enforcing the uptake of measures.

One downside of using environmental taxes over a cap-and-trade programme is the uncertainty around whether it can sufficiently reduce nutrient losses. To determine the reduction in nutrient losses resulting from a tax requires a regulatory agency to know dischargers' mitigation cost curves, which is potentially an unreasonably high knowledge requirement. Setting the tax rate too high or too low will result in a different environmental outcome to that intended. Another downside of using a tax approach is that it can financially burden some landowners that do not have the ability to implement cost-effective management options on their farm and thus face a potentially high price of maintaining the status quo. A cap-and-trade programme could allow the flexibility for landowners to directly purchase discharge credits from nearby farmers who could reduce their nutrients in a more effective. A tax requires all landowners that continue to discharge nutrients to make a payment to the government and then hope that they receive some form of tax relief in return. Thus, there could be significant distributional differences between the two approaches.

For each case study, we estimate the price necessary to achieve the same nutrient reduction target investigated in the catchment-wide cap-and-trade programme. This is supported by a sensitivity analysis that sets the tax above and below this 'optimal' rate. NZFARM investigates the impact of a nutrient tax on nitrogen leaching and phosphorus loss ($/kg/ha) in the Hurunui-Waiau and Manawatu catchment, while NManager places a tax on nitrogen exports for the Rotorua Lakes.

Table 7 Summary of water quality policies assessed

Policy	Principle	Key Features	Advantages	Disadvantages	Catchment Modelled
Promote Good Management Practices	Farmers adopt practices to reduce nutrients on voluntary basis	Not a regulation-based policy Promotion could be led by government or industry	Voluntary nature provides degree of flexibility for landowners to choose to participate Industry-led promotion could remove stigma that promoted practices are 'bad' for landowners	Participants restricted by choice of management practices Practices alone may not meet water quality objectives Uncertain reduction of nutrient discharges	Hurunui-Waiau Manawatu Rotorua
Regulate Land Management Practices	Farmers adopt mandated practices to reduce nutrients	Regulator develops list of acceptable practices that landowners must adhere to	Relatively easy to administer and monitor Rewards landowners who have already implemented approved practices	Regulator tasked with picking 'winning' practices Landowners restricted by choice of management practices Practices alone might not be enough to meet water quality objectives	Hurunui-Waiau Manawatu Rotorua
Cap-and-trade Programme with Grandparenting Allocation and Buyback	Discharge permit based on existing or historic land use and leaching intensity	Existing land use allowed to continue if discharge targets can be met Increases in leaching on farms in future must be offset by reductions elsewhere	Recognises investment in existing land use Cost-effective if there is active trading market Landowners have flexibility on choice to meet reduction requirements	Favours existing intensive land use Penalises 'early adopters' that have reduced their leaching levels before policy was established Could be costly to set up and administer	Hurunui-Waiau Manawatu Rotorua
Cap-and-trade with Benchmark Allocation	Allowances allocated based on a 'benchmark' land use or leaching rate	The same discharge permit applies equally across all land uses	Benchmark level can be flexible and vary across regions within a catchment Minimal effort required to benchmark individual farms	Transfers wealth from existing high leaching to low leaching land uses Costs could be significant for some land users Large changes in land values could occur through redistribution of wealth	Hurunui – Equal Allocation Manawatu – Natural Capital Approach

Policy	Principle	Key Features	Advantages	Disadvantages	Catchment Modelled
Nutrient Discharge Permit Auction	Permit are auctioned to landowners	Discharge permits goes to highest bidders	Favours landowners that are capable of achieving large nutrient reductions Revenue generated for community from sale of permits could be used to offset other costs of programme or to fund additional water quality improvement initiatives Certainty on reduction of nutrient discharges	Costly for landowners that have to purchase discharge permits Transfers wealth from landowners to the community Could see large social and economic impacts for landowners if permit prices are high Uncertain on cost of nutrient discharges	Rotorua
Nutrient Discharge Tax	Nutrient leaching is taxed on a $ per kg basis	Unlimited level of discharges allowed, provided landowner is willing to pay penalty	Favours landowners that are capable of achieving large nutrient reductions Provides economic certainty to landowner as he knows the price he will pay for each kg leached Revenue generated for community from the tax could be used to offset other costs of programme or fund additional water quality improvement initiatives Certainty on costs of nutrient discharges	Actual reductions in leaching uncertain Could heavily penalise landowners that are unable to make significant changes in land use and land management Uncertain reduction of nutrient discharges	Hurunui-Waiau Manawatu Rotorua

2.6 Administration and Transaction Costs

In addition to the costs of nutrient mitigation faced by polluters under a water quality policy, costs associated with developing, implementing, and administering policies to improve water quality may be substantial. In New Zealand the costs of implementing and administering such policies are expected to fall primarily on local governments and landowners, especially if carried out under the auspice of the National Policy Statement for Freshwater (2011). Primary costs for regional councils include transaction costs associated with gathering information, negotiating processes around regional plans and policies, and administrative costs for managing the programme on an on-going basis. In contrast, landowners will likely face costs for developing and submitting farm-level plans for nutrient budgets. In addition, if the policy instrument is a nutrient cap-and-trade programme, landowners will face costs to search and find other people with whom to buy and sell permits and any administrative costs associated with transacting a trade.

A policy administered by a regional council or central government requires public resources and places demands on public-sector capabilities. The extent of the resource needs for programme development, implementation, monitoring, and enforcement depend on the design, coverage, and overall goals of the policy. A potential example is the Lake Taupo Protection Trust was established in 2007 to administer a public fund to reduce nutrients leached to the lake by 20%.[11] This fund is being used to benchmark farms (i.e., determine their leaching rate for the reference year), undertake research projects for potential mitigation options and also to permanently reduce nitrogen losses through land purchases and retiring the associated nutrient permits (called nitrogen discharge allowances). The cap-and-trade programme is administered by Waikato Regional Council, with the council responsible for on-going water quality monitoring, resource consent modifications and compliance.

The cost of trading for landowners includes search and information (such as revising nutrient budgets) costs, contracting and trade approval costs. The cost for trading for agricultural sources can be higher than other sources. This relates to the farm-level cost and complexity of estimating farm nutrient leaching levels, the cost of trading nutrient discharge permits (which is likely to be similar for all sources), and additional costs that may be associated with the challenges of observing the mitigation actions for compliance monitoring and enforcement (Shortle 2012).

Analyses of nutrient trading markets in the U.S. have found that high transaction costs (often the time taken for trades to occur) have contributed to low trading volumes (Shortle 2012). However, as long as the specified environmental goal is being met the lack of trades is of less concern. Some reasons for low or no trade volumes reported in interviews with program managers include lack of trading partners, lack of adequate regulatory drivers (e.g. limits on effluents are not sufficiently stringent to create a demand for trades), uncertainty about trading rules, legal and regulatory obstacles to trading, the existence of cheaper alternatives for point sources to meet regulatory requirements than trading with agricultural and urban non-point sources, and the programmes being too new to have experienced trades (e.g.

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[11] http://www.laketaupoprotectiontrust.org.nz/page/5-Home

Morgan & Wolverton 2005). Many of these impediments could be overcome through improved programme design. Accordingly, better market design could improve market activity and hence economic outcomes. For example, Breetz et al. (2005) find that trust and communication barriers have contributed significantly to low participation rates for farmers in trading experiments in the agricultural sector and conclude that engaging trusted third parties (e.g. traditional agricultural resources conservation agencies) may reduce farmers' reluctance to participate.

Transaction costs can be reduced if the policy is designed with that intent. For example, McDonald and Kerr (2011) find that regulatory agencies can reduce time-of-trade transaction costs if they establish cap-and-trade programmes with established baselines (or benchmarks) for all participants (as opposed to voluntary baseline and credit programmes where not all sources are regulated and trading can occur between the regulated and unregulated sources) and use of standardised ex-post monitoring of trades (as opposed to ex ante approval of individual trades). Trading efficiency can be further improved by encouraging liquidity in the trading market, ensuring that participants have good information, and providing market participants with relative certainty about the future of the programme by explicitly planning for future programme changes.

A range of estimated implementation, administration, and transaction costs for key stakeholders are listed in Table 8. The costs to the landowners from reduced profit as a result of changes in land management are not included as these costs are directly tracked in the economic models used for the specific case studies in Sections 3, 4 and 5. These costs are summed to provide an estimate of the total cost of a given policy option.

Table 8 Range of costs of administration and transactions faced by key stakeholders for various water quality policies

Cost Category	Cost Assumptions	Approximate Cost	Policies Affected
Transaction Costs for Landowner to Trade Discharge Allowances	Based on Waikato Regional Council data on Lake Taupo trading programme; includes cost to modify resource consent	$1250/farm[12]	Cap-and-trade
Farm Nutrient Budgeting Benchmark	Cost for regional council to estimate status quo nutrient leaching; about 40 hours per farm @ $85/hr (based on Greenhalgh 2011)	$3500/farm	Cap-and-trade
Individual Farm Plan Development	Hire consultant to develop plan to improve nutrient management; about 80 hours per farm @ $85/hr (based on Greenhalgh 2011)	$7000/farm	Cap-and-trade, discharge tax
Regional Council Administration	Range of costs for revising regional plans and administering policy (MfE 2011)	$300,000-700,000/year	All regulatory policies
Central Government Administration	Primarily to review regional policies for freshwater management (MfE 2011)	$50,000/year	All policies

[12] Based on range of consent modification costs (Jon Palmer, Waikato Regional Council, pers. comm., Apr 2012)

2.7 Quantifying Costs and Benefits of Good Management Practices not Explicitly Tracked in Economic Models

Nutrient losses from farms can be mitigated by eliminating contact of livestock with waterways through fencing, or forcing runoff to flow through riparian buffer zones or constructed wetlands before entering waterways. These practices also require the construction of bridges and/or culverts to keep the farm accessible to livestock, and often have high capital costs. Regional councils and central government have developed schemes to ensure mitigation compliance by farms and incentives via subsidies and technical assistance (e.g. Dairying and Clean streams Accord; Fresh Start for Fresh Water Fund[13]). A brief overview of the costs and benefits associated with these mitigation options are provided below. Additional estimates for the costs and relative effectiveness of different mitigation options based on other published New Zealand studies are listed Appendix G.

The fencing of streams to keep livestock out of the water has been a widely promoted option for nutrient mitigation in New Zealand. Many regional councils have instituted programmes to subsidise the cost of fence construction, which can vary depending on the type of fence needed and livestock it is keeping out. Monaghan (2009a) estimates the capital cost of building fences at $2–6 per m for dairy, $10–16 per m for sheep and $12–20 for deer with an annual maintenance cost of $0.25–0.70 per m for dairy, $1.10–1.80 per m for sheep, and $1.30–2.00 per m for deer. There is an estimates 3 to 13% reduction of N in fenced waterways (Monaghan 2009b). On a per farm basis, fences are expected to cost between $2200 and $17,400/farm with an average of $6700/farm and a weighted average of $5300/farm and an annual maintenance cost of $1060 and $6400 with an average of $3400 per farm (Neild & Rhodes 2009). The estimated reduction is 0–2 kg N/ha, with an average of about 1 kg N/ha from fencing.

Taylor (2009) estimates the effective reduction of nitrogen (kg N/ha/yr) from selected mitigation options on select farms within the Manawatu catchment. We use these data to calculate the effective reduction in N per kilometre of fence line (Table 9). The same study also tracked the effectiveness of adding culverts along with the fences for some of the farms. Estimates reveal that fencing streams on select farms in the Manawatu can lead to a 1–8% reduction in N leaching levels.

[13] http://www.mfe.govt.nz/issues/water/freshwater/fresh-start-for-fresh-water/cleanup-fund.html

Table 9 Nitrogen leaching mitigation on select Manawatu farms with length of fences and number of culverts needed to comply with the Proposed One Plan (POP) and Dairy and Clean Stream Accord (DCSA)

Farm	Length of fence (km)	Total Effective Reduction (kgN/ha/yr)	Effective Reduction per km fence (kgN/ha/yr)	Culverts Built (no.)	Current N for Whole Farm (kgN/ha/yr)	Reduction in N due to fence/culvert (%)
Barrow	3.7	0.2	0.05	-	25	0.8
Stoney Creek	1.6	2.5	1.56	-	31	8.1
Jala	3.8	1.5	0.39	15	31	4.8
Windwood	2.2	2	0.91	7	25	8.0
Muskit	32	2	0.06	-	34	5.9
Waka	1.2	1	0.83	-	35	2.9

Planting riparian buffers and constructing wetlands are also viable options to mitigate N and P leaching, as they filter nutrients contained in farm runoff. The cost of a riparian buffer and its effectiveness depends greatly on the width of and plants in the buffer as well as the characteristics of the surrounding land (i.e. the runoff coming off a slope or flat land, etc.). A case study in the Bog Burn catchment, Southland found that a 4-m wide riparian buffer costs $1/planted m of exotic species and $2.50/ planted m of native species with an opportunity cost of lost productive land and fencing cost to exclude livestock of about $8/m Monaghan (2009b). A literature review by Muscutt et al. (1993) on the effectiveness of buffer zones on P transport found that total P can be reduced between 44 and 93%, depending on the slope and width of the buffer.

Finally, the construction of wetlands has also been implemented in some catchments in New Zealand. In addition to reducing nutrient loads, wetlands also have a number of co-benefits such as enhancing biodiversity, flood control, and improving groundwater recharge. Neild and Rhodes (2009) found the reduction in N leaching was approximately 0.9 kg N/ha for constructed wetlands with a cost around $15,000. Monaghan (2009a) estimates the capital cost of building a wetland at $800 per ha, assuming that 1% of farm area is taken out of production at an annual cost of $100 to $200/ha/yr. A summary of the likely costs and benefits[14] of these mitigation options on a per-ha-per-year basis is listed in Table 10.

Table 10 Estimated economic costs and nutrient reduction benefits of select mitigation options

Mitigation Option	Initial Cost ($/ha)	Maintenance Cost ($/ha)	Opportunity Cost ($/ha)	Nutrient Reduction (kg/ha)	Annualised Cost ($/kg/ha)
Fencing Streams	$300	$11.33	$8.00	1.0 kgN	$40.18
Riparian Buffer	$500	$8.00	$53.33	1.2 kgN	$78.27
Wetland Construction	$800	$0	$150.00	0.9 kgN	$220.31

[14] Per hectare estimates are based on a 300 ha farm that has 3 km of streams on its property. Annualised costs are discounted at 5% across on a 20-year lifetime of the option.

2.8 Estimating Adoption of Good Management Practices

Voluntary approach

The extent to which GMPs are voluntary is the subject of considerable debate in the literature. For the purpose of this report, we denote a voluntary approach as being any measure of GMP that is taken in an unregulated framework. Accordingly, industry-promoted practices such as those included in the Dairying and Clean Streams Accord (MfE 2003) are considered to be voluntary.

Voluntary agri-environmental policies have been shown to have limited effectiveness in inducing permanent change in farmers' attitudes and behaviours, especially when farmers see little benefit from implementing given practices. For example, Beswell et al. (2007) assessed the adoption of voluntary stream fencing among dairy farmers in four New Zealand catchments and found that farm-specific factors influence the decisions farmers make. Specifically, they noted that adoption may be slow in the absence of proven on-farm benefits and that the promotion of the GMP must be linked to these benefits. This last result is consistent with Bewsell and Kaine (2005), who found that a farmer's decision to adopt management practices depends on his or her perception of the benefits of those practices, and that these perceptions are based on the systematic evaluation production possibilities for each individual farmer rather than sustainability or environmental concerns.

'Involvement' may represent another impediment to adoption of agricultural innovations (Bewsell & Kaine 2005; Kaine 2008; Bewsell & Brown 2011), where involvement is defined as a motivational state that indicates the cognitive effort required to pursue a given activity (Kaine 2008). In this framework, adoption rates depend crucially on involvement levels. For example, Bewsell and Brown (2011) surveyed 20 dairy farmers and found a low level of interest in nutrient budgeting and planning. Using this as a proxy for involvement, the authors argue that farmers will comply with policy requirements without making significant changes to the way in which they manage their farms until such time that their involvement in nutrient budgets increases. In contrast, high levels of landowner involvement in either an issue or a policy may delay adoption of GMPs, including those that would unambiguously increase profits.

The extent to which policies contribute to meeting landowners' idiosyncratic goals – whether economic, social, or environmental – may also influence adoption rates. For example, Pannell et al. (2006) find that landowners will not adopt GMPs if they do not perceive that the management options in question significantly contribute to achieving their goals. Even when policies enhance the achievability of goals, they further find that adoption is based on subjective perceptions and that these perceptions depend on the process of learning, the characteristics of the individual landholders, the broader social environment, and the characteristics of the management practice.

More broadly, Burton et al. (2008) argue that farmers undertake GMPs if and only if two conditions are met: (1) The practice must be compatible with commercial interests and must provide economic benefits to the landowner; and (2) The practice must represent minimal change to the current farming system. Even when these conditions are met, however, voluntary adoption of GMPs is likely to be slow. In particular, Feder and Umali (1993) find that adoption rates typically follow a sigmoidal curve in which a small number of pioneers are followed by a gradual increase in the number of adopters, who are in turn followed by remaining laggards. Indeed, Smeaton et al. (2011) have demonstrated such a pattern in New Zealand, even where GMPs for nutrient leaching and greenhouse gas emissions have very modest impacts on profitability for most farms. They argue that the reasons for farmers delaying adoption of GMPs include lack of managerial skill, increased risk associated with implementing new practices, and significant capital investments necessary to implement the policies.

Given such theoretical and empirical evidence, it is not surprising that the Dairying and Clean Streams Accord (MAF 2011) has found that rates of adoption for industry-promoted practices have varied across the different GMPs and regions. For example, a national-level assessment on the four key targets in the Accord revealed that only 46% of dairy farms have a nutrient management plan against a goal of 100% by 2007. At the same time, 99% of farms had bridges or culverts at regular crossing points against a goal of 90% by 2012, although there is tremendous variation across New Zealand.[15]

Using information from these studies, we estimate likely rates of adoption for the GMPs assessed in this report. The rates and key input to our assumptions are presented in Table 11. These rates are then used to estimate the likely reduction in nutrients exported from diffuse sources in the Hurunui-Waiau and Manawatu catchments from the current estimates to establish whether the proposed nutrient reduction targets in each catchment could be met strictly from the voluntary measures included in this study. As noted earlier, NManager does not allow modelling the impact of individual GMPs for the Rotorua case study. Instead, we look at costs and benefits of restricting landowners to manage their land based on two different benchmark nutrient leaching rates.

[15] 27% of Manawatu farms have complete stock exclusion from waterways via fencing but 81% are fully compliant on dairy effluent; in contrast, 65% of farms in Canterbury meet each of these measures. (Regional data were not published for the other Accord targets.)

Table 11 Assumed voluntary adoption rates for GMPs used in NZFARM

Good Management Practice	Keys to Adoption	Possible Adoption Rate in 2022
Dairy		
Stock Exclusion via Fencing Streams	Dairying and Clean Streams Accord has goal of 90% by 2012; Mean percent of bank length with stock exclusion in 2011 was 78% nationally (MAF 2011). Fonterra will include stock exclusion from Accord-type waterways as a condition of supply at start of 2012/2013 season.	100%
Reduced N Fertiliser	Could see voluntary reductions as high as 40% reduction in N if cost savings with minimal change in productivity are proven	75%
Apply DCD	On-going debate about the productivity benefits of DCDs in certain areas of New Zealand (Gillingham et al. 2012), but could have voluntary increase in application if consistent productivity gains are observed; NZ Emissions Trading Scheme could encourage rate of uptake because of nitrous oxide reduction benefits.	50%
Wintering Off	Possible if can secure cost-effective ways to achieve this, as land and feed constraints are sometimes a hindrance.	50%
Feed Pad	Typically produces nutrient reductions at minimal cost over the long-run. Constraint could be the initial capital cost.	75%
Riparian Planting	More costly than simply fencing, but can provide additional nutrient reductions.	50%
Sheep, Beef, and Deer		
Stock Exclusion via Fencing Streams	Feasible on plains and foothill pasture; more difficult to do so on large, steep farms in the hills. Recently encouraged by Beef and Lamb New Zealand.	60%
Apply DCD	On-going debate about the productivity benefits of DCDs in certain areas of New Zealand (Gillingham et al. 2012), but could have voluntary increase in application if consistent productivity gains are observed; NZ Emissions Trading Scheme could encourage rate of uptake because of nitrous oxide reduction benefits.	50%
Reduced N Fertiliser	Most hill farms already use minimal N.	25%
Riparian Planting	More costly than simply fencing, but can provide additional nutrient reductions. Would likely need industry promotion or economic incentives for wide-spread adoption	50%

Regulatory approach

A regulatory approach to implementing GMPs would essentially mandate landowners to comply with a list of acceptable activities or face enforcement. This approach is more appropriate for farmers who will not take action unless forced to do so, either for economic or political reasons. It will also typically encourage a faster and wider rate of adoption, but often at a greater cost – both to the farmer and the agency promoting the adoption of GMPs.

Under a regulatory approach, rules must be relatively straightforward to enforce and management practices must be easy to monitor. The size of the penalty must also be large enough to incentivise change by the landowner. If the cost of non-compliance is insignificant compared with benefit of not complying, then landowners will typically risk being penalised and pay the fine rather than cooperate (Blackett 2004).

For the purpose of this study, we assume that any regulated GMP would be adopted by 100% of the landowners. The effectiveness of each GMP is measured by the estimated reduction in nutrients versus the potential losses in net revenue for the farmer. We also estimate any likely administrative costs for developing and enforcing the GMP programme at the catchment-level to assess the overall cost of the regulation.

2.9 Other Factors to Consider for Water Quality Policy

Other land-based mitigation strategies

Individualised property plan

Individualised property plans are often prepared by farm consultants or other land management experts that can provide the landowner with specific feasible management options for their farm. The options available to the farmer are likely similar to those GMPs included in the case studies, or the additional mitigation options listed in Appendix G. The net benefits of hiring a consultant to perform an individual property plan would depend on the relative cost of developing and implementing the plan plus the loss of profits from implementing the mitigation options suggested by the expert. In many cases, an individual plan will discover other ‘quick fixes’ for the landowner that could result in benefits that were not originally perceived.

Catchment plan

A catchment plan is a typically a voluntary measure where landowners can take both collective and individual actions to reduce nutrient load. For example, farmers have the ability to plant trees at the paddock level, but it may require land and cooperation from several farms to construct a wetland or buffer large enough to effectively reduce nutrient loads within the catchment. Alternatively, a recent study of P runoff mitigation options for Lake Rerewhakaaitu near Rotorua concluded that building a series of detention dams at strategic locations in a sub catchment could contain and slow down a significant amount of runoff, but landowners and council staff are still working through the process to get these dams constructed (Parker et al 2012).

The ability to delineate spatial zones within NZFARM and the catchment-wide configuration of NManager allow us to simulate, to some extent, the likely outcome of a catchment plan because the models themselves estimate the 'optimal' way to reconfigure the landscape given the nutrient reduction targets. However, the lack of spatial detail within the models means they are unable to assess the specific changes in management that are occurring at the individual farm-level. Additionally, the models do not account for mitigation options such as the construction of wetlands or 'optimal' dairy effluent management. We believe though that the costs of taking this approach would be similar to the costs of some GMPs included or trading policies investigated in the case studies. Additional research will have to be conducted to assess the administrative and transaction costs of establishing and coordinating a catchment plan.

Allocation approach with offsets

Another formulation of a nutrient cap-and-trade policy is where only some of the sources are capped (akin to the baseline and credit programmes discussed earlier in this report). For instance, only higher leaching enterprises are capped in a catchment at a benchmark rate, and these enterprises are required reduce their nutrient losses to the benchmark level or pay other landowners not covered under the policy (i.e. not included in the cap) to reduce their nutrient losses. Other activities that already have low nutrient leaching rates (e.g. forestry) are basically capped at their current leaching rate (i.e. grandparented). Landowners who have nutrient losses below the benchmark rate could receive 'offset' payments from the higher leaching landowners who purchase these 'voluntary reductions'. This is somewhat similar to the Horizons Regional Council natural capital approach and Environment Canterbury equal allocation approach assessed in the case studies. In these approaches all landowners in a zone was allocated the same number of discharge permits, and then required them to meet the restricted limit through changes in land management, land use, or purchasing permits from other landowners. The biggest difference with the allocation approach with offsets is that some landowners in the catchment are not covered under the policy. In an efficient market with many landowners willing and able to trade discharge permits, the allocation approach with offsets would likely result in a similar outcome as a cap-and-trade scheme involving all landowners in the catchment.

Other farm-based mitigation technologies

The models used in this report do not account for all possible changes in land management that could be implemented to effectively reduce the level of nutrients being transported from diffuse sources to the local waterways (e.g. McKergow et al. 2007; Monaghan 2009a). For example, McDowell and Nash (2012) developed a review of the cost-effectiveness and suitability of mitigation strategies to prevent phosphorus loss from dairy farms and found that costs from on-farm mitigation strategies such as maintaining optimum soil test P concentrations and improved irrigation management ranged from $0 to $200 per kg P conserved. For this analysis, we use a select number of management practices available to reduce nutrient loadings, but it is not an exhaustive list. The models in our report also assume constant technology and therefore do not account for potential improvements in efficiency or uptake over time. As a result, the costs of the policies assessed in this study could likely be overstated. A list of estimates for the costs and relative effectiveness of different mitigation options from selected New Zealand studies are provided Appendix G.

Accounting for point source pollutants

While this report has focussed on agricultural (or non-point or diffuse source) mitigation options to meet water quality goals, mitigating point source discharges may also be important for some catchments. Typical point sources include sewerage plants and urban storm water drains, and including them in a trading programme is likely to be economically and politically valuable. In terms of economic efficiency, it is could be beneficial to include point sources in a trading programme as they are likely to have a different cost structure for mitigating nutrient losses, providing more cost heterogeneity between potential participants in a trading programme. Including point sources in a nutrient trading programme theoretically means that the marginal costs of mitigation are equalised across all sources of pollution, not just land use. To the extent possible, regulatory packages should target both non-point and point sources to make achieving the environmental goal as efficient as possible as this will allow the environmental goal to be achieved at lowest cost. Including urban sources of pollution would also be valuable for political reasons as it promotes equity in how a water quality goal is achieved.

Each case study makes unique assumptions about what sources are included in the water quality policy/nutrient reduction targets. NZFARM sets region-specific nutrient load limits from land-based sources in the catchment based on percentage changes from the total N and total P loads estimated in the baseline (i.e. reference year) case. It does not incorporate any point source nutrients into the baseline or the policy case. Thus, the amount of mitigation necessary to meet a comprehensive nutrient target for a catchment (i.e. including all sources of pollution) would have to follow the assumption that point sources must also reduce their nutrient emissions by the same percentage as non-point sources. Future analyses could focus on the cost savings from integrating point source and non-point source pollutants into a comprehensive policy for the Hurunui-Waiau and Manawatu catchments if the relevant data are available.

NManager also does not have the ability to estimate mitigation on non-agricultural land either. Instead, changes in non-agricultural nitrogen leaching are incorporated by reducing the ‘unmanageable loads’ (see figures in Chapter 5). The simulations presented here (unless explicitly stated otherwise) assume that non-agricultural sources reduce nitrogen leaching by 50 t by 2022, as stated in the most recent BOPRC policy documents (Bay of Plenty Regional Council 2012).

Māori-specific issues

Māori have a distinctive role in catchments as tangata whenua, but also fill many other, potentially conflicting, roles: small and large pastoral landowners, forest owners, and water users. These various roles bring about a number of issues that Māori landowners will face under any regulation to improve water quality. Here we briefly discuss two pressing issues: the implications of land use restrictions for landowners of underdeveloped land; and the potential difficulty for small Māori landowners to take advantage for complex policy.

Experience in the Rotorua catchment has suggested that Māori land is on average less developed than non-Māori land; that is, has lower production intensity (and nutrient leaching rates) than the land’s potential. Reasons for this include the unique ownership, decision making, and funding challenges that stem from the cooperative ownership restrictions on Māori land as a result of the Te Ture Whenua Māori Act 1993 (the Māori Land Act).

Additional to these management restrictions, in Lake Rotorua some Māori landowners decided early on to limit the intensity of their land due to concern about falling lake water quality. This lower level of development has serious implications for Māori landowners if regulation restricts nutrient discharges to a rate proportional to current discharges. Such a restriction would take away the option to intensify in the future, a cost that would be borne disproportionately by all underdeveloped farmers. Differences in intensification must also be considered if a nutrient trading programme is to be implemented, particularly when considering any free allocation of permits; grandparenting permits would leave Māori (and other underdeveloped) land owners less wealthy than owners of similar but intensified land (Kerr & Lock 2009).

A related issue is the difficulty experienced by small landowners or land under decentralised management structures, such as much Māori land, when dealing with complex water quality policy. A participant in the Motu Nutrient Trading Study Group (NTSG) for Lake Rotorua expressed concern about the ability of small Māori landowners to take advantage of a nutrient trading scheme due to its complexity and the long-run implications of a short-term decision to sell nutrient discharge permits. To help protect small landowners in a trading scheme, the NTSG suggested that permits should be allocated over several time periods so that all future permits are not sold by mistake early on, and that regulatory agencies could support small landowners make good decisions about trading, particularly in the early years of a trading programme (Kerr & McDonald 2011). This approach has been followed in the Lake Taupo trading programme, where the Lake Taupo Protection Trust provides business advisors to help participants make good trading decisions.

2.10 Key Caveats, Assumptions, and Limitations of this Analysis

There are several aspects of reducing nutrients and improving water quality not covered in this report. While the economic models used for the analysis are relatively complex, the data and computational limitations prevent us from modelling all farms, their individual characteristics, and unique decisions. Rather, our modelling approach looks across the catchment using relative homogenous areas and representative farms whose objective is to maximise profits. The estimates presented here are not intended to be the final say on what the most effective water quality improvement policy should be. Instead, the scenarios presented are developed to highlight and compare a possible set of responses to various nutrient reduction policies, given the set of assumptions and land management options included in the models. This is a key reason why we do not quantify all the costs and benefits of each policy in monetary terms, and instead report the relative changes in the catchment's nutrient discharges and revenue streams resulting from each policy scenario. A summary of the key caveats, assumptions, and limitations for this analysis is as follows:

- We define a 'cost-effective policy' as a modelled policy that achieves the nutrient target in the catchment at the least cost to the landowners, given the specified management options.
- Our economic analyses depend on the datasets and estimates provided by biophysical models like OVERSEER and SPASMO, and farm budgeting models such as FARMAX. Estimates derived from other data sources may provide different results for the same catchment. Thus, the tools and analysis presented here should be used in conjunction with other information during the decision making process.

- Data and model limitations prevent this analysis from including all possible N and P mitigation strategies that could be implemented in a given catchment. Some mitigation options not explicitly included are some farm-level mitigation options (e.g. optimum soil test P) and catchment-wide solutions (e.g. series of constructed wetlands). Tracking additional mitigation options could lower both the overall cost of the policy and the cost to individual landowners.
- The economic models do not track or account for nutrient mitigation from point sources. Incorporating the costs of mitigating point source nutrients may change the relative cost-effectiveness of the policies. The Hurunui-Waiau and Manawatu case studies assume a constant nutrient attenuation rate across the entire catchment area and that nutrients from diffuse sources will all reach the waterway of concern within 10 years. The Rotorua case study assumes that there are several groundwater lag zones within the catchment, and that nutrients exported from some farms can take up to 200 years to reach the lake.
- The economic models do not explicitly account for all administrative and transaction costs of the various policies. Doing so could alter the estimates for the distributional impacts to farmers, land-use change, and the overall cost of the different policies.
- The models are static and assume that technology, climate, input costs, and output are all constant for the duration of the policy. However, the aim of the models is to compare policy options at a given point in time.
- NZFARM tracks both N and P, while NManager only tracks changes in N. We acknowledge that there are other important factors and metrics to consider beyond N and P for assessing changes in water quality, such as sediment and faecal coliform.
- With the exception of the voluntary GMP scenarios, the analysis assumes full compliance for each nutrient reduction policy. Actual outcomes will differ if individuals do not understand the policy or choose not to comply.
- Each case study uses catchment-specific economic data, biophysical data, options for land management, and policy assumptions. In addition, the Hurunui-Waiau and Manawatu catchment studies use the same economic model but the Rotorua case study uses a different model. Thus, the estimates from one case study are not directly comparable with another, although limited comparisons can legitimately be made between the Hurunui-Waiau and Manawatu cases because they use the same economic model.

3 Case Study #1 Hurunui-Waiau Catchment, Canterbury

3.1 Introduction

The Hurunui-Waiau catchment in Canterbury is comprised of braided rivers, shallow stony soils, hill country grazing, and lowland irrigated pastures. The Hurunui and Waiau Rivers are the two largest rivers in the catchment. Their headwaters are located in the main divide of the South Island and are largely free of human influence, but as these rivers emerge onto the flat land of the plains some of their flow is used for drinking (domestic and stock) and for irrigation. Salmon farms and small-scale hydroelectric power generation also utilise water from the catchment. Both rivers provide important habitat for trout, salmon and whitebait fisheries. The catchment also provides important habitat for braided riverbed nesting birds and its headwaters provide habitat for threatened species such as blue duck. A variety of water-based recreation activities including kayaking and jet boating also take place in the Hurunui-Waiau catchments. These values can be degraded if the flow in the river is insufficient, there are changes in the natural frequency of floods, water quality deteriorates or the river is modified by structures.

Two Ngāi Tahu hapu, Ngati Kuri and Ngāi Tuahuriri, are situated within the Hurunui and Waiau river catchments. Ngati Kuri's interest extends from Parinui o Whiti (White Bluffs) in the north to the Hurunui River in the south, east from the Main Divide and out to sea. Ngāi Tuahuriri's interest extends from the Hurunui River in the north to the Hakatere/Ashburton River in the south, east from the Main Divide and to the ocean and beyond. The mauri of the Waiau and Hurunui rivers represents the essence that binds the physical and spiritual elements of all things together, generating and upholding all life. All elements of the natural environment possess a life force, and all forms of life are related. Mauri is therefore a critical element of the spiritual relationship of Ngāi Tahu Whānui with the rivers.

There are several issues of significance to Ngāi Tahu regarding water in Canterbury. Some of the key ones include the ownership of water, the discharge of contaminants to water from agricultural and industrial run-off, and the risk to losses of traditional uses from those discharges. Desired outcomes for iwi, as specified in the Canterbury Natural Resources Regional Plan (2009), include holding the right to tradable water and recognition as the kaitiaki of water, i.e. to exercise power in a manner beneficial to the resource of water.

The catchment is approximately 582,000 ha in size and land use is consists of 43% natural area, 42% sheep and beef, 5% forest plantation, 4% dairy, and 6% other land use (arable, horticulture, deer, etc.). A map showing land use in the catchment as of 2010 is shown in Figure 3. It is estimated that about 31,820 ha of the catchment are irrigated for dairy, sheep and beef, and arable and horticultural crops.[16] Proposals have been submitted to implement the Waitohi scheme of Hurunui Water Project (HWP) that will effectively increase irrigated area in the Hurunui plains area from 22,000 to 63,500 ha, increasing the total irrigated area of

[16] Of the approximately 31,820 total ha of irrigation in the catchment, about 22,000 ha of irrigation are in the Hurunui plains area, while almost 10,000 ha are located in the Waiau plains.

the catchment to over 72,000 ha (ECan 2012). This proposed change will likely result in changes in land use and land management and is a key subject of the modelling section of this case study.

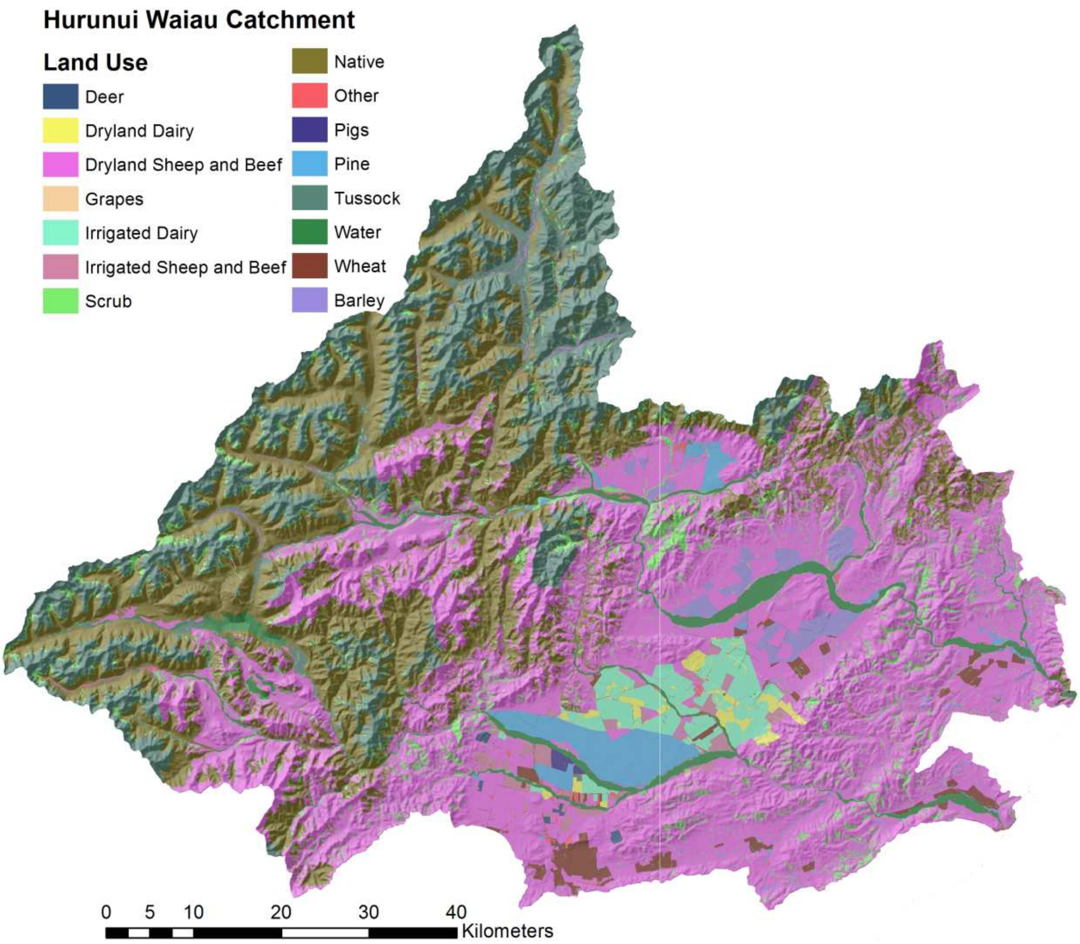

Figure 3 2010 Land use in Hurunui and Waiau Catchments (ECan, pers. comm.)

3.2 Water Management Issues

The Hurunui-Waiau catchment has experienced a large increase in dairy production in recent years. Concurrently, water quality and availability are decreasing. A number of irrigation developments are also being explored (e.g. HWP) that will intensify production further. In response to water management issues the Canterbury region has established zone committees under the Canterbury Water Management Strategy. In July 2011, the Waiau-Hurunui Zone Committee released its Zone Implementation Programme (ZIP) (Environment Canterbury 2011b), which contained recommendations as to how water management issues in the Waiau-Hurunui Zone should be addressed. The Hurunui and Waiau River Regional Plan (HWRRP) (Environment Canterbury 2011a) was developed as a response to the recommendations in the ZIP that required a statutory response through the 1991 Resource Management Act.

The HWRRP has proposed targets for N and P limits for the Hurunui River that maintains water quality at 2005–2010 levels (hereafter “2010 levels”). The Hurunui Waiau ZIP sets out in some detail the non-statutory implementation actions, such as the development of good practice guidelines, which aim to lower the nutrient concentrations in the main stem and tributaries while at the same time providing headroom for additional land to be developed and intensified within the Hurunui and Waiau catchments.

The most relevant water quality policy to consider for this case study is the HWRRP (Environment Canterbury 2011). The plan sets the load limit in the catchment, in tonnes per year, of dissolved inorganic nitrogen (DIN) and/or DRP at the 2010 level. The annual DIN load measured at the State Highway 1 (SH1) monitoring site is allowed to increase 20% above 2010 levels prior to 2017, but must return to 2010 levels or better thereafter. DIN at SH1 as well as DIN and DRP at the Mandamus flow recorder site is to be maintained at current levels for all years. According to water quality monitors, there was an average of 693 tonnes/yr of DIN and 10.2 tonnes/yr DRP recorded at SH1 between 2005 and 2010 (Table 12). These load limits would have minimal impacts on current farming activities, but could limit landowners that wish to intensify their farming system.

Table 12 Hurunui-Waiau Catchment nutrient load limits (Environment Canterbury 2011)

Monitoring site location	Nutrient Load Limits	
	Dissolved Inorganic Nitrogen (tonnes/yr)	Dissolved Reactive Phosphorus (tonnes/yr)
Mandamus flow recorder	40	3.6
SH1 Flow recorder	693	10.2

Studies have determined that up to 100,000 ha of the Hurunui-Waiau catchment could be irrigated if reliable water could be sourced and distributed to these properties.[17] To irrigate this amount of land, water from both the Hurunui and Waiau Rivers would need to be utilised. It is also highly likely that water from one or both rivers, taken at times of high flow, will need to be stored for use in times of low flow. The HWP is in the process of applying for resource consent to develop a series of dams and infrastructure in the Waitohi catchment to irrigate land in the Hurunui and nearby catchments, as well as generate hydropower. If fully implemented, it is estimated that the Waitohi scheme will effectively increase the irrigated area in Hurunui Plains from 22,000 to 63,500 ha. The impact on nutrient losses in the catchment of additional irrigated land will depend on the policy mechanism implemented to achieve the nutrient targets.

3.3 Data for Hurunui-Waiau Catchment

NZFARM accounts for all major land uses and enterprises in the Hurunui-Waiau catchment. Key enterprises include dairy, sheep, beef, deer, timber, maize, wheat, and fruit. There are a total of 18 enterprises tracked in the model across 6 sub-catchment zones (Figure 4). Not every zone in the catchment will have all these practices (e.g. dairy or horticulture is not present in the hills). The feasible practices for each NZFARM region are determined by bio-

[17] http://www.hurunuiwater.co.nz/

geographical characteristics like slope, soil type, access to water, etc., as well as the enterprises shown in most recent land use maps.

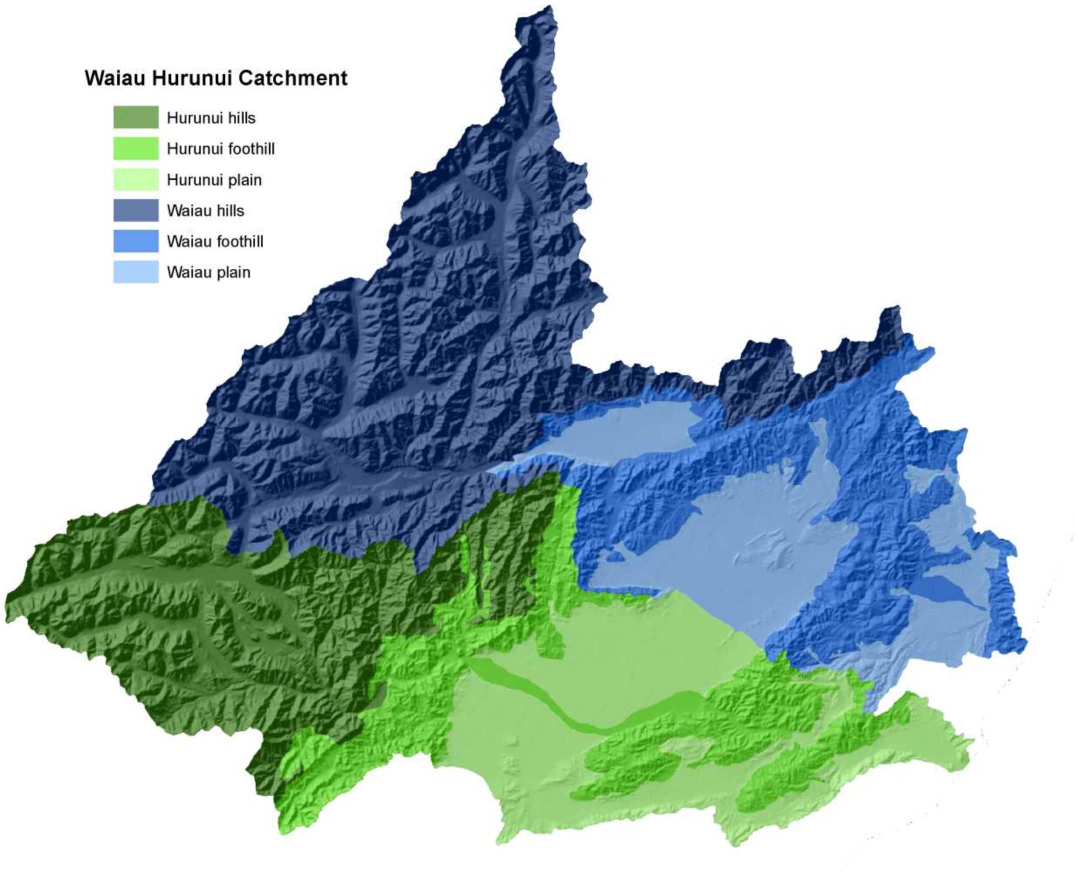

Figure 4 NZFARM regions for Hurunui-Waiau Catchment

Each enterprise requires a series of inputs to maximize production yields given input costs and output prices. The cost of inputs coupled with water and input constraints can limit the level of output from a given enterprise. Outputs and prices for pastoral and arable enterprises are primarily based on data provided by Lincoln University (Lincoln University 2010), Ministry of Agriculture and Forestry (MAF) farm monitoring reports (MAF 2010a), and the 2010 Situation and outlook for New Zealand Agriculture and Forestry (MAF 2010b). All figures are listed in 2009 New Zealand dollars (NZD). Stocking rates for pastoral enterprises were established to match regional figures included in the FARMAX model (Bryant et al. 2010). The physical levels of fertilizer applied were constructed from a survey of farmers in each catchment. Forestry yields were obtained from Kirschbaum and Watt (2011) with timber and pulp prices obtained from MAF (2010b).

Enterprises also face fixed and variable costs ranging from stock replacement costs to deprecation. These costs were obtained from farm consultants (Stuart Ford, The AgriBusiness Group, pers. comm.), the MAF farm monitoring report (MAF 2010a), and Lincoln University (2010). Costs for each enterprise varied across the catchment. Altering input costs or output prices as well as the list of enterprises available for a given region changes the distribution of enterprises (and their area) but total land area remains unchanged across all model scenarios.

N and P leaching rates for all pastoral enterprises in Hurunui-Waiau were estimated using OVERSEER (2010) to match the soil and productivity conditions in the catchment, while N and P leaching rates for grains and horticulture were estimated using SPASMO (Clothier et al. 2008). Estimates (in kg N leached and kg P loss per hectare) were derived from parameterising the two biophysical models using dominant soil types in the catchment and typical farm characteristics for the different regions in the catchment. The estimates for N leaching from pine plantations and native vegetation for both catchments were taken as an average from the literature (e.g. Parfitt et al. 1997; Menneer et al. 2004), and range from 1 to 4 kgN/ha. We assumed no P loss from forest plantations or native forest land.

GHG emissions for most enterprises were derived using the same methodology as the New Zealand GHG Inventory (NZI), which follows the IPCC's *Good Practice Guidance* (2000). Pastoral emissions were calculated using the same emissions factors as the NZI, but applied to per hectare stocking rates specific to the catchment. Forest carbon sequestration rates were derived from regional lookup tables (Paul et al. 2008). All emission outputs are listed in tonnes per carbon dioxide equivalent (CO_2e). To be consistent with the NZI (MfE 2011), all emissions were converted to CO_2e using the 100 year global warming potentials of 21 for methane (CH_4) and 310 for nitrous oxide (N_2O).

3.4 Water Quality Policy Scenario Analysis

This study models the impacts of several water quality policy scenarios ranging from placing caps on N leaching and P losses to imposing GMPs on existing farms. Most water quality policies assessed using NZFARM include ways to reduce nutrient losses by (1) requiring specific targets to meet regional water quality standards, (2) imposing an environmental tax on farming outputs (e.g. $/kgN/ha leached), or (3) mandating the use of specific management practices. Where data and methods were not available to model the policy explicitly, we rely on alternative literature sources to provide a mix of qualitative estimates and quantitative discussion. The explicit policies investigated for the Hurunui-Waiau catchment include:

1. The development of the Waitohi Irrigation Scheme
2. Implementation of good management practices
3. Cap-and-trade programme with varying allocation
4. Direct tax on nutrient discharges

As outlined above, NZFARM estimates on-farm nutrients in the form of total N leached (kgN/ha) and total P loss (kgP/ha) using biophysical models such as OVERSEER and SPASMO. On-farm nutrient leaching cannot be directly translated to water quality impacts without the use of hydrological models that can distinguish between exports (nutrients discharged from the land) and loads (nutrients reaching the water body). We assume a lag time of 7 years or less for the catchment, which also correlates to the length of time that NZFARM is parameterised for when simulating long-run farmer response to policy changes. Additionally, because many of the estimates presented are from NZFARM, the modelling outputs should be interpreted as relative changes rather than absolute values. This approach also allows us to use total N and total P as a proxy for measuring changes in water quality because the percentage change at the point of discharge should be in line with the relative change in the waterways over the long run, given the assumption of small lag times and constant attenuation rates.

The effectiveness of the each policy is assessed by comparing nutrient losses between current levels (i.e. the baseline) and each scenario and the cost of achieving a policy. The cost component primarily consists of reductions in farm profit estimated using NZFARM. To the extent possible, we include likely costs of establishing and administering each policy into the analysis and display changes in nutrient discharges, farm profits, and land use across the different catchment zones modelled in NZFARM.

The baseline calibration and policy scenarios assumptions for the NZFARM modelling are listed in Table 13.

Table 13 NZFARM baseline and policy scenario assumptions, Hurunui-Waiau Catchment

Key Baseline Assumptions	Proposed Policy	Key Policy Assumptions	Catchment Nutrient Measurement	NZFARM Nutrient Reduction Measurement	Nutrient Time Lag from Source to Waterway	Economic Response Time Lag
2010 commodity prices held constant Land use and intensity held constant No water quality policies imposed	HWRRP - Maintains N and P loads at 2010 levels Waitohi Irrigation Scheme – Increases total irrigable area in catchment by about 130%	Commodity prices same as baseline. If regulated, landowners are 100% compliant. Nutrients in the catchment are at the limit and cannot increase	HWRRP load limits of DIN and DRP	Set cap of total N and total P to equal load limits	<7 years	<10 years

Baseline scenario – no water quality policy

The baseline scenario assumes that there is no water quality improvement policy in place. The Hurunui-Waiau catchment comprises nearly 582,000 ha, of which about 31,820 ha are irrigated. Almost all of the catchment's irrigation occurs in the plains region, as this area has the highest productivity and revenue potential. Total net catchment income from land-based operations in the baseline case is estimated at $240 million NZD. Total N leached is about 2,930 tonnes/yr while P loss is about 45 tonnes/year. This equates to an average of 5.0 kgN/ha and 0.07 kgP/ha across all land in the catchment. A summary of the key baseline economic and environmental outputs is listed in Table 14. It is these figures that the policy scenarios are compared to.

Table 14 Key outputs for Hurunui-Waiau Catchment: No policy

Net Revenue (million $)	N Leaching (tonnes)	P Loss (tonnes)	Total GHGs* (tonnes)	Net GHGs* (tonnes)	Irrigated Area (hectares)
$240.0	2,930	45	1,572,300	956,970	31,820

* Total GHGs are greenhouse gas emissions from on-farm activities. Net GHG emissions include the annual increment in carbon sequestration from forests and scrub.

The enterprise areas in Hurunui-Waiau catchment are shown in Figure 5. Dryland sheep and beef farming dominate the region, especially in the hills and foothills. A majority of the dairy production currently takes place in the plains region, as it is heavily reliant on access to water. With the exception of some forest plantations in the foothills, nearly all the non-sheep and beef production in the catchment occurs in the plains regions, which have access to irrigation and overall better growing conditions.

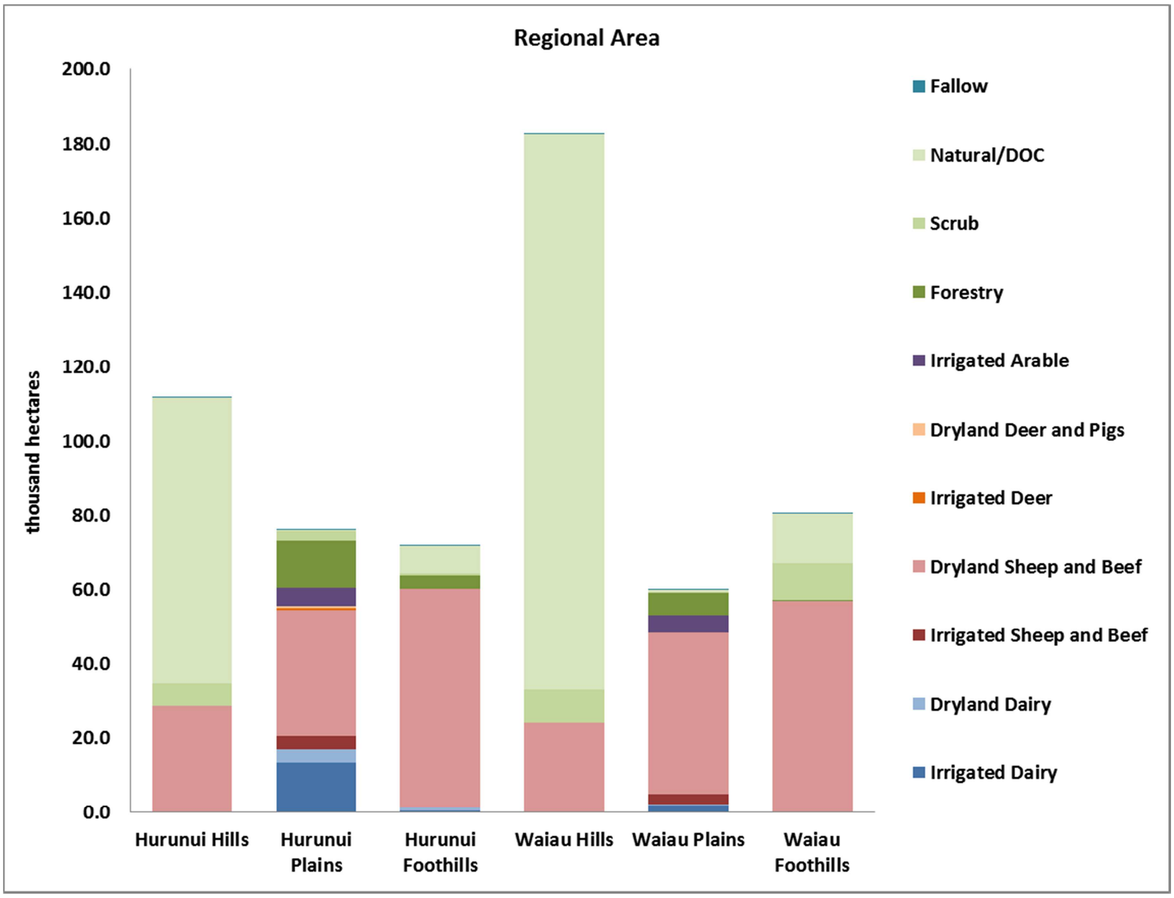

Figure 5 Regional enterprise area (‘000 ha), Hurunui-Waiau Catchment: No policy

The variation in N leaching and P loss rates on a kg per ha basis is shown in box plots in Figure 6 and Figure 7, respectively. The box plots enclose 50% of the data. The top and bottom of the box mark the limits of ± 25% of the variable population. The lines extending from the top and bottom of each box mark the minimum and maximum values within the data set that fall within an acceptable range. Any value outside of this range, called an outlier, is displayed as an individual point.

These figures illustrate how nutrient leaching rates can vary widely for the same enterprise because of differences in location, stocking rate, soil type, irrigation scheme, fertiliser application, and management practices. The spread in N leaching rates for dairy indicates that it has the greatest mitigation potential on a per hectare basis, while sheep and beef has the greatest P mitigation potential. Additional data outlining the net revenue produced per kg nutrient leached is presented in Appendix F.

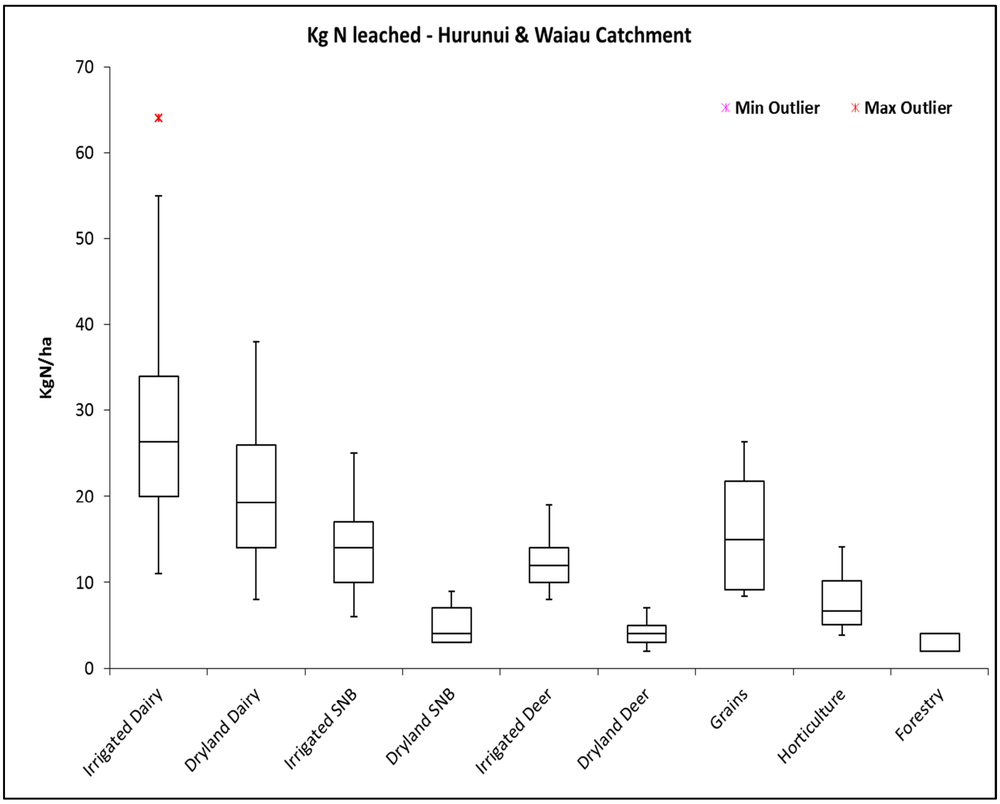

Figure 6 Range of N leaching rates (kgN/ha) for key enterprises in Hurunui-Waiau catchment (SNB refers to sheep and beef; grains refer to arable)

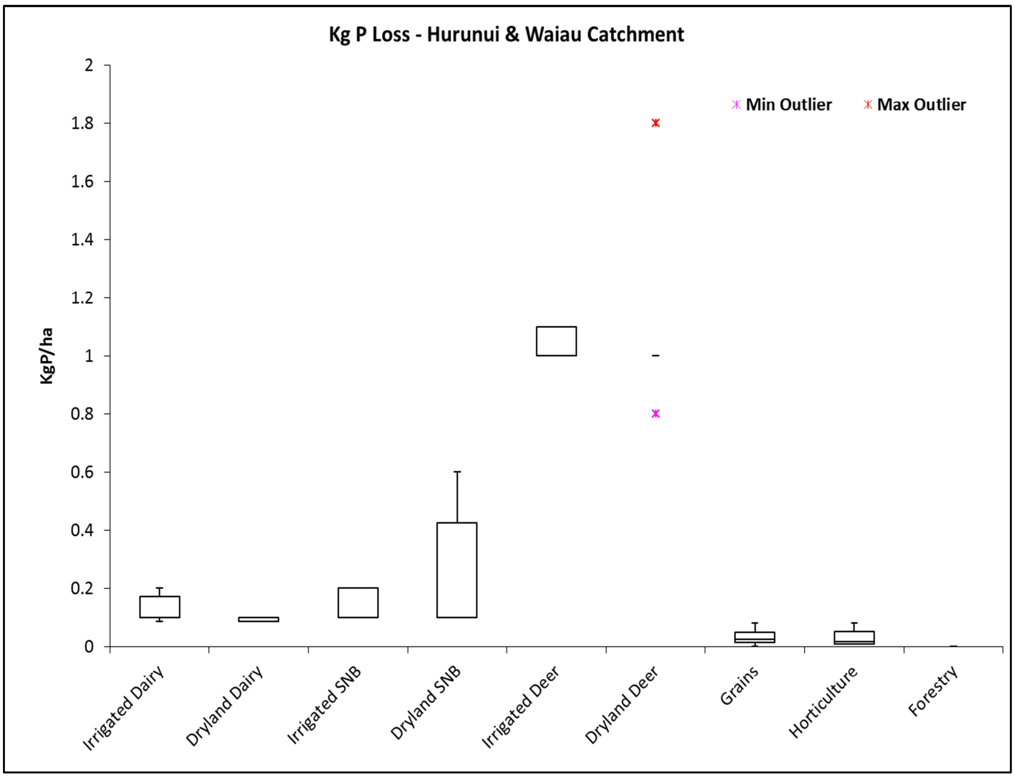

Figure 7 Range of P loss rates (kgP/ha) for key enterprises in Hurunui-Waiau catchment (SNB refers to sheep and beef; grains refer to arable)

Waitohi irrigation scenario – no water quality policy

We model the economic and nutrient discharge impacts of the Waitohi Irrigation Scheme in the absence of any nutrient limits. Key outputs listed in Table 15 indicate that the 186% increase in irrigated land results in a 10% increase in net catchment revenue and a 27% increase for landowners in the Hurunui Plains. Figure 8 shows how the enterprise mix would change in the catchment. Most of the change is the conversion of dryland to irrigated sheep and beef, with additional dairy and arable land being added primarily through deforestation. Changes in land use intensity also increase N leaching by 24% and 58% for the total catchment and Hurunui Plains, respectively. P losses also increase by 4% for the catchment and 59% for the Hurunui Plains. These estimates indicate that an irrigation scheme without any mechanism to constrain nutrient loads will negatively impact water quality.

Table 15 Key outputs for Hurunui-Waiau Catchment and Hurunui Plains: Waitohi Irrigation Scenario

	Net Revenue (million $)	N Leaching (tonnes)	P Loss (tonnes)	Total GHGs (tonnes)	Net GHGs (tonnes)	Irrigated Area (hectares)
Total Catchment						
Estimate	$264.3	3,620	46.8	2,053,800	1,644,800	73,170
Change From Baseline	10%	24%	4%	31%	72%	130%
Hurunui Plains						
Estimate	$114.8	1,870	4.5	1,154,800	1,154,800	63,530
Change From Baseline	27%	58%	59%	142%	148%	186%

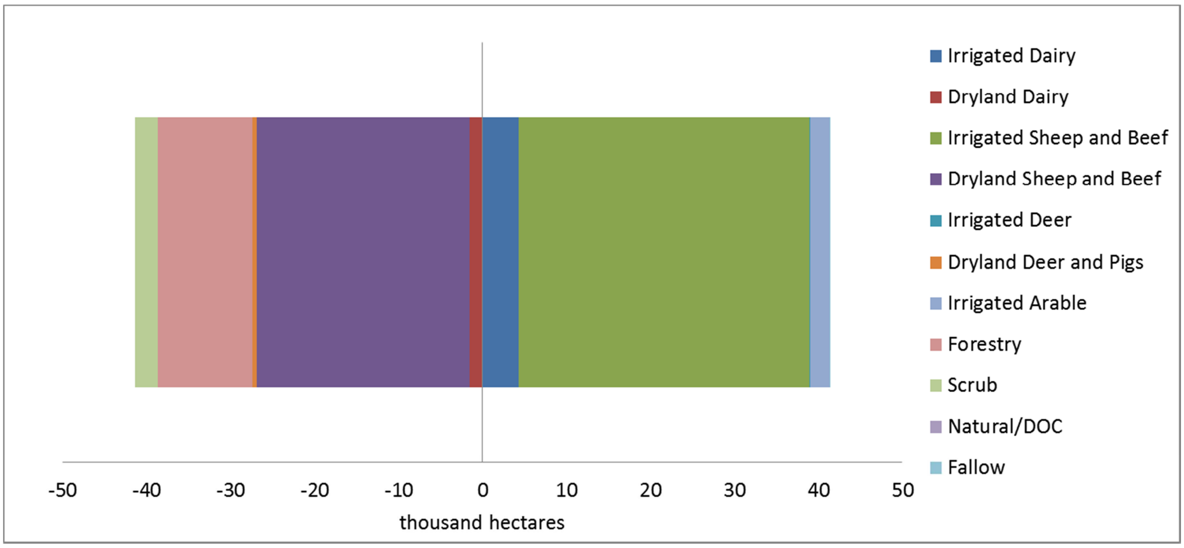

Figure 8 Change in aggregate enterprise area (‘000 ha) from baseline: Waitohi Irrigation Scheme

Given that an increase in irrigated land will mean that nutrient targets will not be met will have a number of implications, including:

i) Increases in the frequency and duration of nuisance periphyton blooms in both the main stem of Hurunui River and its tributaries;
ii) Increases in the frequency and duration of breaches of nitrate toxicity criteria (i.e. Hickey & Martin (2009) criteria used in HWRRP development), particularly in the Hurunui tributaries, some of which already regularly breach these criteria. The Hurunui main stem (e.g. at State Highway 1) would push closer, but may stay below, toxicity criteria;
iii) Reduced mauri, aquatic ecosystem health and biodiversity value as a result of (i) and (ii) above;
iv) Reduced amenity and recreation (swimming, angling) value as a result of (i) above.

Therefore, if the Waitohi Irrigation Scheme were implemented, a policy would need to be implemented to maintain water quality levels at 2010 levels.

Policy #1. Uptake of Good Management Practices (GMPs) without Waitohi Irrigation Scheme

For this policy, we quantify the net costs and effectiveness of existing pastoral enterprises adopting different GMPs. This could be achieved through voluntary or regulatory approaches. This assessment uses data collated for the NZFARM model plus additional information on stock exclusion from waterways (fencing) and riparian planting, which are the two GMPs not represented in NZFARM (see Section 2.6).

For this analysis, we assume that land use remains at baseline (2010) land use but management practices can change. For all land where a mitigation practice is not but could be applied, we compare nutrient losses and profits with and without the GMP. These results are then aggregated to sector level to obtain the total catchment estimate. The estimates for dairy and other pastoral farms for each GMP at the catchment level are shown in Table 16, while estimates for each region are listed in Appendix F. The analysis assumes 100% adoption of each GMP, allowing us to estimate the technical potential for each management practice. These figures can be adjusted downward for voluntary approaches where 100% adoption is unlikely. The assumed adoption rates are outlined in Table 11. There is a large variation in nutrient reductions, costs, and profits resulting from the implementation of different GMPs.

For the dairy sector, reducing fertiliser use reduces N losses 8–18% and profits 4–10%. Applying DCDs could increase profits 8% because of improved pasture growth and reduce N losses by 21%. Feedpads reduce N losses by 15% with about a 1% increase in profits. Wintering off reduces N losses by 38% with a 23% decrease in profits. Combining wintering off with either DCDs or a feedpad for dairy farms gives some additional mitigation and in most cases, reduces the total costs because of some of the productivity benefits. Of the GMPs considered, only reducing stocking rate, constructing feedpads, fencing streams, or doing riparian planting reduce P losses.

For other pastoral enterprises, only a small fraction of sheep, beef, and deer pasture is intensively fertilised. The area where fertiliser applications could be reduced is in the Hurunui and Waiau Plains, resulting in a 7–16% reduction in N leaching and a corresponding reduction in profits of 5–9%. DCDs could be applied but they do not produce the same returns for sheep and beef as for the dairy sector. For sheep and beef N leaching was reduced by 20% with profits also decreasing by 17%. Fencing streams or riparian planting are the only two GMPs considered that can impact both N and P, reducing profits by 8–18%.

Table 16 Estimated nutrient reductions of GMPs for pastoral enterprises in Hurunui-Waiau Catchment

GMP	Voluntary Adoption Rate	Area ('000 ha)	Decrease in N leaching (t)	Decrease in P losses (kg)	Change in N (%)	Change in P (%)	Average cost ($/kgN)	Average cost ($/kgP)	Total Cost ($'000	Profit Chg (%)
					Dairy					
DCD	50%	13	-130	0	-21%	0%	-23	-	-3050	8%
Feedpad	75%	13	-95	-205	-15%	-15%	-5	-2132	-438	1%
DCD + Winter off	50%	13	-329	0	-52%	0%	12	-	3879	-9%
Feedpad + Winter off	50%	13	-298	-205	-47%	-15%	31	45202	9280	-23%
Fertiliser to 80%	75%	18	-63	0	-8%	0%	35	-	2198	-4%
Fertiliser to 60%	75%	19	-121	0	-16%	0%	35	-	4276	-8%
Fertiliser to 50%	0%	19	-145	0	-18%	0%	37	-	5313	-10%
Wintering off	50%	13	-240	0	-38%	0%	38	-	9088	-23%
Max Stocking Rate of 3 cows/ha	0%	4	-125	-430	-53%	-50%	42	12302	5290	-36%
Exclude Stock via Fencing	100%	1	-1	-21	0%	-1%	44	2591	53	-1%
Riparian Planting	50%	9	-12	-516	-1%	-23%	83	1967	1015	-3%
					Sheep, Beef, Deer, and Pigs					
Fertiliser to 80%	25%	3	-4	0	-7%	0%	39	-	160	-5%
Fertiliser to 60%	25%	3	-9	0	-16%	0%	31	-	271	-8%
Fertiliser to 50%	25%	3	-9	0	-16%	0%	35	-	325	-9%
Exclude Stock via Fencing	60%	152	-152	-3846	-12%	-9%	44	1720	6615	-8%
Riparian Planting	50%	127	-152	-9616	-12%	-23%	83	1306	12555	-18%
DCD	50%	251	-140	0	-20%	0%	85	-	11864	-17%

By combining feasible GMPs for all pastoral farms in the catchment we estimate the reduction in nutrient losses from voluntary and regulatory approaches (Table 17). This assessment maximises reductions of N leaching and P losses but does not necessarily minimise costs to the landowner. The latter issue is addressed in detail in the analysis of the various cap-and-trade policies below.

The impact of GMPs is determined using a weighted average of adoption by GMP, as described in Section 2.6. The nutrient reductions associated with the most effective GMPs (i.e. DCDs and riparian planting) on approximately 50% of the eligible land area reduces N leaching by 6% and P losses by 11%. Profit for the landowners who have implemented these practices is expected to decline by about 11%.

If all landowners in the catchment were regulated and required to apply DCDs and undertake riparian planting, and all dairy farmers had to winter their cows off the farm, then N leaching would be reduced by about 18% and P losses would decline by about 23% (Table 15). This would reduce net catchment revenue by 14%. It would impose costs on the regulatory agency to monitor and enforce the compulsory adoption of these practices.

Table 17 Estimated nutrient reductions of most effective voluntary and regulatory GMPs (by level of reduction) in Hurunui-Waiau Catchment

Measure	Adopt Rate	Area (k ha)	N Chg (t)	P Chg (t)	N Chg (%)	P Chg (%)	Avg Cost ($/kgN)	Avg Cost ($/kgP)	Total Cost ($ mil)	Profit Chg (%)
DCD + Riparian Planting	50%	132	-220	-5	-6%	-11%	52	1720	11.2	-11%
DCD + Riparian Planting+ Wintering Off	100%	264	-630	-10	-18%	-23%	46	1306	29.3	-14%

Following the loading limits specified in the HWRRP, N and P have to be maintained at current levels to meet water quality standards in the region. Based on the NZFARM baseline estimates of total N and total P from land-based sources we estimate that total nutrient loads are approximately 2,930 tN/yr and 45.2 tP/yr. Increasing irrigation to levels estimated under the Waitohi scheme could mean nutrients increase by 690 tN/yr and 1.6 tP/yr in the Hurunui catchment.

If 50% of farmers voluntarily adopt the GMPs that produce the largest nutrient reductions (i.e. applying DCDs and undertaking riparian planting on pasture) then N leaching could be reduced by about 220 tN/yr from baseline estimates and P losses could be reduced by about 5 tP/yr. This would provide some leeway for land use intensity to occur in the catchment, but not at the levels expected with the Waitohi Irrigation Scheme as N targets would not be met. Landowners that implement these practices could see profit reductions of about 11%, although this would vary by farm location and enterprise.

If Environment Canterbury required through regulation all farms in the Hurunui-Waiau catchment had to apply DCDs, plant riparian strips along their streams and, if applicable, winter dairy cows off farm, it could reduce N leaching by 630 tN/yr and P loss by 10 tP/yr (Table 15). Requiring the adoption of these GMPs could reduce N losses to levels close to those required to meet the nutrient limits outlined in the HWRRP, even if the Waitohi Irrigation Scheme is implemented. Our estimate of N leaching is about 10% above the 2010 nutrient target suggesting that additional changes in land management is likely needed, or that some land use change is necessary to meet the nutrient limits. As we do not track all possible GMPs that could be utilised in the catchment (optimal effluent management, improved irrigation, etc.), it is possible that these additional nutrient reductions could be achieved using a larger list of acceptable GMPs.

Policy #2. Implement nutrient cap-and trade programme with Waitohi Irrigation Scheme

A cap-and-trade programme is often considered as one of the mechanisms to meet nutrient targets as it provides flexibility to landowners allowing them to cost-effectively meet their targets rather than requiring all landowners to meet individual targets on their own land (i.e., command and control). This option has been investigated for a number of nutrient reduction targets in New Zealand and is currently being implemented in the Lake Taupo catchment (Environment Waikato 2009). We assess three different cap-and-trade programmes within the Hurunui-Waiau catchment with different allocation and trading options.

Farmers are allowed to increase their land use intensity beyond what they hold discharge permits for but they must acquire permits from other landowners in their specified trading area to cover any additional nutrient discharge. This ensures the cumulative nutrient leaching targets for the catchment are met. Some landowners might find it more advantageous (i.e. profitable) to reduce their nutrient leaching intensity and sell excess permits to others, while others will find it profitable to purchase allowances to increase their land use intensity.

The initial allocation of permits for each cap-and-trade programme scenario is outlined in Table 18. The key differences between the scenarios are how the initial permits are allocated and allocated and the region where the trades can occur. Each scenario ensures that the 2010 nutrient reduction target is achieved at the catchment level, but the cost of doing so can vary across different landowners, the community, and waterways. Because the policy applies the polluter pays principle, it does not necessarily protect past capital investment and could cause social disruption and changes in land values. The impact on the individual landowners depends on how permits are allocated and who farmers can trade with.

All scenarios are modelled using NZFARM. While additional nutrient reductions could be achieved from implementing practices not included in NZFARM it is likely that these practices would have to be implemented at costs equal to or greater than the practices modelled here. For example, while riparian planting is an effective way to reduce N leaching and P losses in the catchment, the high unit cost of doing so could make it cost-prohibitive for a cap-and-trade programme that allows landowners to determine their own methods of reducing nutrients on their land. Additionally, as NZFARM is based on the nutrient reductions for representative farms within the catchment it is likely that some farmers could implement a specific GMP more cost-effectively than the representative farm.

Table 18 Initial allocation of nutrient discharge permits (tonnes/yr) and eligibility for trading across regions for cap-and-trade programmes: Hurunui-Waiau Catchment

Cap-and-trade Scenario		Hurunui Hills	Hurunui Plains	Hurunui Foothills	Waiau Hills	Waiau Plains	Waiau Foothills
Number of Farms		17	250	135	23	187	111
Baseline Total N		275	1182	239	404	615	212
Baseline Total P		14.4	2.8	5.9	14.4	0.6	7.1
Catchment-wide Grandparenting		← Trading permitted across all regions in catchment →					
Initial Permits	Total N	275	1182	239	404	615	212
	Total P	14.4	2.8	5.9	14.4	0.6	7.1
Zone-Restricted Trading		↻	↻	↻	↻	↻	↻
		Trading only allowed within same zone					
Initial Permits	Total N	275	1182	239	404	615	212
	Total P	14.4	2.8	5.9	14.4	0.6	7.1
Equal Allocation Approach			← Trading only in two specified regions →				
Initial Permits	Total N	275	1203	221	404	452	208
	Total P	14.4	3.7	5.0	14.4	0.6	7.1

Policy #2a. Grandparenting allocation with catchment-wide cap-and-trade programme

For this scenario, each landowner is allocated permits based on the nutrient losses associated with their baseline (2010) enterprise mix. This allocation option is often referred to as grandparenting, and allows existing land uses to continue at the owners discretion, but only within the property's existing discharge permit. Because the cap on nutrient loads is fixed at 2010 levels, landowners are only constrained if they increase the nutrient intensity of their enterprise mix. This is likely to occur if the Waitohi Irrigation Scheme was implemented.

We estimate the economic and environmental impacts on the catchment if the irrigation scheme is implemented, but landowners are required to meet the nutrient load targets outlined in the HWRRP. That is, all landowners are allocated permits equal to their 2010 leaching levels and can buy or sell these permits at the catchment level. A sensitivity analysis where nutrient loads are capped between 10 and 80% below baseline levels is presented in Appendix B to highlight the possible non-linear response of land use, land management, and farm profitability under a more constrained nutrient policy scenario.

Key outputs for this policy and its comparison to the baseline are listed in Table 19. Changes in enterprise area across the six regions of the Hurunui-Waiau catchment are shown in Figure 9. Estimates indicate that it is possible to add additional irrigation in the Hurunui Catchment and still meet the catchment's nutrient targets. However, the increase in catchment net revenue are reduced from +10% to +6% (i.e. the Waitohi Irrigation Scheme with and without a catchment nutrient limit), while revenue gains in the Hurunui Plains is reduced from +27% to +18%. Allowing trading across the catchment encourages landowners in the Hurunui Plains to increase their land use intensity by purchasing permits from other regions, mostly from the Waiau Plains, thereby maintaining relatively high gains in profit. This makes sense given that many GMPs can be undertaken in plains at relatively low cost (Appendix B). More detail on the optimal distribution[18] of nutrient permits for this and other cap-and-trade policy scenarios is shown in Appendix C.

Table 19 Key outputs for Hurunui-Waiau Catchment and Hurunui Plains: Grandparenting allocation with catchment-wide cap-and-trade and Waitohi irrigation scheme

	Net Revenue (million $)	N Leaching (tonnes)	P Loss (tonnes)	Total GHGs (tonnes)	Net GHGs (tonnes)	Irrigated Area (hectares)
Total Catchment						
Estimate	$255.0	2,930	45.1	1,707,000	987,900	69,840
Change from Baseline	6%	0%	0%	9%	3%	119%
Hurunui Plains						
Estimate	$107.2	1,371	4.1	787,500	787,500	60,190
Change from Baseline	18%	16%	44%	65%	69%	171%

[18] This is similar to the equilibrium distribution of permits after trading takes place. Likewise, if permits were allocated in this manner initially, no trades would be made as the market would already be in equilibrium.

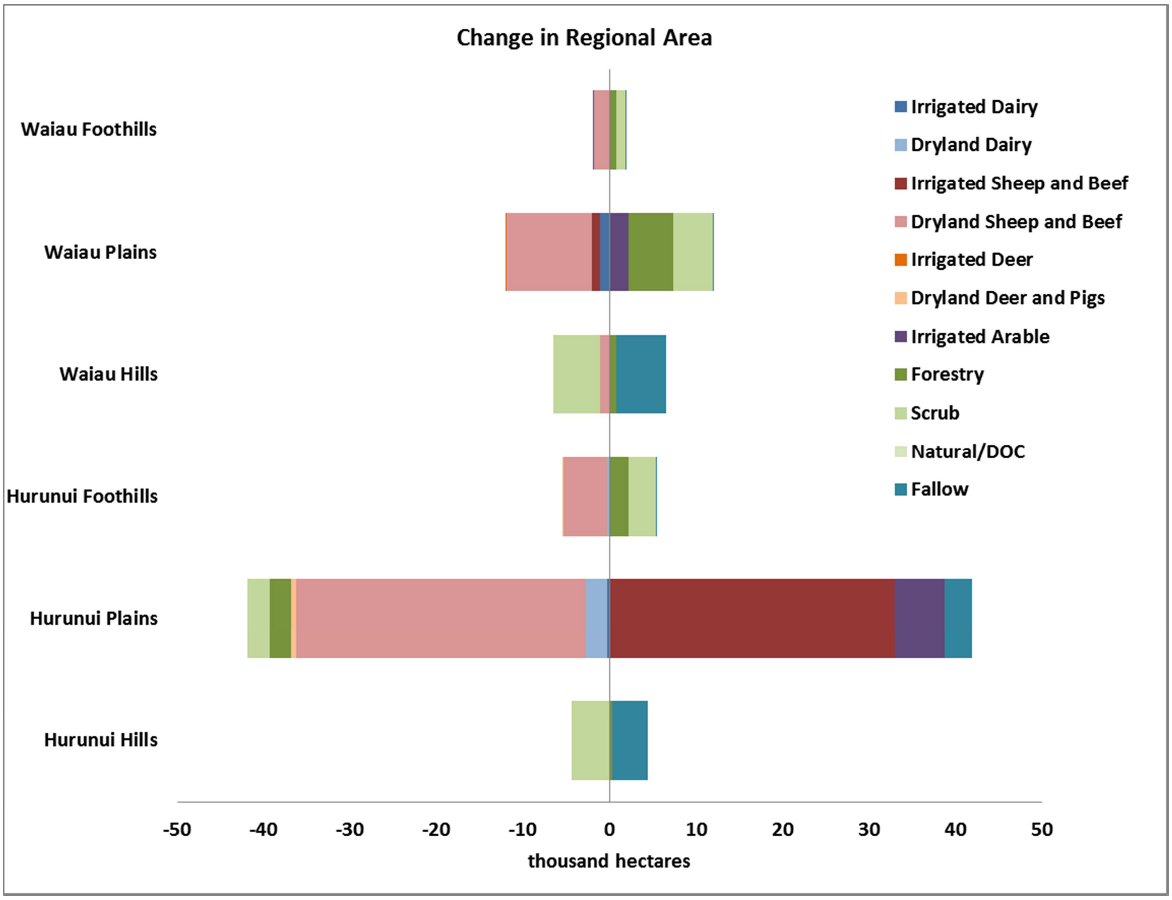

Figure 9 Change in aggregate enterprise area (‘000 ha) from baseline: Grandparenting allocation with catchment-wide cap-and-trade and Waitohi irrigation scheme

A grandparenting allocation with trading across the entire catchment is likely to be one of the more economically efficient policy options for the catchment as a whole, but it does impact on the landowners, community, and waterways. For example, landowners in regions that sell their permits would only choose to reduce their nutrient loads beyond the required target if there is a net gain in income from doing so. Therefore, the more permits a landowner is allocated, the more opportunity they have to either meet their nutrient reduction target or go beyond the target and sell these reductions to other landowners.

The distribution of the regional costs and benefits of the policy, including administrative and transaction costs, changes in profits for farmers from production changes and the buying and selling of permits in the catchment, is shown in Figure 10. As expected, landowners in the Hurunui Plains benefit the most. The Waiau Plains also benefit positively, even when accounting for transaction costs, because they are able to sell excess permits at a higher price than the cost of reducing nutrients. All the other regions face a slight loss if the possible transaction costs for becoming eligible to participate in the trading programme are accounted for. Hence, some financial assistance might be necessary to entice landowners from regions that are not at the limit to become active participants in the cap-and-trade programme. Summing across all cost and benefits yields a 5% benefit to the catchment over the pre-Waitohi Irrigation Scheme baseline scenario.

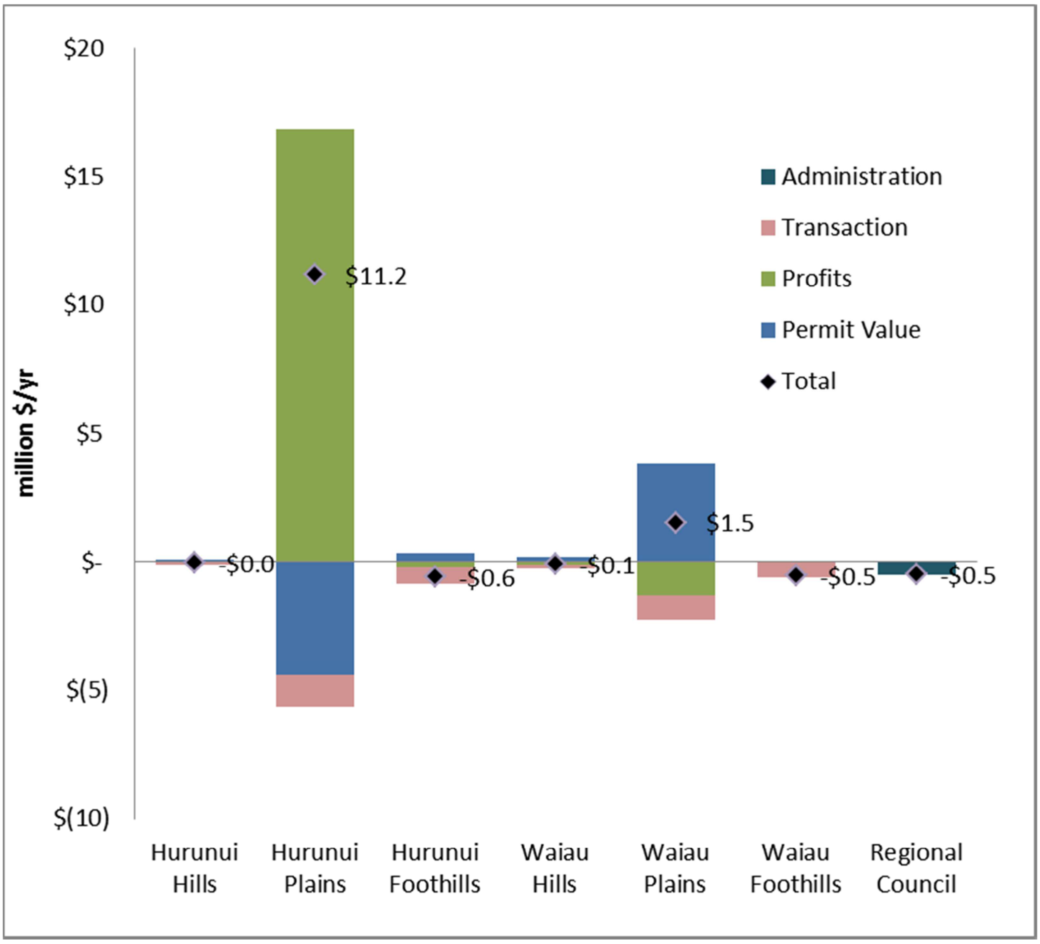

Figure 10 Regional distribution of costs and benefits: Grandparenting allocation with catchment-wide cap-and-trade and Waitohi irrigation scheme

It should be noted that meeting the nutrient discharge targets at the catchment level does not necessarily mean that water quality will be maintained for every sub-catchment in the Hurunui-Waiau catchment. First, if N and P loads to the Hurunui Plains streams, drains and groundwater increase by 16% and 44% respectively (Table 17), it is unlikely that the water quality load limits (N and P) and the in-river objectives these are designed to achieve (i.e. defined outcomes for periphyton, mauri, ecosystem health, biodiversity, amenity and recreation) would be met. Tributaries in the Hurunui Plains that experience increases of nutrients at these levels are likely to face the following consequences Norton and Kelly (2010):

i) Significant increases in the frequency and duration of nuisance periphyton blooms in all the Hurunui River tributaries;

ii) Significant increases in the frequency and duration of breaches of nitrate toxicity criteria in the Hurunui tributaries (with the possible exception of Dry Stream);

iii) Reduced mauri, aquatic ecosystem health and biodiversity value as a result of (i) and (ii) above;

iv) Reduced amenity and recreation (swimming, angling) value as a result of (i) above

This suggests that if most sub-catchments in the Hurunui-Waiau catchment were also to maintain 2010 water quality levels, an alternative policy or trading programme design would be needed to account for the likely increase nutrient discharges in the Hurunui Plains.

Policy #2b. Grandfathering allocation with zone-restricted cap-and-trade programme

Policy #2b is similar to policy #2a except permits can only be traded within a given NZFARM zone or region (e.g. Hurunui Foothills) of the catchment rather than anywhere within the grater Hurunui-Waiau catchment. All landowners are still allocated permits to correspond to their 2010 N leaching level, but they can only buy or sell these permits within their zone. This policy is more restrictive, with fewer permits traded in a local market and possibly higher permit costs. It may also be more costly to administer because the regulatory agency would have to oversee six trading markets instead of one catchment-wide market. However, there could be an advantage from a water quality perspective as the policy avoids some possible "local hot spot" water quality degradation that may result from trades occurring in different parts of the catchment.

Key outputs for this policy and its comparison to the baseline are listed in Table 20. The change in enterprise area in the Hurunui Plains relative to the baseline is shown in Figure 11. All other zones in the catchment maintain their baseline land use and management mix because they were already at the optimal level of production and are not required (or incentivised through trading) to reduce their nutrient loads. Estimates indicate that it is still possible to add additional irrigation in the Hurunui Plains, but not as much as that planned through the Waitohi Irrigation Scheme. Changes in net revenue are smaller than the catchment-wide trading policy as landowners in the Hurunui plains can only trade with the Hurunui plains and subsequently are likely to pay higher costs of mitigation. As a result, there is a higher investment in forestry with less conversion to dairy. Additionally, farmers are willing to leave some pastures fallow while intensively farming other parts to reduce their overall nutrient leaching rates.

Table 20 Key outputs for Hurunui-Waiau Catchment and Hurunui Plains: Grandparented allocation with zone-restricted cap-and-trade programme with Waitohi irrigation scheme

	Net Revenue (million $)	N Leaching (tonnes)	P Loss (tonnes)	Total GHGs (tonnes)	Net GHGs (tonnes)	Irrigated Area (hectares)
Total Catchment						
Estimate	$250.9	2,930	45.2	1,639,000	921,800	60,900
Change from Baseline	5%	0%	0%	4%	-4%	91%
Hurunui Plains						
Estimate	$101.4	1,181	2.8	545,800	431,800	51,230
Change from Baseline	12%	0%	0%	14%	-7%	131%

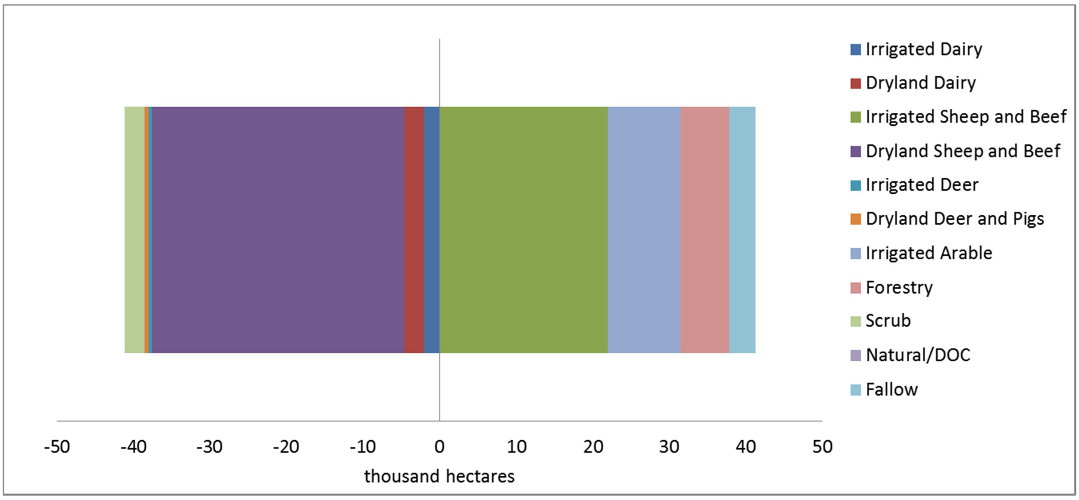

Figure 11 Change in aggregate enterprise area ('000 ha) from baseline: Grandparented allocation with zone-restricted cap-and-trade programme with Waitohi irrigation scheme

The zone-restricted trading programme has minimal on waterways in the catchment, as permits can only be traded within a given zone and therefore nutrients discharges will be maintained at 2010 levels for all NZFARM zones. The only region in the catchment that is really affected by this scenario is the Hurunui Plains, as this is where the Waitohi Irrigation Scheme will be located. The distribution of the costs and benefits of the policy to the landowners from the administrative and transaction costs, and changes in profits from changing production levels and buying and selling permits, as well as regional council costs to administer the programme, are shown in Figure 12. Subtracting the administration and transaction costs from the higher farm profits gives a 4% increase in net catchment revenue compared the baseline (i.e. 2010 land use and production with no Waitohi Irrigation Scheme). Farmers in the Hurunui Plains are still expected to experience an overall benefit from a zone-based cap-and-trade programme, but profits are about 13% less than the catchment-wide trading policy (#2a).

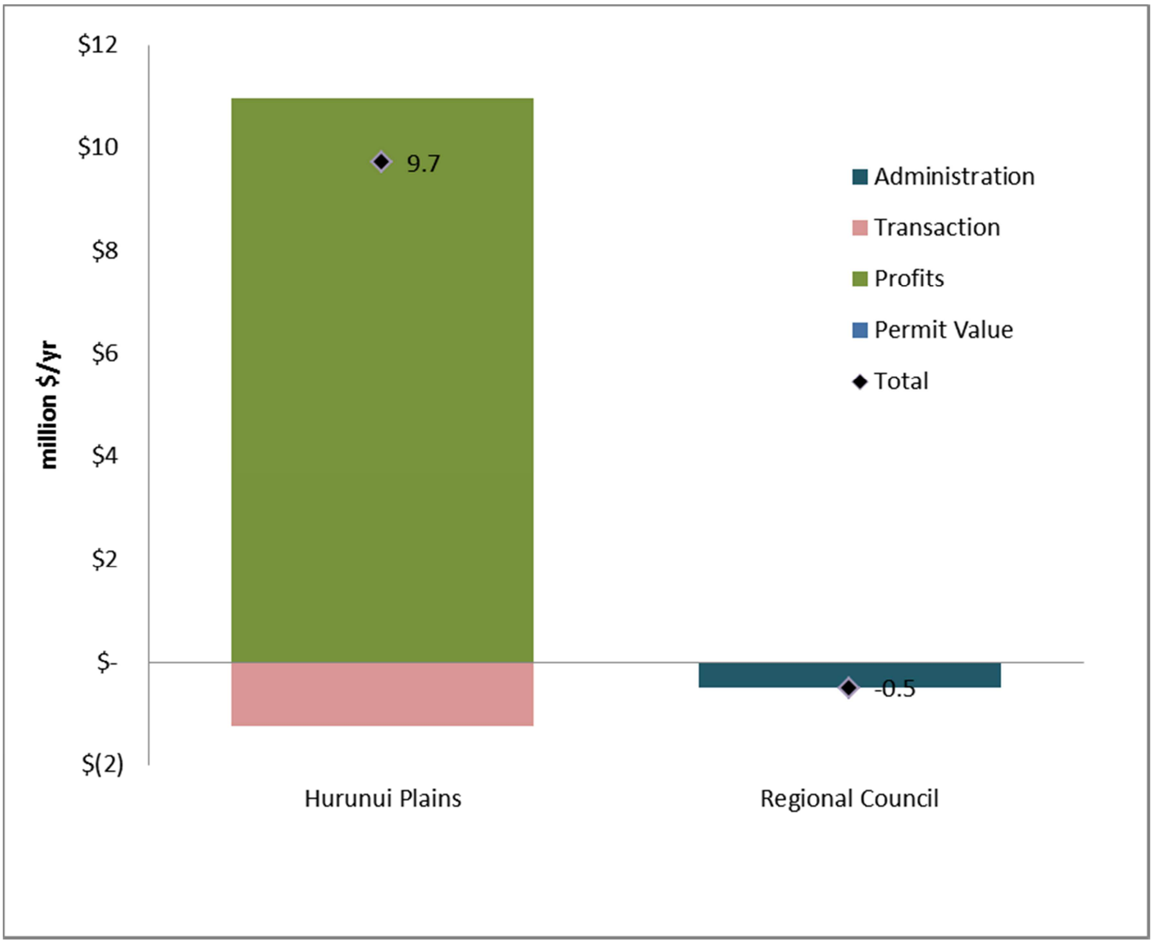

Figure 12 Regional distribution of costs and benefits: Grandparented allocation with zone-restricted cap-and-trade programme with Waitohi irrigation scheme

Policy #2c. Environment Canterbury equal allocation with catchment-wide cap-and-trade programme and Waitohi Irrigation Scheme

The equal allocation cap-and-trade programme is an alternative way to allocate permits. It was developed for Environment Canterbury for situations where catchments were approaching or already over possible nutrient limits (Lilburne & Webb 2012). This proposal is essentially a modified version of an 'averaging' allocation approach where the total permissible load in a "nutrient management zone" (NMZ) is divided equally on an aerial basis between all landowners. The equal allocation modification reduces the permits allocated on land with lower potential production capacity (e.g. hillier and colder area) by reducing the permits allocated for this land below the catchment average as they are assumed to be lower leaching. All land classified as having lower potential production (LPL) capacity is allocated the same per hectare number of permits. Conversely, higher potential productivity land (HPL) is allocated more permits than the catchment average. The benchmark target (kg/ha) will vary between NMZs according to the catchments' water quality objective, derived load limit, and measured water quality target. In some NMZs, the allocated permit levels may be constraining for landowners, while in others there may be the potential for some lower production capacity landowners to still intensify. The programme considers the natural capital of the land by allocating fewer permits to lower potential production areas. This is intended to encourage landowners of good quality land to increase or maintain high levels of intensification (with corresponding higher nutrient losses), thereby maximising productivity in the catchment at a lower environmental cost.

We assessed the equal allocation approach using the following steps. First, all landowners from the Waiau catchment were exempted from the trading programme as this was a separate NMZ that is assumed to remain in compliance as they are unaffected by the new irrigation scheme. Second, landowners on lower potential production capacity land and the conservation estate in the Hurunui Hills region were also excluded from the cap-and-trade programme because they are assumed to have few opportunities to intensify their farms. Third, farmers in the Hurunui Foothills region are designated as being in a LPL area of the NMZ while farmers in the Hurunui Plains are designated as being in the HPL area of the NMZ. The adjustments made for the purpose of this modelling exercise are not exactly how the equal allocation approach would be implemented in reality though. This is because the boundaries for the NZFARM zones do not directly line up with the LPL and HPL boundaries in the Hurunui NMZ. Regardless, this scenario does provide an illustration of the range of impacts that are likely to occur using this approach relative to the other cap-and-trade allocation schemes presented above.

Based on these specifications, landowners located in the Hurunui Plains are allocated permits at an equal (benchmark) leaching rate of 10.5 kgN/ha and 0.06 kgP/ha, while those in the foothills are allocated 5.4 kgN/ha and 0.06 kgP/ha.[19] As with the catchment-wide cap-and-trade policy (policy #2a), landowners are allowed to trade across regions; however, because only the Foothills and Plains regions have been allocated permits in this scenario there is a limited trading area. In this scenario, irrigation is still permitted to increase to the levels estimated under the Waitohi Scheme provided landowners can meet their nutrient targets.

Key outputs for this policy and its comparison to the baseline are listed in Table 21. The change in enterprise area in the Hurunui Plains and Hurunui Foothills relative to the baseline case is shown in Figure 13, as these are the only two regions able to trade permits in this scenario. Allowing trading between the two regions leads to larger increases in net revenue, irrigated area, and GHG emissions relative to the region-restricted cap-and-trade policy (policy #2b). Because irrigated dairy is estimated to have a two- to three-fold higher N leaching rate than the average leaching rate for irrigated sheep and beef and arable crops in the Hurunui Plains, landowners find it more economical to expand these enterprises when facing nutrient load restrictions. NZFARM also estimates that the value of a permit is \$24.50/kg for N and \$200/kg for P. That is, landowners would be willing to pay up to these prices, at the margin, to increase their nutrient discharge as they will could produce additional profit for at least the value of the permit.

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[19] These figures were estimated based on the detailed allocation calculations outlined in Lilburne and Webb (2012).

Table 21 Key outputs for Hurunui-Waiau Catchment and Hurunui Plains: Equal allocation with cap-and-trade programme with Waitohi Irrigation Scheme

	Net Revenue (million $)	N Leaching (tonnes)	P Loss (tonnes)	Total GHGs (tonnes)	Net GHGs (tonnes)	Irrigated Area (hectares)
			Total Catchment			
Estimate	252.4	2,930	45.2	1,687,900	1,350,000	63,900
Change from Baseline	5%	0%	0%	7%	41%	101%
			Hurunui Plains			
Estimate	103.3	1,203	3.7	638,200	572,700	54,300
Change from Baseline	14%	2%	32%	33%	23%	145%

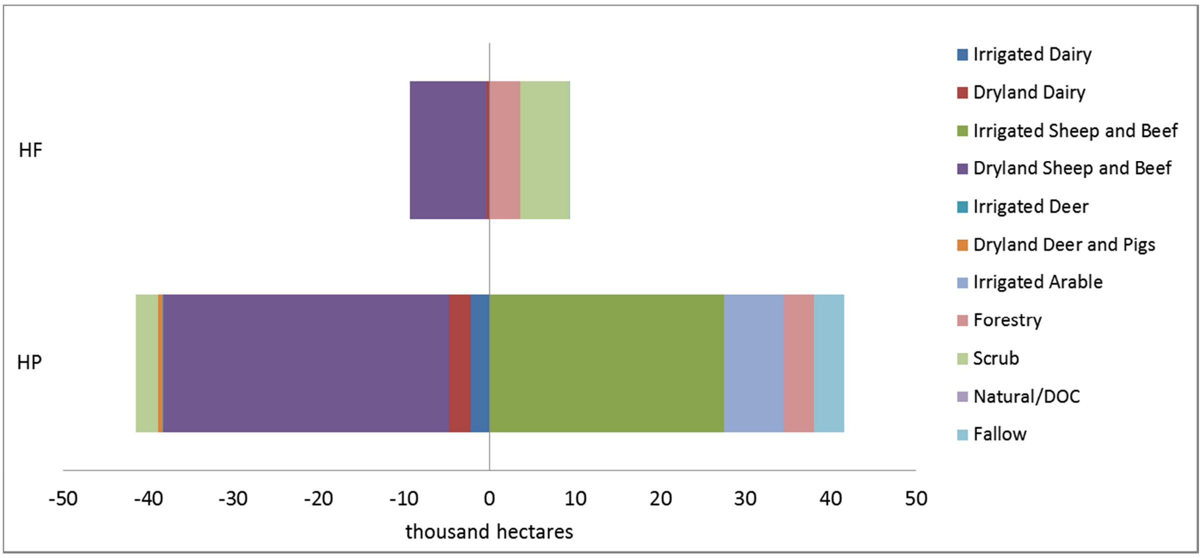

Figure 13 Change in aggregate enterprise area ('000 ha) from baseline: Equal allocation with cap-and-trade programme with Waitohi Irrigation Scheme

The equal allocation approach with a trading programme should have less of an impact on the water quality in the catchment relative to the catchment-wide trading scheme, primarily because there are less permits being purchased by farmers in the Hurunui Plains. N leaching in the Hurunui Plains only increases 2%, but P is still expected to increase by 32%. The relatively high increase in P could result in observable impacts in the local streams such as excessive plant growth that could reduce the recreational and aesthetic values of the region and possibly affect fish and other aquatic animals.

A distribution of the costs and benefits of the policy, including the administrative and transaction costs, and changes in profits for farmers in the two areas of the catchment affected by this policy, is shown in Figure 10. As with the other two cap-and-trade programmes (policies #2a and #2b), landowners in the Hurunui Plains still benefit from adding irrigation and improving intensity, even in the face of nutrient discharge limits.. Farmers in the Hurunui Foothills do not benefit after possible transaction costs associated with being involved in the trading programme are accounted for.[20] If transaction costs were refunded or subsidised for participants in the foothills, they might be more willing to participate in the programme as any change in profit would be more than offset by the price they sell their excess permits for. Summing across all costs and benefits categories yields a 4% increase in revenues for the catchment over the scenario without the Waitohi Irrigation Scheme.

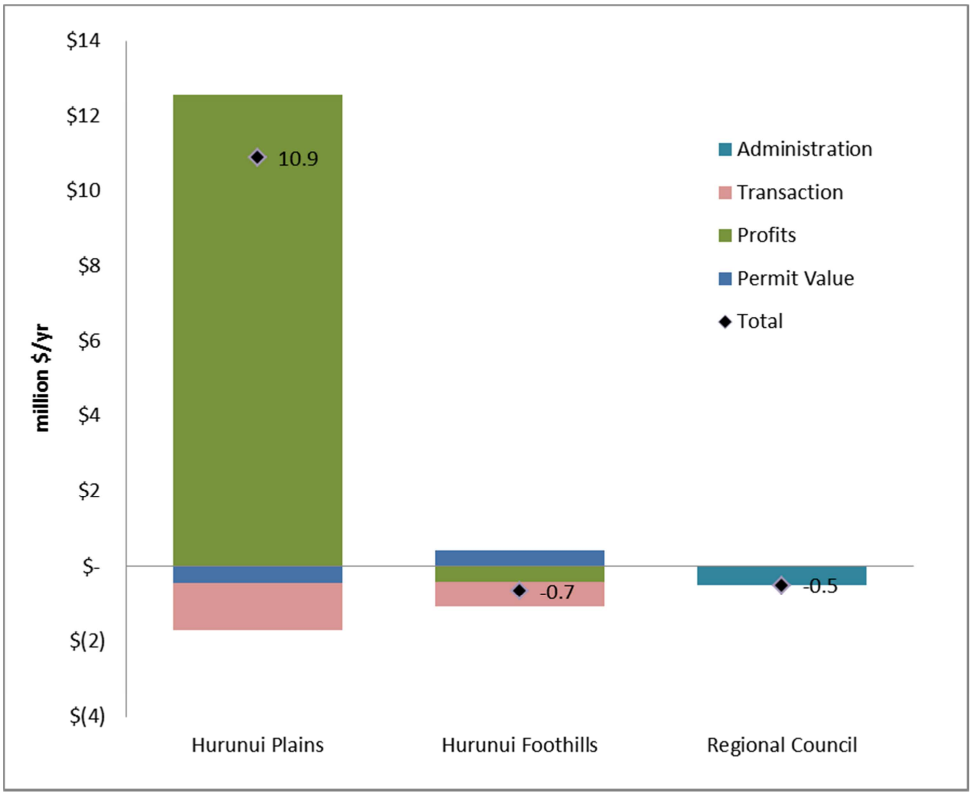

Figure 14 Regional distribution of costs and benefits: cap-and-trade programme Equal allocation with with Waitohi Irrigation Scheme

Policy #3 Direct tax on nutrient discharges

This policy puts a flat tax on each kilogram of N and P discharged. Theory states that if the tax is imposed properly, then this should result in a similar outcome as the catchment-wide cap-and-trade policy Weitzman (1974). Of course, this is based on the assumption that the regulatory agency knows the exact marginal abatement costs for nutrients in the catchment, which in reality are difficult to establish ex ante. Where sufficient water is available to increase the irrigation area to the levels proposed under the Waitohi Irrigation Scheme, the

[20] Note that transactions costs are not accounted for in NZFARM. They are added to the analysis after the equilibrium distribution of permits is estimated. If transaction costs detract all landowners in the Hurunui Foothills from trading, then the result would be the same as the region-restricted trading scheme.

optimal tax level would be the same as the shadow (permit) prices estimated under the catchment-wide cap-and-trade programme.

We estimate that a tax of $23.30 per kgN leached and $118.70 per kgP lost would enable some farmers to add irrigation and increase their land-use intensity but still maintain the 2010 nutrient targets stipulated in the HWRRP at the catchment level. While the tax rate is set at the margin, the average cost for many landowners would actually be lower on a $/kg basis. This is because landowners would find it more cost-effective to implement management changes rather than maintain the status quo and pay the tax for discharging the same amount of nutrients as in the baseline.

The tax approach could have a noticeable difference in farm-level impacts relative to the cap-and-trade approach. This is because landowners must pay a direct tax for all their nutrient discharges rather than purchase excess discharge permits from other farms in the catchment. If all the revenue collected from the nutrient tax were recycled back to landowners in the form of a dividend or reduction of other taxes, then the changes in net catchment revenue would be similar to the grandparented cap-and-trade policy (#2a). This is the assumption we use in this report when presenting catchment-wide estimates for policy #3. If not all the taxes collected were recycled back to the landowner, however, the total costs to farmers would be higher under this policy approach. Furthermore, landowners that might not have the ability to implement more cost-effective management practices on their farm could face a potentially high price of maintaining their current operation.

Landowners' responses can also be sensitive to the tax rate, so it is important to ensure that the rate is set at a level to provide the appropriate economic incentives. We conducted a sensitivity analysis around the optimal tax rate needed to maintain 2010 nutrient targets. A tax rate of $16.00/kgN would increase N and P loads by 10% and 5%, respectively. Setting a tax rate of $24.40/kgN and $655/kgP would reduce nutrients loads by about 10%, thereby allowing additional room for increases in land use intensity on some land in the catchment. Note that in some cases, it might not be necessary to set both a tax on N and P to reach both of the required nutrient reduction targets. This is because the changes in land use and land management incentivised by one tax rate could be enough to meet the catchment-wide target for the other nutrient of concern.

In addition to conducting a sensitivity analysis of the tax rate necessary to increase irrigation but maintain nutrient discharges at 2010 levels, we also investigate the potential abatement costs over a range of N and P discharge taxes. The estimated marginal abatement cost (MAC) curve for N is shown in Figure 15, while the MAC for P is shown in Figure 16. Estimates reveal that the responses to the tax are not linear. This indicates it would be difficult to set the optimal tax to achieve desired nutrient reductions ex ante. A policy with the flexibility to adjust the tax rate over time would better ensure that nutrient reduction targets are achieved over the long run. Taking this flexible approach would not be detrimental to water quality in the catchment due to the relatively short lag times for nutrients to reach a water way from its point of discharge.

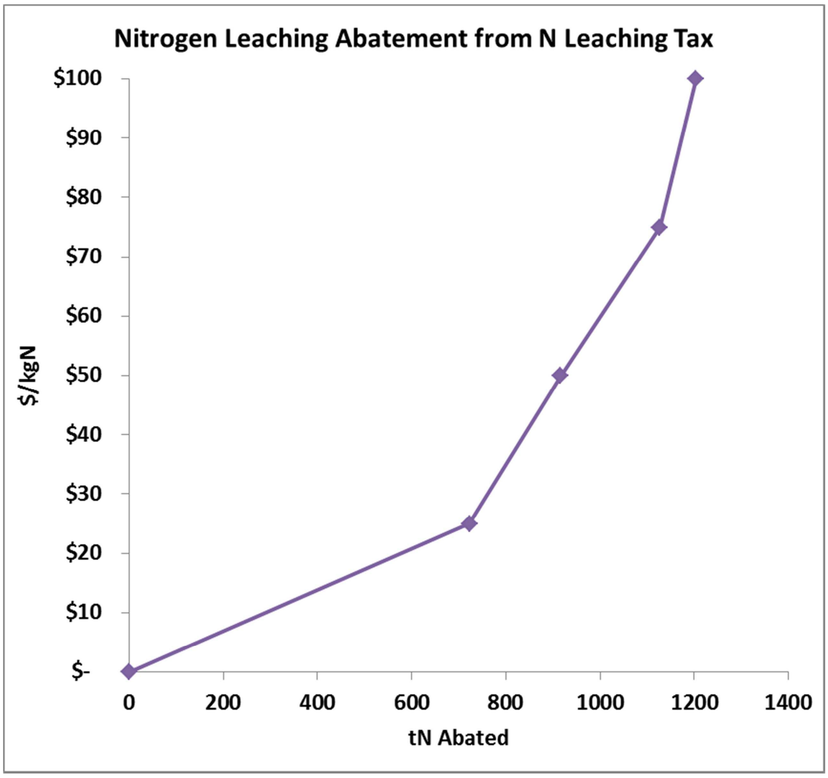

Figure 15 Marginal abatement costs for N leaching: Hurunui-Waiau Catchment

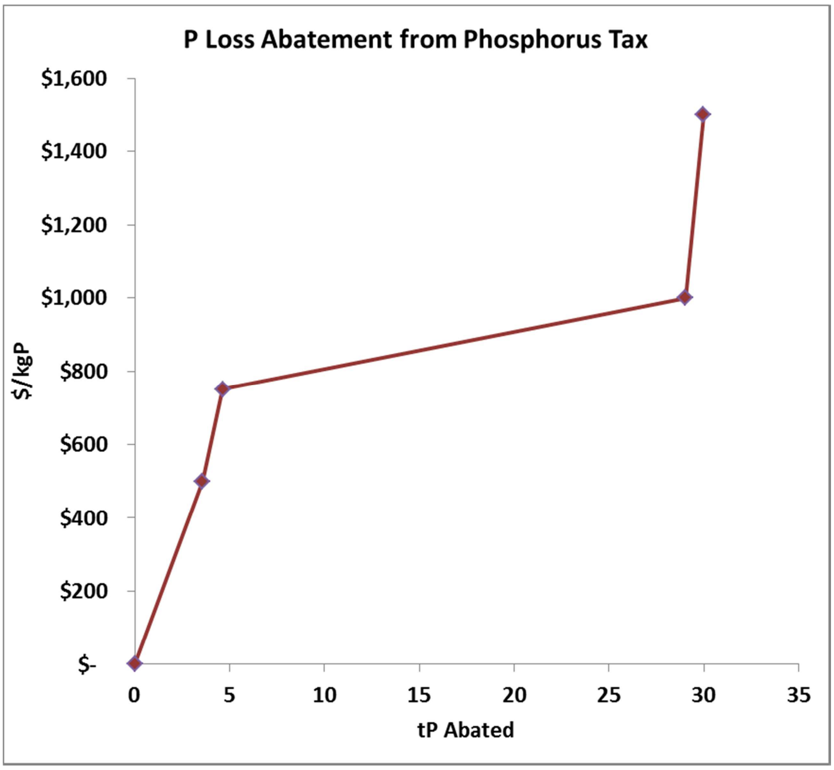

Figure 16 Marginal abatement costs for P loss: Hurunui-Waiau Catchment

Table 22 summarises the key changes in NZFARM outputs from the baseline (i.e. with no Waitohi Irrigation Scheme), and assumes that none of the tax revenue collected by the government is refunded to the landowner. Both revenue and GHGs are more responsive to an N tax than a P tax. This is likely because the assumptions and set of mitigation options included in NZFARM encourage more land-use change in the catchment under the N tax scenario, especially in the Hurunui and Waiau Plains regions. Additional estimates from the varying tax rate scenarios conducted for the Hurunui-Waiau catchment are presented in Appendix B.

Table 22 Key outputs for Hurunui-Waiau Catchment for various N and P tax rates

	Net farm revenue (million $)	Change in N leaching (tonnes)	Change in P losses (tonnes)	Changes in total GHGs (tonnes)	Changes in net GHGs (tonnes)
			$/kgN		
$0	252.4	2,930	45.2	1,687,900	1,350,000
$25	-26%	-25%	-2%	-21%	-92%
$50	-48%	-31%	-6%	-34%	-135%
$75	-68%	-38%	-10%	-45%	-163%
$100	-86%	-41%	-12%	-46%	-158%
			$/kgP		
$0	252.4	2,930	45.2	1,687,900	1,350,000
$500	-9%	-1%	-8%	-6%	-32%
$1000	-17%	-8%	-64%	-14%	-56%
$1500	-20%	-9%	-66%	-15%	-63%

3.5 Summary and Conclusions

In this case study we have considered a number of policies that could achieve nutrient reduction targets in catchment. These policies include the implementation of GMPs, a nutrient cap-and-trade programme with different allocation options, and a tax on nutrient discharges. The water quality limits being discussed for the Hurunui-Waiau catchment are intended to maintain nutrient loads at 2010 levels (Environment Canterbury 2011a). There is also an irrigation project being proposed (i.e. the Waitohi Scheme) for the Hurunui Plains region of the catchment that could nearly double the area of irrigable land in the region (Environment Canterbury 2012).

We assessed a number of variants of each policy and have also assessed the sensitivity of results to different nutrient targets (see Appendices B and C). For each policy we have reported the costs of achieving the nutrient reduction target relative to the no-policy scenario. Where appropriate, we have also reported the estimated land-use change resulting from policy. We do not quantify all the costs the benefits of each policy in dollar terms, rather we report the relative changes in the catchment's nutrient discharges and revenue/profit streams resulting from policy and the complementary long run GHG emissions reductions.

A summary of the water quality scenarios considered for the Hurunui-Waiau catchment is provided in Table 23. The policy scenarios are all compared with a baseline where there is no additional irrigation scheme. Based purely on minimising the cost of the policy, the optimal choice would be to allow the Waitohi Irrigation Scheme to be fully implemented in the catchment, but also to develop a catchment-wide cap-and-trade scheme using a grandparenting allocation approach. Setting a tax of $23 per kgN and $118 per kgP would achieve a similar result, although the impacts could vary at the farm level. Both approaches would enable some farmers to add irrigation and increase their land-use intensity but still maintain 2010 nutrient levels. There may be some adverse water quality impacts for some areas of the catchment should 'hotspots' occur. This would most likely occur in the Hurunui Plains, as this is where the greatest land-use intensification will occur.

Table 23 Summary of water quality policies in Hurunui-Waiau Catchment

Scenario	N Target (tonnes)	% N Target Achieved by 2022	Average Mitigation Cost ($/kg N)	P Target (tonnes)	% P Target Achieved by 2022	Total Annual Cost ($million)	Profit Change from Baseline (%)
Baseline without Waitohi Irrigation Scheme	2930	100%	n/a	45	100%	n/a	0%
Baseline with Voluntary GMP (Policy #1a)	2930	108%	$52	45	104%	$11.2	-5%
Baseline with Regulatory GMP (Policy #1b)	2930	127%	$46	45	111%	$29.3	- 12%
Waitohi Irrigation- No Water Quality Policy	2930	76%	n/a	45	96%	-$24.4	+10%
Waitohi-Catchment-wide Trading (Policy #2a)	2930	100%	n/a	45	100%	-$11.0	+5%
Waitohi-Region-restricted Trading (Policy #2b)	2930	100%	n/a	45	100%	-$9.3	+4%
Waitohi-Equal Allocation Trading (Policy #2c)	2930	100%	n/a	45	100%	-$9.8	+4%
Waitohi-N and P Tax (Policy #3)	2930	100%	n/a	45	100%	-$11.0	+5%

The key findings from the policies assessed for the Hurunui-Waiau catchment are:

- At the catchment level, adding a large irrigation scheme would raise net catchment revenue by 10% through increased production, but would also increase N leaching by 24%, P loss by 4%, and GHG emissions by 72% in the catchment, in the absence of any additional policies to manage water quality and GHG impacts. For the Hurunui Plains, where the irrigation scheme will operate, there would be productivity benefits and increased profits for dairy, sheep and beef, and arable crop farmers who increase their access to water, but N leaching and P loss could both increase by nearly 60%.
- If landowners in the catchment maintained their current land use and adopted GMPs such as applying nitrification inhibitors (DCD), riparian planting, and installing dairy feed pads, it is unlikely the 2010 catchment nutrient loads would be maintained if a large irrigation scheme were implemented (policy #1a-b). The estimated average costs of implementing GMPs are around $50/tN, primarily because of the relatively high cost of these practices for sheep and beef farmers in the catchment.
- Of the policy options modelled, a catchment-wide trading programme with a grandparenting allocation proved to be the most cost-effective[21] for landowners to maintain 2010 catchment nutrient loads with the irrigation scheme implemented. Compared with the baseline, a cap-and-trade programme that allocates permits to landowners based on their 2010 N leaching and P loss levels (i.e. grandparenting) increases net catchment income by 5% (policy #2a). With catchment-wide trading there may still be water quality issues (e.g. localized 'hotspots') in the Hurunui Plains because N leaching is estimated to increase by 16% and P loss by 44% over baseline levels in that area.
- Restricting trading of discharge permits to a specific area of the catchment may reduce the likelihood of 'hotspots', but net revenues only increase by 4% over the baseline (policy #2b).
- We modelled a modified equal allocation approach (policy #2c) where an average permit level per hectare was established and then adjusted for the productive capacity of the land. This generated similar results as a grandfathering allocation with area-restricted trading (policy #2b). Allowing farmers in the more productive Hurunui Plains to purchase permits from landowners in the lower productivity areas (i.e. foothills) would provide flexibility for landowners to increase their own level of nutrient discharges while still meeting 2010 nutrient loads.
- Theoretically, an optimally implemented nutrient tax (policy #3) would produce similar impacts to a catchment-wide cap-and-trade programme (policy #2a, #2c). The N and P tax could, if desired, be varied across different parts of a catchment to meet different water quality limits (policy #2b).
- The optimal N tax rate to maintain nutrients at 2010 levels was to charge all landowners in the catchment $23/kg N and $119/kg P (policy #3). Although this is an 'optimal'

[21] In this report, a 'cost-effective policy' is defined as a modelled policy that achieves the nutrient target in the catchment at the least cost to the landowners. It does not necessarily account for administrative and transaction costs that could make the policy more costly in reality.

solution from a catchment-wide perspective, there could be distributional impacts as not all landowners who would be required to pay the tax would benefit from the new irrigation scheme.

- The marginal costs of abatement for taxes are non-linear making it difficult to establish an optimal tax ex ante. Providing flexibility to adjust the tax over time would better ensure that nutrient load limits are maintained over the long run. If policy makers frequently have to adjust the tax rate, this could generate more economic and social disruption in the transition than a cap-and-trade approach.

4 Case Study #2 Manawatu Catchment, Manawatu-Wanganui

4.1 Introduction

The Manawatu catchment in the North Island's Manawatu-Wanganui region is a river catchment with extensive and intensive land uses. The main water body is the Manawatu River, which runs from hill country in the Tararua ranges to plains and through a gorge to the Palmerston North and coastal side of the catchment. Significant water quality problems already exist in the river driven by both point and non-point source discharges. Water quantity and quality limits setting processes are being developed under the Horizons One Plan (Horizons Regional Council 2012).

The catchment is approximately 575,000 ha in size and land use is divided by 17% dairy, 57% sheep and beef, 18% natural, and 8% other land use categories (arable, horticulture, deer, etc.). Figure 17 shows land use in the catchment as of 2007. About 6,000 ha of the catchment are irrigated for dairy, while all other production is achieved through dryland farming systems.

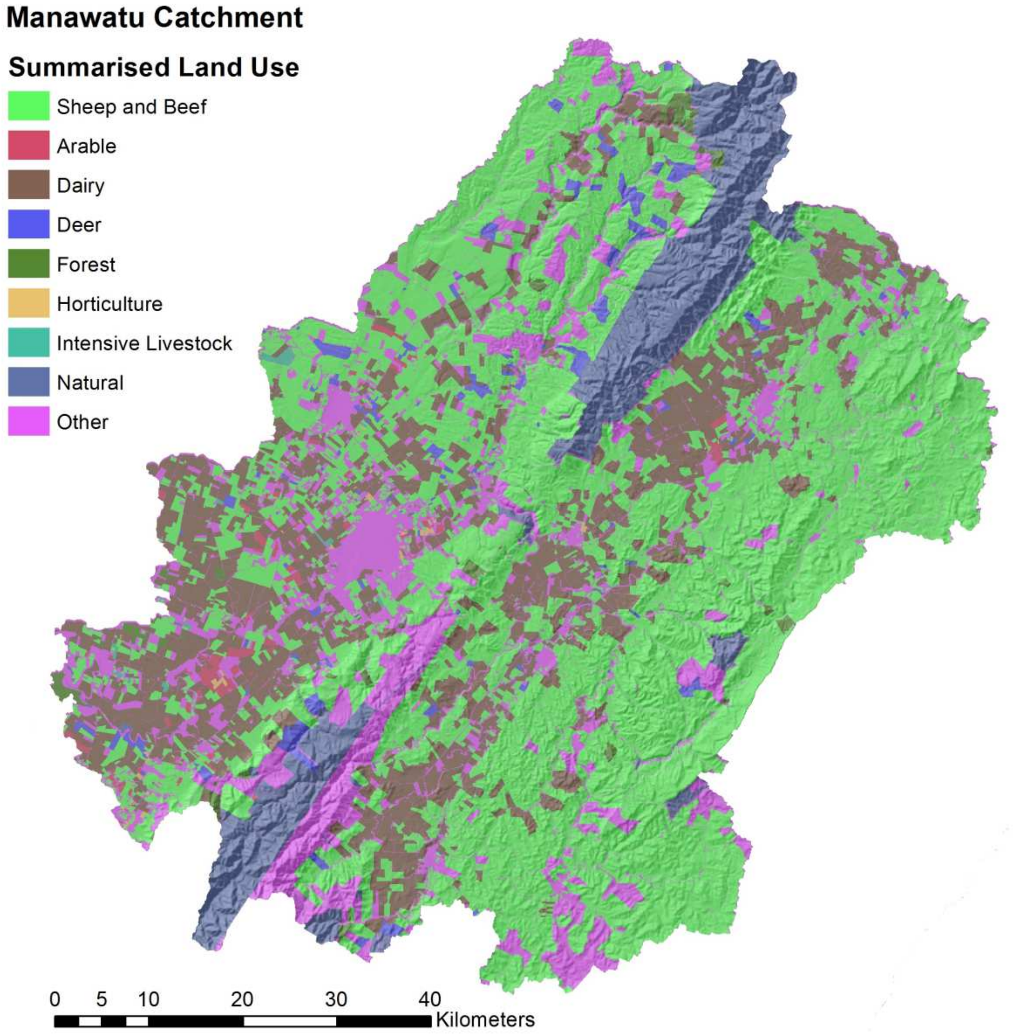

Figure 17 Baseline land use in Manawatu Catchment (Agribase 2007)

Ngāti Kahungunu, Rangitane, Ngāti Raukawa, Ngāti Kauwhata and Muaūpoko all have interests in the Manawatu catchment area and play a significant role as kaitiaki in the catchment. A number of issues of significance to hapū and iwi are identified in the Horizon's One Plan (Horizons Regional Council 2010). The lack of recognition of the special qualities of water, particularly Wai Māori (pure water), in water management policy and planning is a high priority issue in the region. Wai Māori must be maintained for hapū and iwi to be able to carry out traditional cultural activities. Iwi are calling for better management of hazardous substances and nitrate run-off to avoid water pollution, to have the effects of pollution from land uses in the region on traditional food gathering areas, native habitats and ecosystems to be recognised, and for more comprehensive monitoring and enforcement of environmental standards set in plans and consents (Horizons Regional Council 2010).

4.2 Water Management Issues

The state of the Manawatu River has changed over time. The catchment has been modified through land-use change and flood and drainage control works. Water quality concerns have emerged because of both point and non-point source discharges in the catchment. Many of the rivers and lakes have been deemed unsafe for swimming or food gathering, and aquatic life is being damaged (Manawatu River Leaders Accord 2011). Clothier et al. (2007) found that 90% of nitrogen in the Manawatu River is from two main types of non-point sources – dairy, and sheep and beef farming. Dairy alone is responsible for contributing about half the N loading in the river.

Horizons Regional Council (HRC) has recognised the need to limit and reduce nutrient loading in the river to control and improve water quality in the region. Revisions to the draft Horizon's One Plan introduces rules to limit nutrient leaching from dairy farms in targeted catchments. HRC have set the cumulative leaching limits (expressed as kg/ha/yr) based on the soil's Land Use Capability (LUC) classification, as listed in Table 24. Dairy farms in targeted catchments will be required to prepare a nutrient budget and nutrient management plan, and implement practicable farm management practices to minimise nutrient leaching. New dairy farms will be required to comply with the listed nitrogen leaching rates, while all dairy farms in targeted catchments will be required to exclude cattle from all permanent waterways.

Table 24 Horizons One Plan dairy farm nitrogen leaching limits (kgN/ha) for each land use capability class (LUC)

LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII
30	27	24	18	16	15	8	2

HRC has also proposed nutrient concentration targets for rivers that must be met and these new N leaching rules are a key mechanism to meet river based concentration goals. Additional changes to farm management practices and/or limits to further expansion or intensification of nutrient intensive farming could be required to meet the large nutrient reduction targets outlined as part of the One Plan (Ausseil & Clark 2007).

This case study uses an agri-environmental economic model, NZFARM, to investigate some of the economic and environmental impacts of reducing nutrient discharges to from diffuse sources in the Manawatu catchment. For the modelled policy assessment, we assume that the water quality limits for the entire Manawatu catchment would require a reduction of N leaching by 53% and P losses by 49%, similar to those specified by Horizons Regional Council (Ausseil & Clark 2007). Various targets have also been proposed on smaller water management zones in the catchment (Table 24). We also assume that the entire limit would have to be achieved through mitigation from the land-use sector based on the fact that 90% of nitrogen in the Manawatu River is from two main types of non-point sources – dairy, and sheep and beef farming (Clothier et al. 2007). Incorporating additional sources and mitigation options could alter the estimates presented in this report.

We investigate a series of water quality improvement policies, many of which are supported through the use of instruments such as implementing GMPs, various cap-and-trade schemes, and a nutrient discharge tax. As mentioned above, a portion of the policy outlined in the December 2010 version (the Decisions Version) of the proposed Horizons One Plan required that new dairy farms demonstrate compliance with cumulative nitrogen leaching maxima that vary with Land Use Capability (LUC) classification (i.e. natural capital approach), as shown in Table 24. In this report, we evaluate a slightly different set of policy options that follow a natural capital approach by estimating the impacts of a policy where *all* dairy farms must comply with LUC based nitrogen leaching caps,[22] plus an additional policy that requires all pastoral and arable farms to comply. Both these policies also assume that landowners can trade nutrient discharge permits. The baseline scenario modelled assumed that the proposed water quality policy had yet to be implemented. Additional details on the policies modelled are provided in Section 4.4.

[22] This policy option is not the same as the policies for diffuse discharges in the notified version, neither is it the same as that in the decisions version of the Proposed One Plan.

Table 25 Regional nutrient reduction targets for the Manawatu Catchment

NZFARM Catchment Zone	Water Management Zone	Soluble Inorganic Nitrogen	Dissolved Reactive Phosphorus	Total N	Total P
Tararua Hills	Upper Manawatu	-66%	-9%	-64%	-25%
	Tiraumea	-62%	-41%		
Tararua Flats	Mangatainoka	-52%	-10%	-59%	-10%
	Upper Manawatu	-66%	-9%		
Manawatu Hills	Upper Gorge	-39%	-57%	-32%	-42%
	Middle Manawatu and Pohangina	-26%	-26%		
Manawatu Flats	Lower Manawatu	-71%	-88%	-53%	-80%
	Oroua	-68%	-86%		
	Coastal Manawatu	-21%	-67%		
Entire Catchment	Manawatu	n/a	n/a	-53%	-49%

Source: Ausseil & Clark (2007)

4.3 Data for Manawatu Catchment

NZFARM accounts for all the major land uses and enterprises in the Manawatu catchment. Key enterprises include dairy, sheep, beef, deer, timber, maize, wheat, and fruit. There are 16 enterprises tracked in the model across 4 catchment zones (Figure 18). Every catchment zone comprises a subset of these enterprises depending on the land capability (e.g. slope, soil type, access to water, etc.) in each catchment zone and enterprises present in the baseline (2007 reference year).

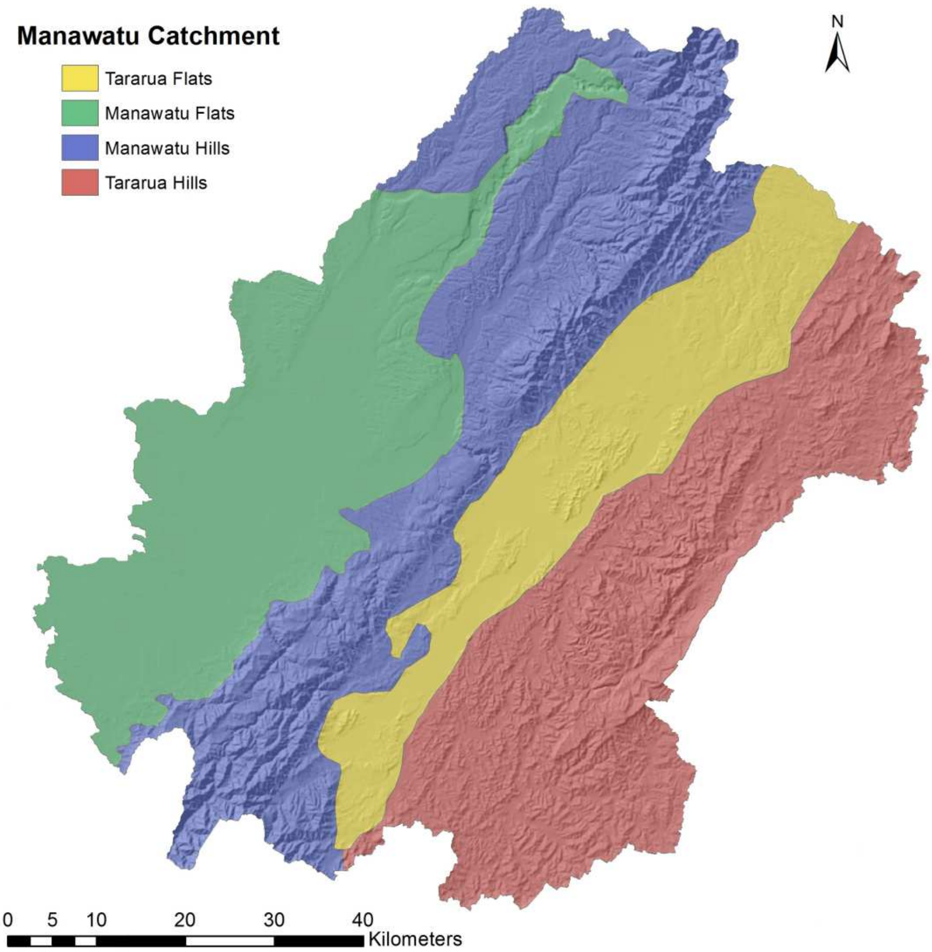

Figure 18 NZFARM catchment zones for the Manawatu Catchment

Each enterprise requires a series of inputs to maximize production yields. The high cost of given inputs coupled with water and input constraints can limit the level of output from a given enterprise. Outputs and prices for pastoral and arable enterprises are primarily based on data provided by Lincoln University (Lincoln University 2007), Ministry of Agriculture and Forestry (MAF) farm monitoring reports (MAF, 2007a), and the 2007 Situation and outlook for New Zealand Agriculture and Forestry (MAF, 2007b). All figures are listed in 2007 New Zealand dollars (NZD). Stocking rates for pastoral enterprises were established to match regional figures included in the FARMAX model (Bryant et al. 2010). Fertilizer application rates were derived from a survey of farmers in each catchment. Forestry yields were obtained from Kirschbaum and Watt (2011) with timber and pulp prices obtained from MAF (2010b).

Specific enterprises also face fixed and variable costs ranging from stock replacement costs to deprecation. These costs were obtained from farm consultants (Greg Sheppard and Brian Clarke, pers. comms.), the MAF farm monitoring report (MAF, 2007a) and Lincoln University (2007). The costs for each enterprise varied across the catchment. A scenario that adjusts the input costs or output prices or adds environmental constraints for a given NZFARM region in the catchment would change the distribution of enterprises (and their aggregate area), but total land area remains unchanged across all model scenarios.

Data on environmental output coefficients were obtained from several sources. N and P leaching rates for all pastoral and arable enterprises in the Manawatu catchment were taken from OVERSEER (2010), except for potatoes, which were estimated using SPASMO (Clothier et al. 2008). N leaching from pine plantations and native vegetation were based on an average from the literature (e.g. Parfitt et al. 1997; Menneer et al. 2004). We assumed no P loss from plantations or native forest lands.

GHG emissions for most enterprises were derived using the same methodology as the New Zealand GHG Inventory (NZI), which follows the IPCC's *Good Practice Guidance* (2000). Pastoral emissions were calculated using the same emissions factors as the NZI, but applied to per hectare stocking rates specific to the catchment. Forest carbon sequestration rates were derived from regional lookup tables (Paul et al. 2008). All emission outputs are listed in tonnes of CO_2 equivalent (CO_2e). To be consistent with the NZI (MfE 2011), we convert all emissions to CO_2e using 100 year global warming potentials of 21 for CH_4 and 310 for N_2O.

4.4 Water Quality Policy Scenario Analysis

This study models the impacts of several water quality policy scenarios that range from placing caps on N leaching and P losses to requiring GMPs on all farms. Most water quality policies assessed using NZFARM include ways to reduce nutrient losses by (1) requiring specific targets to meet regional water quality standards, (2) imposing an environmental tax on farming outputs (e.g. $/kgN/ha leached), or (3) mandating the use of specific management practices. Where data and methods were not available to model the policy explicitly, we rely on alternative literature sources to provide a mix of quantitative estimates and qualitative discussion. The explicit policies investigated for the Manawatu Catchment include:

1. Implementation of good management practices
2. Cap-and-trade programme with varying allocation
3. Direct tax on nutrient discharges

As discussed above, NZFARM estimates on-farm nutrients in the form of total N leached (kgN/ha) and total P loss (kgP/ha) using biophysical models such as OVERSEER and SPASMO. The translation of on-farm leaching cannot be directly translated to water quality impacts without the use of hydrological models that can distinguish between exports (nutrients discharged from the land) and loads (nutrients reaching the water body). As discussed Chapter 2, we assume a lag time of 7 years or less for the catchment, which corresponds to the length of time NZFARM is parameterised to simulate for long-run farmer responses to policy changes. Additionally, because many of the estimates presented are from NZFARM the modelling outputs should be interpreted as relative changes rather than absolute values. This approach also allows us to use total N and total P as a proxy for measuring changes in water quality because the percentage change at the point of discharge should be in line with the relative change in the amount of nutrients reaching the waterways over the long run, given the assumption of small lag times and constant attenuation rates.

The effectiveness of the each policy is assessed by comparing nutrient losses between current levels (i.e. the baseline) and each scenario and the cost of achieving a policy. The cost component primarily consists of reductions in farm profit estimated using NZFARM. To the extent possible, we include likely costs of establishing and administering each policy into the analysis and display changes in nutrient discharges, farm profits, and land use across the different catchment zones modelled in NZFARM.

The baseline calibration and policy scenarios assumptions for the NZFARM modelling are listed in Table 26.

Table 26 NZFARM baseline and policy scenario assumptions

Key Baseline Assumptions	Proposed Policy	Key Policy Assumptions	Catchment Nutrient Reduction Measurement	NZFARM Nutrient Reduction Measurement	Nutrient Time Lag from Source to Waterway	Economic Response Time Lag
2007 commodity prices held constant Land use and intensity held constant No water quality policies imposed	Reduced N by 53% and P by 49%	Commodity prices same as baseline. If regulated, landowners are 100% compliant. Nutrients in the catchment are over-allocated and must be reduced	One Plan concentrations for Soluble Inorganic Nitrogen and Dissolved Reactive Phosphorus	Set % change in total N and total P equal to % change in concentration to meet limits	< 7 years	< 10 years

Baseline scenario – no nutrient reduction policy

NZFARM calibrates the baseline to mimic the distribution of the aggregate enterprises for each catchment zone in 2007, as shown in Figure 17. Total catchment income in the baseline is estimated at $301 million NZD. Total N leached is about 5,400 tonnes/yr, while P loss is about 380 tonnes/year. This equates to an average of 9.4 kgN/ha and 0.7 kgP/ha when all land in the catchment is included. A summary of the key economic and environmental outputs in the baseline is listed in Table 27. All policy scenarios are then compared to the baseline.

Table 27 Key outputs for Manawatu Catchment: No Policy Scenario (Baseline)

Net Revenue (million $)	N Leaching (tonnes)	P Loss (tonnes)	Total GHGs* (tonnes)	Net GHGs* (tonnes)	Irrigated Area (hectares)
$301.0	5,400	380	3,168,000	2,107,000	5,900

* Total GHGs are greenhouse gas emissions from on-farm activities. Net GHG emissions include the annual increment in carbon sequestration from forests and scrub.

The distribution of enterprises tracked in NZFARM is shown in Figure 19. Dryland sheep and beef farming dominate the region, although there are large areas of dairy in the “flats” catchment zones. The “hills” catchment zones also contain some natural bush and scrub along the ridges. All catchment zones contain a small area of forestry plantations. Arable cropping is undertaken primarily in the Manawatu flats, and consists of potatoes, maize, and wheat.

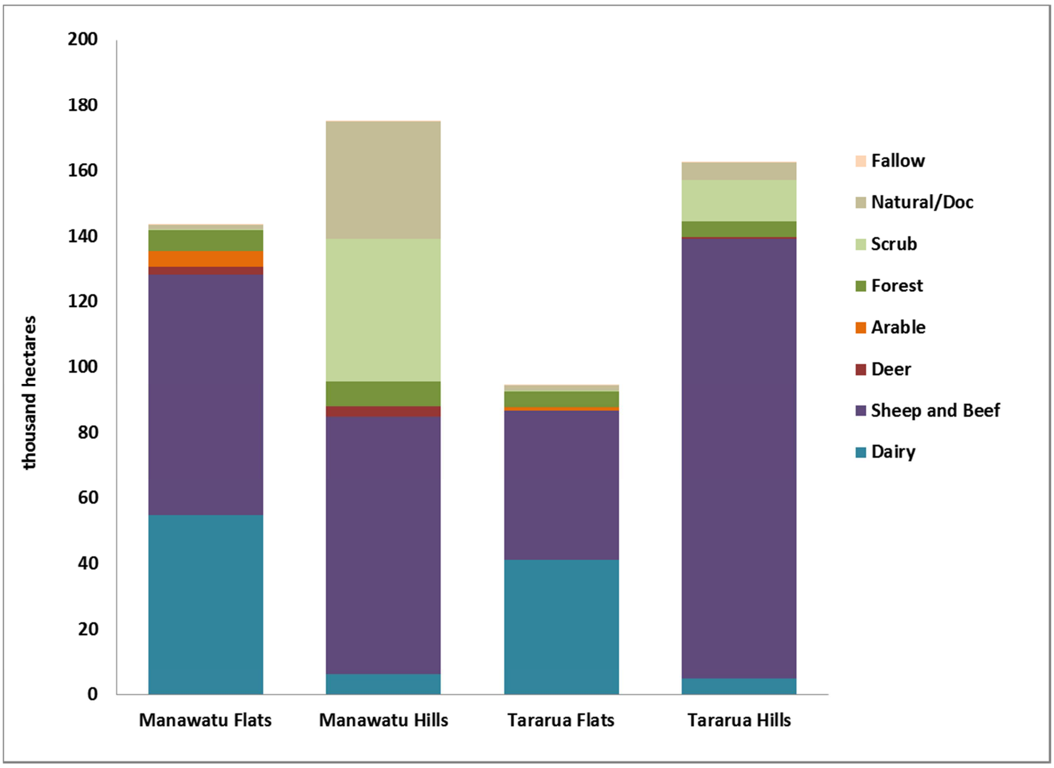

Figure 19 Regional enterprise area (‘000 ha), Manawatu Catchment: No policy scenario

The variation of N leaching and P loss rates on a kg per ha basis are shown as box plots in Figure 20 and Figure 21, respectively. The box plots enclose 50% of the data. The top and bottom of the box mark the limits of ± 25% of the variable population. The lines extending from the top and bottom of each box mark the minimum and maximum values within the data set that fall within an acceptable range. Any value outside of this range, called an outlier, is displayed as an individual point.

These figures demonstrate the variability in nutrient leaching rates for the same enterprise across the catchment. This relates to differences in stocking rate, soil type, irrigation scheme, fertiliser application, and mitigation options implemented. The large spread in N leaching rates for grains and horticulture indicates that it has greater mitigation potential on a per-ha basis compared with other enterprises, while sheep and beef and deer have the best mitigation potential for P. Some of these options will be discussed more explicitly in the policy analysis below. The profit per kg nutrient leached is presented in Appendix F.

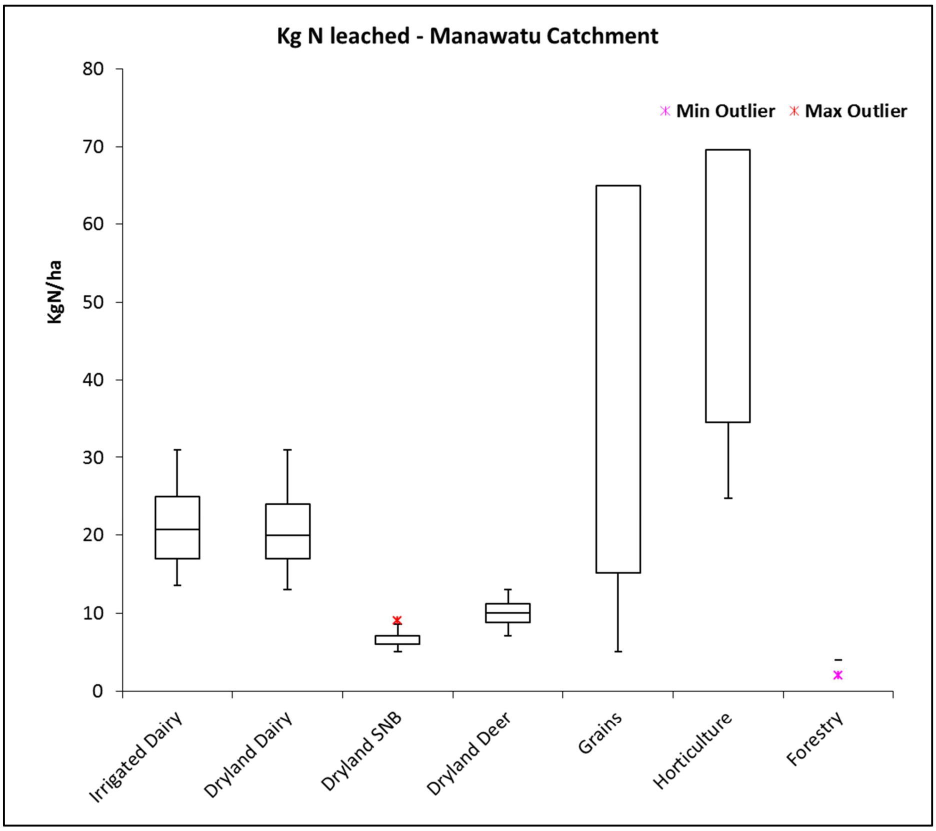

Figure 20 Range of N leaching rates (kgN/ha) for key enterprises in Manawatu catchment (SNB refers to sheep and beef)

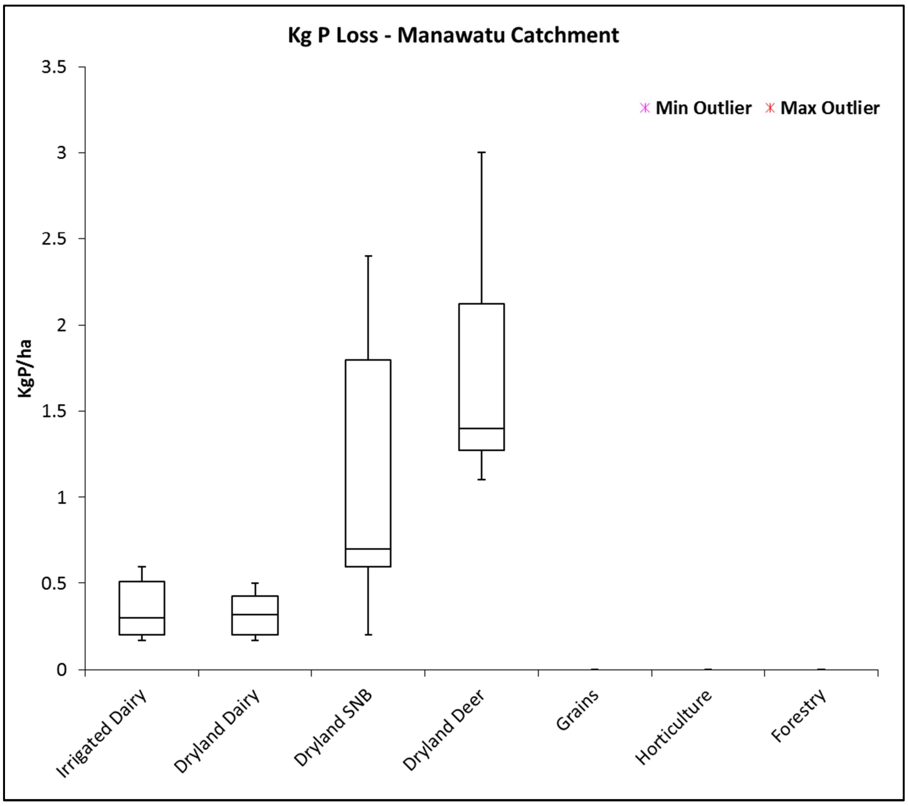

Figure 21 Range of P loss rates (kgP/ha) for key enterprises in Manawatu catchment (SNB refers to sheep and beef)

Policy #1. Uptake of good management practices (GMPs)

For this policy, we quantify the net costs and effectiveness of existing pastoral enterprises adopting different GMPs. This could be achieved through voluntary or regulatory approaches. This assessment uses data collated for the NZFARM model plus additional information on stock exclusion from waterways (fencing) and riparian plantings, which are the two GMPs not represented in NZFARM (see Section 2.6).

For this analysis, we assume that land use remains at the baseline (2007) levels but management practices can change. For all land where a mitigation practices is not in place but could be applied, we compare nutrient losses and profits with and without the GMP. These results are then aggregated to sector level to get a total catchment estimate. The estimates for dairy and other pastoral farms for each GMP at the catchment level are shown in Table 28, while estimates for the catchment zones are listed in Appendix F. The analysis assumes 100% adoption of each GMP, allowing us to estimate the technical potential of each GMP. These figures can be adjusted downward for the voluntary measures based on the assumed adoption rates outlined in Table 11, found in Section 2.7. There is a large variation in nutrient reductions, costs, and profits resulting from the different GMPs.

For dairy farmers in the catchment, reducing fertiliser use reduces N leaching by 10–15% and could feasibly increase profits by 1–2%. Applying DCDs could also feasibly increase profits 13% because of improved pasture growth while reducing N losses by 16%.[23] Feedpads can also reduce N losses by 15% with an 8% increase in profits. Wintering off reduces nitrogen leaching by about 15%, with an 18% increase in average profits. Combining wintering off with either DCDs or a feedpad for dairy farmers gives some additional mitigation while still providing the same gains in profit as the individual GMP. Of the GMPs considered, only constructing feedpads, fencing streams, or doing riparian planting reduce phosphorus losses, with riparian planting having the largest declines for P in the Manawatu, or approximately 23%.

For other pastoral enterprises, only a small fraction of sheep, beef, and deer pasture is intensively fertilised so any changes in fertiliser applications will have little impact on nutrient losses. DCDs could be applied and provide a positive return (14% increase in profits) for farmers who apply them and reduce N losses by 9%. Fencing stock or riparian planting are the only two GMPs considered for non-dairy pastoral enterprises that can impact both N and P, but doing so could reduce profits by 26–66%. This is because NZFARM estimates that sheep and beef farmers in the Manawatu are, on average, to be earning profits of around $200/ha/yr. Therefore, an opportunity cost of up to $83/ha/yr for a riparian strip could be a difficult option to undertake without financial assistance or other incentives.

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[23] There is still an on-going debate about the productivity benefits of DCDs in certain areas of New Zealand (Gillingham et al. 2012). The productivity changes used in this report were obtained by parameterising the FARMAX model (Bryant et al. 2010) for the Manawatu Catchment.

Table 28 Estimated nutrient reductions of GMPs for pastoral enterprises in Manawatu Catchment if 100% Adoption by landowners

GMP	Voluntary Adoption Rate	Area ('000 ha)	Change in N (t)	Change in P (kg)	N change (%)	P change (%)	Average cost ($/kgN)	Average cost ($/kgP)	Total cost ($'000)	Profit change (%)
Dairy										
Fertiliser to 80%	75%	9	-23	0	-10%	0%	-7	-	-161	1%
Fertiliser to 60%	75%	9	-33	0	-13%	0%	-7	-	-244	2%
Fertiliser to 50%	0%	10	-40	0	-15%	0%	-8	-	-308	2%
DCD	75%	80	-323	0	-16%	0%	-52	-	-16,747	13%
Feedpad	75%	80	-301	-3381	-15%	-17%	-79	-7043	-23,813	18%
Winter off	50%	79	-53	0	-3%	0%	0	-	0	0%
Max Stocking Rate of 3 cows/ha	0%	0	0	0	0%	0%	0	0	0	0%
DCD + Winter off	50%	79	-371	0	-19%	0%	-45	-	-16,667	13%
Feedpad + Winter off	50%	79	-344	-3363	-17%	-17%	-69	-7043	-23,686	18%
Exclude Stock via Fencing	100%	29	-29	-1189	-1%	-4%	44	1063	1264	-3%
Riparian Planting	50%	54	-64	-6606	-3%	-23%	83	807	5329	-6%
Sheep, Beef, Deer, and Pigs										
Fertiliser to 80%	25%	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Fertiliser to 60%	25%	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Fertiliser to 50%	0%	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
DCD	75%	269	-158	0	-9%	0%	-29	-	-4630	14%
Exclude Stock via Fencing	60%	199	-199	-30,440	-9%	-9%	44	285	8666	-26%
Riparian Planting	50%	180	-216	-97,920	-9%	-23%	83	182	17,823	-66%

By combining feasible GMPs for all pastoral farms in the catchment we estimate the reduction in nutrient losses from voluntary and regulatory approaches. This assessment maximises reductions in N and P losses but does not necessarily minimise costs to the landowner. The latter issue is addressed in detail in the analysis of the various cap-and-trade policies below.

The impact of voluntary GMPs is determined using a weighted average of GMP adoption, as described in Section 2.6. The nutrient reductions associated with the most effective voluntary practices (i.e. DCD and riparian planting) being implemented on 50% of the eligible land area reduces N leaching by 7% and P losses by 14% (Table 29). Profit for the landowners who have implemented these practices is expected to decline by 1% as the costs for the riparian planting are nearly offset by the productivity gains from applying DCDs. Our interpretation of the HRCs water quality targets (Table 24) estimated that N leaching must be reduced 53% and P losses reduced by 49% to meet water quality standards for the Manawatu catchment. Thus, the voluntary GMP approach would provide some benefits for water quality in the catchment, but would not achieve the necessary nutrient reduction targets.

If all landowners were regulated to apply DCDs and undertake riparian planting, and all dairy farmers had to winter their cows off the farm, then N leaching would be reduced by 15% and P losses would decline by 27% (Table 29). This would cost the average landowner in the catchment about 1% in profits, again because the cost of the planting is nearly offset by the benefits of applying DCDs. It would also cost the government time and money to implement, as effort would have to go into monitoring and enforcing compulsory adoption of these practices to ensure the full environmental gains were realised. As with the voluntary GMP case, a regulatory GMP approach would produce reductions in nutrients and improve water quality in the Manawatu, but it is still not adequate to meet the desired targets specified in Table 24. Thus regulating the adoption of the GMPs we have investigated here will not result in the achievement of water quality targets for the catchment. This indicates that some land use change will be necessary over the long run.

Table 29 Estimated nutrient reductions of the most effective voluntary and regulated GMPs (by level of reduction) in the Manawatu catchment

Management practices	Adoption rate	Area (' 000 ha)	Change in N (t)	Change in P loss (t)	N change (%)	P change (%)	Average cost ($/kgN)	Average cost ($/kgP)	Total cost ($ mil)	Profit change (%)
DCD + Riparian Planting	50%	67	-381	-52	-7%	-14%	2	285	0.9	-1%
DCD + Riparian Planting+ Wintering Off	100%	348	-809	-104	-15%	-27%	2	182	1.8	-1%

Policy #2. Implement nutrient cap-and-trade programme

As discussed in the Hurunui-Waiau catchment case study, a cap-and-trade programme is often proposed for reducing nutrients in catchment because it provides flexibility to landowners allowing them to meet their targets cost-effectively rather than requiring all landowners meet individual targets on their own land (i.e. command and control). We assess three different cap-and-trade scenarios within the Manawatu catchment with various allocation and trading options. The first two scenarios are similar to policies #2a (grandfathering allocation and catchment-wide trading) and #2b (grandfathering allocation with trading restricted to catchment zones) in the Hurunui-Waiau catchment section, except for the size of the nutrient reduction targets. The last scenario mimics the natural capital approach for allocation that has been proposed by HRC.

Farmers are allowed to increase their land use intensity beyond what they hold discharge permits for but they must acquire allowances from other landowners in their specified trading area to cover any additional nutrient discharge. This ensures the cumulative nutrient leaching targets for the catchment are met. Some landowners might find it more advantageous (i.e. profitable) to reduce their nutrient leaching intensity and sell excess permits to others, while others will find it profitable to purchase permits to increase their land use intensity.

The basics of each cap-and-trade scenario in the Manawatu catchment are outlined in Table 30. The key differences between the different scenarios include the initial number of permits available for allocation in each catchment zone and whether trades can occur across the catchment or only within a catchment zone. Each scenario ensures that the same nutrient reduction target is achieved at the catchment level (i.e. maintain N and P at 2010 levels), but the cost of achieving the target varies across different landowners, the community, and specific waterways in the catchment depending on the scenario. Because the policy applies a polluter pays principle, it does not necessarily protect past capital investment and could cause social disruption and changes in land values. The impact on individual landowners depends on how permits are the allocated and who farmers are allowed to trade with.

All scenarios are modelled using NZFARM. While additional nutrient reductions could be achieved from implementing practices not included in NZFARM it is likely that these practices would have to be implemented at costs equal to or greater than the practices modelled in NZFARM. For example, while riparian planting is an effective way to reduce N leaching and P losses in the catchment, the estimated high unit cost of doing so relative to other mitigation options could make it cost-prohibitive for a cap-and-trade programme that allows landowners to determine their own methods of reducing nutrients on their land. Additionally, as NZFARM is based on the nutrient reductions and costs for a representative farm in the catchment zone it is likely some farmers could implement a specific GMP more cost-effectively than the representative farm. Including additional management options not tracked in the model could also have an impact on the estimates presented in this report.

Table 30 Initial allocation of permits (tonnes/yr) and eligibility for trading across catchment regions for each cap-and-trade scenario

Cap-and-trade Scenario		Manawatu Flats	Manawatu Hills	Tararua Flats	Tararua Hills
Land Area (ha)		143,600	175,100	94,300	162,600
Number of Farms		1,847	445	798	389
Baseline Total N		1881	922	1493	1099
Baseline Total P		62	84	26	205
Catchment-wide grandparenting		**Trading permitted across all regions in catchment** ⟷			
Initial Permits	Total N	884	433	702	516
	Total P	32	43	13	104
Region-restricted Trading		↻ **Trading only with landowners in same region**	↻	↻	↻
Initial Permits	Total N	884	627	612	396
	Total P	12	48	21	108
Natural Capital Approach		**Trading permitted across all regions in catchment** ⟷			
Initial Permits	Total N	964	487	633	452
	Total P	73	37	48	35

Policy #2a. Grandparenting allocation, with catchment-wide cap-and-trade programme

For this policy scenario, we estimate the economic and environmental impacts on the Manawatu if landowners must meet the comprehensive nutrient load targets (i.e. the cap) specified by HRC (see bottom of Table 24): a 53% reduction in the annual discharge of total N and a 49% reduction in total P. If landowners were at the limit of discharges, they would be given 100% of the permits. The Manawatu is in a situation where nutrients are already ‘over-allocated,’ such that landowners are discharging nutrients beyond a point where a freshwater objective is no longer being met. Thus, we evaluate a modified grandfathering allocation scheme where all landowners are granted a discharge permit based on existing or historic land use and leaching intensity, but only at the level of 47% of their total land-based N and 51% of their total P leaching levels in 2007. Because this scenario is specified as a catchment-wide programme, all farmers can buy or sell permits anywhere in the Manawatu. A sensitivity analysis where nutrient loads are capped between 10% and 80% below baseline levels is presented in Appendix D to highlight the possible non-linear response of land use, land management, and farm profitability under the cap-and-trade programme with differing nutrient limits.

Key outputs for this policy and its comparison to the baseline are listed in Table 31. Changes in enterprise area across the four NZFARM catchment of the Manawatu catchment are shown in Figure 22. Allowing trading across the catchment encourages landowners in the flats to increase their nutrient discharges by purchasing permits from other landowners located in the hills. This makes sense, given that many of the GMPs discussed in policy scenario #1 can be undertaken in the flats region at relatively low cost. Additionally, the results indicate that not all permits allocated for P loss are used, as it is might not be economically feasible to meet the N leaching targets (with the modelled GMPs) without reducing P beyond the targeted level. More detail on the optimal distribution[24] of nutrient allowances for this and other policy scenarios is shown in Appendix E.

Table 31 Key outputs for the Manawatu catchment: Catchment-wide cap-and-trade programme and grandfathered permits

	Net Revenue (million $)	N Leaching (tonnes)	P Loss (tonnes)	Total GHGs (tonnes)	Net GHGs (tonnes)	Irrigated Area (hectares)
Estimates	$251.2	2536	148	1,689,800	-717,900	5,870
Change From Baseline	-17%	-53%	-61%	-47%	-134%	-1%

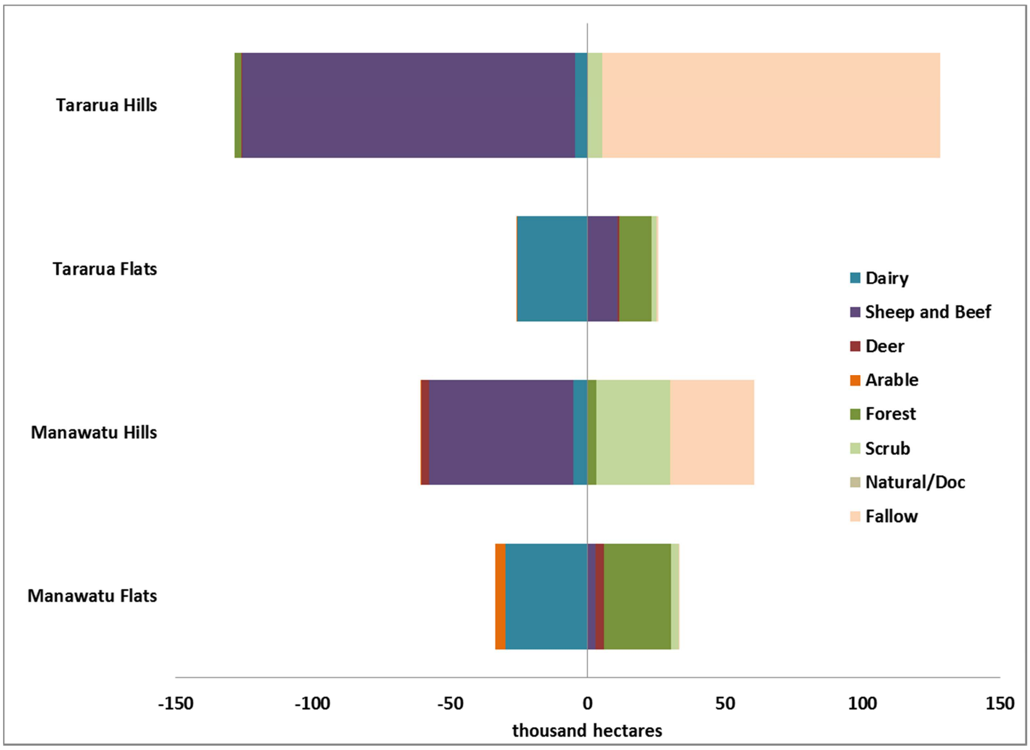

Figure 22 Change in aggregate enterprise area ('000 ha) from baseline: Catchment-wide cap-and-trade programme and grandfathered permits

[24] This is similar to the equilibrium distribution of permits after trading takes place. Likewise, if permits were allocated in this manner initially, no trades would be made as the market would already be in equilibrium.

A grandparenting allocation with trading across the entire catchment is likely to be one of the most economically efficient policy options for the catchment as a whole, but it does have various impacts on the landowners, community, and waterways. For example, landowners in catchment zones that have net reductions in permits would only choose to reduce their nutrient loads beyond the required target if there was a net gain in income from doing so. Therefore, the more permits landowners are allocated, the more opportunity they have either to meet their nutrient reduction target or to go beyond the target and sell these reductions to other landowners.

A distribution of the costs and benefits of the policy including administrative and transaction costs, and changes in profits for farmers is shown in Figure 23. Every catchment zone experiences a financial loss, primarily from the reduction in profits and the transaction costs necessary to trade permits. The Tararua Hills does benefit somewhat from trading, though, as farmers are able to use GMPs or change land use to reduce their discharges beyond their allocated permits and sell any excess permits to landowners in the Manawatu and Tararua flats. Summing across all cost and benefits yields a 22% reduction in net catchment revenue relative to the baseline where there is no water quality policy.

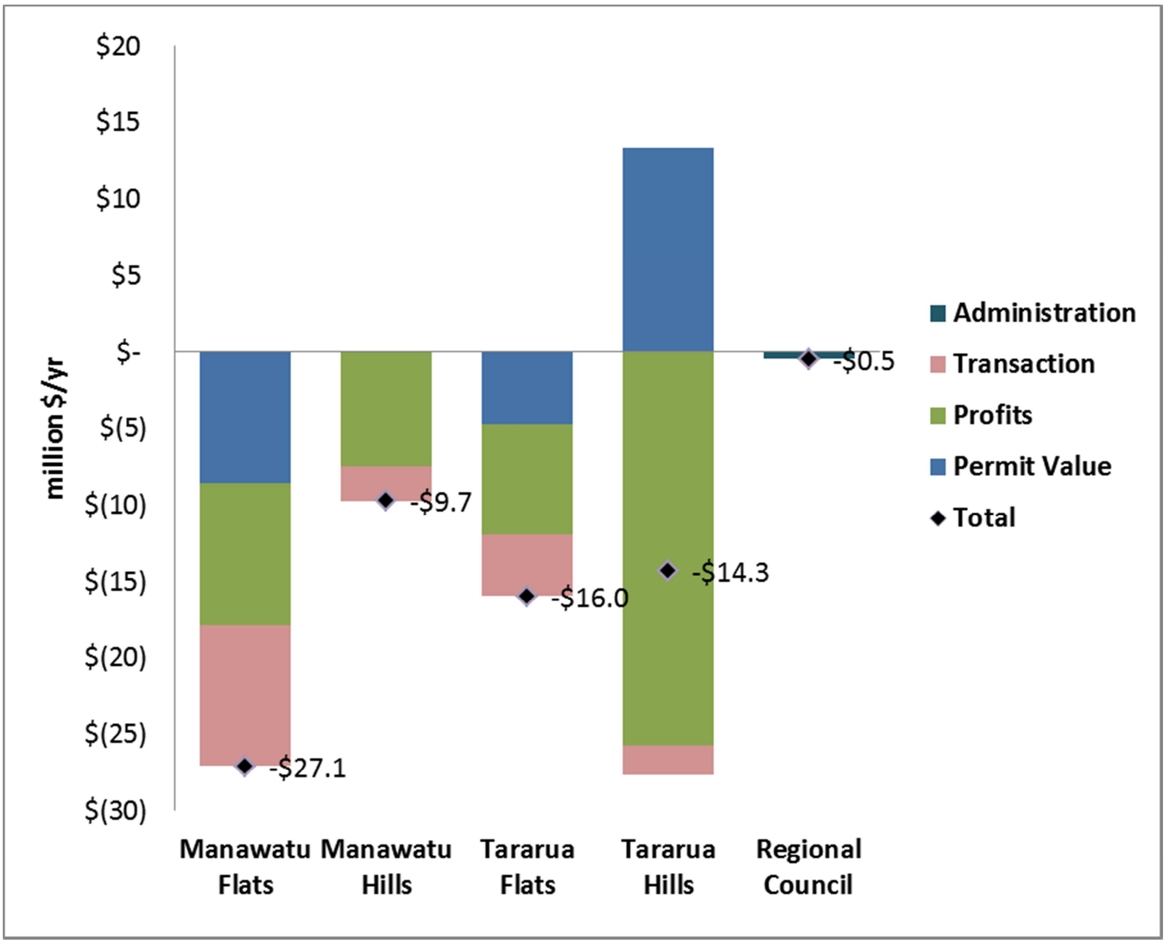

Figure 23 Regional distribution of costs and benefits: Catchment-wide cap-and-trade programme with grandparented permits

Policy #2b. Grandfathering allocation with region-restricted cap-and-trade programme

Policy #2b is similar to policy #2a except permits can only be traded within a given catchment zone (e.g. Manawatu Flats) instead of with landowners located anywhere within the greater Manawatu catchment. That is, all landowners are still allocated permits at a specified percentage of their 2007 nutrient discharge estimates but can only buy or sell permits within the catchment zone where their farm is located. This policy is more restrictive as there are fewer permits available to trade in each catchment zone, which could result in higher costs. It might also be more costly administratively because the regulatory agency would have to oversee four trading markets instead of one catchment-wide market. There may be an advantage from a water quality perspective, because the policy would preserve water quality in some of the catchment zones that may be at risk of ‘hotspots’ because of high nutrient levels in a local (i.e. sub-catchment) water body.

The NZFARM region-restricted nutrient reduction targets were based on the water quality standards set by HRC at the water management zone (WMZ) level. As discussed above, because standards were set at concentrations, rather than loads, we converted DRP and SIN concentrations to loads assuming the same percentage change in total N leaching and P losses at the farm. Table 25 shows the annual total N and total P reduction for the four NZFARM catchment regions based on the HRC concentrations and Manawatu catchment WMZs.

Key outputs for this policy and its comparison with the baseline are listed in Table 32. The change in enterprise area in the catchment relative to the baseline is shown in Figure 24. Farm profit reductions (37%) in this scenario were larger than with catchment-wide trading (17%) as landowners in the flats must meet all nutrient targets on their own and pay higher mitigation costs rather than compensating farmers in other catchment zones to reduce their nutrient loads. This leads to a significant amount of enterprises change in all catchment zones, with sheep and beef and dairy being converted to forestry or scrub, or left fallow. Interestingly, a substantial amount of land is converted to arable cropping in the Manawatu Flats, as it is a relatively profitable, viable enterprise with little or no impact on P loss.

Table 32 Key outputs for the Manawatu catchment: Catchment zone cap-and-trade with grandparented permits

	Net Revenue (million $)	N Leaching (tonnes)	P Loss (tonnes)	Total GHGs (tonnes)	Net GHGs (tonnes)	Irrigated Area (ha)
Total Catchment Values	$189.9	2,520	190.4	1,477,800	-304,800	5,870
Change From Baseline	-37%	-53%	-49%	-53%	-114%	-1%

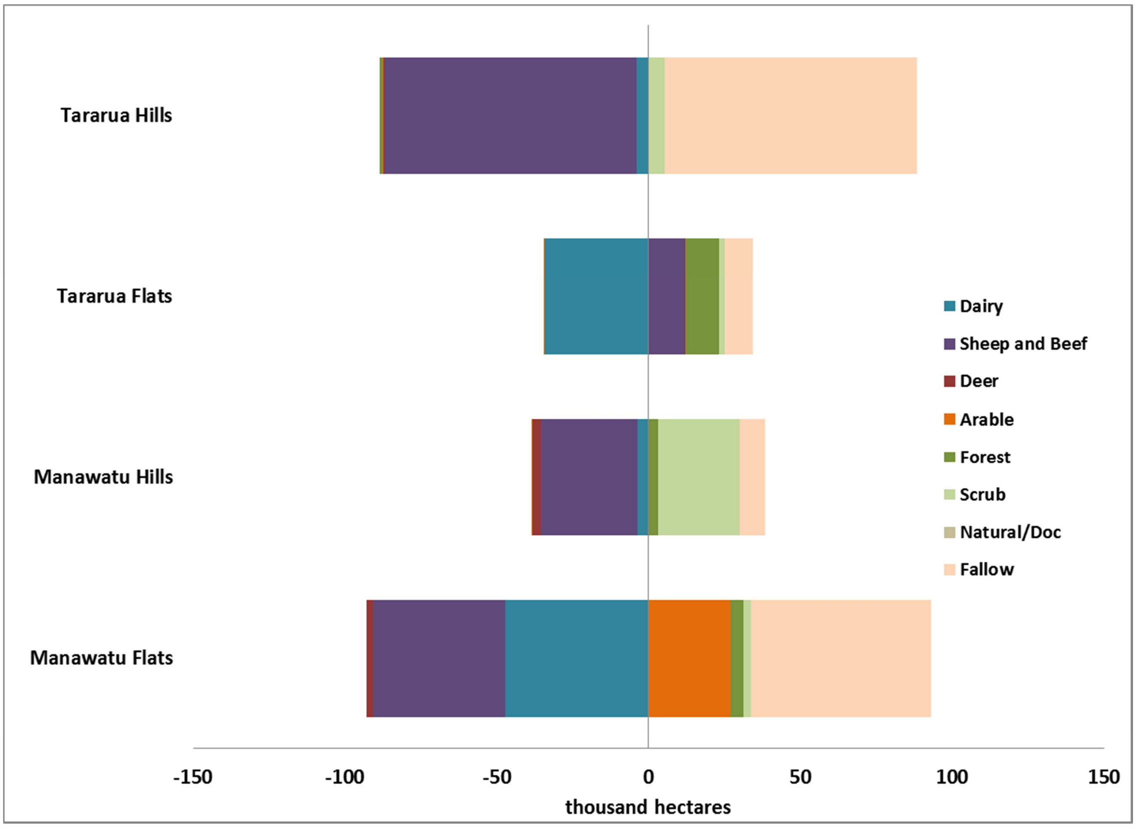

Figure 24 Change in aggregate enterprise area ('000 ha) from baseline: Zone-restricted cap-and-trade with grandparented permits

A zone-restricted cap-and-trade programme in the Manawatu could create significant improvements in water quality for many parts of the catchment, but at a potentially large cost to the landowners, especially when compared with policy #2a. The distribution of the costs and benefits of the policy including administrative and transaction costs, change in profits for farmers and the costs for the regional council to administer the programme is shown in Figure 25.

Landowners in all regions except for the Manawatu Hills face greater costs when trading is restricted to specific regions because (1) they might not be allocated as many permits and are required to produce greater reductions in nutrient discharges, or (2) they are unable to benefit from producing nutrient reductions and then selling their surplus permits for a profit to another NZFARM region. The Manawatu Hills face fewer costs under this policy primarily because their nutrient reduction target is less stringent than some of the other catchment regions. Thus, each landowner in that region is allotted a greater number of discharge permits compared with the catchment-wide policy (Table 30).

Subtracting the administration and transaction costs from the reduction in farm profits yields about a 43% decrease in revenues for the catchment over the baseline where there is no water quality policy. This indicates that while water quality is likely to be improved dramatically in nearly all of the sub-catchments in the Manawatu over the long run, doing so under this policy is nearly twice as costly as the catchment-wide scheme with grandparenting.

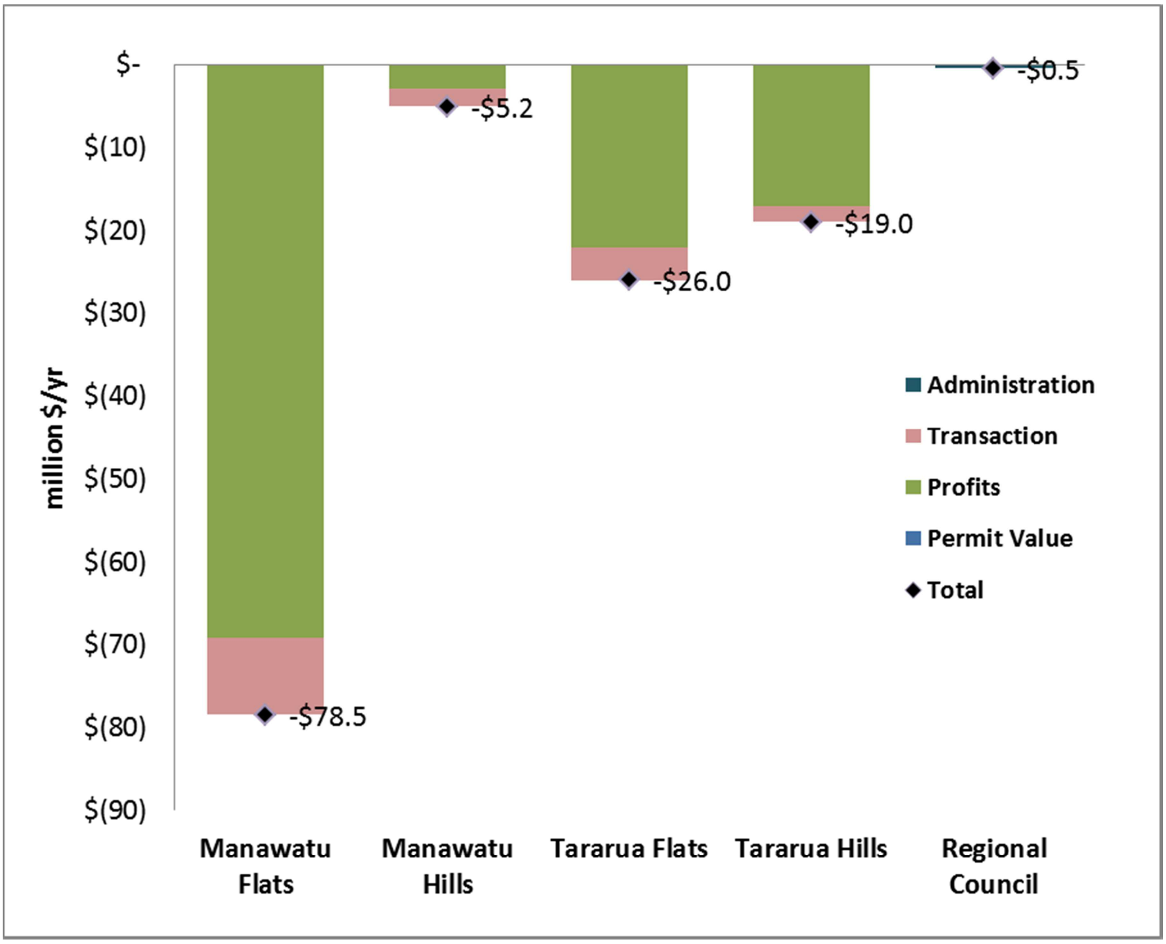

Figure 25 Regional distribution of costs and benefits: Zone-restricted cap-and-trade with grandparented permits

Policy #2c and #2d. Natural capital approach and catchment-wide trading

The revised version of the Horizon's One Plan introduces rules to limit nutrient leaching from dairy farms in targeted catchments based on the soil's land-use capability (LUC) classification, often referred to as a natural capital approach (NCA). The NCA is a benchmark-type scheme that allocates nutrient discharge permits based on the physical characteristics of the land or soil type. This typically reflects either the land's productive potential or vulnerability to nutrient leaching, and is independent of existing land use. The approach supports the sustainable use of both land and water resources by favouring land areas that have good productive potential and/or low leaching rates.

The December 2010 version (the Decisions Version) of the proposed Horizons One Plan required that new dairy farms demonstrate compliance with cumulative nitrogen leaching maxima that vary with LUC classification, as shown in Table 24. For example, the Plan specifies that all dairy farmers in LUC III be permitted to discharge up to 24 kgN/ha/yr from their land. For policy #2c we evaluate a slightly different policy option from the One Plan that still follows a natural capital approach but requires that *all* dairy farms must comply with

LUC based nitrogen leaching caps.[25] Our policy also assumes that dairy farmers can meet their discharge criteria by changing management on their farm, purchasing permits from other dairy farms in the catchment, or changing land use. As a result of the policy assumptions presented in this report, the estimates are *not* directly comparable with analyses of the One Plan.

A summary of the key outputs for the dairy-only NCA allocation policy with catchment-wide trading is listed in Table 33. We estimate that if permits were allocated to all dairy farms based on the maximum per hectare leaching rates, the LUC net revenue would be reduced by about 0.4%, but N leaching in the catchment would be only be reduced by 6%. This is because (1) most dairy farms in the catchment are already in those LUCs that permit discharges of 18 kgN/ha/yr or more and thus need to reduce their N output only marginally to meet the benchmark leaching target; and (2) dairy farms comprise less than 20% of the catchment, and therefore do not have a large enough share of the land mass to meet the catchment targets of a 53% reduction in N on its own. Even if all dairy farms in the Manawatu catchment were converted to forestry, NZFARM estimates that N leaching would only be reduced by about 40%. Additional measures will therefore be necessary to achieve the specified nutrient reduction targets.

Table 33 Key outputs for Manawatu Catchment: Catchment-wide cap-and-trade programme with natural capital allocation approach for only dairy-farms

	Net Revenue (million $)	N Leaching (tonnes)	P Loss (tonnes)	Total GHGs (tonnes)	Net GHGs (tonnes)	Irrigated Area (hectares)
Estimates	$299.7	5,099	352.49662	2,919,877	1,571,364	5,835
Change From Baseline	-0.4%	-6%	-7%	-8%	-25%	-1%

Policy #2d builds upon policy #2c by (1) requiring that all enterprises (not just dairy) initially be allocated discharge permits at the benchmark N leaching rates listed in Table 24, (2) adjusting the number of N permits downwards proportionally for each LUC so that landowners must comprehensively meet the catchment-wide nutrient targets for N leaching (53% reduction), and (3) issuing the same proportion of permits to farmers to meet the target for P loss (49% reduction). These criteria are necessary to develop a policy scenario using a NCA that ensures the comprehensive nutrient reduction targets in the Manawatu catchment are met. As with policy #2a, landowners are allowed to trade permits across the entire catchment. While this will result in very similar results for the catchment as a whole, individual landowners could yet be impacted differently based on the number of permits they are allocated.

The impacts of using the natural capital approach to achieve the nutrient targets are listed in Table 34, while changes in land use from the business as usual case are shown in Figure 26. Results indicate that N leaching and P loss targets can be met when each landowner is

[25] This policy option is not the same as the policies for diffuse discharges in the notified version, neither is it the same as that in the decisions version of the Proposed One Plan.

allocated permits based on their LUC. This is accompanied by a corresponding 17% loss in net revenue from reductions in farm output, changes in land use, and higher costs of production. Most of the change in net revenue occurs in the sheep and beef and dairy enterprises, as land is converted to forests, scrub, and fallow pasture. The large expansion of fallow land is due to farmers converting some of their land to low leaching enterprises to maintain high levels of productivity on other parts of their property. More land use is expected to change in the hills because there are fewer mitigation options and the enterprises have relatively low profitability.

Table 34 Key outputs for Manawatu Catchment: Catchment-wide cap-and-trade programme with natural capital allocation approach for all pastoral and arable farms

	Net Revenue (million $)	N Leaching (tonnes)	P Loss (tonnes)	Total GHGs (tonnes)	Net GHGs (tonnes)	Irrigated Area (hectares)
Estimates	$251.2	2,536	148	1,689,800	-717,900	5,830
Change From Baseline	-17%	-53%	-61%	-47%	-134%	-1%

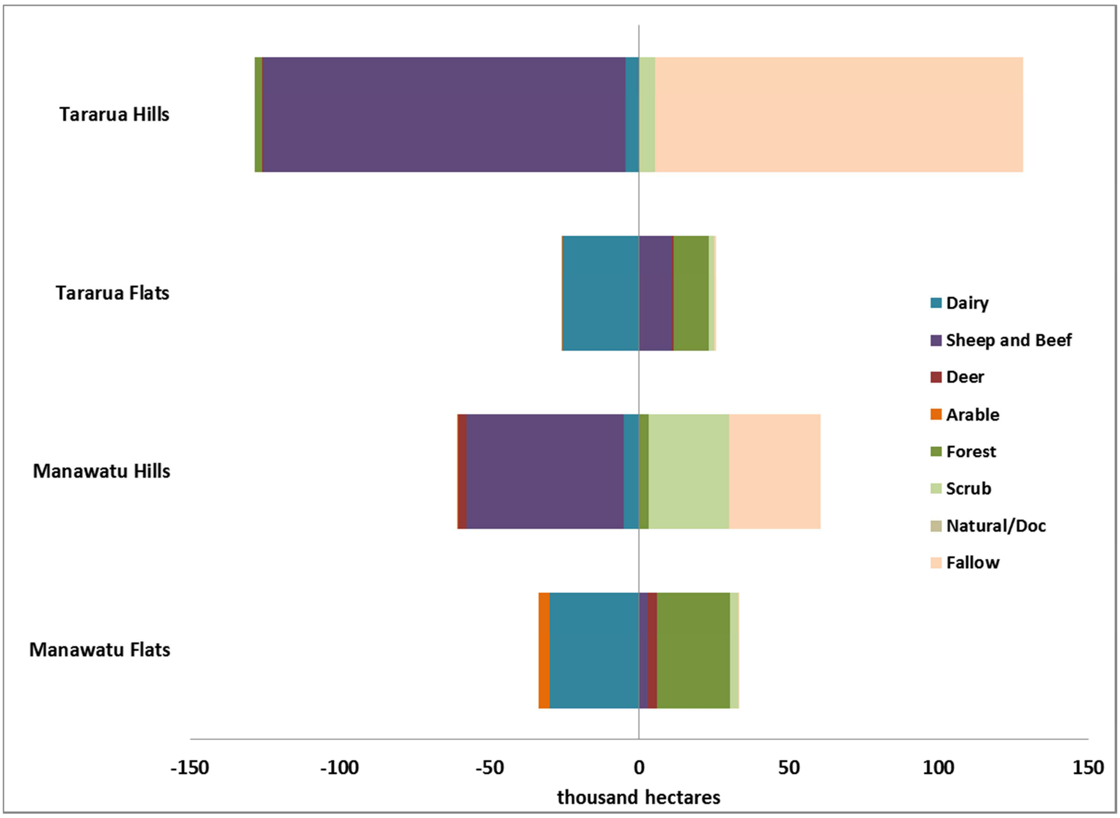

Figure 26 Change in aggregate enterprise area ('000 ha) from baseline: Catchment-wide cap-and-trade programme with natural capital allocation approach

The regional distribution of the costs and benefits of the policy including administrative and transaction costs and changes in profits for farmers in the catchment is shown in Figure 27. As with the catchment-wide cap-and-trade programme with a grandfathering allocation, every catchment zone has revenue losses. Summing across all cost and benefit categories yields a 22% reduction in net revenue for the catchment relative to the baseline where there is no water quality policy, again similar to policy #2a, because although the permits are allocated differently landowners still have the freedom to buy and sell permits across the catchment.

The key difference between policy #2a and this policy #2d is that the total values of the permits traded are different for each region because of the way they were allocated (Table 30). Under grandparenting (#2a), farmers were allocated permits based purely on their current (2007) land use and nutrient discharge rates. In the NCA approach (#2d) landowners are allocated permits based on their LUC and area of their farm. Because the NZFARM region designated as 'Manawatu Flats' comprises a relatively large area of the high-quality LUCs in the catchment relative to its historical nutrient discharge levels, landowners there are provided with a larger number of permits than the grandparenting allocation approach. This approach reduces landowner costs by 11% compared with policy #2a. Landowners in the regions that were not allocated as many permits (e.g. Tararua) could see a 16–17% increase in costs under policy #2d relative to policy #2a.

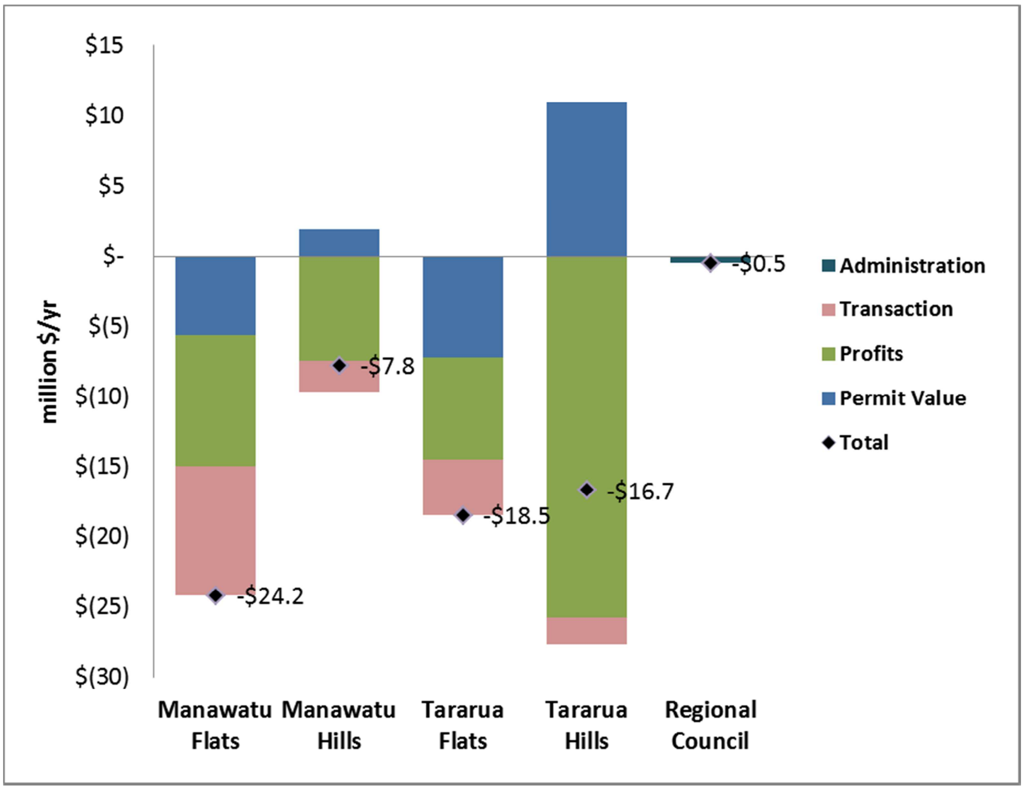

Figure 27 Regional distribution of costs and benefits: Catchment-wide cap-and-trade programme with natural capital allocation approach

Policy #3. Direct tax on nutrient discharges

If the tax is imposed properly and landowners are only taxed for discharges above their baseline (2007) nutrient discharges, this should result in an outcome to the cap-and-trade policies. The optimal tax level would be the same as the shadow (permit) prices estimated under the catchment-wide cap-and-trade scheme (policy #2a). We estimate that this is equivalent to a tax of $36 per kgN and $0 per kgP. Based on this finding, the council might not need to tax P as the land-use and land management changes implemented to meet the N targets also mean the required P loss reductions are achieved. This suggests that a tax could be a relatively efficient option from an administrative standpoint as only one nutrient needs to be regulated. Of course, this finding is dependent on the structure and land-use options tracked in NZFARM and may not hold where an alternative management practice or land use reduced N leaching but increases P losses.

While the tax rate is set at the margin, the average cost for many landowners would actually be lower on a $/kg basis. For the catchment-wide case, the average cost of reducing N was estimated to be about $23/kgN. This is significantly lower than the marginal tax rate because many landowners can implement changes in land management that reduce N at costs lower than the specified tax, thus reducing their overall tax burden relative to maintaining the status quo.

The tax approach could have a noticeable difference in farm-level impacts relative to the cap-and-trade approach because landowners must pay a direct tax for all their nutrient discharges rather than purchase excess discharge permits from other farms in the catchment. For example, a cap-and-trade scheme with a natural capital allocation approach may benefit some sheep and beef farmers who can sell excess nutrient discharge allowances, whereas a tax would reduce their net profit as they would be required to pay for any nutrients that are discharged from their operation (not just the level over the specified target).

If all the revenue collected from the nutrient tax were recycled back to landowners in the form of a dividend or reduction of other taxes, the changes in net catchment revenue would be similar to the grandparented cap-and-trade policy (#2a). This is the assumption we use in this report when presenting catchment-wide estimates for policy #3. If not all the taxes collected were recycled back to the landowner, however, the total costs to farmers would be higher under this policy approach. Furthermore, those landowners who might not have the ability to implement more cost-effective management practices on their farm could face a potentially high price to maintain their current operation.

As in Hurunui-Waiau catchment, we find that landowners' response (via land use and land management changes) is sensitive to the tax rate. Sensitivity analysis of the optimal tax rate found that setting a rate of $22/kgN and $34/kgP would decrease N and P loads by 40%. Setting a tax rate at $66/kgN would reduce loads of each nutrient by about 60%, and again would not require an additional P tax as the practices implemented in response to the N tax is also beneficial for reducing P losses.

In addition to conducting a sensitivity analysis of the tax rate, we also investigate the potential abatement over a wide range of taxes on N and P discharges. The estimated marginal abatement cost (MAC) curves for N is shown in Figure 28, while the MAC for P is shown in Figure 29. Estimates reveal the responses to the tax are not linear, which indicates it would be difficult to set an optimal tax to achieve desired nutrient reductions ex ante. A policy that had the flexibility to adjust the tax rate over time would better ensure that nutrient reduction targets are achieved over the long run. Taking this flexible approach would not be detrimental to water quality in the catchment due to the relatively small lag times for nutrients to reach a waterway from its point of discharge. Additional estimates from the varying tax rate scenarios conducted for the Manawatu catchment are presented in Appendix D.

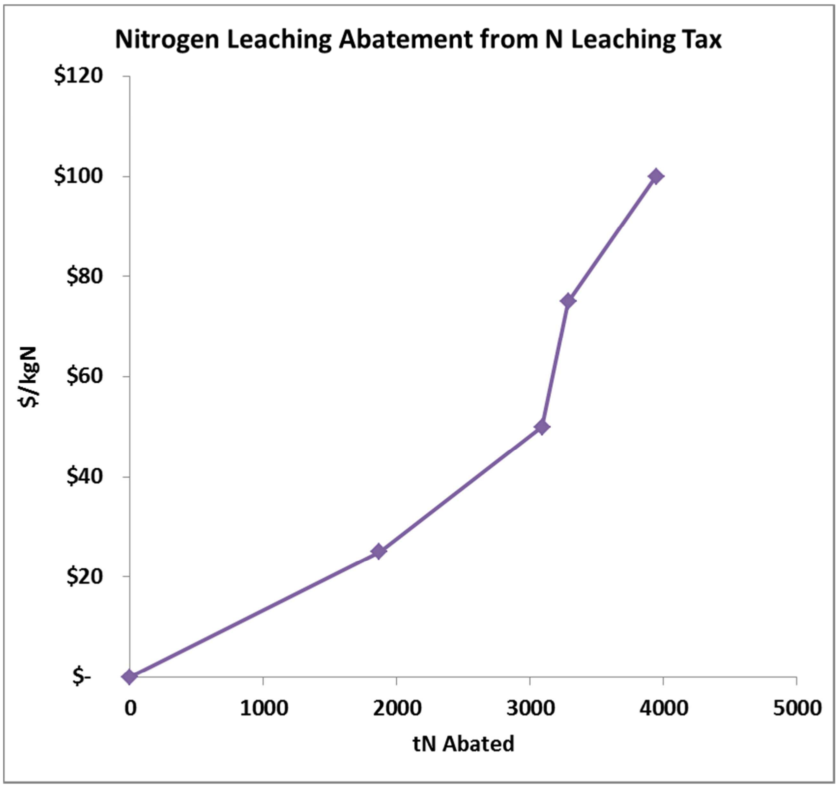

Figure 28 Marginal abatement costs for N leaching: Manawatu Catchment

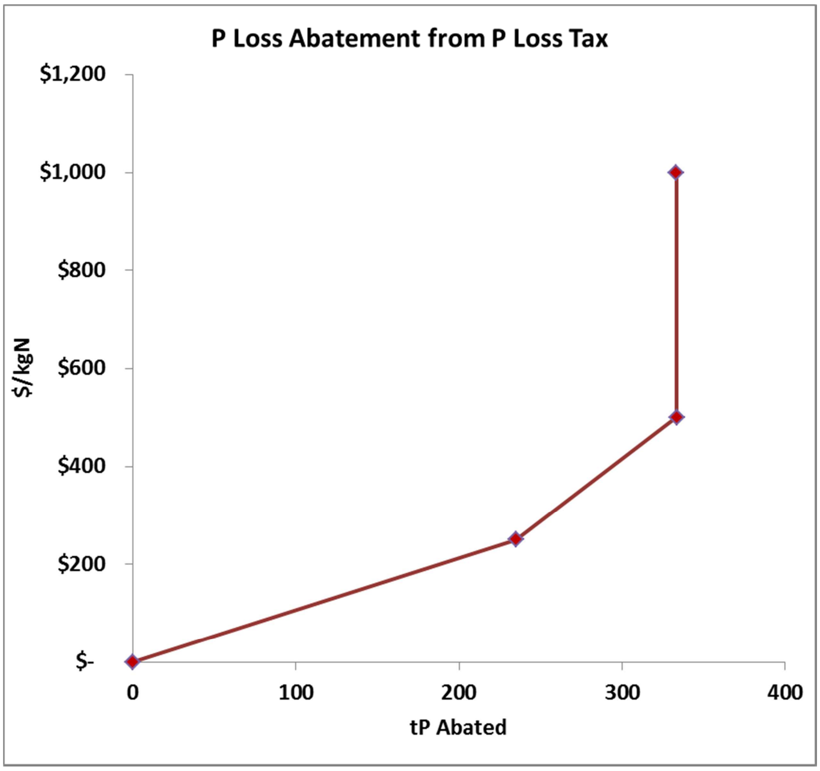

Figure 29 Marginal abatement costs for P loss: Manawatu Catchment

Table 35 summarises the key changes in outputs from the baseline, with detailed figures for land-use change at the different tax rates listed in Appendix D. Net catchment revenue appears to be more responsive to an N tax, but contrary to the Hurunui-Waiau catchment, GHGs are equally responsive to both N and P taxes. Another point is that implementing an N tax results in large reductions of both N leaching and P losses, but implementing a P tax could lead to increases in N leaching as landowners shift away from pastoral enterprises to arable cropping. Thus, solely having a P tax without putting restrictions on N leaching might not achieve the desired water quality targets.

Table 35 Key outputs for Manawatu Catchment for various N and P tax rates

	Change in net revenue (million $)	Change in N Leaching (tonnes)	Change in P Loss (tonnes)	Change in total GHGs (tonnes)	Change in net GHGs (tonnes)
			$/kgN		
$0	$301.0	5,400	380	3,168,000	2,107,000
$25	-36%	-35%	-17%	-23%	-96%
$50	-58%	-57%	-68%	-51%	-144%
$75	-77%	-61%	-72%	-53%	-151%
$100	-92%	-73%	-76%	-65%	-131%
			$/kgP		
$0	$301.0	5,400	380	3,168,000	2,107,000
$250	-7%	30%	-62%	-35%	-72%
$500	-15%	65%	-89%	-70%	-138%
$1000	-16%	57%	-89%	-69%	-148%

4.5 Summary and Conclusions

In this case study we have considered a number of policies that could achieve nutrient reduction targets in Manawatu catchment. These policies include the implementation of GMPs, a nutrient cap-and-trade programme with different allocation options, and a tax on nutrient discharges. The modelled nutrient targets for the comprehensive Manawatu catchment are to reduce N leaching by 53% and P losses by 49% (Ausseil & Clark 2007), although varying targets could also be imposed on smaller water management zones in the catchment.

We assessed a number of variants of each policy and have also assessed the sensitivity of results to different nutrient targets (see Appendices D and E). For each policy we have reported the costs of achieving the nutrient reduction target relative the no-policy scenario. Where appropriate we have also reported the estimated land-use change resulting from policy. We do not quantify all the costs the benefits of each policy in dollar terms, rather we report the relative changes in the catchment's nutrient discharges and revenue/profit streams resulting from policy and the complementary long run GHG emissions reductions.

A summary of the water quality scenarios considered for the Manawatu catchment is provided in . The baseline has no water quality policy in place. Based purely on minimising the cost of the policy and meeting the N and P reduction targets, the optimal choice would be to develop a catchment-wide cap-and-trade scheme using a grandparenting allocation approach. Setting a tax of $36 per kgN leached and not placing a tax on P would achieve a similar result. There may still be some adverse water quality impacts for some areas of the catchment should 'hotspots' occur, namely in the more nutrient-intensive flats regions that find it more economical to purchase discharge permits from landowners in the hills.

Table 36 Summary of water quality policies in Manawatu Catchment

Scenario	N Target (tonnes)	% N Target Achieved by 2022	Average Mitigation Cost ($/kg N)	P Target (tonnes)	% P Target Achieved by 2022	Total Annual Cost ($ million)	Profit Change from Baseline (%)
Baseline	2536	0%	n/a	190	0%	n/a	0%
Voluntary GMP (Policy #1a)	2536	13%	$2	190	27%	$0.8	0%
Regulatory GMP (Policy #1b)	2536	28%	$2	190	55%	$1.8	-1%
Catchment-wide Trading (Policy #2a)	2536	100%	$23	190	122%	$64.7	-22%
Region-restricted Trading (Policy #2b)	2536	101%	$45	190	100%	$129.4	-43%
Natural Capital Allocation Trading – Dairy Only (Policy #2c)	2536	11%	$4	190	14%	$1.2	-0.4%
Natural Capital Allocation Trading – Pasture and Arable (Policy #2d)	2536	100%	$23	190	122%	$66.2	-22%
Tax at $36/kgN (Policy #3)	2536	100%	$23	190	0%	$66.2	-22%

The key findings from the policies assessed for the Manawatu catchment are:

- A GMP approach that assumed the most effective voluntary practices (i.e. DCD and riparian planting) would be implemented on 50% of the eligible land in the catchment could reduce N leaching by 7% and P losses by 14% relative to the baseline (policy #1a). This would not achieve the specified nutrient reductions.
- If all pastoral landowners were required by regulation to implement the GMPs of applying DCDs and undertaking riparian planting, and all dairy farmers also had to implement the GMP of wintering their cows off the farm, then N leaching and P loss is estimated to decrease by 15% and 27%, respectively (policy #1b). This would be done at a low average cost ($2/kgN) to the landowner, primarily because applying DCDs could improve productivity, but would not achieve the water quality limits specified by the Regional Council.
- A catchment-wide cap-and-trade programme with a grandparenting-based allocation (policy #2a) proved to be one of the most cost-effective policies of those options modelled to meet the water quality limits at the catchment-level. Net revenue for landowners in the catchment declined by 17% and adding administration and transaction costs further reduced revenues to 22% below 2007 baseline revenues.

- Allocating discharge permits based on LUC is intended to intensify the use of high productivity land while simultaneously reducing nutrient loads. This is referred to as a natural capital allocation approach. Only requiring existing dairy enterprises in each LUC to meet specified nutrients discharge levels results in a 6% reduction in total N compared with the modelled baseline (policy #2c), and less than a 1% reduction in net revenue. This is because (1) most dairy farms are already located on the LUCs with permitted discharges of 18 kgN/ha/yr or more and thus required little change to meet the specified leaching rates stated in the December 2010 version of the Horizons One Plan, and (2) dairy farms comprise less than 20% of the catchment, and dairying therefore does not have a large enough share of the land mass to achieve a 53% reduction in N discharges on its own.
- A natural capital approach could still be a feasible policy to meet nutrient reduction targets if (1) discharge permits based on LUC are allocated to *all* pastoral, arable and horticultural land uses (not just dairy) and (2) *all* landowners are required to collectively meet the HRC's nutrient targets of reducing N by 53% and P by 49% through a catchment-wide trading scheme (similar to policy #2a). In this case, net revenue for landowners in the catchment was estimated to decline by 17%, and adding administration and transaction costs further reduced revenues to 22% below baseline revenues.
- The grandparenting (policy #2a) and natural capital approaches (policy #2d) for allocating nutrient discharges have similar estimated impacts at the catchment level when all landowners are covered, given that the policies are designed to (1) cover nutrient losses from all landowners and (2) cap nutrients at the levels necessary to meet the HRC water quality limits. However, impacts could vary at the farm-level between grandparenting and natural capital-based approaches because landowners may receive different amounts of permits, depending on allocation criteria used.
- Restricting trades to smaller areas within the Manawatu catchment would reduce the possibility of localized water quality 'hotspots'. However, spatially restricting trades resulted in a modelled decline in revenue of about 43% when accounting for changes in farm profit, administration and transaction costs (policy #2b). This is because farmers in the 'flats' area of the catchment must reduce nutrients in their own area of the catchment rather than purchasing discharge permits from farmers in the 'hills' that may be able to reduce their N and P discharges at a lower cost.
- The cap-and-trade programme and nutrient discharge tax policies assessed could result in significant changes in land use in the Manawatu catchment with land converting from pasture to arable, forests, scrub, or fallow.
- Theoretically, a nutrient tax (policy #3), implemented optimally, will provide similar impacts as a catchment-wide cap-and-trade programme (policy #2a). We estimate that charging landowners a tax of $36/kgN for nitrogen that leaches from their land should achieve the desired nutrient loads set at catchment-level. The average cost of reducing N was estimated to be $23/kgN, which is significantly lower than the tax rate because many landowners can implement changes in land management that reduce N at costs lower than the specified tax.
- In all likelihood there would be no need to tax P as the land use and land management changes implemented in response to the N tax will also achieve the required P loss reductions in the catchment.

- Varying the N and P tax across different parts of the catchment to meet different nutrient reduction goals has similar outcomes to policy #2b. Estimates reveal that the N tax could range from $18.70/kgN in the Manawatu Hills to $89.70/kgN in the Tararua Flats.
- The marginal costs of abatement for a tax are non-linear, which could make it difficult to establish the optimal tax ex ante. Providing flexibility to adjust the tax over time would better ensure that nutrient reduction goals are achieved over the long run but could generate more economic and social disruption in the transition than a cap-and-trade approach if policy makers have frequently to adjust the tax rate.

5 Case Study #3 Lake Rotorua Catchment, Bay of Plenty

5.1 Introduction

Lake Rotorua has seen a significant decrease in water quality over the past 40 years, largely as a result of land-use intensification and pursuant increases in nutrient leaching into the lake (Parliamentary Commissioner for the Environment 2006). The local community has indicated that this decline in water quality is not acceptable, and the regional council is currently considering the optimal policy mix to achieve significant nitrogen discharge reductions. The most recent statements from the council indicate that they aim to decrease annual nitrogen exports in the Lake Rotorua catchment from 755 tonnes per year to 435 tonnes per year (Bay of Plenty Regional Council 2012). As pastoral farming and forestry are the source of approximately 80% of nitrogen flowing into Lake Rotorua, reaching this goal will require changes in land management and use (Bay of Plenty Regional Council 2012).

We consider a number of policies that could achieve the intended nitrogen cuts. The first option is the voluntary or regulatory implementation of ‘good management practice’ (GMP), in which farmers achieve a lower nitrogen leaching rate while holding land use fixed. The second policy is a cap-and-trade scheme for nitrogen, in which a cap is placed on the total leaching of all pastoral sources of nitrogen (i.e., sheep, beef, and dairy) and sources can trade nitrogen-discharge permits among themselves to maximise catchment-wide production whilst still achieving the environmental goal. We devote the majority of the chapter to assessing variants of this policy. The third option considered is a tax on nitrogen leaching; for this option, we also consider the sensitivity of environmental outputs to an incorrectly specified tax. Finally, we assess how different allocations of allowances will affect the distribution of costs across different land uses, the community, and the local government. For each policy, we report the total cost, its distribution across land uses, land-use change, and the resulting nitrogen loads that will ultimately reach Lake Rotorua. Reductions in greenhouse gas (GHG) emissions, a co-benefit that emerges with water quality improvement policies, are reported in the appendix.

All policies are estimated using the agri-environmental economic model NManager, a partial-equilibrium simulation model that uses bio-physical properties of the Lake Rotorua catchment and farmer nitrogen mitigation costs to estimate environmental outcomes and costs of nitrogen regulation in Lake Rotorua. While an earlier version of NManager has been used to measure the costs of some policies discussed here (e.g. Anastasiadis et al. 2011), this report presents the first simulations since several extensions have been added to the model, including an allocation module and a GHG-emissions module. These extensions allow us to investigate issues of crucial importance for policy design, including the impact of different allocation mechanisms on the distribution of costs and the wider environmental impacts of nutrient policy.

The chapter continues as follows: subsection 2 provides a background on Lake Rotorua and the environmental challenges that it faces; subsections 3 and 4 introduce our simulation model, NManager, and detail how it has been updated to undertake the current analysis; in section 5, each policy is discussed in turn.

5.2 Lake Rotorua: Background

Water quality has been declining in Lake Rotorua for at least the last 30 years due to increased levels of nutrients entering the lake. The increase in nutrient levels by agricultural, residential, and commercial sources has led to increased frequency of algal blooms, which limit recreational water use and affect the local fish, plant, and animal populations (Parliamentary Commissioner for the Environment 2006). These historical nutrient exports are still arriving in the lake due to the time lags associated with transporting discharges from their sources through groundwater to the lake (Rutherford et al. 2011). Alongside these historical releases, current exports of nutrients are too high to maintain lake water quality. The sources of nutrient exports are shown in Table 37 (Bay of Plenty Regional Council 2012).

The Bay of Plenty Regional Council (BOPRC) has set a goal of returning water quality to levels last seen in the 1960s (Environment Bay of Plenty et al. 2009). Achieving this goal requires a cut in the amount of nitrogen arriving in the lake each year to 435 tonnes. Nitrogen reaches Lake Rotorua through surface water and ground water. As a result of groundwater lags of up to 200 years, there are significant differences between the amount of nitrogen arriving in the lake in any one year and the amount exported each year. For example, in 2009, inputs into the lake were estimated to be 593 tN/yr, while exports were estimated to be 776 tN/yr (Anastasiadis et al. 2011). If current exports of nitrogen remain constant, then annual nitrogen loads entering the lake will continue to increase over the next 60–70 years and will approach a steady state such that lake loads will be equal to current exports in approximately 2080 (Rutherford et al. 2011).

Table 37 Land use and nutrient sources

Land use	2010 Area (ha)	% of total catchment	Nitrogen exports, tN/yr (2010)	% of total N	total P/yr (2007)	% of total P
Dairy	5050	10.9	273	36.2	4.1	10.5
Drystock	15072	32.5	236	31.3	12.8	32.7
Forest	21182	45.7	75.4	10	2.2	5.6
Urban	3961	8.5	93.4	12.4	3.8	9.7
Lifestyle	1053	2.3	16.7	2.2	0.5	1.3
Geothermal	59	0.1	30.3	4	1.4	3.6
Lake & rain	n/a	n/a	30	4	1.3	3.3
Springs	n/a	n/a	n/a	n/a	13	33.2
Total	46377	100	755[26]	100	39.1	100

[26] NManager uses slightly different land-use maps that result in slightly different predicted nitrogen leaching. See section 5.3 below.

Substantial effort has already been undertaken to improve water quality by reducing the nutrient levels within the lake. Since 2005, Lake Rotorua has had a rule in place to cap nitrogen and phosphorus losses to the lake, although attention has since shifted from capping to reducing nutrient discharges. Land-use change, good management practice, nutrient trading, and others factors have contributed to decreased discharges, but the final policy mix for achieving water quality goals is yet to be decided.

The level of phosphorus leaching is also important for water quality. However, the most recent BOPRC policy documents indicate that "targets for phosphorus in the catchment are on track to be met" (Bay of Plenty Regional Council 2012). Therefore, the focus of this chapter is on managing nitrogen leaching.

5.3 NManager Simulation Model

Costs of policy options are presented as an equivalent annual annuity of meeting the total cost of reaching the nitrogen reduction target. We follow the BOPRC and use a discount rate of 7%. An equivalent annual annuity[27] (EAA) is calculated by transforming the net present value (NPV, the discounted sum of all mitigation costs required to meet the nitrogen reduction target) into a stream of annuities. A risk-neutral regulatory agency would be indifferent between paying the EAA every year for the length of the policy and paying the NPV at the policy's inception.

Mitigation costs are calculated using the profit-mitigation curves outlined in Anastasiadis et al. (2011). As a result, estimated costs of policies do not include the costs of set-up and administration. They also do not include the impact of regulation on land values. Our costs are likely to underestimate the true costs as our simulations assume that farmers adjust instantly and optimally to change; in reality, these adjustments are likely to be slower and less optimal. However, as the current version of the NManager is static, we do not allow for technology change, which would result in overestimates of cost. Finally, the simulations assume full compliance with policies. Actual outcomes will differ when individuals do not understand policy or choose not to comply. See the appendix for further discussion of the NManager model.

All costs are relative to a baseline of business as usual under current regulation. Under 'Rule 11', landowners cannot change their land use or land management if doing so will increase discharges[28] (Environment Bay of Plenty et al. 2009). As profitability is positively correlated with nutrient discharges, we assume that this upper limit on discharges is and will continue to

[27] $EAA = NPV * \frac{(1+\frac{1}{1+r})}{1+\left(\frac{1}{1+r}\right)^t}$, where NPV=Net Present Value, the discounted sum of future costs, r = discount rate and t = length of policy.

[28] Landowners can increase discharges if they offset this by decreasing discharges elsewhere. To our knowledge, this proto-trading system has never been applied by a farmer in the catchment.

be binding; for the baseline case, we assume that discharges will continue at current rates. Key outputs of the baseline scenario are captured in Figure 30[29] and Table 38.

Table 38 Baseline profits

	total	per ha
Profits (Equivalent Annualised Annuity)		
Dairy profits	$7,213,621	$1,345
Sheep/Beef profits	$7,226,372	$470
Total	$14,439,994	
GHG emissions		
Long run annual emissions (tonnes CO_2-e)	120,851	5.8

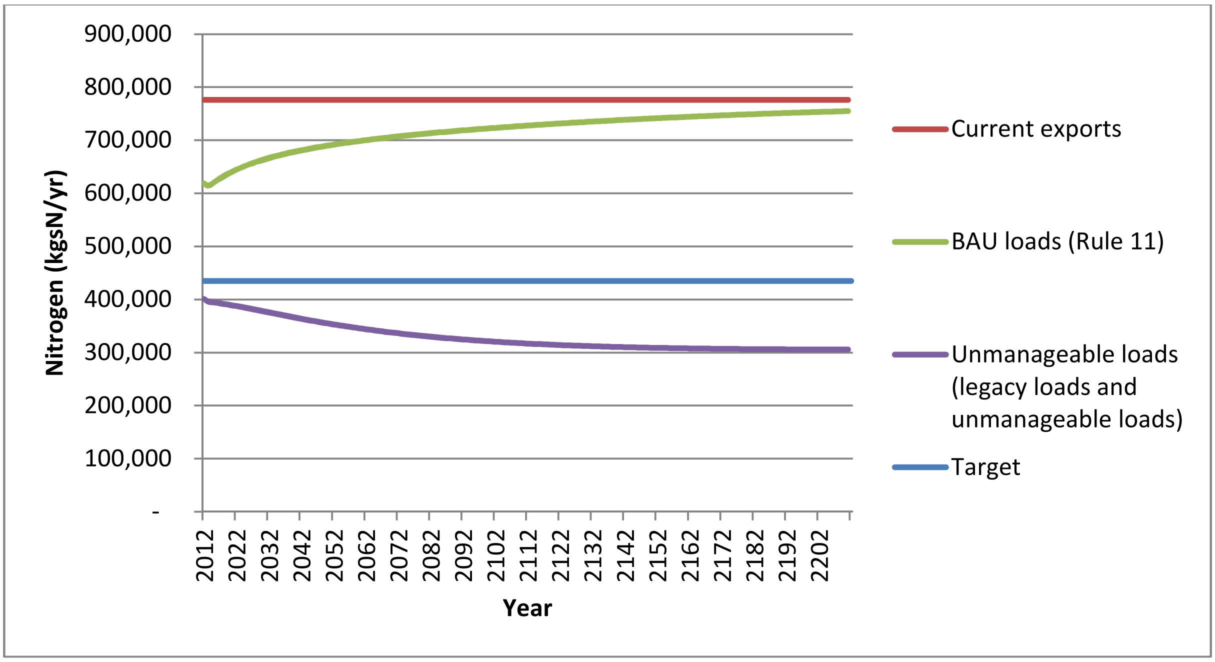

Figure 30 Baseline nitrogen flows

[29] 'Unmanageable loads' are made up of legacy loads and loads considered unmanageable by NManager. Legacy loads are the nitrogen loads that have been released in the past but, as a result of the slow groundwater transport times, are still to arrive in the lake. Unmanageable loads are made up of a catchment-wide allowance of 4 kgN/ha/yr, which is the lowest nitrogen leaching can be lowered to, and nitrogen from sources which we do not have mitigation cost curves for such as urban sources. It is imagined that these urban sources will be managed separately in addition to the mitigation carried out on agricultural land.

5.4 Model Extensions

Two extensions to NManager have been added to augment the work by Anastasiadis et al. (2011): an allocation module and a GHG-emissions module. These extensions allow us to investigate a number of issues crucial for policy design, including the impact of different allocation rules on the distribution of costs, and the complementary GHG impacts of implementing nutrient policy. The model extensions are outlined in detail in Appendix H.

5.5 Potential Policies and Results

Regional councils may use a variety of approaches to meet environmental goals. In this subsection, we consider mandatory GMP, a cap-and-trade scheme for nitrogen, and nitrogen export taxes. We also summarise the results of relevant simulations from Anastasiadis et al. (2011).

Good Management Practice (GMP)

A potential first step towards achieving environmental goals in Lake Rotorua would be for all farms to mitigate nitrogen leaching to a level defined by GMP. GMP could be achieved either voluntarily by farmers (potentially with industry pressure and assistance) or through regulation. We simulate the cost of voluntary or regulatory GMP by estimating outcomes when mitigation is carried out using the least-cost combination of on-farm mitigation methods but not land use change. Dairy mitigation methods considered include application of nitrification inhibitors (DCDs), changes in stocking rates, use of nitrogen fertiliser, wintering cows elsewhere, using imported feed, and combinations of the above. Sheep/beef mitigation methods include changing stocking rates, using N fertiliser, altering the mix of stock classes, using very high fertility ewes, and combinations of the above.

Some of these mitigation techniques could occur voluntarily, while others are likely to be introduced only through regulation. Smeaton et al. (2011) investigate profitability under a number of nutrient mitigation management methods. The authors find that nitrogen discharges can be reduced whilst profitability is maintained under some mitigation methods; it is these management techniques that are most likely to be adopted by farmers without regulation. For dairy farms, these management techniques include use of DCDs, low but non-zero fertiliser application, and lower stocking rates with higher per-head production. For sheep and beef farms, the authors suggest the most successful management approaches will include high fertility ewes and a focus on increasing production per animal over increasing stock. The best combination and intensity of application of each management technique will differ across farms.

Due to limitations in NManager, we cannot simulate the potential impact of voluntary mitigation alone. Instead, we consider two GMP definitions, one which could potentially be achieved voluntarily and one which could only be expected to be reached through regulation. The first GMP definition that we simulate follows Anastasiadis et al. (2011): specifically, we consider good practice nitrogen leaching for dairy land of 28 kgN/ha/yr (down from baseline leaching of 56 kgN/ha/yr) and nitrogen leaching of 10 kgN/ha/yr for sheep/beef land (down from 16 kgN/ha/yr current leaching). This reduction would be difficult and costly for landowners to achieve and would only be achieved through regulation. We also assess outcomes under a less stringent GMP definition proposed by BOPRC that could potentially be achieved by voluntary actions by farmers. The BOPRC GMP stipulates that dairy nitrogen leaching should be 40 kgN/ha/yr and that sheep/beef leaching should be 14.4 kgN/ha/yr (Bay of Plenty Regional Council 2012). We assume that the GMPs are achieved in equal steps over ten years, with farmers meeting progressively more restrictive discharge limits each year until the GMP is fully achieved in 2022.

Our simulations are estimated assuming 100% compliance. As discussed earlier in the report, this is assumption is potentially unrealistic. Lower compliance will decrease the costs of the policy to farmers but will also proportionately decrease the nitrogen reductions achieved under the policy. To be consistent with later simulations, we also assume that an additional 50 t of nitrogen is reduced by non-agricultural sources. This assumption is shown in our simulations as a reduction in unmanageable loads, and the cost of this additional reduction is not included in our cost estimates as we have no way of robustly estimating it.

Results

Figure 32 shows that while both definitions of GMP will decrease the nitrogen loads arriving at Lake Rotorua relative to baseline, neither will achieve the regional council's long run environmental goal of 435 tN/yr. Indeed, the BOPRC GMP will barely restrict loads to current levels: nitrogen arriving in the lake will decrease over the short term but will increase over time due to historical discharges and unmanageable loads, despite the long run decrease in nitrogen exports from farmland of approximately 110 tN/yr.[30]

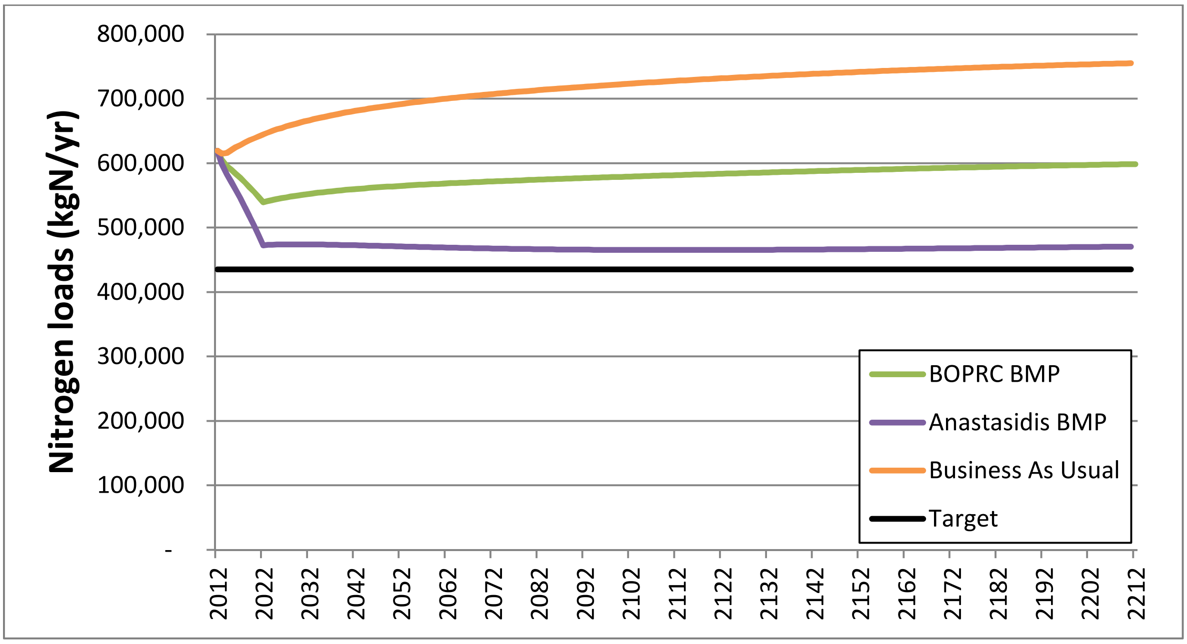

Figure 31 Nitrogen loads resulting from GMP regulation

[30] BOPRC recognise this and argue that land-use change will also be required to meet the communities' environmental goals.

Table 39 shows that the costs borne by farmers meet the GMP requirements are significant. Meeting the less restrictive BOPRC GMP restrictions will decrease total long-run farm profits by approximately 5%, while meeting the more stringent Anastasiadis GMP regulations will reduce the net present value of long-run profits from agricultural production in the Rotorua catchment by 10%. Under both definitions of GMP, mitigation will be carried out disproportionately on dairy land relative to sheep/beef land due to the tighter cuts called for on dairy land and the greater costs in terms of lost profit required to achieve GMP leaching rates on profitable dairy land. A final point to note is that while the Anastasiadis GMP costs are 330% of the BOPRC GMP costs, the reduction in exports is 220% of the BOPRC GMP. The non-linearity of costs occurs as there are increasing marginal costs of mitigation; that is, the more that farmers have to mitigate, the harder (and more expensive) it becomes. This non-linearity of cost is explored in the nutrient trading section.

Table 39 Mitigation costs of meeting GMP regulations

	BoPRC GMP			Anastasiadis GMP		
EAA of mitigation costs	Total	$/ha/yr	% decrease in BAU profits	Total	$/ha/yr	% decrease in baseline profits
Dairy mitigation costs	$697,388	$130	-10%	$1,589,982	$296	-22%
Sheep/Beef mitigation costs	$82,801	$5	-1%	$974,856	$63	-13%
Total	$780,188		-5%	$2,564,838		-18%

Cap and trade

Nutrient trading markets limit (or cap) the total annual nutrient leaching permitted in a catchment to a level that will achieve the environmental goal. This cap is then divided into allowances to discharge (permits), and participants in the trading scheme are required to return a permit for every unit of nitrogen leaching from their property. Those participants who do not hold enough permits to cover their discharges must either reduce their discharges or buy additional permits from other participants who have surplus allowances.

Nutrient trading markets are theoretically attractive for a number of reasons. First, because regulation targets the cumulative total of discharges rather than individual discharges, participants have flexibility in their own levels of discharging, i.e. as long as they hold enough allowances to cover their leaching, participants can increase, maintain, or decrease their discharges, as has happened in Lake Taupo. They can also mitigate leaching in any way that can be measured, including land-use change. This flexibility encourages profit-maximizing landowners to mitigate as long as their cost of mitigation is less than the market price of a permit; those with low mitigation costs will mitigate and profit by selling permits to those with higher mitigation costs. Using NManager, Anastasiadis et al. (2011) find that a trading scheme will achieve environmental goals for Lake Rotorua at a lower total mitigation cost than other options.

However, implementing and administering a trading scheme can be complex and more expensive for both administrators and participants than simpler command-and-control regulation. Trading systems require sophisticated monitoring of discharges and the creation of a new trading market. These set-up and administration costs cannot be calculated using NManager. Additionally, if a trading scheme is to be implemented, then the regulatory agency must allocate allowances, which can be a time-consuming and politically contentious process. Allocation is discussed at the end of this subsection.

We model an export-trading market based on that outlined in Kerr and McDonald (2011). At the end of each year, participants have to return enough allowances to cover the nitrogen that leaches from their property over the year, which is estimated using the biophysical model OVERSEER. Participants can trade freely throughout the year to ensure that they will be in compliance. Participants are not responsible for the level of leaching associated with forestry (4 kgN/ha/yr) as leaching cannot be decreased below this level.

Meeting the target with cap and trade

The BOPRC have indicated that they wish to reduce 200 tN through land-use change and 70 tN from moving all farms to GMP. We first examine the costs of meeting the BOPRC goal of reducing nutrient leaching from rural land by 270 tN by 2022 with the remaining reductions to meet their 320 tN reduction target to be achieved by non-agricultural sectors. We allow this reduction to occur through the most efficient combination of land use and management change, and transition to this 270 tN reduction target in ten annual 27 tN reduction steps. We assume that the additional 50 tN of reductions decrease unmanageable discharges by annual 5 tN reduction steps (denoted as ‘in lake decreases’ in the appropriate figures); the cost of these additional reductions are not included in the policy cost reported as we are unable to estimate them. Later in this section we investigate the additional costs associated with achieving the 320 tN reduction through agricultural abatement alone, consider the potential savings of achieving environmental targets over a longer time frame, and explore how costs increase as nutrient reductions become more ambitious. The distribution of costs under different allocation schemes is explored in detail in section 5.5.

Figure 32 gives the environmental outcomes of an export cap-and-trade scheme with a 270 tN nitrogen leaching target by 2022. Immediately clear is the importance of unmanageable loads: while nutrient exports decrease by 270 tN within 10 years, the loads of nitrogen reaching the lake do not achieve the long-run sustainable load goal of 435 tN per year until approximately 2100 due to unmanageable legacy loads. These long delays between costly nitrogen export reductions and nitrogen-load outcomes could be an issue in any catchment in which nitrogen travels at least in part through groundwater and in which the groundwater lags are long.

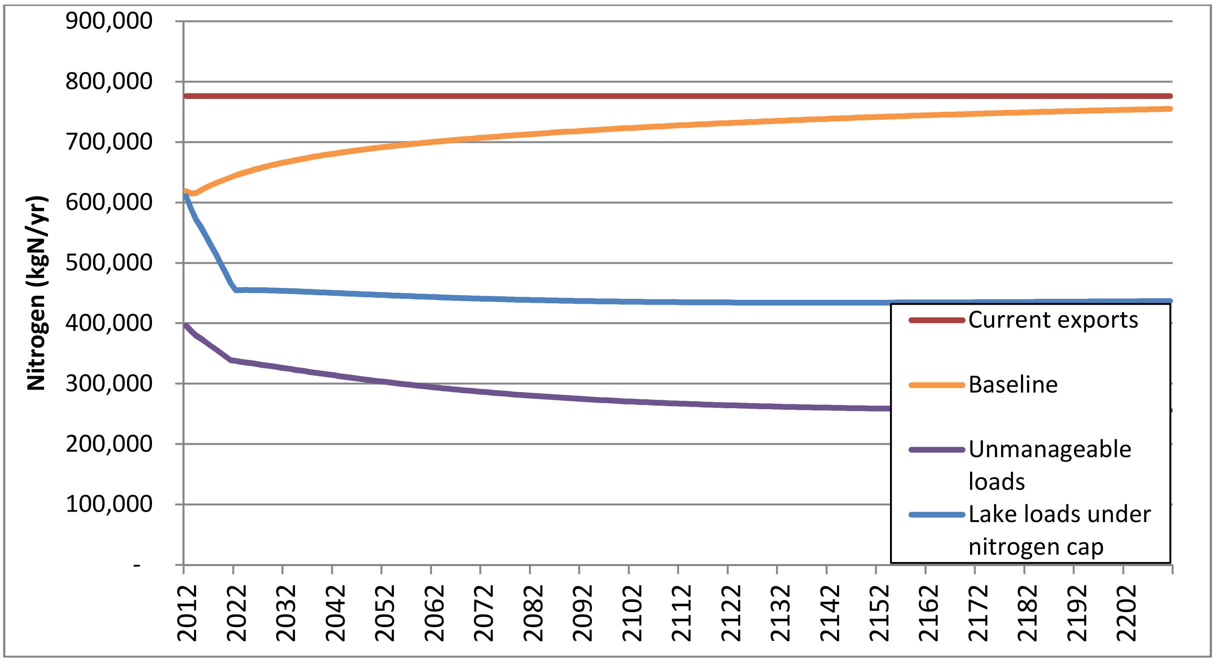

Figure 32 Nitrogen loads resulting from cap-and-trade regulation with a2022 reduction target of 270tN

Table 40 makes clear that land-use change is sure to play a significant role in achieving nitrogen cuts in the catchment. NManager predicts that in the long-run cost of reducing nitrogen discharges by 270t will require that more than 55% of current dairy land will need to convert to sheep/beef land given current prices and current technology. Land-use change would be even greater if the full 320 tN reduction was to be achieved on agricultural land alone: efficiently achieving this goal would result in zero dairy land in the catchment and about 2,000 ha of new forestry land.

Table 40 Land use change under a cap-and-trade scheme with a nitrogen reduction target of 270t by 2022

Long run land use	BAU		270tN reduction		320tN reduction	
	Area(ha)	Percentage	Area(ha)	Percentage	Area(ha)	Percentage
Dairy	5,363	13%	2,285	5%	0	0%
Sheep/Beef	15,375	37%	18,453	44%	18,564	44%
Forestry	21,023	50%	21,023	50%	23,198	56%

We also consider the cost of achieving the environmental goal, and distribution of mitigation cost across the different land uses (Table 41). Reducing nitrogen discharges by 270 tN by 2022 will cost approximately $3.2 million in equivalent annual annuity terms. Efficiently achieving this goal will see a disproportionate amount spent on mitigating dairy land. Achieving the 320 tN reduction from agricultural land will cost an additional $1 million EAA every year. These additional cuts are considerably more expensive as costs increase by 32% but nitrogen is only reduced by an extra 19%, again reinforcing the non-linearity of achieving tighter targets. The long-run-allowance price gives an indication of the additional cost of mitigating at higher levels: at the 270 tN target, participants would be charged $30 to be allowed to release an additional kg of nitrogen, while at the margin under the 320 tN target, they would be charged $34.40.

Table 41 Costs of meeting nitrogen targets under cap-and-trade policy

	270 tN (by 2022)		320 tN (by 2022)	
Mitigation costs ($/yr)	Total	$/ha/yr	Total	$/ha/yr
Dairy mitigation costs	$2,241,901	$418	$2,962,776	$552
S/B mitigation costs	$965,908	$63	$1,275,151	$83
Total	$3,207,809		$4,237,926	
Long run allowance price	$30.00		$34.40	

Achieving environmental targets over a longer time period

The final cap-and-trade policy approach that we consider is the potential cost savings of delaying mitigation. Implementing caps more slowly will decrease costs for a number of reasons, only some of which are captured by NManager. A key cost saving occurs because of discounting: we value costs faced today more than future costs. Following BOPRC, we discount future costs at a 7% annual rate in NManager, which effectively means that we value costs faced ten years from now half as much as those we face today. As well as discounting, we would expect that achieving environmental goals over a longer time period will be cheaper because it allows time for learning and technology development. Additionally, achieving 270 tN of nitrogen leaching cuts in 10 years may be seen as politically unacceptable and therefore not credible. A key determinant in the success of environmental markets is participant certainty, ensuring that participants see targets as credible and sustainable in the long run will be crucial to incentivize the learning and behaviour change needed (Karpas & Kerr 2011). Finally, evidence of land-use change in response to changes in market conditions suggests switching land use is a slow process (Kerr & Olssen 2012). Such evidence suggests adjusting land use quickly will be costly and may justify slower transitions to minimize cost.

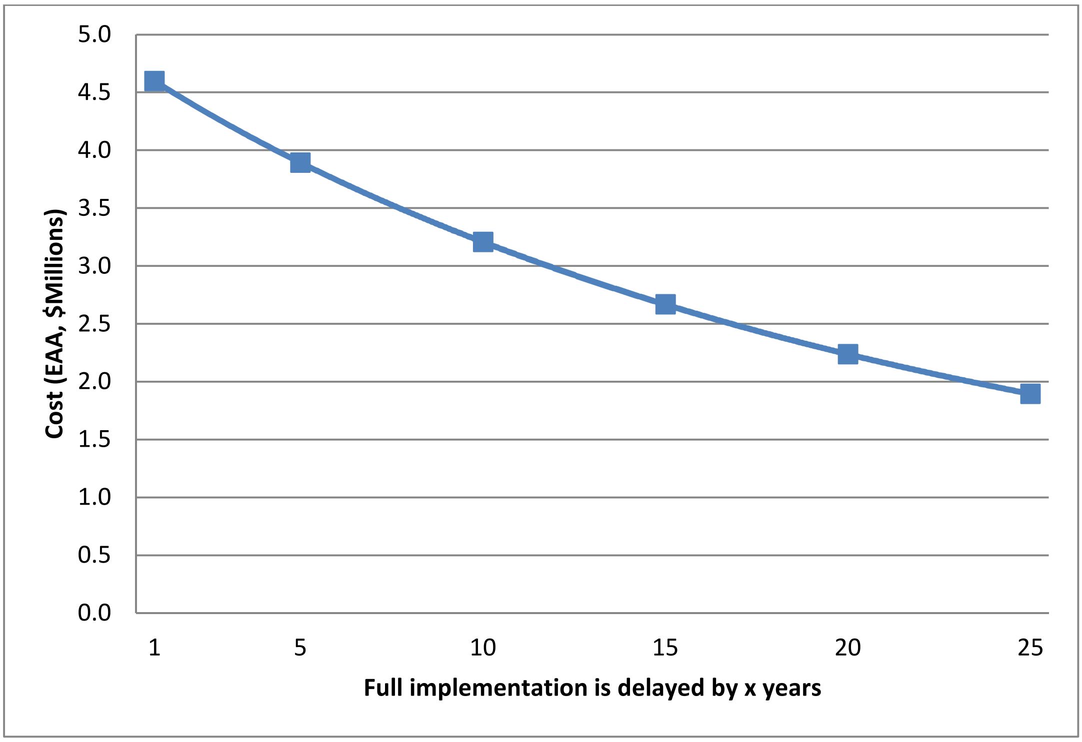

Figure 33 Cost savings of delaying nitrogen target implementation under cap-and-trade policy

To investigate the potential cost savings of delaying policy, we simulated a number of 270tN nitrogen-leaching-reduction caps in NManager. The fastest sees full implementation occur in one year and the slowest phases in the reduction over 25 years. Figure 33 shows the cost savings of slowing implementation. Implementing the reductions in 1 year rather than over 10 years would increase costs by 43%, while the savings from spreading over 10 years rather than over 5 years are still 21%. Delaying full implementation of the policy by an additional 5 or 10 years will save 17% and 30%, respectively. The additional savings from delaying further become increasingly smaller; delaying so that implementation occurs over 25 years saves only an additional 11% compared with the 20-year target.

Of course, delaying the full implementation of regulation will also delay improvements in the lake. Figure 34 shows the environmental impacts of delaying the policy. In the short term, there are differences in the nitrogen loads reaching the lake under the different policy timelines; however, these loads converge in the long run. Given the long-run nature of the water quality goals of the Lake Rotorua catchment and the significant cost savings of achieving these goals more slowly, achieving these targets over a somewhat longer time horizon may be justified.

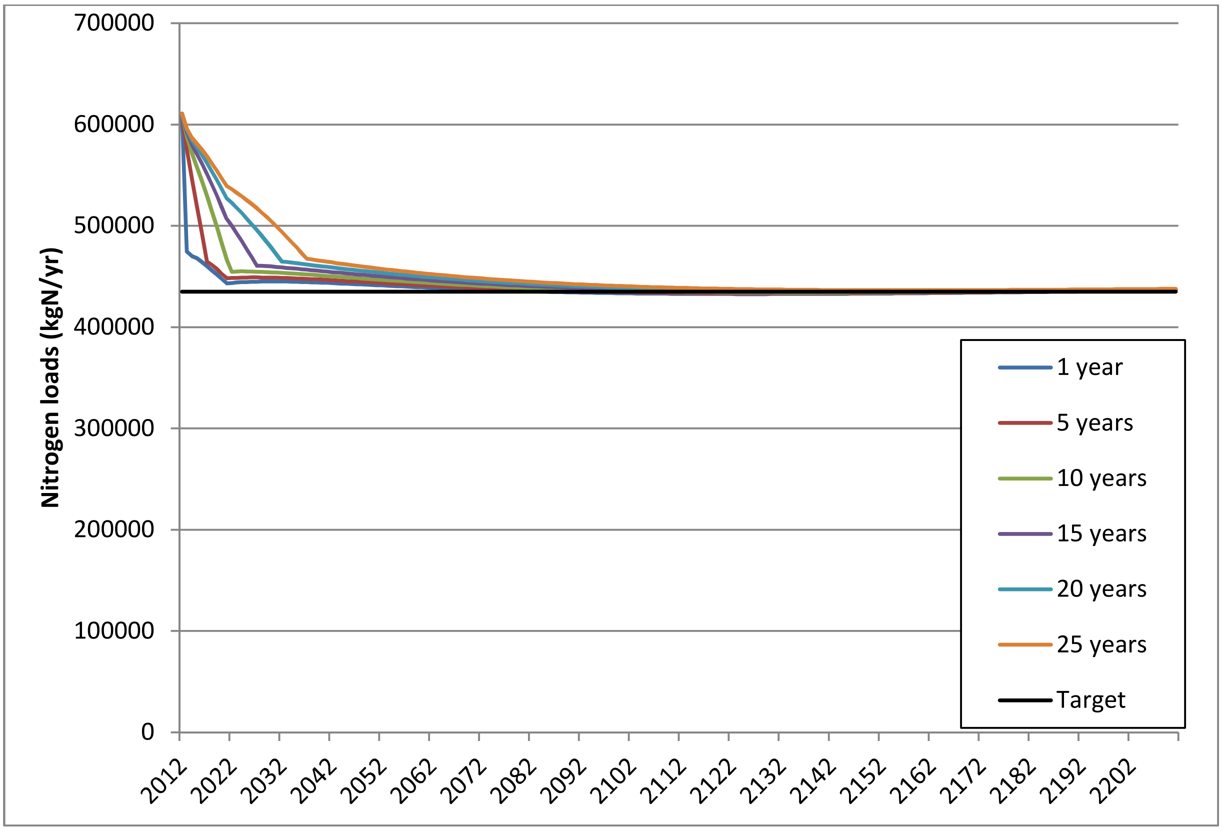

Figure 34 Nitrogen loads resulting from delaying implementation of nitrogen targets

Non-linearity of cost

We simulate a series of nutrient targets to investigate how the total cost of achieving an environmental goal changes as the ambition of nutrient reduction target increases. Figure 35 demonstrates that costs increase at a faster rate as the nitrogen reduction target becomes more ambitious. For example, the cost of increasing nitrogen reductions by 50 t from 70 t to 120 t increases costs by $480,000 per year, while increasing reductions by 50 t from 320 t to 370 t costs $1,200,000 per year. This is a result of all farmers facing increasing marginal costs of mitigation; that is, the first units of mitigation are easier (and cheaper) than later mitigation. The BoPRC target of 270 t of reductions is shown in red.

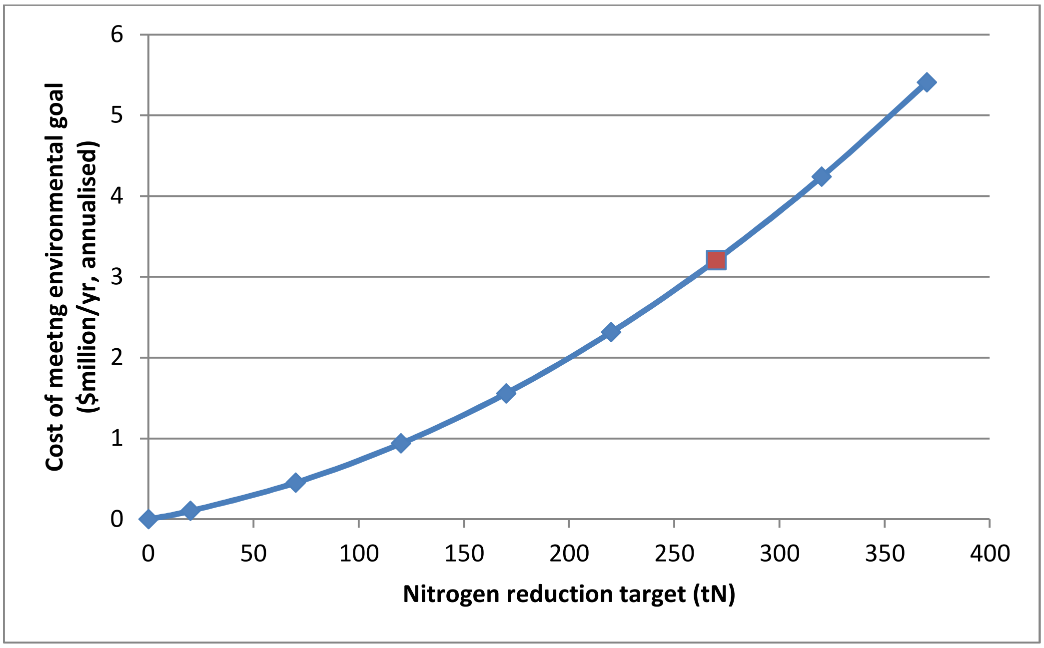

Figure 35 Catchment wide cost of achieving more stringent environmental targets

5.6 Nitrogen Export Taxes

The final policy we consider is nitrogen export tax. Profit maximizing nitrogen dischargers will decrease their nitrogen leaching if the benefit of leaching another unit of nitrogen is less than the tax rate of exporting an additional kg of nitrogen. This ensures marginal costs of mitigation will be equalized at the level of the tax rate across the catchment, and the efficient distribution of mitigation occurs.

There are benefits and costs of implementing an environmental tax on nitrogen exports relative to other policies. A tax provides a certain price for landowners and is easy to understand. It allows participants to plan ahead and invest with confidence. The tax collected can be used by the council to decrease other taxes (a so-called 'double dividend'), or can be invested in research and innovation and education to further address the environmental problem. If tax evasion and avoidance could be minimised, a nitrogen tax would equalise marginal costs of mitigation across the catchment which would theoretically distribute mitigation effort efficiently around the catchment (identically to a cap-and-trade scheme).

Administering a nitrogen tax will be simpler and therefore cheaper than a cap-and-trade scheme, as it will not require the allocation of allowances or the establishment of trading rules and mechanisms. However, regulatory agencies will still need to collect data to estimate nitrogen exports; this will make a nitrogen export tax difficult and costly relative to command-and-control-type regulation. There is also a key downside of using environmental taxes over a cap-and-trade scheme – environmental uncertainty. To know what level of mitigation would occur at any tax rate, regulatory agencies would need to know dischargers' mitigation cost curves, which is potentially an unreasonably high knowledge requirement. Setting the tax rate at too high or too low a level will result in a different environmental outcome to that intended.

In this section we use NManager to explore the potential for adverse environmental outcomes or higher costs under imperfectly set taxes. We assume that the council's environmental aim remains to reduce agricultural nitrogen leaching by 270 tN/yr by 2022.[31] The tax rate that will achieve this goal is equal to the nitrogen permit prices estimated under the cap-and-trade scheme with the same environmental goal. We assess the environmental and cost outcomes of setting this tax 10% higher or lower than this optimal tax to assess the sensitivity of outcomes to tax rate misspecifications. The long-run tax rates are shown in Table 42.

Tax rate sensitivity results

The environmental outcome of setting the incorrect tax rate is shown in Figure 36. Setting the tax rate at 90% of the correct level, that is a long run tax of $27.00 per kgN/yr rather than $30.00 per kgN/yr, meaning that the environmental goal is never met. In the long run, the level of nitrogen loads are 30 tN more than the target: the reductions carried out are only 88% of the reductions required. Conversely, setting the tax too high (i.e. at a long-run rate of $33.00 per kgN/yr rather than $30 per kgN/yr) means the environmental target will be overshot by approximately 33 tN, and that the environmental target is met more quickly; the 435 tN goal is achieved before 2030, approximately 70 years earlier than the $30 tax achieves the goal.

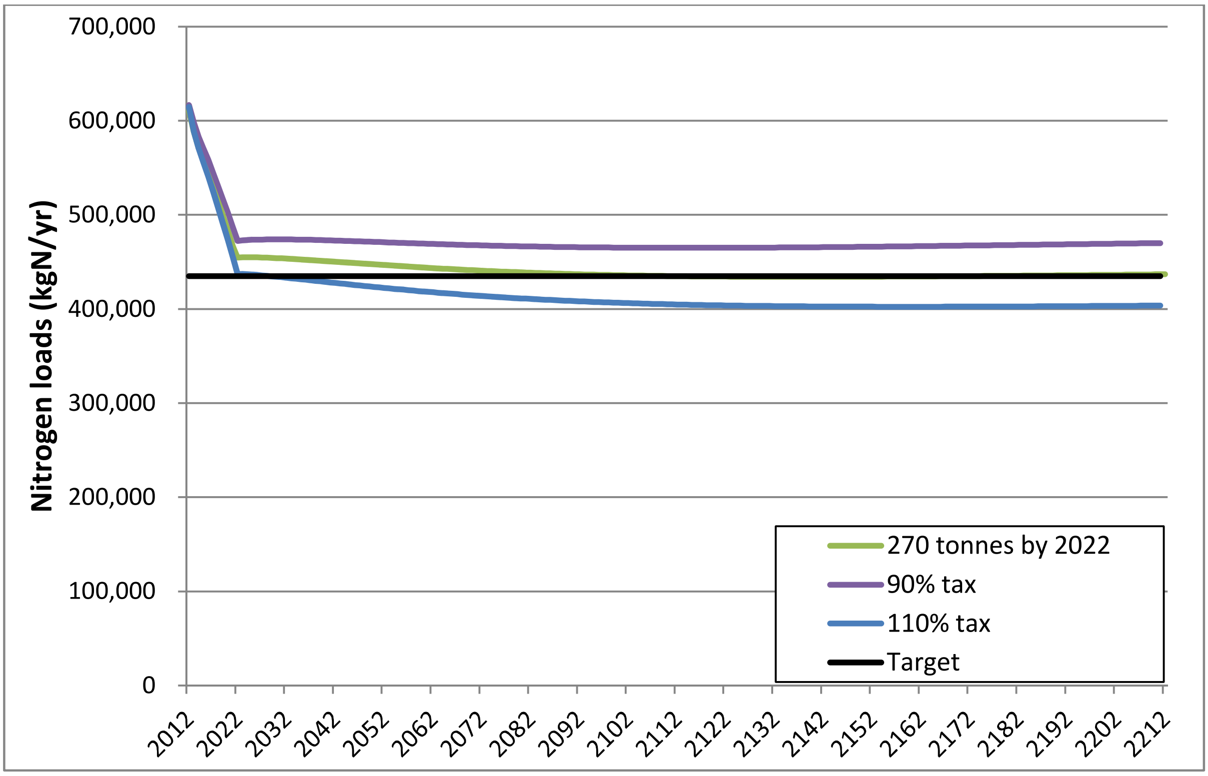

Figure 36 Nitrogen loads resulting from a tax on nitrogen exports

[31] We also assume that the council removes an additional 50 tN from other sources by 2022. As in the nitrogen trading section above, we do not price these reductions as we have no ability to reliably estimate costs of non-agricultural mitigation.

However, this additional environmental benefit comes at significant cost. Table 42 shows that the 110% tax rate results in additional mitigation costs of 22%, which occurs despite the tax rate only increasing by 10%. This result makes intuitive sense as all of the cheap mitigation options have already been carried out under the $30 tax and the mitigation carried out under the $33 tax all cost between $30 and $33 dollars per kgN.

One caveat is that the simulations we have run do not allow for the regulator agency to 'learn' and alter the tax rate. If the regulatory agency was monitoring farmers' nitrogen exports to enforce compliance with the policy, it would be straightforward for the council to measure the responsiveness to the initial tax rate. They could then adjust this tax rate to ensure that total nitrogen exports were meeting the desired levels. Incorporating this learning would significantly lower the cost of over- or under-shooting the 270 tN reduction tax rate.

Table 42 Mitigation costs under nitrogen taxes

EAA of mitigation costs	90% of 270 tN tax rate		270 tN (by 2022)		110% of 270 tN tax rate	
	Total	$/ha/yr	Total	$/ha/yr	Total	$/ha/yr
Dairy mitigation costs	$1,786,283	$333	$2,241,901	$418	$2,745,479	$512
Sheep/Beef mitigation costs	$770,456	$50	$965,908	$63	$1,182,253	$77
Total	$2,556,739		$3,207,809		$3,927,731	
Long run tax	$27.00		$30.00		$33.00	

5.7 Other Simulations

Anastasiadis et al. (2011) simulate the costs of two additional policies to achieve nitrogen reductions in Lake Rotorua – land retirement and a more complex 'vintage' trading market that considers the time lags between nitrogen export and arrival in the lake. These simulations were carried out under slightly different nitrogen targets, but the general results still apply. We summarise the key conclusions from these simulations below.

Land retirement

Anastasiadis et al. (2011) investigate the cost of achieving nitrogen reduction targets through land-use change alone, i.e. with no on-farm mitigation. This equalises the marginal cost of land use change, but does not equalise both marginal costs of mitigation and land-use change as in the export-trading market. The authors find that as a result, using a land-retirement scheme is almost 25% more expensive than an export-trading scheme. High levels of land-use change might also be expected to be associated with greater social disruption and community costs.

Vintage trading scheme

Anastasiadis et al. (2011) also investigate the potential efficiency gains of taking account of the time that nitrogen exports from properties actually arrive as lake loads. Due to significant groundwater lags in Lake Rotorua, cost-effectiveness gains could be achieved by shifting the timing of mitigation between different areas of the lake so those properties closest to the lake, whose nitrogen leaching most immediately impacts lake loads, can mitigate more now. This would allow those properties in the back of the catchment, whose nitrogen exports will not affect lake loads for decades, to defer the cost of mitigating nitrogen until later, reducing the net present value of mitigation. To test the cost savings of such a policy, the authors simulate a 'vintage' market, where participants have to hold allowances time-dated with the average year their nitrogen leaching will arrive in the lake.

Clearly such a scheme would be administratively complex and more difficult for participants to understand. Anastasiadis et al. (2011) also find that for Lake Rotorua the costs savings of increasing complexity are very small. The authors emphasise that this result is specific to the Lake Rotorua catchment, and that under the following conditions significant savings may be available in catchments: (1) where nitrogen reaches the water body predominantly through groundwater with little immediate surface water nitrogen leaching; (2) where there is a more even distribution of land with short lag times; and (3) where less stringent environmental targets allow for more flexibility in mitigation.

5.8 Allocation

In this section we assess the wealth impacts of introducing nitrogen reduction policy and how this is distributed across communities in the catchment under various free allocation schemes. The cost estimates presented in earlier sections are the total cost of mitigation required to achieve the nitrogen reduction goal on each land use and in total. The simulations in earlier chapters show that to achieve the nitrogen reduction target cost effectively the majority of mitigation expenditure will need to occur on dairy farms. However, this is not the same as saying that dairy farmers will bear the cost of this mitigation; that is determined by the allocation of allowances. Free allocation of allowances effectively works as a lump sum transfer of wealth to the recipient and can be used to distribute the costs of achieving nitrogen reduction policy across different land users and the community. There is no 'right' way to allocate allowances as there is no generally agreed upon definition of how cost should be fairly shared. The 'best' allocation system will be the one that the community agrees is fair and is politically feasible. Kerr and Lock (2009) discuss a number of potential principles for cost sharing to achieve nitrogen reduction goals in Lake Rotorua, and outline the importance of considering efficiency alongside equity if allocation occurs in a trading scheme with limited flexibility or transaction costs.

We assess the wealth implications of achieving the proposed BoPRC target of a 270t reduction in nitrogen by 2022 under the export trading policy described in section 5.5. All wealth comparisons are relative to the baseline case outlined in section 5.3. As a result, the option values of being able to increase nitrogen leaching are not included in the wealth changes documented below: these options were lost at the implementation of 'Rule 11' restrictions on expansion in 2005. For this reason we do not report the wealth implications of introducing a cap-and-trade scheme on foresters; as the cap-and-trade scheme we simulate allows for a baseline leaching of 4 kgN/ha/yr, forestry will be relatively unaffected by the implementation of such an export trading system. If instead we quantified the costs of this policy relative to a no-regulation state we would have to consider wider costs, including the cost of losing the option to intensify on forestry and underdeveloped land at the time Rule 11 was introduced.[32] The three allocation schemes we consider are outlined below.

Auction

The first allocation mechanism we assess is 100% auctioning, that is, zero free allocation. Under this allocation scheme, both sheep/beef and dairy farmers must purchase an allowance for every unit of nitrogen they discharge. Allowances end up in the hands of those who value them the most through an auction where farmers will theoretically bid up to their marginal cost of mitigation for an allowance. We assume no transaction costs. As mentioned in section 5.5, the first 4 kgN/ha/yr are considered unmanageable and participants are not held responsible for this leaching.

Grandparenting with buyback

We also investigate outcomes under a grandparenting allocation; that is, participants are freely allocated allowances at a rate proportionate to their leaching before the introduction of regulation. To avoid strategic behaviour grandparenting should be based on unchallengeable data on leaching rates prior to any indication that free allocation based on current leaching will occur. If care is not taken recipients may boost current exports in order to get more generous free allocations. Grandparenting can be at any proportion of previous discharges; below we present outcomes with 100% free allocation, where all sources are freely granted allowances equal to their baseline discharges. The regulatory agency would have to then buyback enough of the freely allocated allowances at the market price to achieve the nitrogen reduction goal. Because the market price will be equal to the marginal cost of mitigating the last unit of nitrogen to meet the cap and sources have increasing marginal costs of mitigation, this buyback will more than fund the mitigation of sources, whose initial mitigation costs will be lower than the market price of allowances.

Bay of Plenty Regional Council 'good management practice' allocation

The final allocation regime we consider is motivated by a BoPRC cost sharing proposal in the recent proposed regional plan information documents (Bay of Plenty Regional Council 2012). They propose a cost sharing arrangement where farmers are responsible for shifting their farm to best practice while the rest of the costs of achieving the nitrogen reduction target will be covered by the wider community (local, regional, and central government). BoPRC defines best practice for dairy farms as nitrogen leaching of 40 kgN/ha/yr (a decrease of 16 kgN/ha/yr, or approximately 30%), and nitrogen leaching of 14.4 kg/ha/yr for sheep/beef farms (a decrease of 1.6 kg/ha/yr, or 10%).

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[32] In actual fact, owners of underdeveloped land and foresters will benefit from a move to a trading system such as that simulated here, relative to the status quo of Rule 11. A trading scheme allows these landowners to purchase nitrogen credits and intensify their land use if the benefits of intensifying outweigh the costs of allowances and conversion. While this additional flexibility is a benefit relative to Rule 11, the costs borne by these landowners at the introduction of Rule 11 will only be outweighed if this flexibility is matched by generous free allocations of permits that allow these affected landowners to intensify at little cost.

Allocation results

Figure 37 compiles the total costs borne by landowners currently in dairy, sheep/beef, and by the community to meet the 270 tN by nitrogen reduction by 2022 on agricultural land.[33] If all allowances are auctioned at the inception of policy, that is there is zero free allocation, the community will receive more than $80 million in allowance payments ($5.3million EAA). This money can be spent in any way the community sees fit: it could be used to reduce rates, pay for additional mitigation, invested in research on mitigation options, or spent on other priorities. The money could also be returned to land owners to help offset the cost of purchasing allowances and carrying out the mitigation required to achieve the nitrogen reduction goal. The total cost of mitigating and purchasing allowances is large for both sheep/beef and dairy land owners, in total in NPV terms it costs them approximately $77 million ($5 million/yr) and $52 million ($3.4 million/yr), respectively. Table 43 presents these costs in per ha terms: under an auction allowance regime sheep and beef farmers will see a reduction in per ha profits of 47% relative to baseline profits. Dairy farmers will see an even larger reduction in baseline profits of 70%.

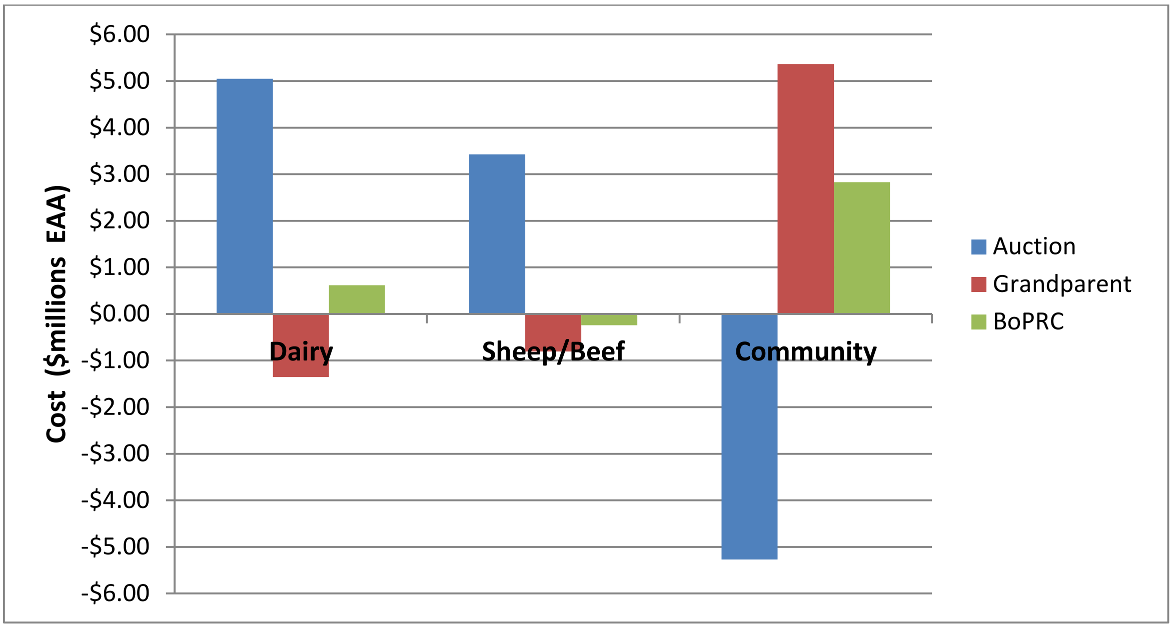

Figure 37 Distribution of costs under a nitrogen cap-and-trade scheme with varying allocation of allowances

Both sheep/beef farmers and dairy farmers would see their profits increase under a 100% grandparenting with buyback allocation scheme. Sheep/beef profits would increase by 11% relative to baseline, while dairy would see an even larger increase in baseline profits of 19%. This occurs because the community buyback will more than cover the mitigation costs

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[33] Note that if the community will fund the additional 50 tN reduction required to reach the 320tN reduction goal, the cost of this mitigation to the community will be additional to the numbers reported here. Any costs of scheme set up and administration on the regulator side, or compliance costs on the participant side are also absent from our analysis.

farmers face. Using this allocation mechanism the community would face a total cost of $82 million ($5.4 million/yr) to achieve the nitrogen reduction goal, while sheep/beef farmers and dairy farmers in aggregate benefit by more than $30 million ($2.1 million/yr). Allocating allowances to cover more than the cost of mitigation could be justified if the aim of free allocation was to compensate for the lost option value that farmers faced when Rule 11 was imposed. However, if this was the aim of the allocation regime additional allowances should go to the land that was most likely to intensify if it was not restricted by Rule 11. The land most likely to intensify would have been underdeveloped land with low nitrogen leaching.[34] Instead, grandparenting gives the majority of these extra allowances to dairy land which presumably was already at the limits of intensification and therefore faced a relatively small lost option cost.

Table 43 Distribution of cost per ha and relative to baseline profits under a nitrogen cap-and-trade scheme with varying allocation of allowances

	Dairy		Sheep/Beef	
Cost per ha under allocation ($EAA/ha)	$/ha/yr	% change in baseline profits	$/ha/yr	% change in baseline profits
Auction	$941	-70%	$223	-47%
Grandparent with buyback	-$252	19%	-$52	11%
BoPRC GMP	$115	-9%	-$16	3%

The final allocation scheme we consider is a cost sharing between BoPRC and landowners where the council will freely allocate allowances up to a good management practice level, and buyback allowances to ensure that the nitrogen reduction target is reached. Landowners are expected to cover the costs of any leaching above the GMP level. The total cost faced by regulatory agencies to achieve the nitrogen reduction target under this allocation scheme is just under $43 million ($2.8 million/yr). Under this allocation dairy farmers will see their costs decrease by a total of just under $10 million ($0.6million/yr), or 9% of BAU profits. Comparatively, sheep/beef farmers will see a slight increase on BAU profits of 3%, a cumulative gain of just over $3 million ($0.2 million/yr). The different outcomes for dairy and sheep/beef landowners reflect the relative cuts in BAU dischargers and their respective marginal costs of mitigation.

5.9 Māori Perspective

Māori have a distinctive role in water catchments as tangata whenua, but also fill many other, potentially conflicting, roles: small and large pastoral landowners, forest owners, and water users. These various roles bring about a number of issues that Māori landowners will face under any regulation to improve water quality. Here we briefly discuss two pressing issues:

[34] A large portion of underdeveloped land in the catchment is Maori land. This land was underdeveloped at the time of Rule 11 due management restrictions, limited investment funds, and conscious decisions to minimise the impact on the lake.

the implications of land-use restrictions for landowners of underdeveloped land; and the potential difficulty for small Māori landowners to take advantage for complex policy.

Experience in the Rotorua catchment has suggested that Māori land is on average less developed than non-Māori land; that is, has lower production intensity (and nutrient leaching rates) than the lands potential. Reasons for this include the unique ownership, decision making, and funding difficulties that stem from the cooperative ownership restrictions on Māori land as a result of the Te Ture Whenua Māori Act 1993 (the Māori Land Act). Additional to these management restrictions, in Lake Rotorua some Māori landowners decided early on to limit the intensity of their land due to concern about falling lake water quality. This lower level of development has serious implications for Māori landowners if regulation restricts nutrient discharges to a rate proportional to current discharges. Such a restriction would take away the option to intensify in the future, a cost which would be borne disproportionately by underdeveloped farmers. Differences in intensification must also be considered if a nutrient trading scheme is to be implemented, particularly when considering free allowance allocation mechanisms; grandparenting allowances would leave Māori (and other under-developed) land owners less wealthy than owners of similar land (Kerr & Lock 2009).

A related issue is the difficulty of small landowners or land under decentralised management structures, such as much Māori land, dealing with complex water quality policy. A participant in the Motu Nutrient Trading Study Group (NTSG) for Lake Rotorua expressed concern about small Māori landowner's ability to take advantage of a nutrient trading scheme due to its complexity and the long run implications of a short term decision to sell allowances. To help protect small landowners in a trading scheme, the NTSG suggested that allocations are given out in tranches over time so that all future allowances cannot be sold by mistake early on, and that regulatory agencies support small landowners to make good decisions around trading, particularly in the early years of a trading scheme (Kerr & McDonald 2011). This approach has been followed in the Lake Taupo trading scheme; the Lake Taupo Protection trust provides business advisors to help participants make good trading decisions.

5.10 Conclusions and Future Work

In this case study we have considered a number of policies that could achieve nutrient reduction targets in catchment. These policies include the implementation of GMPs, a nutrient cap-and-trade programme with different allocation options, and a tax on nutrient discharges. The provisional water quality target proposed for the Rotorua catchment is to reduce agricultural N loss by approximately 60% by 2022 (reducing the annual N load to the lake from 755 tN to 435 tN in the long run). The agricultural sector is expected to reduce 270 tN of the desired 320tN. The remainder will come from non-agricultural sources.

For each policy we have reported the mitigation costs of achieving the nitrogen reduction target and how this will be efficiently spent across land uses. Where appropriate we have also reported the predicted land-use change resulting from policy. While we cannot quantify the benefits of each policy in dollar terms, we have reported the Lake Rotorua nitrogen loads that will result from policy and the complementary long run GHG emissions reductions. Finally, we have discussed the distributions of cost across different land uses and the wider community under a selection of different free allocation schemes. We have assessed the sensitivity of results to model assumptions where possible. A summary of the water quality scenarios considered for the Manawatu catchment is provided in Table 44. The baseline assumes there is no water quality policy.

Table 44 Summary of water quality policies in Rotorua Catchment

Scenario	N Target (t)	N Target Achieved by 2022	N Target Achieved by 2100	Average cost ($/kgN)	Total annual cost ($ mil)	Change in profit (%)
Baseline	435	0%	0%	n/a-	n/a-	0%
BoPRC GMP	435	70%	58%	$7	$0.8	-5%
Stringent GMP	435	89%	91%	$11	$2.6	-18%
270tN export reduction by 2022	435	94%	100%	$9	$3.2	-22%
320tN export reduction by 2022	435	87%	100%	$5	$4.2	-29%
Tax at $30kg/N	435	94%	100%	$4	$3.2	-22%
Tax at $27kg/N	435	89%	91%	$9	$2.6	-18%
Tax at $33kg/N	435	100%	109%	$11	$3.9	-27%

To summarise, the key findings from the policies assess in this case study for the Rotorua Catchment are:

- Implementing a mix of GMPs on pastoral land such as applying DCDs, reducing N fertiliser, importing feed, and adjusting the mix and level of stock would decrease the N loads arriving at Lake Rotorua relative to baseline, but by less than the 270 t reduction required to achieve the regional council's long run environmental goal of 435 tN/yr (policy #1a & b). In over-allocated catchments such as Lake Rotorua land use change as well as management changes may be required to meet environmental goals.
- Even when nutrient exports decrease by 270 tN in 10 years, the loads of N reaching the lake do not achieve the long run sustainable load goal of 435 tN per year until approximately 2100 due to unmanageable legacy loads. These long delays between costly N export cuts and N load outcomes could be an issue in any catchment where some N travels through groundwater and the groundwater lags are long.
- Reducing N discharges by 270 tN by 2022 was estimated to cost $3.2million per year (policy #2a). A large amount of this cost would be spent on mitigation efforts on dairy land, relative to the land area occupied by dairy farms. If agriculture had to meet all the required N leaching reductions (i.e. 320 tN) it will cost an additional $1million per year (policy #2b). This equates to a 30% increase in costs for only an additional 18% decrease in nutrients.
- A reduction of 270 tN could also be achieved by a $30/kg N tax. Setting the tax at $27/kg N only achieves a reduction of 240 t N while a $33/kg N tax gave a reduction of 303t N (policy #3a, b & c).
- The distribution of costs in a cap-and-trade programme is determined by the choice of allocation scheme. Allocating permits based on current discharges (i.e. grandparenting) and then buying sufficient permits back to achieve the N reduction target would cost

the regulatory agency a modelled $5.4 million/year with farm profits increasing by more than 10%. Conversely, auctioning all permits would net the regulatory agency $5.3million and farm profits would fall by 39–70%.

6 Summary and Conclusions

This report assesses the impacts on water quality and farm revenues from different policy options – regulation, cap-and-trade programmes, and taxes – to maintain or reduce nutrient loads in three New Zealand catchments. Despite the results being unique to these catchments, some of the findings from our policy analysis could be generalised to gauge the possible impacts on other regions of the country. However, the actual impacts in other catchments will vary depending on the physical, geographic, and social conditions in each catchment.

For each policy scenario, we report the mitigation costs of achieving the nutrient reduction target to improve water quality and the resulting changes in farm income, represented by net revenues in the catchment. Where appropriate, the predicted land-use change resulting from each scenario is also reported. We do not quantify all the costs and benefits of each policy in monetary terms, rather we report the relative changes in the catchment's nutrient discharges and revenue streams resulting from policy plus the long run change in GHG emissions. A recap of the important findings for each catchment is included below, and a summary of the key impacts on N for each policy scenario is listed in Table 45. Additional policy scenarios that demonstrate the impacts from several different nutrient targets and tax levels in the Hurunui-Waiau and Manawatu catchments are included in Appendices B–E.

Hurunui-Waiau Catchment

The water quality limits being discussed for the Hurunui-Waiau catchment are intended to maintain nutrient loads at 2010 levels (Environment Canterbury 2011a). There is also an irrigation scheme being proposed for the Hurunui Plains area of the catchment that could more than double the area of irrigable land in the catchment (Environment Canterbury 2012). The policy scenarios are all compared to a baseline where there is no additional irrigation scheme. Our modelling indicated the following:

- At the catchment level, adding a large irrigation scheme would raise net catchment revenue by 10% through increased production, but would also increase N leaching by 24%, P loss by 4% and GHG emissions by 72% in the catchment, in the absence of any additional policies to manage water quality and GHG impacts. For the Hurunui Plains, where the irrigation scheme will operate, there would be productivity benefits and increased profits for dairy, sheep and beef, and arable crop farmers that increase their access to water, but N leaching and P loss could both increase by nearly 60%.
- If landowners in the catchment maintained their current land use and adopted GMPs such as applying nitrification inhibitors (DCD), riparian planting, and installing dairy feed pads, it is unlikely that the 2010 catchment nutrient loads would be maintained if a large irrigation scheme were implemented (policy #1a-b). The estimated average costs of implementing GMPs are around $50/tN, primarily because of the relatively high cost of these practices for sheep and beef farmers in the catchment.

- Of the policy options modelled, a catchment-wide trading programme with a grandparenting allocation proved to be the most cost-effective[35] for landowners to maintain 2010 catchment nutrient loads with the irrigation scheme implemented. Compared with the baseline, a cap-and-trade programme that allocates permits to landowners based on their 2010 N leaching and P loss levels (i.e. grandparenting) increases net catchment income by 5% (policy #2a). With catchment-wide trading there may still be water quality issues (e.g. localized 'hotspots') in the Hurunui Plains because N leaching is estimated to increase by 16% and P loss by 44% for over baseline levels in that area.
- Restricting trading of discharge permits to a specific area of the catchment may reduce the likelihood of 'hotspots', but net revenues only increase by 4% over the baseline (policy #2b).
- We modelled a modified equal allocation approach (policy #2c) where an average permit level per hectare was established and then adjusted for the productive capacity of the land. This generated similar results as a grandfathering allocation with area-restricted trading (policy #2b). Allowing farmers in the more productive Hurunui Plains to purchase permits from landowners in the lower productivity areas (i.e. foothills) would provide flexibility for landowners to increase their own level of nutrient discharges while still meeting 2010 nutrient loads.
- Theoretically, an optimally implemented nutrient tax (policy #3) would produce similar impacts to a catchment-wide cap-and-trade programme (policy #2a, #2c). The N and P tax could, if desired, be varied across different parts of a catchment to meet different water quality limits (policy #2b).
- The optimal N tax rate to maintain nutrients at 2010 levels was to charge all landowners in the catchment $23/kg N and $119/kg P (policy #3). Although this is an 'optimal' solution from a catchment-wide perspective, there could be distributional impacts as not all landowners who would be required to pay the tax would benefit from the new irrigation scheme.
- The marginal costs of abatement for taxes are non-linear making it difficult to establish an optimal tax ex ante. Providing flexibility to adjust the tax over time would better ensure that nutrient load limits are maintained over the long run. If policy makers have frequently to adjust the tax rate, this could generate more economic and social disruption in the transition than a cap-and-trade approach.

Manawatu Catchment

The water quality limits modelled for the Manawatu catchment would require a reduction of N leaching by 53% and P losses by 49%, similar to those specified by Horizons Regional Council (Ausseil & Clark 2007). We assume the entire limit would have to be achieved through mitigation from the land-use sector based on the fact that 90% of nitrogen in the Manawatu River is from two main types of non-point sources – dairy, and sheep and beef

[35] In this report, a 'cost-effective policy' is defined as a modelled policy that achieves the nutrient target in the catchment at the least cost to the landowners. It does not necessarily account for administrative and transaction costs that could make the policy more costly in reality.

farming (Clothier et al. 2007). Part of the policy outlined in the December 2010 version (the Decisions Version) of the proposed Horizons One Plan required that new dairy farms demonstrate compliance with cumulative nitrogen leaching maxima that vary with Land Use Capability (LUC) classification (i.e. natural capital approach). We evaluate a policy option where *all* dairy farms must comply with LUC based nitrogen leaching caps,[36] plus other options such as implementing GMPs, various cap-and-trade schemes, and a nutrient discharge tax. The baseline scenario modelled assumed that the proposed water quality policy had yet to be implemented. The findings from the policies modelled are:

- A GMP approach that assumed the most effective voluntary practices (i.e. DCD and riparian planting) would be implemented on 50% of the eligible land in the catchment could reduce N leaching by 7% and P losses by 14% relative to the baseline (policy #1a). This would not achieve the specified nutrient reductions.
- If all pastoral landowners were required by regulation to implement the GMPs of applying DCDs and undertaking riparian planting, and all dairy farmers also had to implement the GMP of wintering their cows off the farm, then N leaching and P loss is estimated to decrease by 15% and 27%, respectively (policy #1b). This would be done at a low average cost ($2/kgN) to the landowner, primarily because applying DCDs could improve productivity, but would not achieve the water quality limits specified by the Regional Council.
- A catchment-wide cap-and-trade programme with a grandparenting-based allocation (policy #2a) proved to be one of the most cost-effective policies of those options modelled to meet the water quality limits at the catchment-level. Net revenue for landowners in the catchment declined by 17% and adding administration and transaction costs further reduced revenues to 22% below 2007 baseline revenues.
- Allocating discharge permits based on LUC is intended to intensify the use of high productivity land while simultaneously reducing nutrient loads. This is referred to as a natural capital allocation approach. Only requiring existing dairy enterprises in each LUC to meet specified nutrients discharge levels results in a 6% reduction in total N compared to the modelled baseline (policy #2c), and less than a 1% reduction in net revenue. This is because (1) most dairy farms are already located on the LUCs with permitted discharges of 18 kgN/ha/yr or more and thus required little change to meet the specified leaching rates stated in the December 2010 version of the Horizons One Plan, and (2) dairy farms comprise less than 20% of the catchment, and therefore dairying on its own does not have a large enough share of the land mass to achieve a 53% reduction in N discharges.
- A natural capital approach could still be a feasible policy to meet nutrient reduction targets if (1) discharge permits based on LUC are allocated to *all* pastoral, arable and horticultural land uses (not just dairy) and (2) *all* landowners are required to collectively meet the HRC's nutrient targets of reducing N by 53% and P by 49% through a catchment-wide trading scheme (similar to policy #2a). In this case, net revenue for landowners in the catchment was estimated to decline by 17% and adding

[36] Note: this policy option is not the same as the policies for diffuse discharges in the notified version, neither is it the same as that in the decisions version of the Proposed One Plan.

administration and transaction costs further reduced revenues to 22% below baseline revenues.

- The grandparenting (policy #2a) and natural capital approaches (policy #2d) for allocating nutrient discharges have similar estimated impacts at the catchment level when all landowners are covered, given that the policies are designed to (1) cover nutrient losses from all landowners and (2) cap nutrients at the levels necessary to meet the HRC water quality limits. However, impacts could vary at the farm-level between grandparenting and natural capital based approaches because landowners may receive different amounts of permits, depending on allocation criteria used.
- Restricting trades to smaller areas within the Manawatu catchment would reduce the possibility of localized water quality ‘hotspots’. However, spatially restricting trades resulted in a modelled decline in revenue of about 43% when accounting for changes in farm profit, administration and transaction costs (policy #2b). This is because farmers in the ‘flats’ area of the catchment must reduce nutrients in their own area of the catchment rather than purchasing discharge permits from farmers in the ‘hills’ that may be able to reduce their N and P discharges at a lower cost.
- The cap-and-trade programme and nutrient discharge tax policies assessed could result in significant changes in land use in the Manawatu catchment with land converting from pasture to arable, forests, scrub, or fallow.
- Theoretically, a nutrient tax (policy #3), implemented optimally, will provide similar impacts as a catchment-wide cap-and-trade programme (policy #2a). We estimate that charging landowners a tax of $36/kgN for nitrogen that leaches from their land should achieve the desired nutrient loads set at the catchment-level. The average cost of reducing N was estimated to be $23/kgN, which is significantly lower than the tax rate because many landowners can implement changes in land management that reduce N at costs lower than the specified tax.
- In all likelihood there would be no need to tax P as the land use and land management changes implemented in response to the N tax will also achieve the required P loss reductions in the catchment.
- Varying the N and P tax across different parts of the catchment to meet different nutrient reduction goals has similar outcomes as policy #2b. Estimates reveal that the N tax could range from $18.70/kgN in the Manawatu Hills to $89.70/kgN in the Tararua Flats.
- The marginal costs of abatement for a tax are non-linear, which could make it difficult to establish the optimal tax ex ante. Providing flexibility to adjust the tax over time would better ensure that nutrient reduction goals are achieved over the long run but could generate more economic and social disruption in the transition than a cap-and-trade approach if policy makers have frequently to adjust the tax rate.

Rotorua Catchment

The provisional water quality target proposed for the Rotorua catchment is to reduce the annual N load to the lake from 755t N to 435t N in the long run, with agricultural N loss to fall by approximately 60% by 2022. The agricultural sector is expected to reduce 270t N of the desired 320t N. The remainder will come from non-agricultural sources. The water quality target for total N in the Rotorua catchment is significantly lower than the two river catchments modelled because it is a much smaller catchment. The baseline assumes there is no additional water quality policy over and above current settings. The key findings from the policy options modelled for the Rotorua catchment are:

- Implementing a mix of GMPs on pastoral land such as applying DCDs, reducing N fertiliser, importing feed, and adjusting the mix and level of stock would decrease the N loads arriving at Lake Rotorua relative to baseline, but by less than the 270 t reduction required to achieve the regional council's long run environmental goal of 435 tN/yr (policy #1a & b). In over-allocated catchments such as Lake Rotorua land use change as well as management changes may be required to meet environmental goals.
- Even when nutrient exports decrease by 270 tN in 10 years, the loads of N reaching the lake do not achieve the long run sustainable load goal of 435 tN per year until approximately 2100 due to unmanageable legacy loads. These long delays between costly N export cuts and N load outcomes could be an issue in any catchment where some N travels through groundwater and the groundwater lags are long.
- Reducing N discharges by 270 tN by 2022 was estimated to cost $3.2million per year (policy #2a). A large amount of this cost would be spent on mitigation efforts on dairy land, relative to the land area occupied by dairy farms. If agriculture had to meet all the required N leaching reductions (i.e. 320 tN) it will cost an additional $1million per year (policy #2b). This equates to a 30% increase in costs for only an additional 18% decrease in nutrients.
- A reduction of 270t N could also be achieved by a $30/kg N tax. Setting the tax at $27/kg N only achieves a reduction of 240 tN while a $33/kg N tax gave a reduction of 303 tN (policy #3a, b & c).
- The distribution of costs in a cap-and-trade programme is determined by the choice of allocation scheme. Allocating permits based on current discharges (i.e. grandparenting) and then buying sufficient permits back to achieve the N reduction target would cost the regulatory agency a modelled $5.4 million/year with farm profits increasing by more than 10%. Conversely, auctioning all permits would net the regulatory agency $5.3million and farm profits would fall by 39–70%.

Generalized Findings

While the impacts of water quality policies will differ between catchments there are some findings that we can generalize from the three case studies. These include:

- The policy scope and stringency of the nutrient reduction goals affects the economic impact of the policy. If nutrient limits are established prior to major declines in water quality occurring then the economic burden of reaching the specified limits is significantly lower. This is illustrated in the difference in estimates of the total costs of policies #2 and #3 for the Hurunui-Waiau and Manawatu catchments. The proposed policy to maintain current water quality in the Hurunui-Waiau allowed the flexibility to increase their intensity and net revenues by about 5%, while the large reductions in nutrients proposed for the Manawatu meant that landowners had a reduction in profit by 22% or more.
- The economic impact of large reductions in nutrients, while large, was less in percentage terms than the required nutrient reduction, e.g. achieving a 53% reduction of N in the Manawatu catchment would reduce catchment net revenue by 22% (under optimal policy settings that enable a dynamically efficient adjustment to limits; and

assuming well-informed economically-rational decision making by land users). This, of course, depends on mitigation technologies available and the willingness and ability to invest in the adoption of GMPs, change land use, or participate in a trading programmes.

- In catchments where the nutrient load is significantly above the limit (e.g. Manawatu or Rotorua), it is unlikely that a policy to implement GMP voluntarily or mandatorily will achieve the necessary reduction in discharges. Our simulations suggest that additional policy instruments may be required and it is likely that some level of land use change will be needed, though this will depend on the severity of the problem and individual catchment characteristics.
- The average cost of nutrient reductions can vary both within and across modelled catchments. Key reasons include current land use and land management, feasible mitigation options, and biophysical aspects such as soil type and topography.
- The modelled costs of reducing P loss are significantly larger than N leaching on a per unit basis. This is likely due to the small amount of P in the catchment relative to N, and hence that the value of output per unit of P is also higher to mitigate than the same unit of N. There are also limited management practices included in the model that are specific for controlling P loss.
- The marginal abatement costs (i.e. the cost of reducing an additional unit of N or P at the limit) are also different between the three catchments. This also indicates that there is likely to be a high level of variation in mitigation potential across catchments in New Zealand.
- Economic theory shows that a pollution tax and cap-and-trade programmes should result in equally efficient nutrient reductions provided there is perfect information about the pollution sources and how landowners would react to alternative instruments that put a price on nutrient outputs. We find this in the three catchments assessed for this report. The cost savings may be somewhat undercut, however, by the administration and setup costs of establishing a tax or nutrient trading programme. Additional transitional costs are likely in a tax regime if policy makers cannot set the optimal tax rate ex ante, and adjust the tax rate frequently.
- Although tax and trading scheme can theoretically achieve the same level of nutrient reductions at the same cost at the catchment-scale, the two approaches can have different distributional implications. Some landowners would face lower costs from a cap-and-trade programme from selling excess nutrient reduction permits. In the tax case, the government receives tax revenue from the landowners and has the ultimate decision on how to utilise the funds, such as by decreasing other taxes or investing in research, education, or alternative mitigation options to assist with the policy.
- If all the revenue collected from the nutrient tax were recycled back to landowners in the form of a dividend or reduction of other taxes, then the changes in net catchment revenue would be similar to the grandparented cap-and-trade policy. This is the assumption we use in when presenting catchment-wide estimates for the tax policies in this report. If not all the taxes collected were recycled back to the landowner, however, the total costs to farmers would be higher under this policy approach. Furthermore, landowners that might not have the ability to implement more cost-effective management practices on their farm could face a potentially high price of maintaining their current operation.

- How discharge permits are allocated does not have large economic impacts at the catchment level. However, different allocation systems can lead to significantly different distributional impacts. For instance, in the Manawatu catchment, the natural capital allocation approach would reduce the cost of meeting the nutrient limit for those located in high-productive land by 11% compared with a grandparenting allocation. At the same time, those located in less productive areas would face 16–17% higher costs to meet the limit with a natural capital allocation. If landowners were able to trade permits, the equilibrium result at the catchment level will be similar regardless of how the permits were distributed (i.e. natural capital, grandparenting, etc.). These findings are based on the assumption that an efficient trading market exists and all landowners are profit maximisers. Impacts may differ where there are high transaction costs, spatially restricted trading, or there is an unwillingness to buy and sell permits even if it is economically efficient to do so.
- The larger the geographical area for trading, the more cost-efficient the programme is likely to be. This results from a more diverse set of land-uses, landowners, and tradable permits. However, there may be a greater possibility of localised water quality 'hotspots' with catchment-wide trading than where trades are restricted to smaller areas.
- Land-use change in response to changes in market conditions is typically a slow process. Evidence suggests that adjusting land use quickly will be costly, and may justify slower transition pathways to minimize cost.

Table 45 Estimated Impacts of Nutrient Reduction Policies

Catchment[a]	Scenario	N Target (tonnes)[b]	Total N in 2022 (tonnes)	% N Target Achieved by 2022[c]	% N Target Achieved by 2100[c]	Average Mitigation Cost ($/kg N)	Time to Achieve (years)	Total Annual Cost ($ million)[d]	Profit[e] Change from Baseline (%)
Hurunui-Waiau	Baseline without Waitohi Irrigation Scheme	2930	2930	100%	100%	n/a	0	n/a	0%
	Baseline with Voluntary GMP (Policy #1a)	2930	2710	108%	108%	$52	10	$11.2	-5%
	Baseline with Regulatory GMP (Policy #1b)	2930	2300	127%	127%	$46	10	$29.3	- 12%
	Waitohi Irrigation- No Water Quality Policy	2930	3620	76%	76%	n/a	Not	-$24.4	+10%
	Waitohi-Catchment-wide Trading (Policy #2a)	2930	2930	100%	100%	n/a	10	-$11.0	+5%
	Waitohi-Region-restricted Trading (Policy #2b)	2930	2930	100%	100%	n/a	10	-$9.3	+4%
	Waitohi-Equal Allocation Trading (Policy #2c)	2930	2930	100%	100%	n/a	10	-$9.8	+4%
	Waitohi-N Tax at $23/kgN and P Tax at $119/kgP (Policy #3)	2930	2930	100%	100%	n/a	10	-$11.0	+5%
Manawatu	Baseline	2536	5400	0%	0%	n/a	0	n/a	0%
	Voluntary GMP (Policy #1a)	2536	5019	13%	13%	$2	Not	$0.8	0%
	Regulatory GMP (Policy #1b)	2536	4591	28%	28%	$2	Not	$1.8	-1%
	Catchment-wide Trading (Policy #2a)	2536	2536	100%	100%	$23	10	$64.7	-22%
	Region-restricted Trading (Policy #2b)	2536	2520	101%	101%	$45	10	$129.4	-43%
	Natural Capital Allocation Trading – Dairy Only (Policy #2c)	2536	5076	11%	11%	$4	10	$1.2	-0.4%
	Natural Capital Allocation Trading – Pasture and Arable (Policy #2d)	2536	2536	100%	100%	$23	10	$66.2	-22%
	Tax at $36/kgN (Policy #3)	2536	2536	100%	100%	$23	10	$66.2	-22%
Rotorua	Baseline	435	755	100%	100%	n/a	0	n/a	0%
	BoPRC GMP (Policy #1a)	435	539	68%	58%	$7	Not	$0.8	-5%
	Stringent GMP (Policy #1b)	435	472	88%	91%	$11	Not	$2.6	-18%
	Catchment-wide Trading - 270tN reduction (Policy #2a)	435	454	94%	100%	$9	92	$3.2	-22%
	Catchment-wide Trading - 320tN reduction (Policy #2b)	435	479	86%	100%	$5	147	$4.2	-29%
	Tax at $30/kgN (Policy #3a)	435	454	94%	100%	$4	92	$3.2	-22%
	Tax at $27/kgN (Policy #3b)	435	472	88%	91%	$9	Not	$2.6	-18%
	Tax at $33/kgN (Policy #3c)	435	436	100%	109%	$11	16	$3.9	-27%

n/a: not applicable

[a] Each case study catchment uses different economic data, biophysical data, options for land management, and policy assumptions. The Hurunui-Waiau and Manawatu catchment scenarios were modelled using NZFARM, while Rotorua was modelled NManager. Thus, the estimates from each case study are not directly comparable.

[b] Nutrient reduction targets are set simultaneously for N and P for Hurunui-Waiau and Manawatu. Rotorua targets are only for reductions in N leaching.

[c] Values greater than 100% indicate that additional nutrient reductions beyond the target have been achieved. In the case when the policy requires a simultaneous reduction in N and P, the economically optimal solution could be to change land use or land management in a manner that reduces one nutrient beyond the target level.

[d] Negative costs in the Hurunui-Waiau catchment imply that there is an increase in net revenue from increase in intensity due to implementation of Waitohi Irrigation Scheme.

[e] Farm profit is measured as annual earnings before interest and taxes, or the net revenue earned from output sales less fixed and variable farm expenses.

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