Motupipi Catchment Nutrient Management: A Landcare Research Integrated Catchment Management project with landowners of the Motupipi Catchment, Golden Bay, 2008

PREPARED BY:

Andrew Fenemor[1], Hilary Fenemor[2] and Simon Gaul[3]

[1]Landcare Research
16 Paruparu Road
Nelson 7010

[2]Water Quality Consultant
Brightwater

[3]Ravensdown Fertilizer Cooperative Ltd
PO Box 3028
Richmond
Nelson

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PREPARED FOR:

Tasman District Council
Private Bag 4
Richmond
Nelson

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Reviewed by:	*Approved for release by:*
Les Basher Senior Scientist Soils and Landscape Responses	Alison Collins Science Leader Soils and Landscape Responses

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Purpose of Project

The aim of this project was to develop a catchment-wide view of the sources of nutrients reaching the Motupipi River and Estuary in Golden Bay, and using a collaborative ICM approach to assist landowners in the catchment to identify land management actions which would help to reduce the nutrient load.

At the initiative of Tasman District Council, funding from the Foundation for Research Science and Technology (FRST) has been made available to Landcare Research, and support provided by local Ravensdown Key Account Manager Simon Gaul, to complete this work.

The project involved developing a whole-catchment-scale nutrient budget assessing all inputs, including:

- indigenous forest
- exotic forestry
- gorse and broom
- agricultural
- contributions from consented discharges to land or water including dairy shed effluent and domestic sewage from dwellings not connected to the sewer
- inputs introduced to the catchment from groundwater springs.

The second component was to help landowners or occupiers (with more than 2 hectares) identify good nutrient management practices on their individual properties.

Expected outcomes of this project are:

- identifying landforms, farm management practices and possible hotspots for nutrients reaching the Motupipi River and estuary
- providing landowners with some factual information and independent feedback on their nutrient losses
- building a picture of contributions of different parts of the landscape to the catchment hydrology and nutrient flows
- providing a forum and further information for discussion on improving nutrient status of the Motupipi River and estuary
- demonstrating value of working together, and potentially build some pride in collective action to improve water quality while maintaining production
- landowners building collective awareness of actions they can contribute to improve catchment health.

1. Background

The Motupipi catchment drains an area of approximately 2700 hectares in the lower Takaka Valley of Golden Bay (Fig. 1). The catchment topography is made up of around 1000 ha of flat to gently undulating land, 1200 ha of steep hill country, with the remainder rolling hill. The catchment geology is complex, with Takaka limestone underlying the entire catchment with various prominent outcrops. Tarakohe mudstones on the river terraces are poorly drained with sheet run-off possible after heavy rain. Rockville and Bainham gravels are present in the terraces. Recent river alluvium is present in the west as part of the Takaka River floodplain.

A complex pattern of soils exists in the catchment. The sedimentary soils are predominantly well drained with pockets of imperfect to poorly drained soils in valley floors to the bottom of the catchment and around the coastal margin with the Motupipi Estuary. A summary of soil characteristics for the catchment has been compiled from Dr Iain Campbell's recent soil descriptions for the Lower Takaka Valley. Estimations of soil drainage and clay content have been made from these descriptions by Dr Les Basher of Landcare Research and are tabulated in Appendix 2.

Tasman District Council (TDC) has been monitoring water quality at over 70 sites around the region as part of its State of the Environment surface water quality sampling programme. The surface water quality of the Motupipi catchment is poor (James, 2007), having:

- high nutrient (N and P) levels
- moderately high faecal bacteria counts
- low dissolved oxygen
- moderately high amounts of fine sediment deposited in the bed of the river
- excessive algal and other plant growth in summer
- macro-invertebrate populations in poor health
- impoverished fish populations.

The local community have identified impacts on whitebaiting and shellfish collection downstream as primary concerns, along with the poor appearance of the lower reaches of the river due to the blooms of filamentous algae and a brown phytoplankton. While poor water quality is not solely caused by land management, attention to nutrient management would help improve water quality.

Landowners and community groups have already been taking action to improve water quality, such as exclusion fencing and planting along streams and use of Eco-N nitrification inhibitors so we would expect water quality to improve gradually beyond the results reported in 2007.

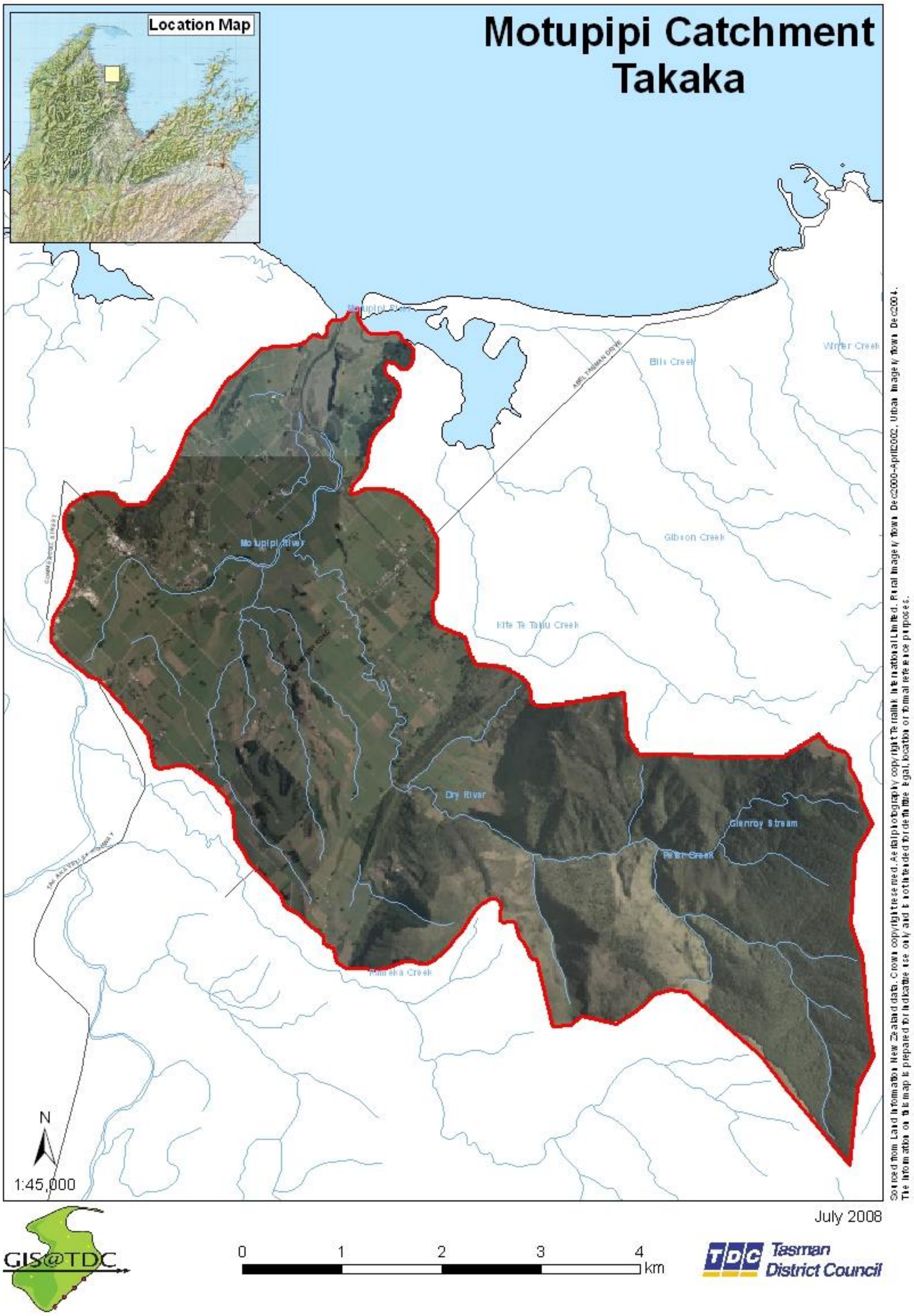


Fig. 1 Motupipi catchment, Golden Bay

2. Project Methodology

The project applies experience from the Integrated Catchment Management (ICM) process in the Motueka ICM research programme (http://icm.landcareresearch.co.nz/) to working with land users in the Motupipi catchment. The premise is that understanding each property's contribution to catchment water quality will help land users to work together to improve water quality, with – in this case – a focus on nutrient management.

The project began with a kick-off meeting organised by Barbara Stuart of the NZ Landcare Trust on 31 October 2007 with farmers and community members. In December 2007, 43 landowners with more than 2 hectares within the catchment were asked to participate in developing a nutrient budget for the whole catchment based on the 2006/2007 year (August 2006–July 2007).

During February–May 2008 owners of 10 larger farmed blocks who agreed to participate were visited for a farm walk-over, discussion of nutrient management and sketching of property information on maps. For participating landowners, calculated N and P losses from Ravensdown's OVERSEER™ nutrient budgeting model were compiled to map losses across each farm block. Owners of smaller farmed blocks in the catchment were telephoned for land use information, and N and P losses from these blocks were calculated in OVERSEER™ version 5.3.1 using default values provided in the software.

GIS maps of each of the larger farms were compiled for the landowner based on existing GIS data and information provided during the walk-over including location of riparian fencing, use of nitrification inhibitors (Eco-N used in this catchment so far) and the boundaries of nutrient blocks, exotic forest, native vegetation, areas of gorse and broom, silage pits and culverted or bridged crossings. Those landowners were also provided with maps for their farm showing the latest soil information based on recent work carried out by Dr Iain Campbell for TDC. GIS data already available included aerial photography, soils, topography, rivers and streams, wells, some land use data, and land cover.

Each participating farmer has also received an individual summary of nutrient losses for each block on their property and a brief report identifying management issues with suggestions for further actions which would further improve surface water quality in the Motupipi. For an outline of the format of the report refer to Appendix 3. Opportunity was provided to discuss these individual recommendations and the draft of this report at a meeting with participating farmers held on 4 August 2008.

Maps of catchment N and P losses by farm block are presented in this report along with a map showing stock exclusion/riparian fencing and areas which have received Eco-N in the catchment and a discussion of the hydrological functioning of the catchment. If no information was available for a block as owners were not able to be contacted or declined to take part, average loss values from similar properties with a similar land use within the catchment have been attributed to that block.

3. Nutrients

Plants require 19 different essential elements or ‘nutrients’ to grow successfully. Most are obtained from the soil through plant roots. Nitrogen (N) and phosphorous (P) are the two key nutrients most likely to limit plant growth. They are also the most likely to be lost from the soil profile in significant amounts. Soil P concentrations are related to the parent material from which the soils are formed. whereas soil N can be fixed from the atmosphere by some plants. Phosphorous needs to be added to the soil to sustain productivity if it lost in products such as timber, meat, wool, crops etc. or because of leaching and erosion.

Plant nutrients are ‘lost’ from the soil when they leave the plant rooting zone before they can be taken up by plant roots. This can occur through a variety of mechanisms including loss to the air (volatilization), erosion by water or wind, or by being ‘leached’ by water in their soluble forms down through the soil. Phosphorous binds well to soils and is predominantly lost by erosion attached to sediment rather than leaching. Nitrogen is primarily lost by volatilization to air and leaching.

Losses of nutrients from land depend on topography, rainfall, soil type, drainage, land use and land-management practices. For example, for pastoral farms relevant management practices include the size of the grazing animal, stocking density, feed intake, type of feed, and stock management in winter.

Lost nutrients can stimulate undesirable growths of aquatic plants and algae when flushed into surface waters and at high concentrations can also make groundwater unsuitable for drinking.

A review of recent New Zealand based research on a range of productive land use systems by Menneer et al. (2004) shows the potential for nitrogen and phosphorous loss generally follows this order:

NATIVE FOREST	<	EXOTIC FOREST	<	SHEEP/ BEEF/ DEER	<	ARABLE/ MIXED CROPPING	<	DAIRY	<	VEGETABLES (MARKET GARDENS)

Table 1 shows nitrogen losses for different land uses in New Zealand. As soil type and climate vary, there is a large variation in nitrogen losses, so it is hard to place an overall "ideal" for each land-use type.

Table 1 Summary of research on nitrogen losses in New Zealand (Menneer et al. 2004)

Land Use Type	**Nitrogen Leaching Loss (kg N/ha/year)**	
	Range	**Mean**
Market Gardening	80-292	177
Dairy Pasture*	15-115	65 (40*)
Mixed Cropping or Arable Farming	35-110	61
Orcharding (only one kiwifruit study)	50	50
Sheep	6-66	21
Forestry	3-28	3

* Menneer et al. note that while published data from research studies on N leaching from cattle grazed systems in NZ indicate a range of 15–115 kg N/ha/yr with an average of 65 kgN/ha/yr, most of these studies included high rates of N fertiliser, and the average fertiliser N use of a New Zealand dairy farm is only approximately 100 kg N/ha/yr. Therefore typical N loss is approximately 40 kg N/ha/yr.

Phosphorous losses for different land uses are ranked in a similar order. The P losses from forestry systems range from 0.07 to 0.10 kg P/ha/yr, whereas in hill country sheep farms P transfer to waterways is in the range of 0.11–0.75 kg P/ha/yr. For sheep and cattle systems, reported P losses were between 0.8 and 2.37 kg P/ha/yr, and lower for sheep alone. For dairy, reported losses range from 0.5 to10 kg P/ha/yr, the greatest losses occurring from a dairy catchment in an extremely high rainfall area of Westland (Menneer et al. 2004; Monaghan et al. 2007).

A recent report on improving nutrient efficiency in a Waikato dairy catchment (Longhurst & Smeaton 2008) gave an average N loss of 45 kg N/ha/yr (range 31–52) and an average P loss of 2.2 kgP/ha/yr (range 0.7–4.3).

4. Nutrient Budgeting using the OVERSEER™ Model

Nutrient budgeting is carried out to enable landowners to see at a glance whether farm inputs match farm outputs. It also helps identify where changes can be made to reduce nutrient losses, increase nutrient efficiency on the farm, and as a consequence reduce on-farm costs.

Nutrient budgets such as OVERSEER™ (http://www.agresearch.co.nz/overseerweb/) use an accounting procedure to estimate the amounts of N and P leached **in an average year** from the base of the soil profile in each farming block by adding all N and P inputs to the block and subtracting the N and P content of the farm outputs. Soil reserves are also taken into account by the model as an input for P but not for N. Estimates of losses to the environment by volatilization, erosion, leaching or surface run-off are made drawing on datasets taken from NZ research. The error margin associated with N and P losses predicted by OVERSEER™ is ±30%.

Inputs to OVERSEER™ include N and P in fertilizer applied, effluent added, in rainfall, in irrigation water, in supplementary feed used on that block, and in N fixed by clover. Outputs include product (meat, milk, wool), supplements taken off and sold or used in another farm block, losses of N to the atmosphere by volatilization, losses to water of P and N in leachate and surface runoff, and any change in soil storage. The version of the OVERSEER™ model used for the 2006/07 budgets **does not** make allowances for reduced losses achieved by the use of nitrification inhibitors, riparian fencing or plantings, or wetlands.

Nitrogen is the only soil nutrient that is 'zero based' for any year. No account is taken of nitrogen reserves already within the soil profile as the model assumes N not converted to farm outputs , leached or lost to the atmosphere is stored (immobilised) indefinitely as organic nitrogen in the soil profile and is no longer plant available or likely to be lost from the soil. This assumes soils have an infinite capacity to store surplus nitrogen as organic nitrogen. In reality the nitrogen storage capacity of soil is finite (Schipper et al. 2004).

Schipper et al. (2004) have estimated the potential for NZ soils to continue to store (immobilize) organic nitrogen. When the C:N ratio of soils is reduced to less than 10 there is increased potential for organic N in soil to be hydrolysed by soil enzymes or mineralized by soil microbes to inorganic forms (ammonium, nitrate). Through modeling they conclude that a substantial proportion of NZ soils will reach maximum storage of N over the next 50 years. The concern is that when maxiumum storage is reached, there will be an increase in losses of N in leachate from pastoral farming above those predicted by OVERSEER™. Their message is that opportunities to reduce nitrogen inputs in pastoral farming should be taken now, wherever possible.

5. Managing Nitrogen and Phosphorous Losses from Pastoral Land

In grazing systems, animal urine is the principal source of leached N. The amount of N under a cow urine patch is equivalent to approximately1000 kg N/ha, and is in a form that is readily converted to nitrate, a soluble easily leached form of nitrogen. These N levels are well above the N uptake requirements of pasture and consequently significant leaching losses can occur. The more intensive the pastoral farming, the greater the potential for leaching losses as there are more urine spots per hectare.

For sheep-grazed pastures, annual nitrate leaching losses are generally lower than for cattle. Sheep have a smaller bladder and urinate more often in smaller volumes. The amount of N under a sheep urine patch is equivalent to approximately 500 kgN/ha. Strong camping behaviour by sheep beneath trees, around gateways, and on ridges and hill crests can increase the potential for losses of both N and P. This behaviour can be exploited to reduce N and P losses by locating gateways and shade trees away from surface water, areas with a high water table or areas vulnerable to surface flooding.

During winter when rainfall exceeds evaporation, soil drainage is high and plants are not actively growing so more N from urine is leached than at other times of year. Winter leaching of N can be exacerbated by dry summer conditions, which result in a build-up of nitrate levels in soil by autumn. Leaching is also exacerbated by irrigation, especially via soil macropores and when excess irrigation causes drainage to groundwater. In comparison with urine N, dung N is bound up in complex organic compounds that are insoluble and cannot be leached until they are broken down by soil microbes, which is a gradual process.

Ledgard et al. (2000) found direct leaching of fertiliser N had only a marginal effect on nitrate leaching under grazing and only when N applications are excessive (> 400 kg N/ha/yr) or are untimely (e.g., 50 kg N/ha in winter). This suggests that within farm systems, opportunities to achieve reductions in nitrate leaching from pasture soils lie in strategic grazing management to minimize urine additions to pasture, particularly over winter months and avoiding inputs of fertilizer N > 200 kgN/ha/yr or winter applications of fertilizer N.

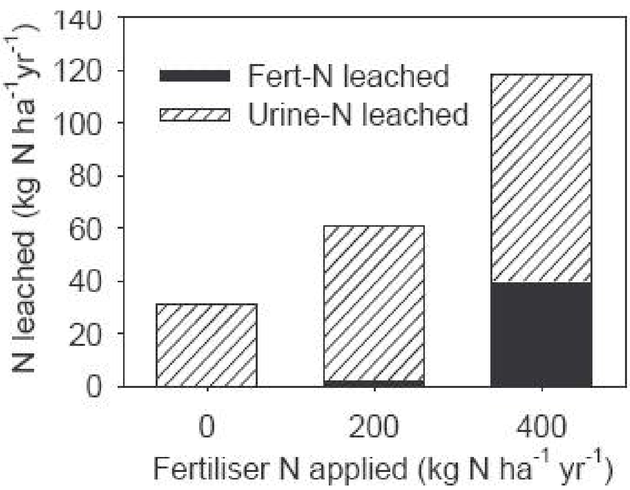


Fig. 2 Nitrate leaching from dairy pasture with 3.3 cows/ha and 3 rates of N fertilizer applied (from Ledgard et al. 2000)

A recent summary (Ledgard 2001a) of data from New Zealand and overseas studies has shown that nitrate leaching increases exponentially with increased N inputs. Reducing inputs will reduce outputs.

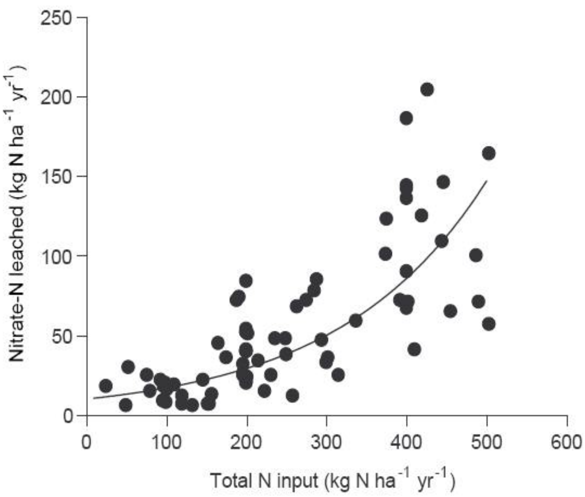


Fig. 3 Nitrate leaching from grazed pasture systems as affected by total N input from N fixation and/or N fertilizer application. Data are a summary of studies in NZ, France and the UK (Ledgard, 2001a)

Nitrogen in urine is present as urea. Once voided by the animal, urea in the soil is converted to ammonium by urease in the soil and this occurs most rapidly under moist soil conditions (McLaren & Cameron 2005). Ammonium is then converted to ammonia gas (volatilization) or converted to nitrate (nitrification) by soil bacteria. Nitrate is more readily leached from soils than ammonium.

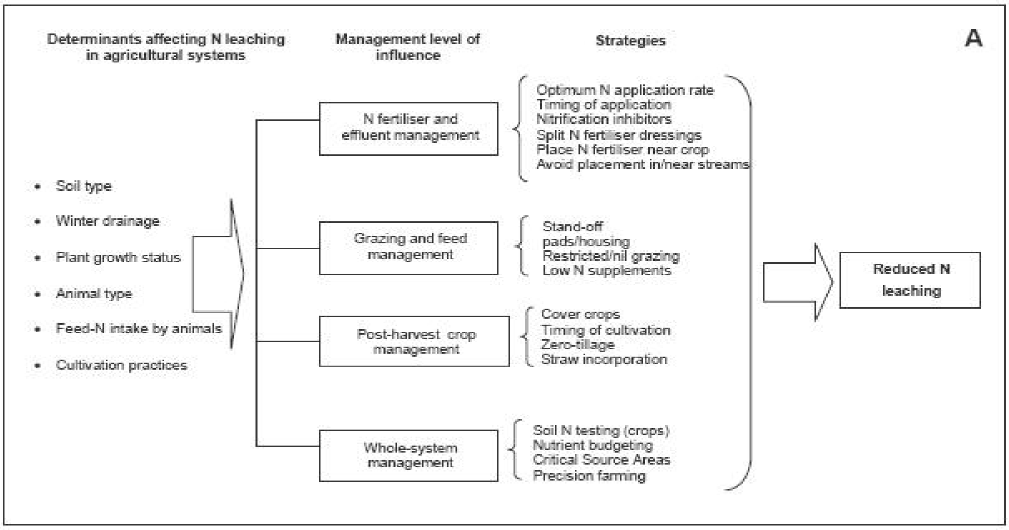
Nitrification and urease inhibitors can be used to try and reduce losses from both fertilizer applications of urea and urine spots. Nitrification inhibitors restrict the microbial conversion of ammonium to nitrate. Urease inhibitors restrict the conversion of urine to ammonium.

Experiments using the nitrification inhibitor dicyandiamide (DCD) in large intact soil cores have been shown to reduce nitrate leaching from a single urine application by between 40 and 76% depending on the season (spring or autumn) of treatment application (Di & Cameron 2002b). DCD is available in NZ in three proprietary products: Eco-N from Ravensdown Fertiliser Co-operative; N-Care from Ballance AgriNutrients Ltd; and Taurine from Summit Quinphos Ltd.

In a review of nitrification and urease inhibitors, Edmeades (2004) concludes they are a potentially useful tool to increase the efficiency of the N cycle within NZ pasture. However ,he highlights the limitations of drawing conclusions on performance from small-scale trial studies and advocates the need for full-scale, long-term field trials to assess efficacy on-farm in a variety of climatic and soil conditions. Several larger trials are under way.

Phosphorous loss is determined by the parent material of the soils (some are naturally high in P), farm fertilizer inputs (including re-used effluent), and supplementary feed inputs. P is typically lost from land by erosion attached to sediment. Riparian strips and grass swards across steeper slopes can be used to capture sediment. Exclusion of stock from waterways prevents bank erosion of streams and reduces soil erosion and therefore P loss.

Figure 4 summarizes the main factors affecting N and P losses from farms in NZ, and gives a summary of management strategies that can be employed to reduce those losses. These management strategies are frequently referred to as 'Best Management Practice'. Appendix 1 is a summary of Best Management Practices for dairy, sheep and beef, and forestry land uses developed for the Sherry catchment, a catchment similar to the Motupipi.



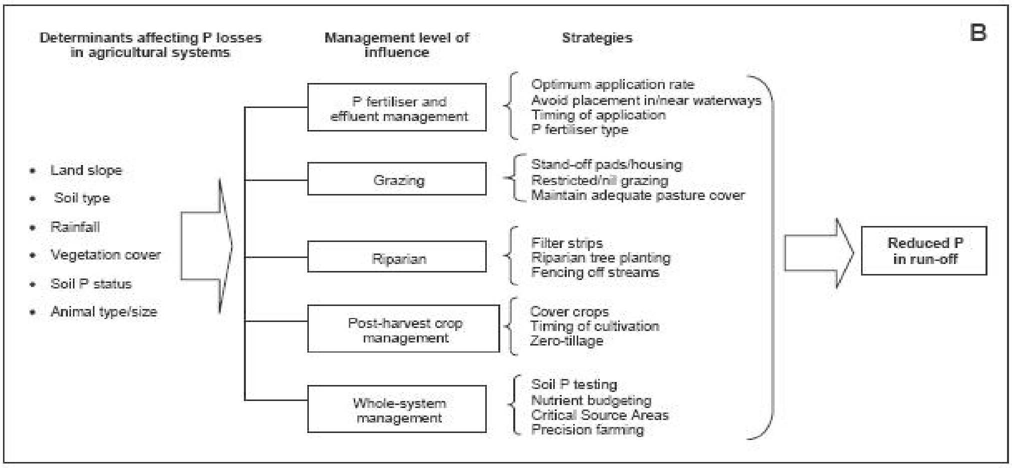


Fig. 4 Determinants of N and P losses and management strategies to reduce losses (Menneer et al. 2004)

A recent report for Environment Waikato (Longhurst & Smeaton 2008) on improving nutrient efficiency in two predominantly dairy catchments used the latest model of OVERSEER™ and UDDER a farm profitability model, to estimate the reduction in nitrogen losses achievable from a range of mitigation measures. This table is reproduced here as Table 2. The information is not directly transferable to the Motupipi catchment as soils, climate and topography will be different. However it does give some idea of how the latest version of OVERSEER™ could be used in this catchment to develop a similar table.

Table 2 Potential options for reducing N leaching in the Upper Waikato Catchment

Option	Likely % reduction in N leaching	Likely profitability of option **	Caution...
Don't apply fertiliser N in winter	5 (0-10)	– to O	May need other management changes
Reduce N fertiliser use & reduce milk production	15 (0-35)	–	If current N use is high (>200kg N/ha) reduced N use may increase profit
Changing effluent system from ponds to land application	10 (5-15)	+	Set-up costs, deferred irrigation can be practiced from redundant ponds to minimise capital costs
Apply FDE * over larger area & use less N fertiliser	10 (5-15)	+	Depends on current FDE area
Nitrification inhibitor (DCD)	8 (5–10)	– to O	More research required under high rainfall; more profitable in South Island
Use Wintering Pad/Stand-Off pad/animal shelter (Herd Home)	10 (5-15)	–	Increased work, capital cost including infrastructure, availability, or price, of bark or sawdust could be a problem. Profitable only at high payouts (benefits do not include effects of reduced pugging, stock condition)
Sell off silage in autumn & have a shorter lactation	5 (0-15)	– –	Unprofitable due to foregone milk production
Reduce use of brought-in feed	4 (0-7)	– to +	Depends on quality, use and price of brought-in feed and payout
Change brought-in feed to low protein source (e.g. maize silage)	2 (0-5)	–	Depends on current level of brought-in feed and feed costs
Increase winter grazing off	15 (10-20)	++	Dependent on availability & cost, transfers N loss to other catchments and so may not be acceptable, requires system changes
Replace winter crop with grass-to-grass	5 (0-15)	O to +	Typically only a small area is cropped, profit depends on need for pasture renewal
Reduce stocking rate & increase per-cow production	1 (-5 to 5)	– / +	Profitable on very high stocked farms, change will require increased management skill
Conversion to organics	25 (15-35)	++	Appears highly profitable at lower milk payouts however further research required regarding costs of production and production levels
Put in artificial wetland	? (0-5)	– –	Highly farm specific (contour, soil)

* FDE = farm dairy effluent

** Likely profitability of option

++	Profitable	–	Slightly unprofitable
+	Slightly profitable	– –	Unprofitable
O	Neutral		

6. Estimating Nitrogen and Phosphorous Losses in the Motupipi Catchment

6.1 Pastoral land

Nutrient budgeting had been initiated in the catchment within the dairy sector through the Clean Streams Accord using the OVERSEER™ nutrient budgeting model. This project used existing information and developed budgets for the remainder of the pastoral land within the catchment using the same model.

In consultation with participating property owners, Simon Gaul has identified several nutrient management blocks for each farm (typically 3–6 blocks, depending on the size of the farm) based on physical boundaries, soil type and farm-management practices, i.e. areas receiving effluent from the dairy shed, areas receiving washwater from Fonterra's Takaka Dairy Factory, and areas used for cropping.

For each of these blocks, calculated N and P losses have been compiled and mapped from Ravensdown's OVERSEER™ version 5.2.6 modelling for the period August 2006–July 2007. In response to comments on results at the farmer meeting on 4 August it was noted that the calculated losses are only as good as the input data used by Ravensdown for each block. It was also noted that when nutrient blocks have been drawn onto maps they extend to the closest fence line or physical boundary and do not match the actual application area for re-used effluent or fertilizer inputs. This allows for the transfer of nutrients by grazing stock as deposited urine and dung over the entire block.

Smaller block holders generally had less detailed information available, with only a few keeping records of fertilizer application volumes or carrying out soil tests. OVERSEER™ version 5.3.1 (http://www.canesis.co.nz/overseerweb/download.aspx) has been used to model losses for the smaller blocks for the same time period using default values provided in the model and available rainfall, slope and soil data for the catchment. The smaller blocks were each treated as a single block based on the predominant land use in that block.

6.2 Non-pastoral land

The LINZ Land Cover Database (2002–2003) was used to identify areas of indigenous forest, exotic plantation forest and gorse and broom within the catchment as these land uses are not modelled in OVERSEER™. Data from research carried out around NZ have been used to estimate losses of N and P from these land uses within the Motupipi catchment. An explanation of the methodology used to estimate losses from these land uses follows.

Indigenous forest

Within New Zealand native forests, N is fixed by native nitrogen-fixing plants which include tree tutu, *Coriaria arborea*, native brooms, blue-green algae, some lichens, kōwhai (*Sophora* species), matagouri (*Discaria toumatou*), and free-living micro-organisms. Nitrogen is also introduced by rainfall, birdlife and resident feral animal populations. The average annual loss for an undisturbed indigenous forest soil in New Zealand is reported to be 1.7 kg N/ha (Barton et al. 1999).

DOC has advised that they do not have any huts or toilet blocks on their land within the catchment.There are feral populations of goats, deer, pigs, possums and mustelids but no population estimates have been carried out. As TB risk is low, DOC are not actively managing feral animals.

For the purpose of this report an average loss of 2 kg N/ha/yr and 0.1kg P/ha/yr from native bush has been used.

Exotic plantation forest

Introduced nitrogen-fixers are often sown with plantation forests and are actively fixing N between the young trees for 5 years until the canopy closes. Introduced nitrogen-fixers include clovers (*Trifolium* species), tree lupin (*Lupinus arboreus*), Scotch broom (*Cytisus scoparius*), and gorse (*Ulex europaeus).*

Nitrate leaching from a newly converted pasture-pine plantation was measured at 18 kg N/ha over 15 months (Parfitt et al. 2002). Nitrate leaching losses of between 3 and 5 kg N/ha/yr are reported to occur in undisturbed exotic forests grown in New Zealand (Parfitt et al 1997; Magesan et al. 1998).

The greatest potential for loss from forestry systems exists when pasture is first converted to forest, and then some 25 years later when the forest is harvested. At forest harvest, the clear-felling of trees and subsequent mineralization of harvest residues leads to a build-up of soil organic N and can increase nitrate leaching. However, the amount of N leached is usually low, and has been estimated to be <10 kg N/ha/yr for the first 2 years after clear-cutting of pine forest (Dyck et al.,1981; Parfitt et al. 1997; Smith et al. 1994). The P losses from forestry systems range from 0.07 to 0.10 kg P/ha/yr (Menneer et al. 2004).

The bulk of exotic forest in the Motupipi catchment is in the middle of the production cycle so an average loss of 3 kg N/ha/yr and 0.1 kg P/ha/yr has been assumed.

Gorse and broom

Nitrogen leaching measurements from two gorse stands on pumice soils near Rotorua (one established for 10 years, the other 20 years) show an average loss of 99.5 kg N/ha over a 20 month period, or 60 kgN/ha/yr (Mageson & Wang 2008). The literature review included in the report quotes an earlier estimate of nitrogen loss of 36 kg N/ha/yr from work done in NZ by Dyck et al. in 1983 on a 20-year-old stand of gorse.

For this report a midrange value from these two studies (50 kgN/ha/yr) has been used to estimate potential losses from patches of gorse and broom in this catchment. Phosphorous losses have been assumed to be the same as those for forestry at 0.1 kgP/ha/yr.

6.3 Consented discharges

Discharges authorised by TDC discharge permits or permitted activity rules within the catchment that contribute to the nutrient load to the catchment are:

- Fonterra Takaka factory discharge of washwater and whey permeate to land within the catchment
- Dairy-shed effluent discharges to land
- Dairy-shed effluent discharges direct to water
- Domestic sewage from dwellings, halls and businesses within the catchment not connected to a sewer.

The contribution of N and P from the irrigation discharges of Fonterra factory washwater and dairy shed effluent has been included in the OVERSEER™ budgets for each block where it takes place.

Estimates of the N and P lost from the one dairy shed effluent discharge direct to the Motupipi River have been based on cow numbers as the consent does not require monitoring of nitrogen or phosphorous in the effluent discharged. on average, 300 cows are expected to produce around 1770 kgN/yr and 210 kgP/yr. The ponds are desludged annually and the sludge is applied to land on the farm. Losses from the dairy shed effluent have been reduced by 25% to allow for the re-use of nutrients in the sludge on land. The net loss of nutrients from this river discharge is expected to be around 1300 kgN/yr and 150 kgP/yr.

Parts of the lower catchment are served by the Takaka sewerage scheme which pumps domestic wastewater from those properties out of the catchment. The remaining114 properties within the catchment not connected to the sewer discharge their domestic wastewater to land after treatment on site. The bulk of these properties rely on a septic tank followed by a soakage field as a treatment system.

TDC hold no specific information on septic tank performance within the Motupipi Catchment (J. Trembath, TDC, pers. comm.) so an assessment of likely nutrient losses has been made using data from elsewhere in NZ.

Figures from the Ministry for the Environment report raw domestic sewage in NZ typically contains 30–80 g/m^3 of total nitrogen (TN) and 10–20 g/m^3 total phosphorous (TP) whereas the overflow from a septic tank contains 25–50 g/m^3 of TN and 10–15 g/m^3 TP. Environment Bay of Plenty report that they expect a conventional septic tank and soakage field in their region to exert a nutrient load of 4 kg nitrogen/person/year and 0.15 kg phosphorous/person/year. Septic tanks and their drainage fields appear to be highly effective at trapping phosphorous and preventing it reaching waterways.

Assuming each septic tank in the catchment serves an average of four people, around 1800 kgN/yr and 70 kgP/yr is expected to be lost from septic tanks in the catchment.

6.4 Other discharges

From time to time discharges likely to contain N and P that are not consented will occur. Likely sources within this catchment include:

- Fonterra Takaka
- Sewer overflows from sewerage reticulation
- Spillages of milk or dairy shed effluent from dairy farms
- Silage pits.

Improvements in factory management and a recent change in the product mix following the Fonterra factory fire in 2005 have reduced non-consented discharges to the Motupipi River system. No particular spill events or accidental discharges from the Dairy Factory are recorded in TDC files for the 2006/07 period that this report covers.

TDC's sewerage reticulation has experienced occasional pipe ruptures due to the poor quality and installation of the pipeline. Spills of up to 3 m^3 have occurred, with up to ten events occurring in a bad year. Allowing for a worst case of ten events of 3000 litres in a year, this would have contributed around a maximum of 2.4 kg N/yr and a maximum of 0.6 kg P/yr if it all reached the Motupipi River.

TDC is carrying out a major upgrade of the sewer and the lower bridge pumping station within the Motupipi catchment this year and this is expected to significantly reduce the frequency of sewage overflows. The new pumping station near Burnside Drive is to have 48 hrs of storage and an automated alarm system with response activated from Richmond (Kim Arnold, TDC, pers. comm.).

Dairy shed effluent collection systems including sumps and ponds are also potential areas of risk of non-consented discharge – those located close to waterways or in areas likely to be flooded present the greatest potential risk for an accidental spillage. In particular, the sealed bases of storage sumps and ponds are vulnerable to damage in a major flood event or during desludging.

Silage pits are also potential sources of nutrients. NZ literature indicates that leachate volumes from silage pits range from 30 to 200 litres/tonne DM, so, 3–20 m^3 of leachate would be produced from a 100-tonne silage pit. This would contain 69–460 kg N (or the equivalent nitrogen generated by 1–7 ha of dairy farming) and 3–20 kg P. Seven silage pits are known to be currently in use in the catchment. Based on 100 tonnes DM per pit per year and using average leachate production figures, losses of 2000 kg N and 80 kg P can be expected.

Best management practice for ensilage production focuses on siting pits well away from water on concrete pads, with a leachate collection sump. As pointed out by farmers at the project meeting on 4 August, additional wilting of grass will also reduce leachate generation. The leachate collected is typically diluted and re-used as a fertilizer on farm. Virtually all leachate is generated from the stack within 10 days after laying down the silage. Management of leachate is required daily during this period to ensure a rainfall event does not lead to problems with leachate overflowing from the collection sump. Currently no silage pits in the catchment have leachate collection.

7. Nitrogen and Phosphorous Losses in the Motupipi Catchment

In the Motupipi catchment approximately 55% of the land is in pasture, 40% in native vegetation, 3% gorse and broom, and 2% exotic forestry. Less than 1% of the catchment is used for cropping or horticulture. The data gathered for this project estimate the percentage contribution of N and P losses from all known sources within the Motupipi catchment. Pastoral farming contributes 80% of the N and 81% of the P loss from the catchment.

The maps produced in Figures 4 and 5 show the intensity of N and P losses from land use across the catchment based on the land blocks and sources described above. Table 3 summarizes the estimated N and P losses across the catchment for each of the different land uses and known discharges to land or water. Table 4 summarises the range and average losses predicted by the OVERSEER™ model used for all pastoral land uses within the catchment and the estimates derived from literature for land uses that could not be modelled.

Table 3 Estimated N and P losses for the Motupipi Catchment from all known inputs

Land Use/ point discharge	**Area in Catchment (ha) (% of catchment)**	**Estimated Nitrogen loss kgN/yr (% total loss)**	**Estimated Phosphorous loss kgP/yr (% total loss)**
Pasture	1517 (55%)	49 147 (80%)	1829 (81%)
Gorse & Broom	88 (3%)	4402 (7%)	9 (<1%)
Silage pits (7 @ 100 tonnes DM/pit) – estimate of loss from base of pits in catchment		2000 (3%)	80 (3.5%)
Native Vegetation	1100 (40%)	1938 (3%)	97 (4.3%)
Septic Tank discharge to land		1800 (3%)	70 (3.1%)
Dairy Shed discharge to Motupipi R		1300 (2%)	150 (6.7%)
Cropping	9.2 (<1%)	367(<1%)	7 (<1%)
Exotic forest	54 (2%)	168 (<1%)	6 (<1%)
Sewer overflows		2.4 (<1%)	0.6 (<1%)
ROUNDED TOTAL	2768 ha	61 124 kgN/yr	2249 kgP/yr

Table 4 Average nutrient loss by use kg/ha/yr, Motupipi Catchment 2006/07

Land use (* from literature)	Average Nutrient loss in Motupipi catchment 2006/07 by land use Kg/ha/yr	
	Nitrogen (range)	Phosphorous (range)
Pastoral - Dairy	40.5 (11–63)	0.8 (0.1–7.5)
- Cattle	16 (11–22)	1.5 (0.1–3)
- Sheep	15 (5–22)	1.6 (0.1–3.2)
Gorse and Broom*	50	0.1
Exotic forest*	3	0.1
Native forest*	2	0.1

Comparisons between the data in Table 4 and data from elsewhere in NZ in Table 1 can be drawn but are of limited use as actual losses vary considerably around the country depending on soil type and climate and do not solely reflect farm management practice. Motupipi catchment N and P loss for pastoral land fall within the ranges quoted in recent literature for New Zealand overall. While nitrogen loss is below the national average for dairy and sheep, phosphorous losses are higher than average in a few locations. These higher losses of P are associated with land that has:

- received whey and whey permeate from the Fonterra dairy factory in the past
- naturally high P levels because of the parent material from which the soils are formed. [Soil information in the upper catchment is limited with only a few soil tests available so some high P soils may not have been captured in Figure 5]

The version of OVERSEER™ 5.2.6.0 used in this project **does not** take into account the benefits of stock exclusion fencing around waterways or the use of nitrification inhibitors. Figure 6 shows management practices already in place to reduce nutrient losses (for participating farmers only).This includes use of a nitrification inhibitor (Eco-N) and exclusion fencing along waterways. Losses from the properties that have implemented these management strategies are expected to be lower than predicted by the model.

The most recent updated version of OVERSEER™ released in March 2008 **does** take into account both of these factors along with constructed or natural wetlands. It would be useful to use this updated version of the model to run some scenarios for individual properties, similar to those carried out by Longhurst and Smeaton (2008) to predict:

- the reduction in N and P losses from management strategies in place now
- reduced losses for the recommended additional management strategies on a farm by farm basis.

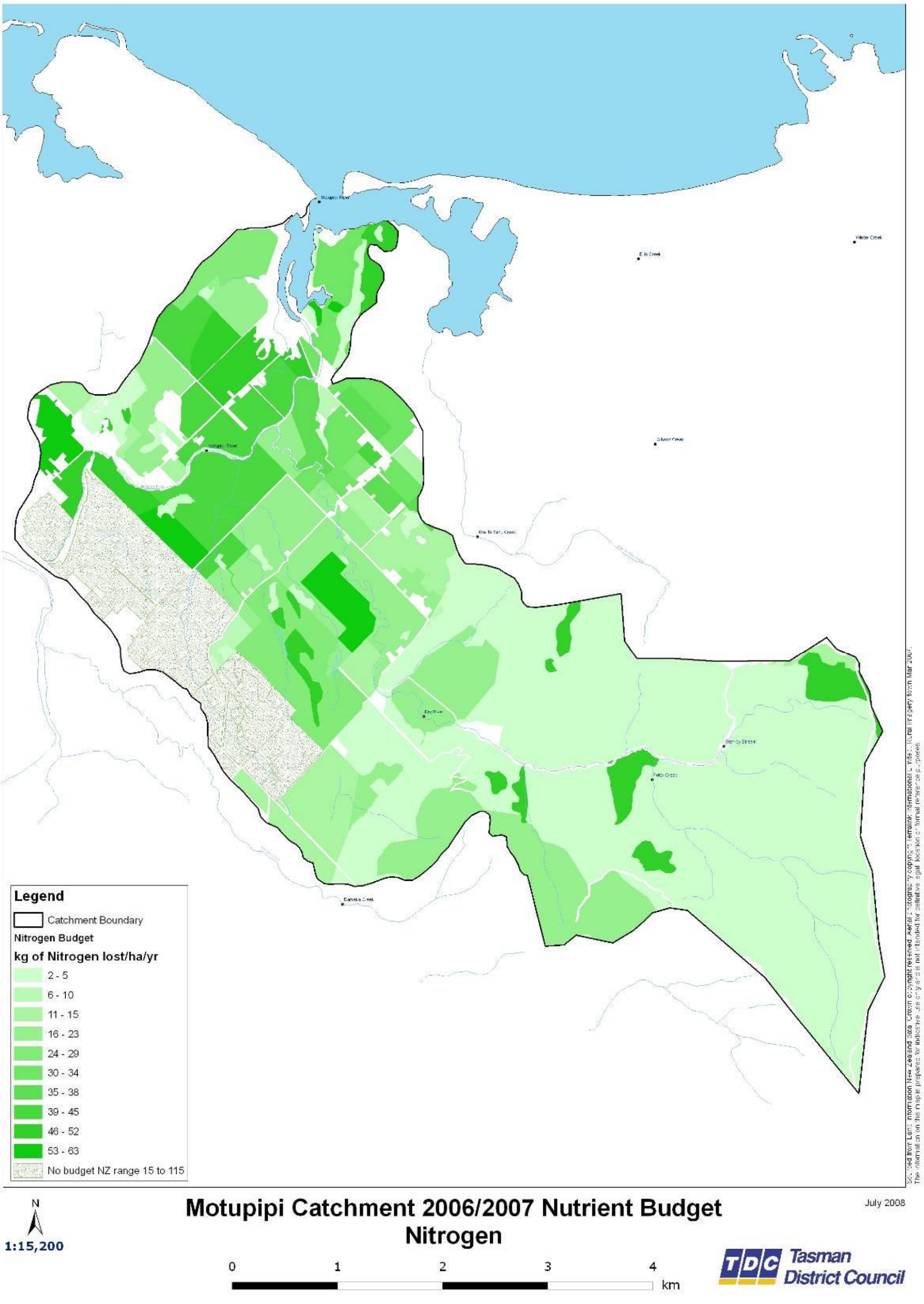


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Fig. 5 Mass of nitrogen per hectare lost from land in soil drainage or surface run-off for the Motupipi Catchment, August 2006–July 2007

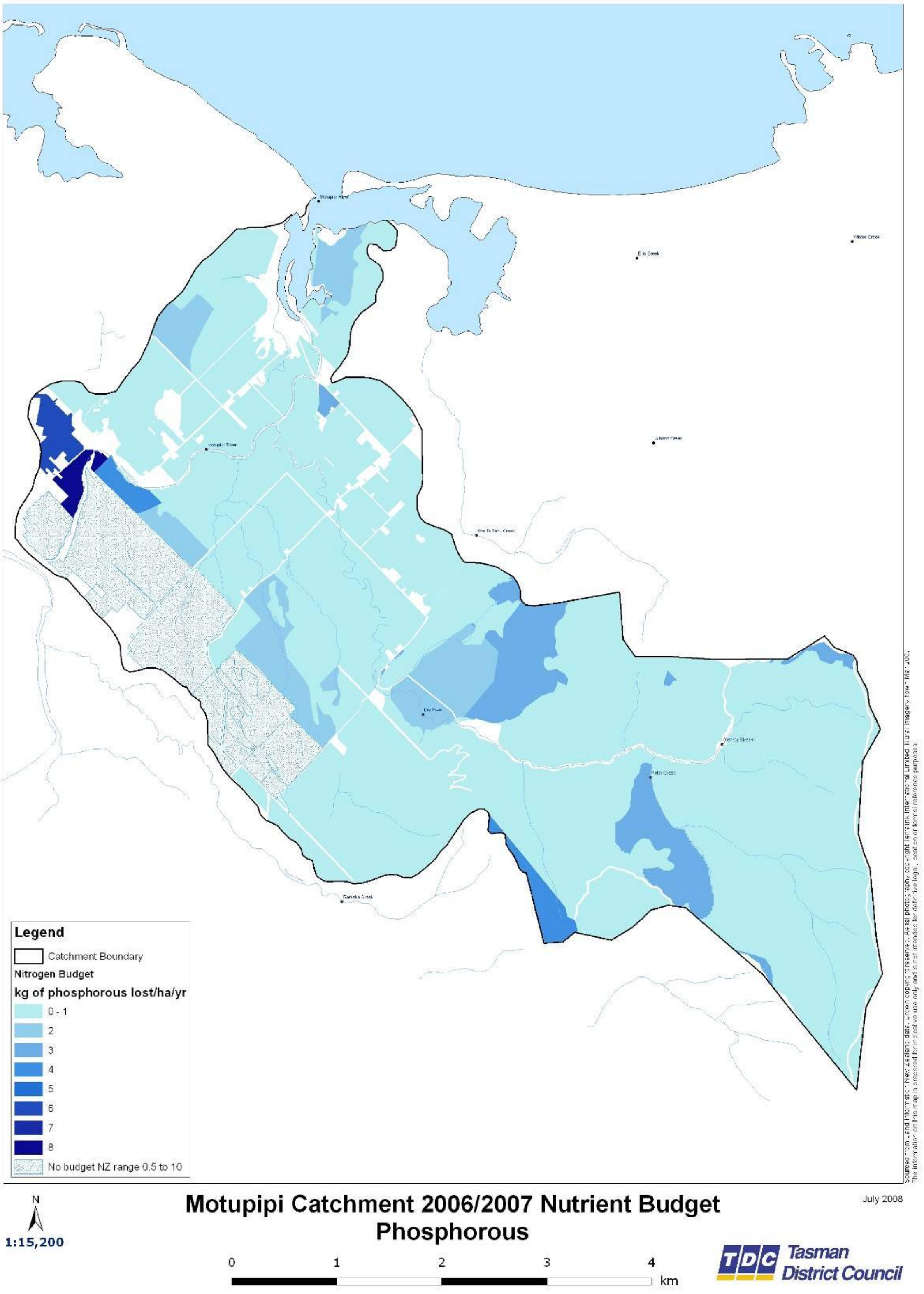

Fig. 6 Mass of phosphorous per hectare lost from land in soil drainage or surface run-off for the Motupipi Catchment, August 2006–July 2007

8. Hydrological Connectivity

Nutrient budgets such as OVERSEER™ use an accounting procedure to calculate the amounts of N and P leached from the base of the soil profile in each farming block. The link between these nutrient loads and water quality of the streams is the hydrology of groundwaters and surface water flows (including farm drainage). These flows govern what proportion of nutrients reaches the streams and how quickly this occurs.

In the Motupipi catchment, there are two main groundwater systems: the alluvial aquifer in the west, connected to the Motupipi River and fed via river gravels from the Takaka River, and the karst limestone extending east of the Motupipi to the Pikikiruna Range. Note that the boundaries of the Motupipi limestone aquifer are unknown and probably are not the same as those of the surface water catchment, therefore karst springs discharging into the Motupipi may be fed from beyond the Motupipi catchment.

The alluvial gravels, an old flood deposit of the Takaka River, range from only 1–2 m to more than 20 m deep (Stevens & James 2007). Gravels are shallow over impermeable Tarakohe mudstone (papa rock) especially south of the river (Thoma 1997) and this will short-circuit groundwater flows into the river when the soil is saturated to more than field capacity. Groundwater flow within these gravels is expected to be parallel to and into the river; a portion of the alluvial groundwater will seep directly into the estuary rather than into the Motupipi River. Springs in the gravels nearer Takaka are recharged from the Takaka River and from rainfall on land upgradient. Typical groundwater seepage velocities in alluvial aquifers like this would be 1–5 m/day, while in karst caves they could be much faster.

The limestone Motupipi aquifer discharges during wetter periods via springs draining to the alluvial gravels and the Motupipi River. Given that water level records from the Cserney limestone bore (GW6418 near Butchers Corner) fluctuate by almost 10 metres and rise to within 1 metre of the ground in the period 1988–2006 (Fig. 8), it is possible that flow reverses from the gravels into the limestone as karst water levels fall. It is also possible that a portion of the flow from the limestone aquifer flows towards Clifton, perhaps only during periods of higher water levels in the aquifer.

Mueller (1992) describes the Motupipi limestone aquifer as hydrologically separate from the band of limestone running from East Takaka to Clifton and out to sea at Tarakohe. Of relevance to this report is that sinkholes – including those within the farmed part of the catchment – are among the sources of recharge to the limestone, capturing runoff from Dry River and overland flow during rain. The Dry River only flows 15–20 times per year as it loses its flow into both the Waikoropupu Aquifer and the Motupipi limestone aquifer (Mueller 1992).

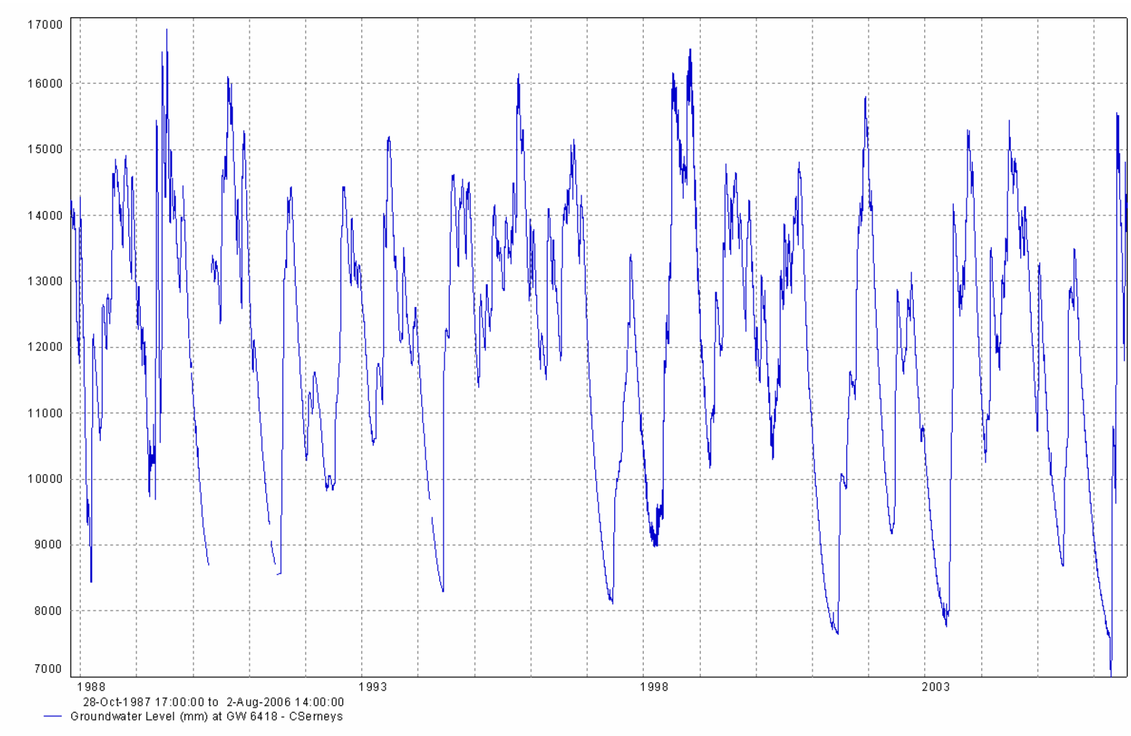

Fig. 8 TDC groundwater levels 1988–2006 in the Cserney bore WWD6418, mm above mean sea level (ground level =16.41 m)

To help visualize the possible contribution of groundwater flows to water quality of the Motupipi River, Table 5 presents a 'conceptual water balance' for rainfall in the Motupipi catchment. Based on the assumed areas of mudstone, limestone and gravels shown in Table 5, some 17% of catchment rainfall is likely to be recharging the Motupipi limestone aquifer and 7% adding to the groundwater flow in the gravels sourced from the Takaka River.

Table 5 Conceptual water balance for rainfall recharge in the Motupipi catchment (asterisked values are estimates only)

Motupipi Topographical Catchment Area	2800 ha		
Annual Rainfall (a)	1800 mm	Mean Motupipi River discharge	0.5 m^3/sec
Annual Evaporation* (b)	700 mm (40%)	Mean annual river discharge (c)	660 mm (36%)
Effective rainfall (b–a)	1100 mm		
Rainfall losses to groundwater (a–b–c)	440 mm (24%)	35% mudstone* (discharges to river)	Part of 660 mm above
		40% limestone* (68% of losses to groundwater)	300 mm (17%)
		25% alluvial gravels* (32% of losses to groundwater)	140 mm (7%)

TDC (Stevens & James 2007) note that nitrate-nitrogen levels from a limestone bore near Takaka Hospital (WWD6601) within the Motupipi limestone aquifer but just outside the topographical boundary of the Motupipi catchment have had a consistent median value of 2.1 g/m^3 since 1991. Compare this with the ANZECC trigger value for eutrophication of surface waters at 0.44 g/m^3 and the drinking water limit of 11.3 g/m^3. Nitrate-nitrogen measured in limestone wells further up the Takaka Valley is far lower than 2.1 g/m^3 (Glenn Stevens, pers comm.) suggesting that the Motupipi 'background' limestone water quality is impacted by land-use practices. Also, by comparison, nitrate-nitrogen in the gravel aquifer next to the Motupipi River is less than 1.5 g/m^3 and in the Takaka River typically less than 0.5 g/m^3 (Stevens & James 2007).

If we assume the same volume of annual recharge entering the Motupipi limestone beneath the catchment also discharges annually, and that it has the 'background' concentration of 2.1 g/m^3, then some 18 000 kgN/yr is contributed from karst springs, about 30% of the nitrogen losses calculated from pastoral farming. In other words it is possible that about 30% of the nutrients lost from farms enter the limestone aquifer to be discharged at some later time.

In summary, the connectivity of the Motupipi land uses to the Motupipi River and tributaries is governed by the two underlying aquifer systems – the Takaka River gravels and the Motupipi limestone – and by the topography and permeability of the soils. The nitrate content of the Motupipi limestone and to a lesser extent the alluvial gravels suggests the background water quality of springs and groundwater recharging the Motupipi River is impacted by land use in the catchment. Therefore, best management practices should consider impacts of land uses and discharges not only on the rivers and streams directly but also on the groundwater underlying the Motupipi catchment, as that groundwater is likely to end up in the Motupipi River or estuary.

9. Land Management Practices and Recommendations for the Future

9.1 Nutrient loss targets

No water quality goals or targets are set down in the Tasman Resource Management Plan (TRMP) for the Motupipi River system or aquifers in the catchment. The Motupipi Estuary is identified in Schedule 25.1F of the TRMP as an Area of National Importance for natural ecosystem values.

The Resource Management Act sets a minimum standard for water quality in section 107 that restricts the grant of a discharge permit to water or land or a coastal permit if any of the following effects are likely to occur in the receiving waters after reasonable mixing:

- The production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials
- Any conspicuous change in the colour or visual clarity
- Any emission of objectionable odour
- The rendering of fresh water unsuitable for consumption by farm animals
- Any significant adverse effects on aquatic life.

State of the Environment monitoring in the catchment for the 2006/07 season by Tasman District Council shows that N and P losses across the catchment are contributing to elevated N and P concentrations in both surface water and groundwater. The data collected suggest some of the minimum standards in section 107 of the RMA are under threat; however, this hinges on the interpretation of the words ‘unsuitable’, ‘significant’, and ‘conspicuous’ in this context.

In the final section of his July 2007 draft report, Trevor James suggests some management goals and specific targets for water quality and aquatic ecology in the Motupipi catchment. The water quality goals relevant to nutrient management in the catchment include maintaining water quality in the Motupipi River so that it is:

- acceptable for swimming.
- acceptable for fishing (e.g., eel and whitebait)
- acceptable for fish spawning
- able to support and sustain an aquatic ecosystem.

The Third Schedule of the Resource Management Act sets out guidelines for the type of water-quality targets required to achieve these goals. Trevor James has drawn on this to develop a set of target values for the Motupipi River in Table 2 of his report. The difficulty remains that it is hard to calculate how much current N and P losses need to be reduced to achieve the targets proposed based on the information available for this catchment.

Robertson and Stevens (2008) in a partner project on the Motupipi Estuary recommend reducing nitrogen input to the estuary to a total daily maximum load of 50 kgN/day (18 250 kgN/yr) to prevent the brown phytoplankton bloom which occurs in the salt water wedge in the upper estuary at present. The estimated nitrogen loss for the catchment estimated by this study for 2006/07 is 61 124 kgN/yr potentially entering the western arm (only) of the estuary. Based on this hydrological assessment, we estimate that some 80% this N and P will enter the surface water of the catchment (Motupipi river, Labyrinth Lane drain, Burnside drain plus other small drains draining directly to the estuary). In addition, some of the N and P lost to groundwater will enter the estuary as seepage into estuary margins.

If all the 61 124 kgN/yr did find its way into the estuary, then the proposed target of 18 250 kgN/yr needed to limit phytoplankton blooms would be exceeded at by approximately three times.

9.2 Possible land management responses

The second strand to this project was to visit as many of the larger land owners as possible to develop a nutrient management plan for each property. Plans produced, which are confidental to the landowner, summarize nutrient management strategies already in place and recommend additional nutrient management strategies for consideration for the future. The template for the individual reports is presented as Appendix 3.

Our observation is that good progress is being made by participating Motupipi landowners, especially among dairy farmers under the Clean Streams Accord. Management practices in place to reduce nutrient losses include fencing to exclude stock from waterways and tomos, riparian plantings in some locations, nutrient budgeting, bridging or culverting of most crossings of waterways with permanent standing water and the use of nitrification inhibitors in some areas as shown in Figure 7. However the benefits have yet to show through in improved surface or ground water quality in the Motupipi catchment.

It is important that landowners continue to build on the efforts put in to date, proceed with planned work and look at opportunities for carrying out the additional management strategies suggested to them. The March 2008 version of OVERSEER which includes riparian strips, use of nitrification inhibitors and wetlands can be used as a predictive tool on farm to estimate which mitigation measures will give the best reduction in nitrogen losses for that particular property. Table 2 provides some insight into the relative benefits of mitigation measures proposed for a dairy catchment in the Waikato which will be of some relevance to the dairy sector in this catchment.

Based on the farm visits with participating farmers, the following are among the specific recommendations to landowners who were visited as part of this study, with the aim of further improving water quality in the Motupipi River and estuary:

- Continuation of fencing of watercourses and drains from stock
- Streambank planting to provide stream shade, filtering of surface runoff and potential denitrification of shallow groundwater entering the stream
- Erosion protection along streambanks to reduce sediment input
- Fencing off and retention of remaining wetlands
- Use of irrigation scheduling or soil moisture monitoring for irrigation and application of effluent or Fonterra factory washwater, to avoid exceeding field capacity of soils, which leads to leaching or surface runoff
- Application of Eco-N nitrification inhibitors especially near stream margins where leaching and runoff is most immediate
- Fencing off and restricted stocking around tomos/sinkholes/wells likely to be sinks for runoff
- Siting and management of silage pits to minimize leachate loss
- Moving from nutrient budgeting to nutrient management planning at farm level, with assistance from fertilizer reps or farm advisers
- Consideration of the development of a Landowner Environmental Plan (whole farm environmental plan) that identifies Best Management Practices and an implementation programme for each property in the catchment.

Assistance with these suggestions is available through farm sector organisations, fertilizer companies, the NZ Landcare Trust and/or the council.

10. Summary

The aim of this study was to carry out a nutrient budget for the Motupipi catchment and provide suggestions to participating farmers on how they might further reduce nutrient losses to the Motupipi River and estuary from their property through developing a nutrient management plan. All parcels of land over 2 hectares in size were included in the budget but site visits were limited to the larger land owners.

In the Motupipi catchment approximately 55% of the land is in pasture, 40% in native vegetation, 3% is gorse and broom, and 2% is exotic forestry. Less than 1% of the catchment is used for cropping or horticulture. The data gathered for this project estimate the average annual loss of N from the catchment to be 61 124 kgN/yr and 2249 KgP/yr, with an error bound of ± 30%. Pastoral farming contributes 80% of the N and 81% of the P loss from the catchment.

The alluvial gravel and karst limestone aquifers underlying the Motupipi catchment store and transfer leached N and P to the Motupipi River, Motupipi Estuary and probably farther north. Assuming that rain falling within the Motupipi catchment also ultimately discharges within the catchment, some 17% of the catchment rainfall may be reaching the limestone aquifer in the west and 7% reaching the gravel aquifer to the east. Based on a consistent nitrate-nitrogen level of 2.1 g/m^3 in limestone bore water near Takaka Hospital, some 30% of the nitrogen losses from the catchment are calculated as occurring via the karst limestone aquifer. Further work to understand the hydrology and vulnerability of the groundwater of the catchment would check these estimates, in order to understand the groundwater contribution to water quality of the river and estuary.

Robertson and Stevens (2008) recommend that the Nitrogen load to the estuary should be below 18 250 kgN/yr to reduce the macroalgal and phytoplankton blooms evident in the upper estuary; this compares with the 61 124 kgN/yr calculated as lost in the catchment for 2006–07. Many Motupipi farmers, assisted by community volunteers on some properties, have made good progress with riparian fencing and improved fertilizer management. While we would expect the results to start showing through in water quality monitoring, N and P levels so far remain high in both surface water and groundwater. This suggests additional work to reduce N and P losses from pastoral land is required to achieve an improvement in surface water quality in the catchment. A starting point would be for landowners to proceed with the recommendations made to them in their individual nutrient management plans, and for non-participating landowners to seek similar advice.

11. Acknowledgements

Thanks to the Motupipi landowners who agreed to participate in this study, those who showed us around their properties, provided their nutrient budgeting and related information, and attended the pre- and post-project meetings. Thanks also to the dedicated work behind the scenes from Jenny Eyles, GIS specialist at TDC who created the farm and catchment scale maps from this work; Trevor James, TDC Water Quality scientist who initiated this project and provided useful guidance; Glenn Stevens, TDC Water & Land scientist who provided groundwater data; and Lew Metcalfe and Ian Goldschmidt of Fonterra who provided dairy sector feedback. We acknowledge the enthusiastic support of Barbara Stuart, NZ Landcare Trust, who organised the Motupipi catchment meetings.

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13. Appendices

Appendix 1: Best Management Practices for Land Owners for Water Quality Improvement

ACTIVITY	WATER QUALITY BMPS (BEST MANAGEMENT PRACTICES)	RESOURCES
FERTILIZER USE **Goal – to keep soil nutrients at optimum levels for land use while minimising losses and costs.** **2002 Statistics data shows usage of fertiliser for each agricultural sector as follows:** **Forestry – 0.01 Tonnes/ha** **Sheep – 0.18 Tonnes/ha** **Beef – 0.23 Tonnes/ha** **Grain – 0.75 Tonnes/ha** **Dairy – 0.81 Tonnes/ha**	**Planning** • Use a nutrient budget to account for all nutrient inputs, including re-used stock wastes. • Use soil and plant tissue analysis to adjust fertilizer rates to plant needs. • Application of fertilizer is permitted by rules 36.5.2 and 36.5.3 of the Tasman Resource Management Plan (TRMP). Check you comply. **Storage** • Place fertilizer storage and loading sites more than 50 metres from open water. • Contain any spills and clean up. **Application** • Use Fertmark registered fertilizer to ensure and low levels of impurities in product. • Use Spreadmark accredited companies to apply fertilizer to ensure accurate application. Use GPS and GIS technology for precise application and record keeping purposes. • Do not apply fertiliser when wind speed exceeds 15 km/hr. • Utilize positive wind direction to avoid drift into buffer zones or open water. • Avoid applying fertilizer to saturated soils or when tile drains are running. • Avoid applying near or into waterways and troughs, or to places where stock provide fertility such as gateways, stock camps. **After application** • Avoid surface run-off by not irrigating heavily for two weeks after application and not applying fertiliser before forecast high rainfall events. • Schedule irrigation to meet plant requirements to minimize leaching losses • Use riparian strips (streambank vegetation), existing wetlands or constructed wetlands to	• OVERSEER, available free from www.AgResearch.co.nz. • Making dollars and sense of nutrient management www.dexcel.co.nz • Code of Practise for Nutrient Management, 2007 plus Nutrient Management Plan Template www.fertresearch.org.nz • Getting smart with Nutrients NZ Farm Environment Award Trust www.maf.govt.nz/sff/about-projects/search/04-037/index.htm • Chapter 36 Tasman Resource Management Plan, Tasman District Council www.tdc.govt.nz • Using nitrogen: what is best practice? K Cameron et al., South Island Dairy Event 2005 www.side.org.nz/Papers

	capture sediment and nutrients flushed from the land by rainfall.	
NITROGEN (N) Potential for losses to air (volatilization), and to water from applied fertilizer and any stock waste. **Recent research has concluded greatest pastoral farm N losses occur from urine spots**	**Planning** • Avoid total N inputs greater than 150 to 200 kg/ha/yr • Avoid late summer or autumn cultivation of pastures. • Avoid application in mid to late autumn to fallow land unless there is a cover crop. • Reduce individual N application amounts on soils where - groundwater lies under permeable sediments (e.g., gravels), - or water table is high - or there is subsurface mole and tile drainage • Use a low volatility N fertilizer especially if applying N at rates above 30 kg/ha : CAN (1% loss on average at 30kgN/ha) <DAP (5%)< Urea (11%). **If using urea** • Keep individual applications of N to a maximum of 50 kg/ha. (Research reports losses to air from urea of 12% at 30 kg/ha, 17% at 50 kg/ha, 25% at 100kg/ha.) • When using urea light irrigation after application to wash urea into soil is reported to reduce losses to air to 1%. • Consider using urease inhibitors (e.g., SustaiN) when applying urea to slow down conversion of urea to the more volatile ammonium carbonate. **Application** • Apply N when soil temperatures is above 6 ^{o}C at 10 cm depth at 9.00 am as it is warm enough for plants to grow and take up nutrients. • Apply N to pasture at least 25mm high. • On severely compacted soils, use soil aeration techniques prior to application. **Capturing nitrogen in urine spots** • Use nitrification inhibitors (which slow down conversion of ammonia in the urine to nitrate by nitrifying bacteria in the soil) to reduce leaching of nitrate from urine spots. Application required in May and August after grazing for best results. Reported reduction in nitrate leaching of up to 60% in grazed pasture systems from May post application through to end of September. Also reported reduction in cation leaching by 50% and nitrous oxide emissions by 75%. •	

<table>
<tr>
<td>PHOSPHATE (P)
Potential for losses greatest for soluble phosphate (Olsen P) during fertiliser application and greatest for soil associated P as a result of soil erosion.</td>
<td>Planning
• Apply P in summer when low rainfall is expected, but avoid applying during a drought until after rain has promoted re-growth.
• Use a low solubility P fertilizer (RPR < Serpentine super< super phosphate) when soil pH < 6.0 and annual rainfall is > 800 mm.
• If using a high solubility P fertilizer apply it in split dressings if the single application rate would exceed 100 kg P/ha.
• Use split dressings- if high rainfall or irrigation likely,
- on very sandy soils
- when slope is greater than 25 degrees
• Don't exceed optimum soil Olsen P level for your land use.

Application
• Apply P to pasture at least 25mm high.
• On severely compacted soils, use soil aeration techniques prior to application.

Post-application
• Avoid irrigating for two weeks after applying P.
• Minimize risk of soil erosion on farm as P is lost with sediment.</td>
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<td>PASTURE MANAGEMENT AND STOCK MOVEMENT

Goal – to manage stock on farm to reduce impacts on water quality. Nitrogen, Phosphorous and disease causing microbes including Campylobacter, Cryptosporidium, Giardia and salmonellae are of particular concern. (NZ is reported to have one of the highest rates of infection for these diseases in the world.)</td>
<td>Stock management
• Keep livestock out of waterways, bogs, seeps and wetlands.
• Exclude stock from grazing saturated soils in autumn and winter.
• Bridge or culvert dairy herd crossings. Check with TDC to see if resource consent required.
• Provide alternative water in stock troughs, shade and shelter to encourage stock away from waterways.
• Use stand-off pads during autumn/winter for cattle.
• Control runoff from stock tracks, sheep/cattle yards and races, directing it away from open water

Pasture management
• Permit vegetation to grow in open drains as this can achieve a 40–100% reduction of E.Coli in 25–150 metres respectively.
• Limit potential for soil erosion through:
- Conservation tillage and contour cultivation.
- Maintaining pasture sward.
- Filter strips or swards across slopes.</td>
<td>• Clean streams: a guide to managing waterways on Tasman–Marlborough farms www.tdc.govt.nz

• Best management practices to mitigate faecal contamination by livestock of NZ Waters. NZ Journal of Agricultural Research, 2007, 50: 267–278 www.rsnz.org

• Growing greener grass: a guide to good pasture management. NZ Farm Environment Award Trust www.maf.govt.nz/sff/about-projects/search/04-037/index.htm

• Winning margins: waterways on</td>
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	- Riparian plantings for stream bank protection. - Planting slopes vulnerable to slips. - Cut-off drains for stormwater control. • Maintain soil structure by avoiding over cropping, treading damage and soil compaction from machinery. • Monitor soil health using Visual Soil Assessment (VSA). **Silage production** • Make silage at high dry matter so it has less leachate. • Silage pits should be sealed and leachate collected and re-applied to top of silage in the pit or applied to land away from water. • Discharge of leachate from a silage pit to water is likely to require resource consent under the TRMP, check with TDC. **Other tools to reduce stock impacts** • Use riparian strips to re-capture sediment, nutrients and microbes flushed from the land into surface and subsurface flows by rainfall. [Shading effects of riparian strips also help to keep stream temperatures low, reducing potential for algal growth and reduced oxygen levels. Elevated temperatures and reduced oxygen concentrations can stress instream fauna.] • Use existing wetlands and/or constructed wetlands to capture sediment, nutrients and microbes in surface and subsurface flows.	farms. NZ Farm Environment Award Trust www.maf.govt.nz/sff/about-projects/search/04-037/index.htm • Visual Soil Assessment method. Landcare Research www.landcareresearch.co.nz/research/soil/**vsa** • Chapter 36, Tasman Resource Management Plan, Tasman District Council www.tdc.govt.nz
STOCK WASTE MANAGEMENT **Goal – to manage collected stock wastes to reduce impacts on water quality. Nitrogen, Phosphorous and disease causing microbes including *Campylobacter, Cryptosporidium, Giardia* and *salmonellae* are of particular concern.**	**Solid manure, offal, dead stock** • Hot compost any collected solid stock waste for re-use under cover away from surface or groundwater. This reduces risk of spreading disease causing microbes and spread of weed seeds in manure. The discharge of leachate to land from composting operations of up to 50 cubic metres is permitted by rule 36.1.9 of the TRMP. Check you comply. • Locate offal pits and away from surface or groundwater. The discharge of leachate to land from offal pits is permitted by rule 36.1.10 of the TRMP. Check you comply. • If burying individual dead stock locate the pit away from surface water or groundwater. **Collection, treatment and re-use of liquid organic wastes (effluent)** • Collect and re-use liquid waste from stand-off pads, dairy shed, silage pits as fertilizer for suitable areas on the property. (Ensure potassium levels are safe for stock.) • Treat liquid stock waste in a sealed (clay lined) two stage anaerobic/aerobic or advanced pond	• A guide to managing farm dairy effluent Tasman/Marlborough www.tdc.govt.nz • Chapter 36, Tasman Resource Management Plan, Tasman district Council www.tdc.govt.nz

	system large enough to match stock numbers in foreseeable future to reduce disease causing organisms before application to land. • Minimize amount of water added to stock waste at source to reduce storage needs and improve treatment. • Apply treated waste to land appropriately – - Avoid applying stock waste to wet or mole tile drained land when drains are flowing. - Provide storage for stock waste to allow deferred application to soils when they are not saturated. - Graze prior to application. - Don't graze for at least 10 days afterwards to minimize animal health risks. - Apply effluent at a low rate well below the infiltration rate of the soil to prevent surface ponding. - Select most suitable areas on farm for application – consider soil drainage class, permeability and slope. - Match application volume to soil moisture deficit. - Prepare an irrigation schedule - Keep records of volume applied and where to for nutrient budgeting/fertilizer purposes. - Regularly maintain pumps and irrigation equipment - Train staff • Discharge of dairy shed effluent to land is permitted by rule 36.1.3 of the TRMP. Check you comply. • Discharge of up to 5 cubic metres per day of waste from housed stock (including birds) or waste from stock or bird processing activities is permitted by rule 36.1.3 of the TRMP. Check you comply. • Any other discharge is likely to require resource consent, check with TDC.	
EARTHWORKS, ROADING AND TRACKING **Goal – to manage earthworks, roading and tracking to reduce**	**Planning and design** • Design earthworks to match soil type, geology, topography, climatic conditions and use. • Minimize tracking to reduce soil disturbance, compaction and erosion. • Fish passage must not be impeded by structures. • Design roading and tracking to keep machinery out of waterways and riparian margins. • Avoid earthworks within 5 metres of permanent waterways except at designated crossings or water access points. • Divert road/track runoff away from crossings using berms, cutouts, culverts or flumes.	• NZ Environmental Code of Practice for Plantation Forestry: parts one–five, Version 1. NZ Forest Owners Association http://www.fitec.org.nz/cop/Contents.htm

risk of erosion and impacts on water quality. Good initial design avoids the need for expensive maintenance in the long term.	• Tasman District Councils rules for land disturbance and roading are set out in parts 18.6 and 18.10 of the TRMP. Check you comply with permitted activity rules or apply for resource consent(s). **When crossing waterways** • Install correctly designed waterway crossings. • Place crossings where waterway banks are solid and beds stable. • Minimise machinery operating in the bed of the waterway when constructing bridges/crossings. • Decommission temporary crossings once replaced. • Avoid in-channel work during fish spawning season. • Use fords for infrequent vehicle use, and in waterways that have hard streambeds, low flows and low in-stream values. • Consider using bridges or low level crossings on larger waterways. • Building consent required for any bridge where fall height exceeds 1 metre. • Bridge structures will need to be approved /certified by a civil/structural engineer. **When carrying out earthworks** • Install appropriate water and sediment controls to prevent runoff flowing directly into waterways such as sediment traps, cut-off drains, culverts, socks, flumes as work progresses. • Maintain water and sediment control structures in effective operating condition as long as needed. • Operate along the contour to minimise runoff being concentrated down cultivated lines. If unavoidable, limit downhill runs to a maximum continuous length of 50 metres. • Stabilise earthworks appropriately as soon as practicable. • Do not incorporate slash or organic material into steep fill batters. • Undertake work in suitable weather for site conditions.	• Clean streams: a guide to managing waterways on Tasman–Marlborough Farms www.tdc.govt.nz • Chapter 18, Tasman Resource Management Plan, Tasman district Council www.tdc.govt.nz • Low-impact tracks and races: a guide to good track and race design and maintenance. NZ Farm Environment Award Trust www.maf.govt.nz/sff/about-projects/search/04-037/index.htm
FOREST PLANTING AND HARVESTING **Goal – to manage forest planting and harvesting to reduce risk of erosion and impacts on water quality.**	**Planning and design** • Do not plant where harvesting will not be possible without serious adverse effects. • Select felling and extraction techniques to minimize effects. • Use extraction techniques that suspend the butt end of the log. • Carry out any earthworks, roading or tracking necessary for harvest so they have time to stabilise before use. • Use appropriate methods such as directional felling to minimise the amount of woody debris deposited in streams. • Undertake work in suitable weather for the site conditions. • Planting of plantation forests is permitted by rule 17.4.8 of the TRMP. Check you comply.	• NZ Environmental Code of Practice for Plantation Forestry: Parts one–five, Version 1. NZ Forest Owners Association http://www.fitec.org.nz/cop/Contents.htm • Chapter 17, Tasman Resource Management Plan, Tasman district Council www.tdc.govt.nz

	Riparian setbacks and management • Rules 17.4.8 and 17.5.8 of the TRMP require planting setbacks of 10 metres from the bed of any river or stream greater than 3 metres average bed width in Rural Zones 1 and 2. • When planting leave a minimum horizontal riparian setback of 5 metres each side of all permanently flowing streams. • Increase riparian setbacks where topography, in stream values, sensitive boundaries or future harvesting complications indicate there is a need. • Avoid harvesting trees in water channels, floodways or riparian areas **Managing slash** • Remove slash and wood debris for ephemeral (intermittent) streams where flood flows have the potential to mobilise the debris and cause damming, erosion or property damage downstream. Use debris traps at strategic locations downstream if this is not possible. • Debris traps usually require resource consent. Check with the TDC to see if consent is required. • Use slash racks to protect culverts when slash build up is expected to be a problem. • Align slash windrows along the contour of sloping land and within broad valley floors to help trap sediment. **After harvest** • Remove all rubbish from the forest and dispose of correctly. • Decompact landings by ripping after use if not required in the future.	
AGRICHEMICALS **Goal – to manage agrichemical use to reduce risk of contamination of soil or water.**	**Planning, storage and handling.** • Agrichemicals applications must be planned, supervised and undertaken by trained personnel with an approved handler certificate. • Follow recommendations and guidelines of the Agrichemicals Standard NZS8409:2004 • Store agrichemicals appropriately. • Store away from waterways and wells. • Time use of agrichemicals to get maximum effect. • For larger applications such as aerial applications use GPS to accurately define boundary of application area. • Follow manufacturers label recommendations. Have material safety data sheets available for all agrichemicals used. • Application of pesticides to land, water and air is a permitted activity subject to conditions in rules 36.6.2 and 36.6.3 of the Tasman Resource Management Plan. Check you comply.	• Agrichemicals Standard NZS8409:2004 • Agrecovery programme www.agrecovery.org.nz Freephone: 0800 (agrecovery) 247326 • Chapter 36, Tasman Resource Management Plan, Tasman District Council www.tdc.govt.nz

	Application • Use appropriate protective equipment. • Apply in suitable weather for the site conditions to prevent spray drift. **After application** • Disperse any residual chemical over the target area at or below standard concentrations – do not dump in a concentrated quantity over a small area. • Triple rinse empty containers and use wash water as part of spray operation – do not dip into waterways. • Return containers to Agrecovery depot for recycling. Two operating in Tasman (Mariri Resource Recovery, Motueka, Mon–Sat 9–8 Sun1–4. Beach Rd Transfer Station, Richmond, 7 days 8–5).	
FUEL AND OIL	**Storage** • Fuel storage systems must conform to the Hazardous Substances and New Organisms (HSNO) Regulations and associated Codes of Practice. • Have an emergency response plan for fuel and oil incidents • Storage of fuel and oil should be in a location where an accidental spill cannot enter a waterway. • Stationary tanks (not wheeled tankers) should have secondary containment (bunding) where storage capacity is > 1000 litres. • Pipes, seals and fittings should be in good condition, leak free and regularly inspected. **Use and disposal** • Machinery should be regularly checked for fuel and oil leaks. Repair, use drip trays to collect leakage in meantime. • Waste oil should be collected and disposed of to an authorised disposal/recycling facility. • Never deliberately release waste oil onto soil.	• ERMA's Code of Practice for the Management of Existing Stationary Container Systems up to 60 000 litre capacity www.ermanz.govt.n/consultations/cop9draft2.pdf
HUMAN WASTE	• Domestic sewage from dwellings on property should be treated through designed septic tanks or similar. Discharge to land should be through a soakage field that complies with the NZ Code of Practice for on-site domestic wastewater management AS/NZS 1547:2000. • Discharge of up to 2000 litres per day of domestic wastewater to land is permitted by rule 36.1.4 of the TRMP. Check you comply. • Discharge of 2000 litres of greywater is permitted by rule 36.1.6 of the TRMP. Check you comply. • The discharge of human waste from a long drop toilet is permitted by rule 36.1.7 of the TRMP as long as it does not serve a dwelling. If you have one, check it complies.	• Chapter 36, Tasman Resource Management Plan, Tasman District Council Rule No 36.1.4 www.tdc.govt.nz • On-site domestic wastewater management AS/NZS 1547:2000. Standards NZ www.standards.co.nz

NON-BIODEGRADABLE REFUSE	• Non-biodegradable wastes such as paint cans, old wire, used fuel oil and filters, old machinery should be recycled if possible or disposed of appropriately off property. Contact TDC to find out best disposal method.	• NZ Environmental Code of Practice for Plantation Forestry: Parts one–five. Version 1. NZ Forest Owners Association. http://www.fitec.org.nz/cop/Contents.htm

Appendix 2: Soil Drainage Characteristics of the Motupipi Catchment

	SOIL DRAINAGE (PERMEABILITY CLASS)	CLAY CONT.	SOIL TYPE	TDC SOIL CLASSIFICATION AND GENERAL COMMENTS
Clifton (Cf)	Moderately well drained to imperfectly drained (3)	M/L	Silt loam with clayey subsoil with slow permeability	➢ Class E ➢ Subject to occasional surface flooding.
Glenview (Gv)	Moderately well drained to imperfectly drained (4)	M/H	Silt loam overlying a clay loam and iron pan at around 70 cm.	➢ Class D ➢ Drainage impeded by iron pan ➢ Imperfectly drained in places with water table less than 50 cm from surface. ➢ In wet periods susceptible to pugging and damage to topsoil.
Hamama (Ha)	Well drained (4)	M/L	Silt loam overlying sandy gravel subsoils at shallow to moderate depth	➢ Class A ➢ Shallow depth to gravel ➢ Moderate water holding capacity
Harihari (Ha)	Imperfectly to poorly drained (3)	M/L	Silt loam	➢ Class F ➢ Groundwater table present due to flooding and ponding of flood waters.
Karamea (Km)	Well drained (4)	M/L	Silt loam overlying fine to coarse sand	➢ Class A ➢ May be susceptible to compaction due to weak subsoil structure
Karangarua (Ka)	Poorly drained (2)	M	Peaty loam	➢ Class C ➢ Water table present in 64% of observation sites at average depth of 43 cm
Mahinapua (Ma)	Well drained with moderately rapid permability (6)	L	Loamy sand	➢ Class B ➢ In some places may have impeded subsoil drainage
Motupipi (Mo)	Well drained (4)	M/H	Silt loam	➢ Class A ➢ Good moisture storage
Okari (Ok)	Excessively well drained (7)	L	Sand	➢ Class G ➢ Poor moisture storage
Pisagh (Ps)	Well drained to moderately well drained (4)	H	Silt loam on top of a deep clay loam to clay subsoil.	➢ Class B ➢ Unstable friable topsoil
Pohara (Po)	Imperfectly drained (3)	M	Silt loam overlying a heavy silt to clay loam	➢ Class D ➢ Water table sometimes present in lower subsoil

Rameka (Ra)	Well drained (4)	H	Silt loam to heavy silt loam	➢ Class A ➢ Good moisture storage
Rototai (Ro)	Well drained to imperfectly drained (4)	M	Silt loam to sandy clay loam	➢ Class B ➢ Imperfectly drained on lower slopes where land merges with Karangarua soils
Tadmore (TmH, Tm)	Well drained (4)	H	Heavy silt loam over well structured silt loam to clay loam	➢ Class E ➢ Good moisture storage ➢ Susceptible to erosion.
Takaka (Tk)	Well drained (4)	M	Silt loam	➢ Class B ➢ Susceptible to flooding ➢ Limited moisture storage due to sandy subsoil
Tarakohe (ThH, Th)	Well drained (4)	M/H	Shallow to deep silt loam. Rock outcrops.	➢ Class F – small amt Class C ➢ These soils overlay Takaka Limestone formation (Karst). Sinkholes formed by dissolution activity.
Tata (Ta)	Well drained to excessively drained (5)	M/L	Heavy silt loam overlaying sand	➢ Class A ➢ Subject to flooding in places
Te Tahu (Tt, Tt1)	Well drained to excessively drained (5)	M/L	Silt loam overlying sandy gravel	➢ Cass A
Waingaro (Wa)	Imperfectly drained (3)	M	Heavy silt loam	➢ TDC Class C soil ➢ Severe topsoil poaching may occur with stock grazing under wet conditions ➢ Susceptible to surface ponding
Waitapu (WtH)	Well drained (4)	H	Heavy silt loam overlying clay loam and sandy clay	➢ Class E ➢ Some slopes are unstable and subject to earth flow. ➢ Slopes predominantly between 15 and 25 degrees.

Appendix 3: Landowner individual report template

Motupipi Catchment 2006/07 Nutrient Budget
(Confidential to landowner)

Property details:
Includes contact information, date of visit, land use, stock numbers for whole farm, property area within the catchment

Nutrient inputs:
Nutrient Budget Information – Summary table of N and P losses predicted for each farm block created by Simon Gaul for the nutrient budget carried out by him for that farm using OVERSEER version 5.2.6.0. on a kg/ha/yr basis and a kg/yr basis calculated using the area for each farm block. Total losses for whole farm calculated.

Effluent management on farm. Application details if re-used as fertilizer.

Silage/balage production on farm.

Nutrient management strategies in place now:
Brief summary of on farm management strategies to manage nutrient loss including stock exclusion fencing, stock management over winter, bridged or culverted crossings, storage for deferred irrigation of dairy shed effluent, use of nitrification inhibitors, wetlands, riparian plantings.

Concerns:
Where the landowner raised concerns regarding particular matters likely to effect N and P losses both on farm and off-farm within the catchment they were recorded.

Additional management strategies worth considering:
Individual recommendations were made to landowners:

- Continue fencing of watercourses and drains from stock
- Streambank planting to provide stream shade, filtering of surface runoff and potential denitrification of shallow groundwater entering the stream
- Erosion protection along streambanks to reduce sediment input
- Fencing off and retention of remaining wetlands
- Use of irrigation scheduling or soil moisture monitoring for irrigation and application of effluent or Fonterra factory washwater, to avoid exceeding field capacity of soils which leads to leaching or surface runoff
- Application of Eco-N nitrification inhibitors especially near stream margins where leaching and runoff is most immediate
- Fencing off and restricted stocking around tomos/sinkholes/wells likely to be sinks for runoff
- Siting and management of silage pits to minimize leachate loss
- Moving from nutrient budgeting to nutrient management planning at farm level, with assistance from fertilizer reps or farm advisers
- Consider developing a Landowner Environmental Plan (whole farm environmental plan) identifying Best Management Practices and an implementation programme for each property in the catchment.