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Farm Strategies for Contaminant Management

A report by SLURI, the Sustainable Land Use Research Initiative, for Horizons Regional Council

June 2007

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June 2007

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8 February 2007

AgResearch
C/- Alec MacKay
Private Bag 11008
PALMERSTON NORTH

Dear Alec,

Re: The Average Sheep & Beef Farm

Further to our discussion yesterday I make the following notes:

With respect to the average sheep and beef farm, you are referring to those that feed into the Manawatu river catchment above (North) of the Hopelands bridge.

Generally speaking, this takes in an area bounded by the Waewaepa range in the east, Whetukura (north east), Norsewood to the north and the Ruahine range in the west.

Farm sizes vary considerably in this catchment from small (150-200ha) intensively farmed units to the much more extensive stations (2500-3000ha) in size).

In reviewing our Profit Check database and calling on my experience and clientele as a Farm Management Consultant, I believe the average sheep and beef farm in this region would be something like:

• **Total area**	425ha		
• **Effective area**	400ha		
• **Carrying capacity**	4000su (10su/ha)		
• **Sheep:cattle ratio**	70:30		
• **Lambing percentage**	115% MA ewes 20% ewe hoggets		
• **Lamb weaning weight**	27.5kg		
• Average lamb sale weight	31kg (early March)		
• Wool production	5.5kg/ssu		
• **Calving percentage**	88% MA cows 85% R2yr heifers		
• **Calf weaning weight**	210kg (mid April)		
• **Soil fertility**	Olsen P	14	
	Potassium	8	
	Calcium	8-10	
	Magnesium	}	have not really taken
	Sodium	}	much notice of these
	pH	5.6	

- **Fertiliser use** — Predominately superphosphate 180-200kg/ha (16-18kgP/ha) On average 7kgN/ha.
- **Rainfall** — Average 1200ml (range 900ml at Hopelands to 1800ml; under Ruahine Range).
- **Soil type** — Generally derived from sedimentary parent material. Soils are stronger/better structured on Limestone and Greywacke parent material.
- **Livestock policies** — **Sheep:** Romney base breeding and some lamb finishing.
  Cattle: Breeding cows with some steer and bull beef finishing.
- **Stock reconciliation**

MA Ewes	2250
Ewe Hoggets	660
Rams	30
Sheep Stock Units	**2800**
MA Cows	100
R2yr Heifers	25
R1yr Heifers	30
R1yr Steers/Bulls	75
Cattle Stock Units	**1200**
Total Stock Units	**4000**

I trust this précis of the "average" farm helps. If you require further information please feel free to call me.

Yours sincerely,

Greg Sheppard
Farm Management Consultant

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DairyTeam Consultant
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Mobile 0274 519 456

28 February 2007

Dr Alec Mackay
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Palmerston North

DAIRY FARM IN THE UPPER MANAWATU (DANNEVIRKE DISTRICT)

My experience with this district comes from:

1. Working in the district as the Dexcel Consulting Officer from 1997 to 2004, facilitating 3 farmer Discussion Groups that covered approximately 50 dairy farms, and met about 8 times per year. Regular annual analysis of financial and physical data was collected from about 25% of these participants. The 2003/04 data was the last I collected.
2. Working as a private Farm Consultant since Feb 2006 on a monthly individual visit basis. I have 7 clients within the direct catchment's concerned (between Hopelands and Weber Road bridges) and a further 6 clients in the Norsewood and Woodville areas, which are still Manawatu River catchment. I have yet to complete a full dairy season with any of these clients but have some good indications what the statistics will be.

My brief is to describe the average dairy farm in the district, based on the above experience. There is considerable variation between the approx 80 farms so there is some professional guesswork in the following answers.

Farm Size:
About 390 cows milked at peak (Oct/Nov) on 138 hectares (effective in pasture). That is a stocking rate of 2.83 cows/hectare and would require a greater winter/calving number of about 410 cows.

Present Fonterra Fencepost data has 3.06 cows/ha as the stocking rate for district, but that is based on farmers' estimated numbers in winter, prior to calving, which has always overstated cow numbers.

There has been a significant number of split-calving winter milking dairyfarms in the Dannevirke district for about 20 years (more than 15 of the 80 farms in 2004) but most have switched to spring-calving only, seasonal supply as the Fonterra pricing premium is reduced. 1 of my clients still winter milks, and intends to cease within 2 winters.

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....64

All but 2 of my present clients have support land (runoffs), which average 40 hectares. About two thirds of these are within the district. This land usually grazes some replacement youngstock and dry cows, as well as providing silage to the milking area.

Milksolids Production:
In recent years these farms are averaging milksolids production (sold to the factory) about 360-370 kg/cow or 1000-1050 kg/hectare.

Imported Feeds:
While the farm systems are primarily pasture grazing, utilizing 11-12 tonne DM/ha/year, other feeds like maize silage, grass silage or concentrates have increased in contribution throughout the last decade. Such imports average about 1200 kgDM/ha annually. Most farms feed these and home made supplements on pasture. One third of my clients do have feedpad facilities, but I think that would be well above the district average.

An additional 1000 kgDM/ha as dry cow grazing is sourced away from the milking platform in winter (June/July). It is unusual to see all dry cows away, with maybe 1 cow/ha remaining grazing pasture at home during the dry period.

Most dairyfarms have no replacement youngstock "at home" after early December, another 2000 kgDM/ha sourced elsewhere.

I have no records how much of these feeds involve their own runoffs, but guess it may be half of it.

Soils & Soil Fertility:
About two thirds of the farms are on primarily free draining, shallow loam type soils over shingle subsoils. The remainder are on heavier soils, primarily the Matamau Silt loams. Soil tests would usually show levels of Olsen P 30, MAF K 6-8, Mg 10, and Ca 12.

Fertiliser inputs:
Annual fertilizer inputs typically would be 35kgP, 40kgK and 45 kgS per hectare per year as one dressing usually in late spring early summer. Fertiliser N has been about 120kg/ha/yr.

Effluent Disposal:
Most of these farms spray effluent onto pasture daily while milking, with traveling irrigators. The regulation is 4 hectares per 100 cows and I think many would cover a slightly greater number of hectares.

I trust this information is of assistance to you.
Yours Faithfully
John Simmonds

Executive Summary

- At the request of Horizons Regional Council we have developed a framework and produced best management practices for contaminant management on farms in the Manawatu-Wanganui region. Primarily we have considered dissolved nitrogen and phosphorus as the prime contaminants of concern.

- Horizons Regional Council asked SLURI, New Zealand's multi-CRI Sustainable Land Use Research Initiative, some 15 questions in order to address farm strategies to limit contaminant management that could be included in the "One Plan". The summary of our responses are listed below.

- This report was peer reviewed by NIWA, and responses to their comments and their constructive suggestions have been incorporated into this final report.

- Further development was carried out after the submission of our initial report in relation to linking N-loss limits to a measure of the landscape's natural capital, and the results of this research is appended here as Appendix 6. Based on the Land Use Capability (LUC) classes on the Land Resource Inventory we have shown it possible to assign loss limits to LUC classes. This can then be linked to the river by summation across the landscape to provide the impact on the river system. Such an approach optimises productive and protective uses of a catchment biophysical resources and natural capital.

Summary of Responses to Horizons' 15 Questions:

1. Farm Types and the Potential Impact on Water Quality.

Horizons Regional Council have identified the 4 intensive forms of farming as being dairying, irrigated sheep and beef, market gardening and cropping. These we rank for nitrogen (N) and phosphorus (P) as

Ranked Nitrogen Loss		Ranked Phosphorus Loss	
Market Gardening	(100-300 kg-N ha^{-1} yr^{-1})	Market Gardening	
Cropping	(10-140 kg-N ha^{-1} yr^{-1})	Cropping	
Dairying	(15-115 kg-N ha^{-1} yr^{-1})	Dairying	(0.2- 1.0 kg-P ha^{-1} yr^{-1})
Sheep/beef	(6-60 kg-N ha^{-1} yr^{-1})	Sheep/beef	(0.1-1.6 kg-P ha^{-1} yr^{-1})

2. What is the best practice acceptable nutrient loss from a farm that Horizons should endorse?

To establish what the target best management practices (BMP) are for sheep/beef and dairy to ensure that water quality in Horizons Water Management Zones (WMZ) meet their quality criteria, we first needed to link what we consider is happening on the farm, with what is observed in the river.

We used the two sub-catchments of Weber Road and Hopelands in the Upper Manawatu WMZ (UMWMZ) to establish that the transmission factor, $\Re$, for dairying was about 0.5, so that whereas Overseer® predicted a farm loss of nitrogen of 31 kg-N ha^{-1} yr^{-1}, the river only 'saw' it as being 15.4 kg-N ha^{-1} yr^{-1}. The transmission factor for sheep/beef was also found to be about 0.5. By observing year-to-year variation in the N loadings across 16 years of measurements at Hopelands, we consider that the variability in our derived results, due to changing annual weather patterns, is of the order ± 20%.

Improvements in dairy-farm operations, through the adoption of best management practices could reduce farm losses by up to a third. If the mitigation options were successful, and if they were capable of application across the whole farm, the loss of N could potentially be reduced to around 21 kg-N ha^{-1} yr^{-1}. For the sub-catchment of Hopelands, if such a reduction in non-point source pollution could be achieved through the adoption of best management practices, this would translate into a reduction in the N loading on the river of 73,545 kg-N yr^{-1}, an improvement of around 18.3%.

Because dairying and sheep/beef each contributes about one half of the total loading of nitrogen in the river at Hopelands, a one third improvement in either will only translate to an improvement of about half of that improvement in the river. Of course, if both farm types were able successfully to improve practices to reduce losses by one-third, there would be a one-third improvement in the river, according to this linear transfer-function approach. We add that the range of mitigation and optimisation measures available to reduce N loss under sheep/beef grazing is less than that possible in the dairy sector.

We also examined the impact of potential intensification patterns using Overseer® and our linear transfer-function. If dairy farms were to intensify to achieve 1200 kg milk solids (MS) ha^{-1} the leaching loss of N is predicted to be 49 kg-N ha^{-1} yr^{-1}, which would result in a 33% increase in N-loading in the river coming from the Hopelands sub-catchment. If sheep/beef farming were to increase the stocking rate through to 12.2 stock units (SU) ha^{-1}, a possible scenario in about a decade's time, the leaching loss of N is predicted to be 9 kg-N ha^{-1} yr^{-1}, which would lead to about an 8.4% increase in river N-loading coming from the Hopelands sub-catchment.

We also investigated a potential dairy-expansion case. There are 31,580 ha of lands better than Class III in the UMWMZ, and currently dairying only occupies 20,534 ha. If dairying were to expand on all to Class III lands or better, there would then be about a 17.8% increase in N loading at Hopelands emanating from the entire UMWMZ, if current management practices prevailed.

Our transfer-function can also be used 'backwards'. Horizons Regional Council informs us that to meet water quality standards in the river at Hopelands, the N-loading should be 341,000 kg-N yr^{-1}, *cf*. the current loading of 744,000 kg-N yr^{-1}. Using an inverse approach, going back from the N loading that achieves the water quality standard in the river, and allocating the load back to the farm-type on the basis of the current proportion of the N-loading in the river, would require that dairy farms only leach 15.1 kg-N ha^{-1} yr^{-1}, and sheep/beef farms 3.8 kg-N ha^{-1} yr^{-1}. If the allocation back to the farm-type were on the basis of the proportion of the catchment in that farm type, the loadings would be 5.8 kg-N ha^{-1} yr^{-1} for both dairying and sheep/beef. These targets would not, in general, seem realistic given current technologies, although the former case represents a halving from current performance, and this is the target in the Dairy Industry's Environmental Strategy. In a subsequent report, we detail how the best management practices required to meet the water quality standard in the river might be split on the basis of the natural capital of the land classes in a WMZ.

3. What are the critical hotspots for nutrient inputs in waterways? Answered as part of responses to questions 2 and 4.

4. Best management practices for effluent application to land if Horizons were to make it a permitted activity. The manual "*Managing farm dairy effluent and Farm Management Issues*" provides a comprehensive list of best practice measures for the application of effluent to land. Horizons should reference the practices listed in Chapter Two 'Land Application" and Chapter Four 'Effluent from Feed Pads, Stand-off Areas and Other Sources, and note the following **"…** *With the advent of stand-off pad, feed pads and herd homes, the volumes of solid effluent applied to land are likely to increase significantly in future years and the council will need to make a decision on the maximum amount of effluent that can be applied based on an N or P loading or on the optimum use of effluent as a nutrient source for plant growth."*

5. What improvements and mitigation measures are likely to be included in Overseer® A new version of Overseer® will be available by December 2007 and include the use and impact of nitrification inhibitors, the role and impact of riparian strips and wetlands, updates of the feed-pad management options, and an update of the greenhouse gas model to meet the new set of IPCC methodologies.

6. What progress has been made in integrating NPlas and Overseer®? Could it be applied to the Manawatu-Wanganui region? Presently, AgResearch has a contract with MAF and Dairy Insight to link their Overseer® model of nutrient management with hydrological and nutrient source models to account for the mitigation impact of riparian strips and wetlands. AgResearch is working with MAF to develop the specifications for this project and will include NIWA. Because the Overseer® model is nationally applicable, so will this riparian strip/wetlands option be nationally available.

7. Best Management Practices to Minimise Faecal Runoff from Farms. Recent reviews have addressed aspects of faecal runoff from rural catchments by examining pathways and models for predicting loads to surface waters. Loadings to waterways are greatest from **surface runoff** and **stock crossings**, but are broadly similar to loadings from drains (notably because of effluent loadings) and dairy shed oxidation ponds with typical effluent strength. Land loadings fall into three broad classes, with the highest loadings occuring where stocking rates are highest, *viz*. wintering pads, block-grazed pasture, and stand-off and feed pads for dairy cattle. The mitigation options, which include the exclusion of animals from waterways, are very closely aligned with those suggested earlier for phosphorus.

8 Should Horizons Regional Council adopt the water-way definition of the Clean Streams Accord to achieve reductions in nutrient and faecal losses? The waterway definition in the Dairying and Clean Streams Accord (Fonterra *et al.* 2003) is: " deeper than a "Red Band" (ankle depth) and "wider than a stride", and permanently flowing". The Accord's target is to have dairy cattle excluded from 50% of streams by 2007, and 90% by 2012. This provides a good stating point for a process that seeks to reduce stock accessing waterways. Compliance is, nonetheless, going to be difficult in many of the region's hill lands. Farm planning will have more potential for reducing stock in waterway, than further regulation. The Accord's definition would, it seems, put the waterway somewhere between an order 2, or 3 stream. It would be interesting to know what length of waterways, both ephemeral and permanent, lies outside the Accord's definition.

9. What are the appropriate upper limits for Table 16-1 in the "One Plan" for N and P? There is no reason at this time we consider to amend the upper limit for reasonable N application (150 kg-N ha^{-1} yr^{-1}) in Table 16-1. Designating a value for P presents more difficulty, because soil chemistry exerts a very large influence on these values. History of P use will also be very important. Decisions about setting a maximum application rate, fits better with the scale of farm plans, rather than with regional scales.

10. Biosolids, Offal Holes & Farm Dumps: Comments on Rules 16-2 & 16-7

We have some comments and suggest some modifications and additions to Rules 16-2 to 16-7 that we consider would achieve best practice. We make comment on 3 of the 5 conditions set out in these two of these Rules, and we add some suggestions taken from the EBoP guidelines.

11. Current Research of Potential Benefit for On-Farm Resource Management. There are a number of projects currently being undertaken by the SLURI partners that could benefit on-farm management of N, P and microbial contaminants. These are briefly summarised in the report for the pastoral, arable cropping and market gardening and perennial horticultural sectors.

12. Trends within the farming community that may influence the format of individual farm resource management plans/strategies The use of Environmental Management Systems (EMS) and allied approaches to on-farm environmental management is increasing in the primary sector in New Zealand. Most New Zealand primary sector EMS-type arrangements have been developed by individual sectors, and are not ISO 14001 accredited, except in some viticultural cases.

13. What would be the most effective way of measuring the actual N and P loss from farms? Several research tools are available but these are either too expensive for use by farmers, or do not produce paddock- or farm-scale results. One of the objectives of the recently-funded Pasture 21 tender is the development of such a measurement tool for pastoral systems. This may prove to be a long term and difficult task, and the use of farm-scale models (such as Overseer®) may be the best option. One possible monitoring tool, a drainage fluxmeter, is discussed in Appendix 2.

14. Why does Overseer® not consider soil-test results to account for the existing N content of soil? The nutrient budgets calculated in Overseer® are accounts of the inputs and outputs of N across the boundaries of the land units being considered. The processes of N accumulation, and release, are considered to be in balance over decadal-timescales. There is an exception when the "Development" options are selected in Overseer®. These assume that more N is being accumulated than released, so total N in the system increases, and the losses are predicted to be lower as a consequence. Defining the conditions where the development options should be invoked is highly subjective, and a test to guide this might be useful. Available soil N is however notoriously difficult to assess in a way that has general application and rapid progress shouldn't be expected.

15. The Waikato Farm Environment Award Trust has produced a guide to preparing a nutrient budget. How useful is this simplified tool? This is a simple and manual nutrient-budget guide, or method, and was of help in situations where land owners had no access to Overseer®. It should not be regarded as a substitute for Overseer®. Since Overseer® is freely available, and accepted by the industry and regulators alike, there seems little reason to adopt anything else. Furthermore, Overseer®'s owners are continually updating the user friendliness and utility of Overseer® through engaging New Zealand's best scientists.

1. Introduction

At the request of Horizons Regional Council we have developed a framework and produced best management practices for contaminant management on farms in the Manawatu-Wanganui region. Primarily we have considered dissolved nitrogen and phosphorus as the prime contaminants of concern.

Horizons Regional Council asked us, SLURI - New Zealand's multi-CRI Sustainable Land Use Research Initiative, some 15 questions in order to address farm strategies to limit contaminant management that could be included in the "One Plan". This report was peer reviewed by NIWA, and responses to their comments and suggestions have been incorporated into this final report.

2. Farm Types and the Potential Impact on Water Quality

Horizons Regional Council have identified the 4 intensive forms of farming as being dairying, irrigated sheep and beef, market gardening and cropping.

We agree that these are likely to have the greatest impact on water quality, both from the perspective of nitrogen and phosphorus (see Table below). It would have been desirable to consider intensive beef cattle operations, but the descriptors in the current database do not allow this group to be identified. Therefore Horizons asked us to consider irrigated sheep/beef farms as the intensive form of this sector.

Table: Intensive forms of farming and their likely losses of nitrogen and phosphorus

Ranked Nitrogen Loss		Ranked Phosphorus Loss	
Market Gardening	(100-300 kg-N ha^{-1} yr^{-1})	Market Gardening	
Cropping	(10-140 kg-N ha^{-1} yr^{-1})	Cropping	
Dairying	(15-115 kg-N ha^{-1} yr^{-1})	Dairying	(0.2- 1.0 kg-P ha^{-1} yr^{-1})
Sheep/beef	(6-60 kg-N ha^{-1} yr^{-1})	Sheep/beef	(0.1-1.6 kg-P ha^{-1} yr^{-1})

These suggested losses primarily relate to N, especially as very little research been done on P losses from market gardening and cropping soils in New Zealand.

Market gardening and cropping can all have high potential effects on water quality. The highest risk associated with these land uses occurs when land is cultivated and left fallow over winter before crops are sown. This often occurs as part of a mixed cropping rotation or when land is leased for cropping.

Nitrate leaching losses from these land uses mainly occur over the winter and vary considerably throughout NZ, largely in response to variations in climate. Nitrate leaching losses also vary at the same location from year to year in response to changes in winter rainfall amounts and patterns. In addition, the crops that are grown often vary with time, and their management varies between growers. Moreover, few leaching loss measurements have been made in the Manawatu. Consequently, it is difficult to make predictions for nitrate leaching losses from cropping and market gardening in the Manawatu.

Published results from throughout New Zealand show, in general, that the risk for winter nitrate leaching is greater from market gardening than from arable cropping (Di & Cameron 2002). This is because vegetable crops are inefficient in their uptake of N and high fertiliser rates are often applied when these crops are grown over the winter. Generally, the P losses from these two land uses are likely to be associated with sediment moving in overland flow when land is cultivated or left fallow over winter before crops are sown.

2.1 Market Gardening

Typical leaching losses from intensive market gardening in New Zealand are 100-300 kg N/ha/yr, with the amount leached often increasing with the rate of N fertiliser applied or with the addition of compost (Spiers *et al*. 1996; Painter *et al*. 1997; Francis *et al*. 2003; Snow *et al*. 2005).

2.2 Cropping

Typical leaching losses from cropping systems in New Zealand are 10-140 kg N/ha/yr (Eco-Link 2000), with the amount leached primarily increasing with the length of the fallow period in the rotation (Francis 1995)

2.3 Dairying

Dairying is, we consider, ranked as the highest risk of the pastoral farming activities. Key factors contributing to this are: there are substantial inputs of N and P in both feed and fertiliser. Furthermore, there are potential point sources of N and P that develop around animal-movement zones along tracks, across water, and on hard surfaces. There is mobilisation through the soil itself and nutrient movement to receiving waters. There is leakiness associated with management of effluent and soil management by both irrigation and drainage. The leaching losses reported from dairy pastoral systems in New Zealand range from 15-115 kg-N ha^{-1} yr^{-1}, with 40 kg-N ha^{-1} yr^{-1} often used as an average value. (Meneer *et al*., 2004) Annual losses of P from dairy pastures subjected to treading damage have been reported at 0.2 -1.0 kg-P ha^{-1} yr^{-1} (Meneer *et al*., 2004).

2.4 Intensive Sheep/Beef

Intensive sheep and beef farms have lower inputs of N and P in fertiliser than dairying, very limited use of feeds, so they have the least non-point source potential. Sheep and beef farms differ from dairying through having lower stocking rates (see summary Table above) and lighter seasonal loadings of animals,, and demands for feed. Sediment loss might, nonetheless, be more important than in dairying, because sheep/beef farms tend to be in sloping, and more erosion-prone lands. Typical leaching losses from sheep and beef pastoral systems in New Zealand are as little as 6 kg-N ha^{-1} yr^{-1} in the less intensive systems (<10-12 SU ha^{-1}) , up to 60 kg-N ha^{-1} yr^{-1} in the more intensive sheep and beef systems, with 10-20 kg-N ha^{-1} yr^{-1} often used as a more typical range (Meneer *et al*., 2004) Annual losses of P from sheep and beef systems have been reported at 0.1-1.6 kg-P ha^{-1} yr^{-1}, with the losses lower under sheep grazing at 0.1-0.7 kg-P ha^{-1} yr^{-1} (Meneer *et al*., 2004).

3. What is the best practice acceptable nutrient loss from a farm that Horizons should endorse?

We wish to establish what the target best management practices (BMP) are for sheep/beef and dairy to ensure that water quality in Horizons' Water Management Zones (WMZ) approaches guideline criteria.

For soluble inorganic nitrogen (SIN) the ANZECC guideline for water quality is 0.444 g-SIN m^{-3}, and for dissolved reactive phosphorus (DRP) it is 0.10 g-DRP m^{-3}. Using actual-flow methods to compute median river loadings at Hopelands in the Upper Manawatu Water Management Zone (UMWMZ) would translate into guideline annual loadings of 358 T-N yr^{-1} for SIN, and 8.1 T-P yr^{-1} for DRP (Roygard 2007). Presently, the annual loadings at Hopelands are two times these: 744 T-N yr^{-1} and 19 T-P yr^{-1}.

To establish the BMPs that would meet such guideline water-quality targets, we first need to link what we consider is happening on the farm, with what is observed in the river. In so doing, we will address the issue raised by Alexander *et al*. (2002) that "… the description of [nitrogen] sources might be improved by including specific estimates of nutrient inputs from fertilizer and animal wastes"

3.1 Upper Manawatu Water Management Zone – A Case Study

We will first carry out our analysis for UMWMZ to verify the transmission factors we will use for the Manawatu-Wanganui region, and we will compare these with other calculations of transmission from land to water.

Next, we will use Overseer® calculations to predict the losses from farms. By linking observations of nutrient loadings in the river to Overseer® calculations of loss at the farm, we will have a tool to link farm practices to water quality, by which we will be able to suggest BMPs that enable water quality targets to be met

We will use the contrasting patterns of landuse in two monitored sub-catchments of the UMWMZ to explore the farm-to-river transmission link for the key landuses of dairying, and sheep/beef. Above the monitoring station at Weber Road, the catchment is dominated by sheep/beef farms. In this Weber catchment the area in sheep/beef farms is over 11 times greater than that in dairy farms. Whereas the area upstream of monitoring at Hopelands, and downstream of Weber Road, the ratio is much less, and there is only a two-fold difference in the area of sheep/beef compared to dairying (Table 1).

First we present the statistics on which our Overseer® calculations will be based. These data were provided by Horizons using their Agribase™ database. Also, in running Overseer® we will take into account the variability of rainfall in the UMWMZ, for as shown in Figure 1, rainfall in the west of the catchment exceeds 1200 mm yr^{-1}, whereas around Dannevirke to the east it is less than 1000 mm yr^{-1}.

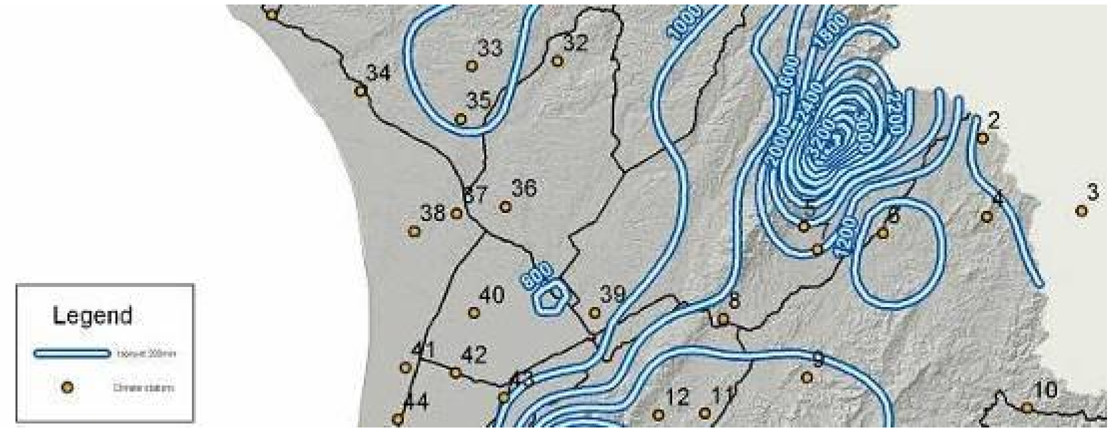

Figure 1. The isohyets of average rainfall across the Manawatu, showng the variation in rainfall in the Upper Manawatu Water Management Zone (UMWMZ) which is covered by stations 2 through 8.

3.2 Linking River Observations to Land Practices: A Framework

To establish the link between the land, and receiving waters, we will use a simple transfer-function approach. We will use Overseer® to estimate the loss rate of N from farms in the WMZ. Initially, we will use Overseer® to predict what the loss rates are from current practices:

$$O\left(L = q^{*}{}_{d}\right) \quad = \quad f\left[F, SN, SF, ST, EM, WMP, ...,\right] \qquad [1]$$

$$O\left(L = q^{*}{}_{sb}\right) \quad = \quad f\left[F, SN, SF, ...\right] \qquad [2]$$

where $O(L{=}q^{*})$ is the Overseer® calculation of the N loss, *L,* being the value of the annual flux of N, q^{*} (kg-N ha^{-1} yr^{-1}), at 600 mm in the soil. The subscript *d* and *sb* refer to dairying and sheep and beef. The loss will be, *inter alia*, a function of *F*, N fertiliser use (kg-N ha^{-1} yr^{-1}), *SN* stock numbers, *ST* stock type, *SF* supplementary feed, *EM* effluent management, and the use of winter management practices, *WMP*.

We adopt an inverse functional notation of O^{-1} for the Overseer® calculation of the N flux q^{*} as

$$q^{*} = O^{-1}(L_{f}) \quad . \qquad [3]$$

We use this notation to indicate that the flux q^{*} is estimated from an Overseer® calculation of loss for a specific farm scenario L_{f}.

This predicted loss q^{*} will be attenuated in the farm-groundwater-river system, so that from the perspective of the river, a back-calculation based on observations in the river would suggest that actually it only "seems" that farms are losing the flux, q (kg-N ha^{-1} yr^{-1}).

Therefore we can estimate transmission factors $\Re$ for both dairy and sheep/beef as:

$$\Re_d = \frac{q_d}{q^*_d} \quad \& \quad \Re_{sb} = \frac{q_{sb}}{q^*_{sb}}. \qquad [4]$$

Here we have chosen to use a transmission factor, $\Re$, however, we could have alternatively written this as its complement, an attenuation factor, which would be 1-$\Re$.

Using this simple, transfer-function approach, from annual average data we can predict the denominators from Overseer®, and we use the Manawatu River in the Upper Manawatu WMZ (UMWMZ) to assess the numerators.

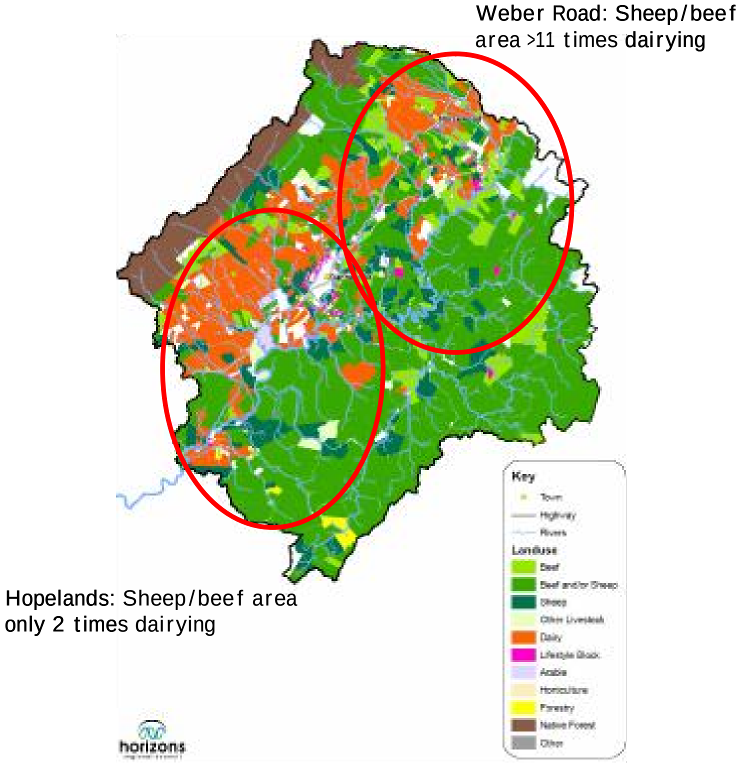

Figure 2: The two sub-catchments of Hopelands and Weber Road in the UMWMZ.

There are two river monitoring stations in the UMWMZ: one at Weber Road, and the other at Hopelands (Figure 2). Because these two catchments, designated W and H, have differing proportions of dairying and sheep/beef farms (Appendix 1), we can set up simultaneous equations to find both $\Re_d$ and $\Re_{sb}$, by first calculating the loss values 'seen' by the river: q_d and q_{sb}. The area of each farm-type in each catchment is A (ha), appropriately subscripted. As well, we need to consider the contribution from the small areas of forest, both native and exotic, and cropping, designated by subscripts f and c. The point-source discharges around Dannevirke, D, (kg-N yr^{-1}) also needs to be accounted for. This D includes point sources discharges at Norsewood, Ormondville, and Oringi, plus Dannevirke itself. Horizons have provided us with the annual river loadings of N at Weber Road and Hopelands: *viz* Q_W and Q_H (kg-N yr^{-1}). These were calculated by the actual-flow method of summing the loadings across the percentile classes of flows to arrive at the annual average required by our approach (Fig. 10 in Roygard, 2007).

3.2.1 Mass Balance Equations

So, on an annual average basis, [5]

$$Q_W = q_d\ A_d(W) + q_{sb}\ A_{sb}(W) + q_f\ A_f(W) + q_c\ A_c(W)$$

$$Q_H - Q_W = q_d\ A_d(H-W) + q_{sb}\ A_{sb}(H-W) + q_f\ A_f(H-W) + q_c\ A_c(H-W) + D$$

GIS data from Horizons were used to determine the areas on dairying (A_d), sheep/beef (A_{sb}), cropping (A_c) and forestry (A_f) in the Weber (W) and the Hopelands less Weber (H-W) catchments. The town area of Dannevirke area (462 ha) was removed from H-W. These are given in Table 1.

Table 1: Areas of land-use types in the two sub-catchments

Land-Use Type	Weber (*W*) - ha	Hopelands (*H-W*) - ha
Dairying (A_d)	5,825	14,709
Sheep/beef (A_{sb})	64,101	33,521
Cropping (A_c)	34	459
Forestry (A_f)	1,987	5,685

The contrast in the respective areas, and downstream trends, of dairying and sheep/beef between the two sub-catchments enables us to solve Eq. [5] simultaneously for q_d and q_{sb}, if we assume q values for cropping and forestry. These assumptions will have only a limited effect on our solution for $\Re$: as their respective areas are not great, especially for cropping; or their fluxes q are known not to be large, as for both exotic and native forests. We assume q_c = 40 kg-N ha^{-1} yr^{-1} from this very small area, and that q_f = 2 kg-N ha^{-1} yr^{-1} applies for forestry. Next, we need to assume a value for the point-source discharges from around Dannevirke. Horizons have advised us that they consider that D contributes 2% of the N loading (kg-N ha^{-1} yr^{-1}) measured at Hopelands (Section 4.2.3 in Roygard, 2007). Horizons annual-average river data on N loading (kg-N yr^{-1}) are given in Table 2.

Table 2: Annual median N loadings in the two sub-catchments

	Weber (*W*)	Hopelands (*H-W*)
N loading (kg-N yr^{-1})	343,000	401,000

Solving Eq. [5], using these values, enables us to calculate q_d and q_{sb}. We can then compare these with the Overseer® calculations of q^*_d and q^*_{sb}, from which we can them estimate the transmissions $\Re_d$ and $\Re_{sb}$. The analysis assumes there is no lag effect, but a direct link between annual N losses at the farm scale with the annual N loadings in the river. In this humid catchment, it would be expected that there is no inter-annual carry-over in nitrogen, so that our annualised results for Overseer® can be linked to the annual average flow in in the river.

3.2.2 Uncertainties and Variability

There will of course be a certain amount of uncertainty in the derived values from Eq. [5]. In the absence of information, we cannot consider measurement errors in the flow and concentration observations, nor in the error in the loading calculation of summing the percentile classes to arrive at the annual figure. However, we consider that these would be quite small relative to the variation that results from the inter-annual variability in river flows due to the changing annual patterns of weather. The variation in weather between years will, we consider, be the largest source of variation in the 'leakiness' performance of farming enterprises. Inspection of river loadings at Hopelands over the last 16 years reveals a standard deviation of about 20% of the mean (744 T-N yr^{-1}). This coefficient of variation will transmit directly through our linear analysis, so that we can expect the derived values of q and $\Re$ to exhibit about a 20% variation across the years.

3.2.3 Diagnostics and Results

In Appendix 2 we demonstrate simple diagnostic uses of Eq. [5] for exploring the impact of changes in land-management practices, and for assessing the impact of land-use changes. Using these equations diagnostically, we discuss specific scenarios in Section 3.7.

General results are given in Table 3, for the range of Overseer® calculations (Table 7). These will be further in Section 3.5.

Table 3: The river-based farm fluxes q, the median (and range) of Overseer® calculations q^* (Table 7), and derived transmission estimates for dairying and sheep/beef

	q (Eq5) kg-N ha^{-1} yr^{-1}	q^* (Eq3) kg-N ha^{-1} yr^{-1}	$\Re$
Dairying	15.4	31 (25-49)	≈ 0.5
Sheep/beef	3.9	7 (6-9)	≈ 0.5

In the absence of data, even as coarse as this for the UMWMZ, we have to estimate $\Re$ for the other two intensive landuses of concern; cropping and market gardening. It would seem reasonable on the basis of farm sizes, plus fertiliser and farm practices, that a transmission factor of 0.5 could also be used, in the first instance, for cropping and market gardening, as indicated in Section 1.

The Overseer® calculations of q^* at 600 mm in the soil can, we consider, be corroborated reasonably cheaply through the use of the new research tool of fluxmeters for monitoring paddock and farm-scale losses. In Appendix 3 we describe the design and use of fluxmeters. Simple versions of these might only cost around $500 per unit, but because of the high spatial variability due to urine patches, an as yet unknown and likely large numbers will be required, adding to the overall cost.

3.3 Comparison with Horizons Regional Council (2007)

Horizons Regional Council is presently drafting a report on nutrient load calculation and nutrient source assessment (Horizons Region Council, 2007). We have compared our calculations for the UMWMZ with those in the draft Horizons' report for the same WMZ.

By comparing the farm-loss predictions of Meneer *et al.* (2004) for dairying of q^* 40 kg-N ha^{-1} yr^{-1}, and of 21 kg-N ha^{-1} yr^{-1} for sheep/beef, with the MfE "Lake Managers Handbook" values for specific yield of 20 and 9 respectively, Horizons had fortuitously assumed a transmission, or attenuation, of $\Re$=0.5 for both farm types.

Table 4. A comparison of the river-based losses of N, *q*, estimated by Horizons (2007), and Eq 5 for the whole UMWMZ above Hopelands

	Specific farm yield of N, *q*, estimated by Horizons (2007), kg-N ha^{-1} yr^{-1}	River-based loss of N, *q*, estimated by Eq. [5], kg-N ha^{-1} yr^{-1}
Dairying	20	15.4
Sheep/beef	9	3.9

Our observational methodology, going from what the river 'senses' back to the land, underestimates the yields compared to those of Horizons who have used a presumed leakage from various land practices, and a transmission coefficient, to go from the land to the river. Not surprisingly, there is agreement in the respective assessments of the proportional contributions of the two farming systems to the annual loading on N in the river for the whole UMWMZ at Hopelands (Table 5).

Table 5. The percentage contribution of farm types to the N loading in the Manawatu River at Hopelands

	Percentage estimated by Horizons (2007)	Percentage estimated from Tables 1 & 3.
Dairying	41%	43%
Sheep/beef	57%	51%

3.4 Comparison with Alexander *et al*. (2002)

Here we have been able to link specific farm types, namely dairying and sheep/beef, to nutrient loadings 'seen' in the river. The transmissions we provisionally calculate are similar to those found in other catchment studies which have not attempted, however, to discriminate between the various land-uses in the catchment. Parts of Table 10 from Alexander *et al.* (2002) are presented here in Table 6, and these are used to provide total landscape transmissions for the 4 sub-catchments, and for the total catchment of the Waikato River. They defined landscape yield as being 'delivery to streams and reservoirs from diffuse and point sources in the landscape', essentially our q^* in Eq. 3. By comparison of their estimation of this landscape yield with that observed for the watershed, they found the transmission for the whole river system is found to be 0.55, with the lowest value for a sub-catchment, being $\Re$=0.25 for Taupo which reflects the lower level of intensification, with 50% of the catchment area being either the lake, or forestry. Another feature of this catchment contributing to the low transmission factor is the depth to ground water. Alexander *et al.* (2002), in their Table 11, also provide data for total phosphorus, including sediment-bound phosphorus, and these can be used to calculate P transmission factors. These range from 0.45 for the whole catchment, down to 0.15 for the Taupo sub-catchment. It seems from their data that the $\Re$ values for dissolved phosphorus are about 0.1 lower than the equivalent for nitrogen.

Other nitrogen transmission values have been found for dairying catchments, and Ross Monaghan reports (*pers. comm.*) an $\Re$ of 0.5 for a catchment in Taranaki, and 0.75 for another monitored catchment in the Waikato.

Table 6. Transmission coefficients $\Re$ derived from Table 10 in Alexander *et al*. (2002) for the Waikato River system, and its sub-catchments

	Landscape Yield kg-N ha^{-1} yr^{-1}	Watershed Yield kg-N ha^{-1} yr^{-1}	$\Re$
Waikato (Total)	19.2	10.6	0.55
Lower Waikato	28.1	15.6	0.56
Upper Waikato	11.0	6.4	0.58
Taupo*	7.7	1.9	0.25
Waipa	24.0	14.7	0.61

*Long lag

Our framework has been able to establish a link beyond the general landscape yield to establish leakage losses from different land-use types. The absolute values of the landscape and watershed yields from Alexander *et al*. (2002) (Table 6) are both generally much higher than we find for the UMWMZ, which reflects the different levels of farming intensification in these two different catchments. We find for the Weber sub-catchment a watershed yield of 4.8 kg-N ha^{-1} yr^{-1}, and 7.4 kg-N ha^{-1} yr^{-1} for the Hopelands sub-catchment. In Table 6, the average for the whole Waikato River systems is 10.6 kg-N ha^{-1} yr^{-1}. Our runs of Overseer® for landscape yield range from 9 through to 49 kg-N ha^{-1} yr^{-1}, with an average of 31 for dairying and 7 for sheep/beef. So the area-weighted average for the whole UMWMZ would be (Eq. 5) 10.7 kg-N ha^{-1} yr^{-1}, compared to the 18 kg-N ha^{-1} yr^{-1} for the Waikato.

3.5 Overseer® calculations for various scenarios

To assess current average annual nutrient loss, we ran Overseer® for specific scenarios which we considered as the standard practices currently being used. The 24 scenarios are briefly described in Table 5, and the Overseer® Nitrogen Reports for all the scenarios are appended in Appendix 4. For dairying, we analysed 13 scenarios, and for sheep/beef we considered 11 farm set-ups. We obtained stock number information from the Livestock Improvement website, discussions with a local farm consultant, and we used our best knowledge of farm practices. (Appendix 4)

The characteristics of the "average" sheep and beef and dairy farm in the UMWMZ used in the Overseer® nutrient budget to estimate the nitrogen leaching/runoff loss, and the phosphorus run-off risk are described in Table 8, along with the calculated N loss (kg-N ha^{-1} yr^{-1}) and P run-off risk rating.

The characteristics of the pastoral operations were obtained following discussions with farm consultants operating in the region. Similarly, the description for the cropping operations, as described in Table 8, were obtained from consultants with a long history of working with growers in the region. In addition to obtaining an estimate of the nutrient loss from the cropping operation, the nutrient losses from the pastoral operation on the farm where crops were being grown was also calculated.

The average N leaching/run-off for the average sheep and beef and dairy farm calculated by Overseer® nutrient model was 7 and 31 kg-N/ha, respectively. With both farm types the dissolved P run-off risk were estimated as low, or low-medium.

Additional runs of the Overseer® nutrient budget (Appendix 4) to investigate the influence of rainfall (900-1400 mm), soil type (poorly drained and free draining) and management practices (including changing soil fertility, fertiliser inputs, production levels, stock policy and effluent management) on nutrient losses highlights that there is considerable variation in the N losses from either sheep and beef (6 to 9 kg-N ha^{-1} yr^{-1}) and dairy (25 to 49 kg-N ha^{-1} yr^{-1}) operations in the UMWMZ. When the same exercise was conducted for P run-off risk, the risk remained low with the sheep and beef, but increased to include moderate risk under intensive dairying.

An important next step in the development of the water management plan for the upper Manawatu is a more detailed study of the nutrient losses from individual farms in each of the major sub catchments. Engaging and involving producers and their sector representative and agribusiness as part of that process, is paramount.

Table 7: A brief synopsis of the scenarios used for Overseer® to predict nitrogen leaching from dairy and sheep/beef farms. The Overseer® Nitrogen Reports for all the scenarios are listed in Appendix 4

	N leaching kg-N ha^{-1} yr^{-1}
Dairying	
Typical farm (Fertiliser – 100 kg-N ha^{-1} yr^{-1})	31
Milk solids down to 800 kg	25
Reduced rainfall at 900 mm	26
Fertiliser at 50 kg-N ha^{-1} yr^{-1}	26
Increase effluent area to 24 ha	30
Increase Olsen P to 50	31
Decrease Olsen P to 20	31
Reduce effluent area to 6 ha	33
Increase rainfall to 1400 mm	34
Poorly drained soil- mole/tile drains	36
Free-draining soil	41
Fertiliser at 200 kg-N ha^{-1} yr^{-1}	44
Milk solids raised to 1200 kg	49

Sheep/Beef	
Typical farm (Fertiliser – 7 kg-N ha^{-1} yr^{-1})	7
Reduced rainfall to 900 mm	6
Stocking rate at 8 SU ha^{-1}	6
No N fertiliser	7
P fertiliser at 32 kg SP SU^{-1}	7
Sheep:beef ratio 90:10	7
Decrease Olsen P to 10	7
Rainfall increase to 1400 mm	8
Sheep:beef ratio 50:50	8
Fertiliser in winter at 50 kg-N ha^{-1} yr^{-1}	9
Stocking rate at 12.2 SU ha^{-1}	9

Note. For each of the scenarios described above associated management changes were also considered

Table 8: Nitrogen leaching runoff and P runoff risk loss estimates from Overseer® for average sheep & beef & dairy farm in the Upper Manawatu water management zone

	Sheep & Beef	Dairy
Area (ha)	400	110
Production levels		
Stocking rate	10 SU ha-1	2.5 cows ha-1
Sheep to cattle ratio	70.30	
Milk solids		1000 kg ha-1
Wool production	5.5 kg SU-1	
Docking	115%	
Pastures	Developing (Browntop)	Highly developed (Ryegrass, white clover)
Supplements	-	1 tonne DM/ha (70% silage)
Grazing system		Dairy heifers grazed off-farm post- weaning
		Cows wintered off
Soils	Silt loam	Wet/free draining soil types
Soil P fertility	Olsen P 14	Olsen P 30
Exchangeable cations	K = 10; Ca = 12; Mg = 20; Na = 5	K = 8; Ca = 12; Mg = 10; Na = 3
Fertiliser inputs		
Phosphorus	18 kg SSP SU-1	Maintenance P, S & K (DAP15S, Potash super)
Nitrogen	7 kg-N ha-1 (urea)	100 kg-N ha-1 (urea)
Effluent disposal		Spray (4 ha per100 cows)
Rainfall (mm)	1200	1200
Feed pad	-	-
Overseer ® estimate		
N leaching/runoff	7 (6-9)1	31 (25 - 49)2
P runoff risk	Low (low)1	Low (low-medium)2

1 The range in N leaching-runoff losses and P runoff risk as a consequence of changing N fertiliser inputs (0-50 kg-N), rainfall (900 – 1400 mm), P fertiliser t (1 to 2xM); Olsen P (10-20 mg ml-1), the sheep cattle ratio (90:10 – 50:50) and stocking rate (8 to 12 SU ha-1) and associated change in maintenance P fertiliser input, with the change in stocking rate.

2 The range in N leaching runoff losses and P runoff/risk as a consequence of changing N fertiliser inputs (50 – 200 kg-N ha-1), rainfall (900 – 1400mm), Olsen P (20-50), effluent area (6-24 ha), Soil type (free and poorly drained) and production (800 – 1200 kg MS ha-1), and associated shift in N fertiliser use (50 – 200 kg-N ha-1) and supplements (0 – 2500 kg ha-1) with the change in production.

Table 9: Nitrogen leaching loss estimates from Overseer® and the LUCI Framework Model for potatoes and barley rotations

Event	**Potato-pasture rotation Opiki1**			**Barley-pasture rotation Waitatapia2**	
Rainfall (mm)[3]	1015			1100	
Soil type	Peat			Sedimentary	
Drainage class	Normal			Poor	
Date pasture ploughed	End Sept			End Oct	
Date main crop sown	Oct			Nov	
Mineral N at sowing main crop (kg N/ha)	100	200		100	200
Fertiliser applied (kg N/ha)	150	150		20	20
Date main crop harvested	Mar			Mar	
Date pasture sown	Mar			Mar	
Min N at sowing pasture (kg N/ha)	OS=not known LFM=estimated by model			OS=not known LFM=estimated by model	
Overseer® estimates					
N leached main crop (kg N/ha)	6	8		5	9
N leached over 12 months (kg N/ha)	9	11		8	12
LUCI framework model estimates (LFM)2					
N leached main crop (kg N/ha)	10	21		9	25
N leached over 12 months (kg N/ha)	10 (15)5	21(15)5		9	25

[1]Using Palmerston North rainfall

[2]Waitatapia weather station used as Ohakea is missing rainfall data 1992-96.

[3]Average for 1993-2006

[4]LUCI framework model estimates are the average results from simulations run from 1993-2006

[5]**Livestock operation** on 150 of 200 ha includes 1000 ewes and lambs, purchased spring sold summer, finishing lambs autumn through spring and 140 yearlings to 2-yr bulls grazing year round. Wintering 2500 stock units (18 SU/ha) with a sheep to cattle ratio of 68:32. Clip 7000 kg wool mostly dry sheep. **Cropping** on the arable block growing 20 ha potatoes, 20 maize, and 10 milling wheat (which will go into winter green feed after harvesting). **Pasture includes** 20 ha of short term annual forage rye, 110 ha of permanent pasture and 20 of new grass. **Supplements**: 200 bales of baleage (100 sold & 100 fed back). **Fertiliser on permanent pasture**: 30N:12P;0K; 16S kg-1 as SSP and Urea

For cropping scenarios, we used two models: Overseer®, and the LUCI framework model (Table 9). Nutrient losses calculated by both the Overseer® nutrient model for all three rotations, and the LUCI framework model for the potato and barley rotations were in general low (6-25 kg-N ha^{-1} yr^{-1}) with estimates from Overseer® lower (6-12 kg-N ha^{-1} yr^{-1}) than those calculated by the LUCI framework model (10-25 kg-N ha^{-1} yr^{-1}). The LUCI framework model is a daily time-step model that was run using 13 years of real weather data (1993-2006) to provide an average value. In contrast, Overseer® is an annual time-step model that uses an annual average rainfall value.

We have some concerns about the veracity of predictions here, as these losses are considerably less than much of the published data on N losses from cropping or market gardening in New Zealand. This is because the cropping operations that were simulated in this study (see Table 9) are markedly different from those already reported in publications. In particular, both the barley and potato crops were sown after cultivation in the spring, after most of the winter drainage had occurred. Also, cover crops were sown after harvest early in the autumn and these removed most of the mineral N from the soil before the start of winter drainage. Through an SFF project (Section 11) we are working to improve the predictive capacity of Overseer®.

Recognising that the cropping operations described in Table 9 are generally limited to only part (10-20%) of the farms total area in anyone year, an estimate of the nutrient loss from the balance of the farm operations was also obtained and then a weighted nutrient loss for the whole farm calculated. The balance of the farm operations in each case was a mix sheep and beef operation (Table 9).

A feature of the analysis of the cropping operations was the lack of data for populating the nutrient models and the lack of field data on the risk cropping operations in the region represent. Developing a research programme to obtain a better understanding of nutrient loss from the major crop types would be prudent. .

There are a range of potential mitigation options for reducing N losses from cropping and market gardening systems.

1. Changing the timing of cultivation from early autumn to late autumn and shortening the length of the fallow period can reduce winter N losses from bare fallow by up to 50% (Francis 1995)

2. When soil has to be cultivated early in the autumn, sowing rapid-growing cover crops early in the autumn can reduce winter N leaching losses compared to bare fallow by up to 50% (Francis 1995)

3. Deducting the amount of soil mineral N content throughout the root zone in N fertiliser recommendations can reduce the amount of unused fertiliser N that remains in the soil at harvest.

4. Splitting fertiliser applications to synchronise N supply to plant demand can result in increased yields with reduced fertiliser application rates while reducing winter losses by up to 50% (Williams *et al.*, 2003). The use of decision support systems are particularly useful for this (Jamieson *et al*. 2006)

5. Using N fertiliser coated with a nitrification inhibitors for winter crops reduced winter leaching by 30% in one study (Martin *et al.*, 2001). However, this resulted in a greater amount of unused fertiliser remaining in the soil at harvest, which increased the leaching risk in the following winter.

Where irrigation is used, its management can be as important as the management of fertiliser in determining N leaching losses (Francis *et al.,* 2007)

In the absence of data mitigation options for reducing P losses from cropping and market gardening systems would concentrate on limiting soil loss when soil are bare, limiting the physical damage to the soil, limiting over land flow and following the fertiliser industry code of practice when using P fertilisers.

3.6 What rates of nutrient loss can be achieved by best practices, and what are these?

It is important when discussing potential mitigation practices, to note that they will vary in both their suitability and effectiveness in reducing nutrient loss from farm to farm, as well they will vary in their cost, in either dollars or time. Implementation will impact on production levels and farm profitability.

Nitrogen In grazing systems loss of N is mainly due to leaching of nitrate down the soil below the roots. This occurs during the period of the year (May to September) when net drainage occurs.

Phosphorus With exception of soils which demonstrate preferential flow, P loss is largely in surface run-off. P is lost in two forms soil bound and dissolved P, with the former the dominant (60-90%). In comparison with N losses, P losses are generally small. Again in comparison to N, a significant proportion of the P loss on an annual basis can occur during single-storm events.

The mitigation options for reducing the losses of P and N from pastoral systems are listed in Tables 10 and 11, respectively. A number of these will be incorporated into Overseer® in the next 12 months including the use and impact of nitrification inhibitors on N, the role and impact of riparian strips and wetlands for both P and N, and an update on feed-pad management options for both N and P. A tool for assessing the mitigation options for reducing soil erosion is an obvious gap.

A number of detailed analysis have been undertaken to assess the potential effectiveness of the mitigation options for reducing the losses of P and N from pastoral systems.

Monaghan et al. (2007) in a modelling analysis of a range of best management practices targeting pollutant source reduction on case study dairy farms located in four contrasting catchments found that the effectiveness and cost of the mitigation options varied due to the contrasting physical resources and management systems of the case farms.

Of the best management practices examined in Monaghan et al., (2007) study nitrification inhibitors offered potentially a cost-effective measure reducing loss of N in drainage water and increasing farm profitability in all 4 case study dairy farms. It needs be remembered that the science behind inhibitors is still in its early stage. While the other best management practices, which included low N feeds, nil N fertiliser, wintering pads and restricted autumn grazing, examined by Monaghan et al. (2007) also reduced N losses to drainage water, like nitrification inhibitors their effectiveness varied, but unlike nitrification inhibitors, generally at a cost to farm profitability. Across the four case study farms the mitigation options had on average the potential to reduce N losses to drainage by one third.

In the absence of significant soil erosion, which is the major source of P contributing to P loss in much of our eroding hill country, limiting P fertiliser use to maintenance inputs and holding soil Olsen P levels in the optimum agronomic range offers two very cost-effective mitigation options for limiting farm P losses. Monaghan *et al*., (2007) found reducing maintenance fertiliser inputs and Olsen P values back to the optimum agronomic range offered the greatest saving and a predicted reduction in P losses by 30-37% in two dairy catchments. In situations where soil P levels are close to the agronomic option the opportunity for cost savings and environmental gains are going to be much smaller, highlighting the danger of prioritising or generalising about the suite of mitigations potential available to a producer.

Shifting from a pond to an effective land-based effluent disposal system which includes ensuring the effluent block is off sufficient size, application rates do not exceed the soils matrix infiltration rate and there is sufficient storage capacity to hold effluent when soils are wet, offers enormous scope for reducing farm P losses. This mitigation option, along with those listed in Table 11 will all come at some cost to the farm business.
In compiling a list of best management practices (Table 10 and 11) as part of the one plan there is considerable merit in including an estimate of the cost effectiveness of each option in add.

Table 10 Mitigation practices for reducing the losses of N from pastoral systems

Mitigation option	Explanation
Land disposal of dairy shed effluent	By treating effluent as a source of nutrients (N, P, K, S, Ca, Mg, etc) rather than waste and applying effluent to ensure that the amount of nutrient applied does not exceed the capacity of the soil to cope (e.g. 150 kg-N ha-1 yr-1) will ensure maximum use of the nutrients for pasture growth and limit the impact of land based application of effluent to the wider environment. The Overseer® nutrient budget model can be used to calculate the optimum area for application of dairy shed effluent.
Restricted autumn/winter grazing	Losses of N from urine patches is responsible for most of the N leaching and nitrous oxide emissions occur from grazed pastures. By removing animals from the grazing area during the period of the year when net drainage occurs, the amount of nitrate lost out of the root zone wil be reduced. This option would generally be used in conjunction with some type of pad or stand-off area.
Winter feed pads/herd homes	The more time animals spend on a feed pad or Herd Home in the autumn and winter months the greater the reduction in N loss from the root zone. Urine collected while the animal is on a feed pad can be returned at lower rates and more evenly at time sof the year when net drainage is unlikely. Management of effluent becomes critical if the benefits of a stand-off pad in reducing losses to the wider environment are to be realised.
Stock expulsion from all streams	Preventing access to perennial streams will reduce direct nutrient contamination from dung and urine and indirectly reduce the amount of vegetation and sediment entering the water ways. Preventing damage to the stream banks will also reduce the amount sediment and P entering the waterway.
Creation of wetland and riparian attenuation zones	Trapping and retaining nutrients and sediment in wetlands and vegetation buffers alongside water courses will reduce direct contamination of waterways. There is a lack of area specific metric data on nutrient N attenuation rates with both these mitigation options.
Fertiliser practices	The fertiliser codes sets out best practices. For example limit the amount of N in each application (30-50 kg-N ha-1) and the total amount (150kg-N ha-1 yr-1, including Effluent N) and the use of fertiliser N in May-July. These actions will reduce the loss of N directly from N fertiliser. The fertiliser industry Fertiliser code of good practices provides reference to all these options.
Low nitrogen feed supplements	Use of feed supplements such as maize silage as an alternative to using fertiliser N boosted grass lowers the amount of N excreted in urine and can reduce nitrate leaching.
Nitrification inhibitors	Nitrification inhibitors target the animal urine patch limiting the bacterial conversion of urine-N to nitrate, which is the main source of N for leaching and nitrous oxide emission. Losses of N from urine patches is responsible for most of the

	N leaching and nitrous oxide emissions occur from grazed pastures Current use of nitrification inhibitors on farms is by broadcast application to land (in slurry or granular forms) in order to try to contact urine patches during the high loss winter/early-spring period. An approach that involves using the animal to deliver the nitrification inhibitor in the urine stream, using a slow-release bolus is under development. There is still a considerable amount of uncertainty surrounding the performance of inhibitors. Ongoing field studies indicate that annual pasture responses to inhibitors may vary from 3-15% and leaching reductions from 20-60%.
Whole farm nutrient budgeting	Nutrient budgets are useful tools for assessing N flows within the farm system and identifying opportunities for reducing N losses. The Overseer® nutrient budget provides and estimate of nitrate leaching loss for each part of the farm under different management.

Table 11 Mitigation practices for reducing the losses of P from pastoral systems

Mitigation option	Explanation
Soil erosion	Limiting sediment movement to waterways from erosion during storm events offers the single biggest opportunity for reduce P loss to waterways. Whole farm planning offers a systematic land evaluation and planning approach for tackling this environmental problem. Because this issue is tackled elsewhere in the one plan, no further comment is made here.
Optimum soil phosphorus fertility	The target range should be the agronomic optimum soil Olsen P levels for each of the soil types on the farm. Soil fertility above the agronomic optimum makes little economic sense and increases the P run-off risk on soils with low (<50%) anion storage capacity. The Optimum agronomic soil Olsen P levels for each of the major soils orders are listed in the booklets On fertiliser use published by the fertiliser industry.
Fertiliser practices	The timing of fertiliser application (summer rather than winter), form of application (sparingly water soluble versus water soluble) and avoiding direct contamination of water ways by fertiliser all offers scope for reducing P losses from the farm. The fertiliser industry Fertiliser code of good practices provides reference to all these options.
Land disposal of dairy shed effluent	By treating effluent as a source of nutrients (N, P, K, S, Ca, Mg, etc) rather than waste and applying effluent to ensure that the amount of nutrient applied does not exceed optimum levels (e.g. Olsen P levels <35 ug ml-1) will ensure maximum use of the nutrients for pasture growth and limit the impact of land based application of effluent to the wider environment. The Overseer® nutrient budget model can be used to calculate the optimum area for application of dairy shed effluent
Deferred and low application effluent irrigation rates	Limiting effluent applications to periods when soils are less than field capacity, limiting the loading on an annual basis and using low application rates all offer options for limiting surface run-off and preferential flow of effluent. Practices which increase the opportunity for effluent to be absorbed into the soil matrix will reduce P losses.
Preventing autumn-winter-spring soil and pasture treading damage	Removing heavy weight animals when soils are wet to free draining soils or a stand-off or feed pad will limit soil and pasture damage. Soils damaged by livestock will have reduced physical function (e.g. infiltration rates). Pastures damaged by livestock will have reduced plant number, which in turn reduces canopy cover exposing the soil surface to rain drop damage. A soil and pasture damaged by treading will contribute more surface run-off and sediment than a well managed soil.
Stand-off/Winter feed pads/herd homes	Management of the P in the effluent is critical if the benefits of a stand-off area in reducing P losses to the wider environment are to be realised.
Stock exclusion from all streams	Preventing access to perennial streams will reduce direct nutrient contamination from dung and urine and indirectly reduce the amount of vegetation and sediment entering the water ways. Preventing damage to the stream banks will

	also reduce the amount sediment and total P entering the waterway.
Creation of wetland and riparian attenuation zones	Trapping and retaining nutrients and sediment in wetlands and in vegetation buffers alongside water courses will reduce direct contamination of waterways. There is a lack of area specific metric data on P attenuation rates with both these mitigation options.
Whole farm nutrient budgeting	Nutrient budgets are useful tools for assessing P flows within the farm system and identifying opportunities for reducing P losses. The Overseer® nutrient budget provides an estimate of P run-off risk for parts of the farm under different management.

3.7 Best management practices and the impact on river-water quality

From the section above, we suggest it could be possible through the adoption of mitigation measures and best management practices to reduce the loss of N from the rootzone, q^*, by up to one third. There would be a commensurate reduction in the amount of N reaching the river, and this could be simply predicted using the linear Eqs [3] and [5]. Indeed, the diagnostic form of these is given in Appendix (2) as Eq. [10]. Here we can predict, using our linear transfer-function model, what the improvement in water quality would be for the Hopelands catchment, for example, if, both for dairy farming and sheep/beef, best practices achieved a 33% reduction in losses.

We explore, using Eq. [10] the impact of this mitigation measure, along with other scenarios.

3.7.1 Impact of Changed Dairying Practices

Adoption of Mitigation Practices: If it were possible through the adoption of mitigation practices to achieve a one-third improvement in dairying practices, then from Table 4 the median loss, q^*, would drop from 31 to just under 21 kg-N ha^{-1} yr^{-1}, such that given a transmission coefficient of 0.5 across the 14,709 ha of dairying in the Hopelands sub-catchment, there would be a predicted reduction of 73,545 kg-N yr^{-1} in the river: a diminution of 18.3% from the 401,000 kg-N yr^{-1} currently observed at Hopelands that comes from the Hopelands sub-catchment. The fact that a one-third improvement in practices does not translate to a 33% improvement in water quality is because the improvement scales with both $\Re_d$ and A_d (Eq. 10), and dairying comprises only 27.1% of the sub-catchment's area.

Intensive Practices: For an intensive practice scenario, we take the case of the greatest leakage for dairying in Table 7, namely q^*_d being 49 kg-N ha^{-1} yr^{-1}. This is for farms where Overseer® simulates leaching when farm practices result in a yield of 1200 kg MS ha^{-1} and in this example no mitigations practices are employed . If these practices were to expand across all dairy farms in the Hopelands sub-catchment, Eq (10) predicts there would be an additional 132,381 kg-N yr^{-1} in the river at Hopelands, a 33% increase over the current loading of 401,000 kg-N yr^{-1}.

3.7.2 Impact of Changed Sheep/Beef Practices

Adoption of Mitigation Practices: Likewise, if it were possible through mitigation measures to realise a one-third improvement sheep/beef practices to limit leaching, from Table 4 the median loss, q^*, would drop from 7 to 4.7 kg-N ha^{-1} yr^{-1}, such that given a transmission coefficient of 0.5 across the 33,521 ha of sheep/beef farms in the Hopelands sub-catchment, there would be a predicted reduction of 39,387 kg-N yr^{-1} in the river: a diminution of 9.8% from the 401,000 kg-N yr^{-1} currently observed at Hopelands, and coming from the Hopelands sub-catchment. As seen in Table 5 dairying and sheep/beef each contribute about one half of the total loading of nitrogen in the river at Hopelands, therefore a one third reduction in N loss from either sector will only translate to an improvement of about half of that in the river. We add that the range of mitigation and optimisation measures available to reduce N loss under sheep/beef grazing is less than that possible in the dairy sector.

Intensive Practices: The case of greatest N-leakage for sheep/beef in Table 7 is our prediction of how a sheep/beef farm might perform in 10 years' time with an annual increase of 2% in pasture production and stocking rate. This farm would by then have 12.2 SU ha^{-1} and the leakage of N from the soil Overseer® predicts to be 9 kg-N ha^{-1} yr^{-1}. If all sheep/beef farms in the Hopelands sub-catchment were stocked at this rate, there would, according to Eq. [10], be an additional 33,521 kg-N yr^{-1} in the river at Hopelands, a rise of 8.4%.

3.7.3 Impact of Changed Areas of Farm Types

The other differentiated forms of Eq. [5], namely Eqs [12] and [14] of Appendix 2, can be used to account for an expansion of, say dairying, or conversely sheep/beef, onto larger tracts of land in any WMZ.

We consider, here for the UMWMZ, that if any farm conversions were to be carried out, they would either involve dairy conversion from sheep/beef, or vice versa, namely conversion of sheep/beef from dairying, with all other things held constant. There is, not surprisingly then, given that there are only two complementary farm types, a symmetry between Eqs [12] and [14].

For the UMWMZ, the values of the right-hand sides of Eqs [12] and [14] are given in the left-hand column of Table 3: $\Re_d\, O^{-1}(L_d)$ =15.4 kg-N ha^{-1} yr^{-1}, and $\Re_{sb}\, O^{-1}(L_{sb})$ =3.9 kg-N ha^{-1} yr^{-1}. So because of the greater N-leakiness of dairy systems (Table 5), an increase in the area of dairying in the UMWMZ, would degrade river-water quality by 11.5 (*i.e.* 15.4-3.9) kg-N yr^{-1} for every hectare converted from sheep/beef. Conversely, because sheep/beef farms have been found to be less leaky, every hectare of dairying converted into sheep/beef in the UMWMZ would improve river-water quality by -11.5 (*i.e.* 3.9-15.4) kg-N yr^{-1}.

We now carry out a scenario analysis of land-use change by considering that dairying might expand on all lands up to Class III in the UMWMZ. Landcare Research (Robert Gibb *pers. comm.*) determined that some 25% of the entire UMWMZ is in Class III lands or better. So from Table 5, this sums to 31,580 ha. Presently, dairying is carried out on only 20,534 ha (Table 5), so there is potential for dairying to expand over another 11,046 ha.

If current dairy practices were to expand onto these lands, we can find the change in river loading as ΔQ by writing Eq. [12] in finite-difference form as

$$\Delta Q = [\Re_d\, O^{-1}(L_d) - \Re_{sb}\, O^{-1}(L_{sb})]\,\Delta A_d$$

So, with the first bracket on the right-hand side being 11.5 kg-N ha^{-1} yr^{-1}, and ΔA_d as 11,046 ha, this predicts that if there were such an expansion, there would be another 132,555 kg-N yr^{-1} in the river at Hopelands, a 17.8% increase on the current loading of 744,000 kg-N yr^{-1}.

3.8 BMPs to meet Water Quality standards

In Eq. [8] (Appendix 2) we have linked the loading in the river, Q, to leakage losses, q^*, from the dominant landuses in a catchment. This equation is presented below for reference

$$Q = \Re_d \, q^*{}_d \, A_d + \Re_{sb} \, q^*{}_{sb} \, A_{sb}$$

We can use this linear transfer-function 'backwards' to infer what these leakage losses, q^*, should be in order to meet the value of Q in the river that meets the water quality standard of 0.444 g m^{-3} of soluble inorganic N (SIN). Dr Jon Roygard of Horizons Regional Council informs us that this water quality standard translates into an annualised river loading of 341,000 kg-N yr^{-1}. Using Eq. [8], with one additional rule about how the terms on the right-hand side should be split, we can predict the result from the BMPs for the respective farm types that would meet water quality standards.

3.8.1 Loading-equity split

Table 5 indicates that dairying and sheep/beef both contribute about equally to the loading of N in the river at Hopelands: namely sheep/beef 51% and dairying 43%. Thus one option, amongst others, is to consider that each farm-type contributes savings in proportion to their fractional make-up Q. So to meet the water quality standard, namely 341 T-N yr^{-1}, the split would be 155.5 T-N yr^{-1} for dairying and 185.5 T-N yr^{-1} for sheep/beef. Given then the respective areas of farms in the UMWMZ (Table 1), and the same transmission coefficient, $\Re$, of 0.5 for dairying and sheep/beef, the farm losses of N that would meet the water quality standard at Hopelands are for the full UMWMZ, according to Eq.[8]:

- For dairying, q^*_d = 15.1 kg-N ha^{-1} yr^{-1}
- For sheep/beef q^*_{sb} = 3.8 kg-N ha^{-1} yr^{-1}.

In the humid environment of the UMWMZ, it would seem that these would be difficult to achieve given current technologies. This would essentially require a halving of the on-farm losses of N, which fortuitously is the target contained in the Dairy Industry's Environment Strategy.

3.8.2 Area-equity split

In Table 1, we see that dairying presently occupies 16.3% of the area of the UMWMZ, whereas sheep/beef covers 77.3% of the catchment. If the load of 341,000 kg-N yr^{-1} which meets water quality standards were equitably split on an areal basis, dairying could only account for 59.3 T-N yr^{-1}. The complement of 281.7 T-N yr^{-1} would be allocated to sheep/beef. For the UMWMZ, this could, according to Eq. [8] only be achieved if there were the same losses from each sector, namely:

- For dairying, q^*_d = 5.8 kg-N ha^{-1} yr^{-1}
- For sheep/beef q^*_{sb} = 5.8 kg-N ha^{-1} yr^{-1}.

For dairying this would not be feasible with current practices and technologies.

3.8.3 Natural Capital Split

In a separate project we have examined an approach to split the load across the catchment according to the natural capital value of the soil as registered by the Land Use Capability class. (Appendix 6)

4. What are the key/critical hotspots of nutrients input into waterways? How should these be managed to reduce their impact on contamination of waterways?

We have elected to answer this query through our responses to questions 2 and 4.

5. Application of effluent to land is currently an activity that requires resource consent. If Horizons were to make it a permitted activity, subject to compliance with best management practices, which best practice measures are recommended?

It is important to remember that for the land owner, the major keys to the successful management of effluent application to land is to have sufficient storage for flexibility, maximise the use of the effluent as a nutrient source for optimum plant growth, and always apply it onto short pasture at the lowest practical application rate with a rest interval between application and grazing.

For Council, success is measured by suitable storage facilities where effluent can be held temporarily if the application system breaks down, or soils are too waterlogged for further liquid application, so the N loading on the land does not effect groundwater, ponding and runoff into surface water is avoided, nuisances from odour or spray drift does not occur and buffer distances between adjoining properties or public roads and the application area are observed.

The manual "*Managing farm dairy effluent and farm management Issues*", developed by the Dairying and Environment Leadership Group in consultation with Regional Councils, AgResearch, NIWA, Dexcel, Spitfire Irrigators Ltd, Effluent & Irrigation Services, Federated Farmers of New Zealand, Fonterra Co-operative Group Ltd, Westland Milk Products New Zealand and Massey University, and last updated in 2006 in a project funded by New Zealand dairy farmers through Dairy InSight brings these goals together. The manual is designed to assist dairy farmers and farm management specialists with the practical, effective, safe and legal management of farm dairy effluent. Available to all land owners, the manual provides a comprehensive list of best practice measures for the application of effluent to land

Horizons should reference the practices listed in Chapter Two '*Land Application*" (e.g. rate of application of effluent, timing of application, etc) and Chapter Four '*Effluent from Feed Pads, Stand-off Areas and Other Sources*', which includes effluent from silage pits, races, crossings and underpasses in the One Plan as best practice measures for the application of effluent to land.

Horizons should note the following

1. *With the advent of stand-off pad, feed pads and herd homes, the volumes of solid effluent applied to land are likely to increase significantly in future years.*

Effluent can be dealt with as liquids, slurry or solids. In general, raw effluent takes the form of slurry. **Liquid** effluent is defined as material containing less than 10% solids. Such material can be conveyed through piping systems by gravity or pumps, and is treated in oxidation ponds or by land application. **Slurry** contains between 10 and 20% total solids and will flow. It is generally spread on land using vehicle spreaders. Effluent exceeding 20% total **solids** is sludge and will not flow. It requires mechanical spreading equipment usually with scrapers, buckets and front-end loaders.

The one plan will need to be able to address all there forms, with the quantities of solid effluent likely to increase in the future.

2. The council will need to make a decision on the maximum amount of effluent that can be applied based on an N or P loading or on the optimum use of effluent as a nutrient source for plant growth.

(a) The N loading (150 or 200 kg-N ha^{-1} yr^{-1}). Table 16-1 in the one plan currently suggests the lesser of the two. This assumes application of N up to the maximum allowable loading follows best practices for effluent disposal described in the dairy industry manual.

(b) Optimum use of effluent as a nutrient source for plant growth.

If this approach was adopted the application rate of effluent would be governed by the potassium (K) content of the effluent. In the past, the rule of thumb was 4 ha per 100 cows to achieve an N loading of 150 kg-N ha^{-1} yr^{-1}. At this application rate the K input is approximately twice maintenance. This would result in a doubling (8 ha per 100 cows) of the effluent block, if the optimum use of effluent as a nutrient source was used as part of best practice. The Overseer® nutrient budget model can calculate the area of the effluent block based an N loading of 150 kg-N ha^{-1} yr^{-1}, 100 kg-K ha^{-1} yr^{-1}or on a maintenance K application. While using K inputs above maintenance does not represent an environmental threat, it does represent poor practice. Obtaining buy in from the industry to include optimum use of nutrients as part of best effluent management practice, would have the bonus of reducing N and P loadings and negate the need for a rule. Excessive K in soils and pasture can result in metabolic problems for lactating animals.

6. What improvements and mitigation measures are likely to be included in Overseer®

Discussions were held with Dr Hilton Furness (Fertiliser Manufacturers' Research Association – a member of the Owners' Committee of Overseer®), and the leader of the Overseer® team within AgResearch, David Wheeler, to find out the future plans for further development of Overseer®.

They noted that it is planned to release a new version of Overseer® by December 2007 and this would include:

- The use and impact of nitrification inhibitors,
- The role and impact of riparian strips and wetlands,
- Updates of the feed-pad management options, and

Priorities for the next update in December 2008 are still being established. Under consideration for further development of the model are:

- Monthly time-steps to take better account of stock movements, and other farm management practices such as multiple calving
- Updating of the market gardening, cropping and horticultural models. This was being assisted through an SFF N management project being carried out for Horticulture NZ by Crop & Food Research, HortResearch, and AgResearch.
- Other considerations, depending on the availability of knowledge and modelling, could include sediment loss and microbes. It is presently unclear as to what modelling strategy might be used for these, given the difficulty in describing the processes. A generalised risk-assessment, and provision of mitigation measures could be an option.
- Other aspects and mitigation measures would be considered by the Owners' Committee on the basis of need, and the provision of appropriate results and robust knowledge.

7. What progress has been made in integrating NPlas and Overseer®? Could it be applied to the Manawatu-Wanganui region?

Presently, AgResearch has a contract with MAF and Dairy Insight to link their Overseer® model of nutrient management with hydrological and nutrient source models to account for the mitigation impact of riparian strips and wetlands. AgResearch is working with MAF to develop the specifications for this project and will include NIWA. The contact for further information is Richard McDowell of AgResearch in Mosgiel.

Because the Overseer® model is nationally applicable, so will this riparian strip/wetlands option be nationally available. The veracity of the predictions will, nonetheless, be dependent on the utility of national calibrations, or the availability of local information.

8. Best Management Practices to Minimise Faecal Runoff from Farms

Recent reviews have addressed aspects of faecal runoff from rural catchments by examining pathways and models for predicting loads to surface waters, namely Collins *et al*. (2005a), and Jamieson *et al*. (2004), as noted by Wilcock (2006).

Loadings to waterways are greatest from **surface runoff** and **stock crossings**, but are broadly similar to loadings from drains (notably because of effluent loadings) and dairy shed oxidation ponds with typical effluent strength. This is because the calculated loads take into account the magnitude of the inputs and the duration of each type of loading.

Land loadings fall into three broad classes.

1. The highest loadings occur where stocking rates are highest, viz. wintering pads, block-grazed pasture, and stand-off and feed pads for dairy cattle.

2. The second group comprises average grazed pasture for dairy and sheep, and land disposal of dairy shed effluent by irrigation. Of note is the high land loading of *E. coli* that can come from intensive sheep farming. Sheep at a stocking rate of 5 sheep ha^{-1} may deliver up to ten times the loading (*E. coli* ha^{-1}) that is produced by dairy cattle grazing at a rate of 3 cows ha^{-1}.

3. A third, smaller group comprises deer and beef cattle farms, based on what is regarded as 'typical' stocking rates, and runoff from dairy farm laneways.

Other important sources of faecal pollution include direct deposition into stream channels from grazing livestock, and runoff from seeps and wetlands that are accessible by stock.

While it is relatively straightforward to calculate loadings it is much more difficult to estimate *in situ* concentrations, without knowledge of die-off rates and breakdown of faecal matter in conjunction with farm grazing management. (Wilcock, 2006).

"Bridging streams intersected by farm raceways is an appropriate mitigation measure for herd crossings, whilst fencing stream banks, ephemeral streams, wetlands, seeps, and riparian areas prone to saturation to keep livestock out will bring improvements in water quality. "Riparian buffer strips not only prevent cattle access to waterways, they can also entrap microbes (and other pollutants) washed down slope in surface runoff, and, where planted in trees, provide shade and improve aquatic habitat." (Collins *et al*., 2005b)

"Soil type is a key factor in the transfer of faecal microbes to waterways. The avoidance of, or a reduction in, grazing and irrigation upon poorly drained soils characterised by high bypass flow and the generation of surface runoff, are appropriate management practices, and are likely to lead to improvements in bacterial water quality". (Collins *et al*., 2005b)

"In addition to the identification of appropriate soil type, timing, volume, location and technique are also key factors in the optimal irrigation of effluent and water. Ideally, dairy shed wastewater should be irrigated onto land only when the water storage capacity of the soil will not be exceeded. This ‘deferred irrigation’ can markedly reduce pollutant transfer to waterways, particularly that via subsurface drains and groundwater.. Spray irrigation results in less risk of soil saturation and hence less surface runoff and microbial contamination of groundwater than the border strip technique.” (Collins *et al*., 2005b) Advanced Pond Systems provide excellent effluent quality and have particular application where soil type and/or climate are unfavourable for irrigation. (Collins *et al*., 2005b)

9. Should Horizons Regional Council adopt the water-way definition of the Clean Streams Accord to achieve reductions in nutrient and faecal losses?

The waterway definition in the Dairying and Clean Streams Accord (Fonterra *et al.* 2003) is:

"… deeper than a "Red Band" (ankle depth) and "wider than a stride", and permanently flowing".

The Accord's target is to have dairy cattle excluded from 50% of streams by 2007, and 90% by 2012.

This provides a good stating point for a process that seeks to reduce stock accessing waterways. Compliance is, nonetheless, going to be difficult in many of the region's hill lands. Farm planning will have more potential for reducing stock in waterway, than further regulation.

The Accord's definition would, it seems, put the waterway somewhere between an order 2, or 3 stream. It would be interesting to know what length of waterways, both ephemeral and permanent, lies outside the Accord's definition. This could then be translated into a fractional area of a given WMZ that might lie outside the accord. It is considered that there would be a large number of ephemeral waterways, even just temporary surface-pondings, that might be accessed by stock and thereby transport nutrients and microbes to receiving waters. This process, even though it would be outside the Accord, would contribute to the leakiness of farms, and would tend to keep the transmission index, $\Re$, higher than expected.

10. What are the appropriate upper limits for Table 16-1 in the "One Plan" for N and P?

As evidenced by the detail of our calculations and analyses here, it is difficult to generalise about nutrients loadings, and so it is hard to prescribe an upper limit. Earlier, we have here tried to prescribe best management practices that will reduce the loss of N and P from farms.

Nitrogen

There are many factors that will influence the upper limit of N which can reasonably be applied with adverse impact. This will, *inter alia*, be influenced by:

- The level of feed intake by the grazing animal. Animal grazing increases the likelihood of N losses through the leaching from urine spots
- The fraction of the N that is applied that might be removed through cut-and-carry during the year.

So at this stage there would seem to be no present reason to amend the upper limit for reasonable N application (150 kg-N ha^{-1} yr^{-1}) in Table 16-1. As Horizons gathers outputs from Overseer® (see Table 7 and the 200 kg-N ha^{-1} yr^{-1} scenario), and other sources, and as other data comes available from areas where N has been used for longer periods of , this value can be reviewed.

Phosphorus

Again, there are many factors that influence P loss. Although P is much less mobile than N, the amount of P that can be applied without adverse effects will be influenced by:

- The grazing animal. Intensive grazing systems would increase the risk of P loss through overland flow, as compared to say, a cut-and-carry operation
- The fraction of P removed by cut-and-carry, relative to that applied will be a lot less in comparison to N. For example, a 10,000 kg-DM pasture, at an N-content of 4% will contain 400 kg-N, but with a P content of 0.4% there will only be 40 kg-P removed.

Designating a value for P presents more difficulty, because soil chemistry exerts a very large influence on these values. History of P use will also be very important. For instance, a capital dressing rate that is appropriate in an undeveloped land setting with soils with high anion storage capacity (ASC), would be excessive in a well developed low ASC soil. Decisions about setting a maximum application rate, fits better with the scale of farm plans, rather than with regional scales. Given the importance of direct contamination of waterways with P, an application rate rule is not a priority at present. The fertiliser industry has developed a comprehensive set of best management practices for P and N use cover such issues as the form and rate of application, timing and method of application. These seek to maximum plant uptake and minimize the impact of fertilisers on the wider environment.

11. Biosolids, Offal Holes & Farm Dumps: Comments on Rules 16-2 & 16-7

We have been asked whether the current conditions on Rules 16-2 to 16-7 are appropriate to achieve best practice.

We have some comments and suggest some modifications and additions to Rules 16-2 to 16-7 that we consider would achieve best practice. We make comment of 3 of the 5 conditions set out in these two of these Rules, and we add some suggestions taken from the EBoP guidelines.

16-4 Biosolids and soil conditioners

Condition (b) There shall be no ponding of material on the soil surface for more than five hours following the application, or any runoff into a surface water body.

Comment: On any site with a slope a ponding that lasts up to five hours will lead to considerable surface runoff and, therefore, pose a risk for surface water contamination (especially with P).
We suggest to omit the time limit and to encourage the farmer to take the specific site conditions into consideration. A possible new formulation of Condition (b) could be:

The rate of application shall not exceed the infiltration capacity of the particular soil and topography (citation from 'Dairy Shed Effluent Treatment and Disposal Guidelines', Environment Bay of Plenty Guideline No. 2003/01), and any runoff into a surface water body shall be prevented.

16-5 Offal holes and farm dumps

Condition (d) The lowest point of the offal hole or farm dump shall be at least 1 m above the seasonally highest water table.

Comment: The distance of only 1 m above the seasonally highest water table seems too small.
We would suggest an increase to 2 m (also suggested by the Environment Bay of Plenty Guideline on Offal holes) and encourage the farmer to select a site with a clayey subsoil (suggested by the Guideline for Offal holes of the Gisborne Regional Council). A possible new formulation of Condition (d) could be:

The lowest point of the offal hole or farm dump shall be at least 2 m above the seasonally highest water table and if possible have a clay base.

Additionally, we suggest inclusion of two more conditions. Both conditions are a part of the Environment Bay of Plenty Guideline on Offal holes.

- Leachate is not allowed to pond or flow away from the hole
- The hole must be covered to prevent stormwater entering

16-6 Farm animal effluent including dairy sheds, poultry farms and existing piggeries

Condition (d) There shall be no ponding of effluent on the soil surface for more than five hours following the application, or any runoff into a surface water body.

Comment: On any site with a slope a ponding that lasts up to five hours will lead to considerable surface runoff and, therefore, pose a risk for surface water contamination (especially with P).
We suggest to omit the time limit and to encourage the farmer to take the specific site conditions into consideration. A possible new formulation of Condition (b) could be:

The rate of application shall not exceed the infiltration capacity of the particular soil and topography (citation from 'Dairy Shed Effluent Treatment and Disposal Guidelines', Environment Bay of Plenty Guideline No. 2003/01), and any runoff into a surface water body shall be prevented.

In addition we suggest including two more conditions. Both of these conditions are a part of the 'Dairy Shed Effluent Treatment and Disposal Guidelines', Environment Bay of Plenty Guideline No. 2003/01. The recent update of the manual "*Managing farm diary effluent and farm management issues"* developed by the Dairying and Environment group provides a comprehensive set of best practices for effluent management.

- Any area receiving effluent by irrigation should be rested for a 14-day period between applications to prevent hydraulic inundation of the soil causing a breakdown in the soil treatment process.

- A contingency plan must be available in the event of pump or irrigator failure to prevent overflow to water or land where it may reach water.

12. Current Research of Potential Benefit for On-Farm Resource Management

There are a number of projects currently being undertaken by the SLURI partners that could benefit on-farm management of N, P and microbial contaminants. These are briefly summarised in the tables below (Tables 12, 13 & 14).

Table 12: Pastoral sector

Name	Major Funder(s)	Research provider(s)[1]	Description[2]	End date
Soil Services	FRST	LCR	Providing underpinning information on the key services provided by soils that mediate the effects of land use on the transport of nutrients and contaminants to ground waters and sustain the versatility and productivity of our landscapes.	Jun 07
Integrated catchment management (Motueka)	FRST	LCR	Implementing a collaborative learning approach with stakeholders to identify and implement sustainable patterns of land, water and coastal uses, as development pressures increase. Programme goals are: i) the equitable allocation of increasingly scarce natural resources, in a manner acceptable to catchment communities; and ii) the application of tools for managing the cumulative effects of land and water use.	Jun 09
SPINFO	FRST	LCR	The overall outcome will be sound, enduring management decisions about land resources and environments made by central government, local government, consultants, researchers, and land-based industries, supported and informed by rapid access to comprehensive, up-to-date, and accurate databases and associated information	Jun 07

			systems.	
Land to Ocean	FRST	LCR	Effective management of New Zealand's dynamic physical environment is dependent on improved understanding of the processes that transfer sediment, nutrients and carbon from land to ocean. Research will provide new knowledge to strengthen the ability to predict and mitigate the effects of changing climate and land use on those transfers, and to underpin an assessment of terrestrial and marine greenhouse gas emissions.	Jun 07
Enhancing surface water quality in managed landscapes	FRST	AgR	Provide management strategies that minimise leaks and contain potential contaminants within the farm boundary without decreasing farm profitability. Our hypothesis is that considerable reductions in farm contaminant losses to waterways can be realised through the development and adoption of farm management practices, management systems and mitigation technologies that effectively contribute to water quality goals at a catchment scale.	Jun 07
Nitrogen and Lake Taupo	FRST	AgR	Ensure high groundwater and lake water quality while enhancing economic and social well-being of Maori and non-Maori landholders, community and policy bodies. This will be achieved through developing, evaluating and promoting implementation of new technologies, improved land use practices and policy methods using an integrated whole-systems research approach.	Jun 10
Livestock	FRST	AgR	Describe the economic,	Jun

intensification			environmental and social impacts of different pastoral land-use options and define systems where deleterious effects can be balanced against economic gains.	09
Pastoral 21	FRST, DI, FertRes, MAF	AGR, NIWA, CFR, Dexcel, ESR, LCR, Lincoln, Massey, Waikato	Provide farmer-friendly tools and technologies for reducing N, P, sediment and FIO losses to water ways.	Feb 11
SLURI	FRST	CRF, HRT, AGR, LCR	N saturation – Soil Services N mineralization soil quality indicator	Jun 08
Catchment Land Use for Environmental Sustainability (CLUES)	FRST (CDRP). MfE, EW, Horizons	NIWA, AgR, HRT, LCR, Lincoln Ventures, Harris Consulting	Allows a GIS user to model present and future nitrogen and phosphorus loads in streams as land use changes, on national, regional and catchment scales. The system also provides data on socioeconomic implications.	

[1]AgR = AgResearch, CFR = Crop & Food Research, HRT = Hort Research, LCR = Landcare Research
[2]Description of the relevant project component

Table 13: Cropping & market gardening

Name	Major Funder(s)	Research provider(s)[1]	Description[2]	End date
Land Use Change and Intensification (LUCI)	FRST	CFR, AgR	Defining the effects of changes and intensification of land use on nitrate leaching losses to groundwater. This contributes to the Integrated Research for Aquifer Protection (IRAP) programme that is producing tools for use by regional councils to develop their second generation regional plans (for groundwater quality)	Jun 08
Nitrogen Managers for Environmental Accountability	SFF, Hort NZ, FAR, FertRes, RCs	CFR, AgR, HRT	Producing an improved on-farm nutrient budgeting tool for arable, vegetable and horticultural land uses	Jun 09
Improving the nitrogen management of potato crops	SFF, Hort NZ, Horizons, EW, Ballance, HBRC	CFR, HRT	Improving nitrogen use efficiency of potato crops using an on-farm decision support system (the Potato Calculator)	Jun 08
Nitrogen management for sustainable maize production	SFF, FAR, FertRes, EW	CFR	Developing a tool (the AmaizeN calculator) for optimising nitrogen management of maize for economic profitability while minimising environmental impacts	Jun 08

Table 14: Perennial horticulture

Name	Major Funder(s)	Research provider(s)[1]	Description[2]	End date
Regulated Deficit Irrigation in kiwifruit	SFF, ZESPRI	HRT, Fruition Horticulture	Management of irrigation in kiwifruit to improve fruit quality	Jun 09
Nutrient Management in Kiwifruit	SFF, Ballance Agri-nutrients, EBoP, Northland RC	HRT	Managing N in kiwifruit	Jun 07
Summerfruit Nutrition	SFF, Summerfruit NZ	HRT	Developing best practice management for nutrients in summerfruit	Jun 09
Blueberries: Irrigation and nutrient management	SFF, Hauhangaroa Trust	HRT	Developing irrigation and nutrient practices for growing blueberries in the Taupo catchment	Jun 09

13. Are there any trends within the farming community that may influence the format of individual farm resource management plans/strategies (i.e. computer literacy, environmental awareness, market accountability, etc)?

The use of Environmental management systems (EMS) and allied approaches to on-farm environmental management is increasing in the primary sector in New Zealand. An EMS refers to a systematic approach to managing the impacts of a production system on the environment. They have been promoted as a tool for simultaneously meeting market and community demands for environmental assurances in the agricultural, horticultural and forestry sectors. Most New Zealand primary sector EMS-type arrangements have been developed by individual sectors, and are not ISO 14001 accredited. Most are reasonably prescriptive in terms of the environmental issues that should be included, the implementation process and the management options that are acceptable.

Table 15 Summary of the main New Zealand programmes for on-farm environmental management

Programme	***Programme Type***					
	Integrated EMS/QA	*EMS*	*Quality Assurance*	*IPM*	*Standards*	*Codes of Practice*
Horticulture						
Sustainable Winegrowing	X					
The Living Wine Group		X				
Kiwi Green[1] (kiwifruit)				X		
NZ Fresh Produce Supplier Programme (fruit & vegetables)			X			
Olive Care™			X			
Pipfruit – Integrated Fruit Production				X		
AVO Green				X		
SummerGreen (Stonefruit)				X		
Livestock						
Project Green (Meat)	X					
SmartPlan™ (Dairy)	X					
Market Focused (Dairy)		X				
Merino Benchmarking Group (Wool)		X				
DeerQA			X			
Individual meat company on-farm QA			X			
FarmPride (Landcorp farms)			X			

Cross-sectoral			
NOSLaM		X	
Greentick	X		
NOSLaM		X	
Enviro-Mark™		X	
Industry practices			
Agrichemical Code of Practice (GROWSAFE)			X
Code of Practice for Fertiliser use			X

In an evaluation of the EMS type arrangements in operation in New Zealand (Table 15), Parminter *et al*., (2004) found they varied a great deal in their intent, content, credibility and environmental performance. Nonetheless, they have been shown to be effective at delivering desired environmental outcomes. They provide an extra policy instrument for achieving such outcomes along with regulation, encouragement through rewarding achievement, economic incentives or educational approaches.

In viticulture there has, through a consortium of vineyards in Martinborough, been successful accreditation to the ISO 14000 series of EMS accreditation. This could be an increasing trend to environmental accountability to secure market share and premium prices. Furthermore, and also in viticulture, a vineyard in Marlborough (Grovetown), has been accredited with being carbon-neutral.

14. What would be the most effective way of measuring the actual nitrogen and phosphorus loss from farms?

Measuring the actual N and P loss from farms is very challenging as these losses vary greatly both spatially and temporally variable. Currently, there are no cost-effective tools available for use by farmers. Several research tools are available (see Appendix 3), but these can be either too expensive for use by farmers, or do not produce paddock- or farm-scale results.

However, one of the objectives of the recently-funded Pasture-21 tender is the development of such an operational measurement tool for pastoral systems. This work aims to produce this device by combining the most cost-effective analytical techniques for measuring N and P concentrations (or their surrogates) with an appropriate method for collecting representative, paddock-scale samples (*e.g.* large lysimeters, ceramic cups).

This may prove to be a long term and difficult task, and the use of farm-scale models (such as Overseer®) may be the only viable option. Options could exist for simple versions of the research tools outlined in Appendix 3 to provide simple month-by-month monitoring, along with these data being able to provide corroboration of Overseer® predictions.

15. Why does Overseer® not consider soil-test results to account for the existing N content of soil?

The nutrient budgets calculated in Overseer® are accounts of the inputs and outputs of nitrogen across the boundaries of the land units being considered. The model does not calculate any change in the stocks of nutrients (*e.g.* total soil-N) within the boundary, and stocks are treated as a stable property of the system. The processes of N accumulation, and release, are considered to be in near balance over decade-timescales. Indicators like available soil N therefore, do not have any useful role in these calculations.

There is an exception when the “Development” options are selected in Overseer®. These assume that more N is being accumulated than released, so total N in the system increases, and the losses are predicted to be lower as a consequence. Defining the conditions where the development options should be invoked is highly subjective and a test to guide this might be useful. Available soil-N is however notoriously difficult to assess in a way that has general application and rapid progress shouldn’t be expected.

16. The Waikato Farm Environment Award Trust has produced a guide to preparing a nutrient budget. How useful is this simplified tool?

This is a simple and manual nutrient-budget guide, or method, and was of help in situations where land owners had no access to Overseer®. It should not be regarded as a substitute for Overseer®. Since Overseer® is freely available, and accepted by the industry and regulators alike, there seems little reason to adopt anything else. Furthermore, Overseer®'s owners are continually updating the user friendliness and utility of Overseer® through engaging New Zealand's best scientists.

References

Alexander, R.B., A.H. Elliot, U. Shankar, and G.B. McBride 2002. Estimating the sources and transport of nutrients in the Waikato River Basin, New Zealand. *Water Resources Research* 38(12) 1286, doi 10.1029/2201 WR000878, 2002.

Collins, R.; Elliott, S.; Adams, R. (2005a). Overland flow delivery of faecal bacteria to a headwater pastoral stream. *Journal of Applied Microbiology 99*: 126-132.

Collins, R.; McLeod, M.; Hedley, M.; Horne, D.; Hanly, J.; Close, M.; Bagshaw, C.;Donnison, A.; Ross, C.; Matthews, L. (2005b). Pathogen Transmission Routes:farm animals to waterways – Best Management Practices. NIWA Client Report: HAM2005-071, prepared for MAF.

Di HJ, Cameron KC 2002. Nitrate leaching in temperate agroecosystems: sources, factors and mitigating strategies [Review]. Nutrient Cycling in Agroecosystems 64(3): 237-256.

Eco-Link 2000. Implications of groundwater nitrate standards for agricultural management. Technical Paper 2000/15, No., MAF Policy. 136 p.

Fonterra, Local Government New Zealand, Ministry for the Environment, and MAF. 2003 Dairying and the Clean Streams Accord, 5pp.

Francis G, Thomas S, Barlow H, Tabley F, Gillespie R 2007. Management strategies to minimise nitrate leaching losses from arable soils. Designing Sustainable Farms - critical aspects of soil and water management. 20th Annual Workshop of the Fertilizer and Lime Research Centre. 8-9 February 2007, Pp. In Press.

Francis GS 1995. Management practices for minimising nitrate leaching after ploughing temporary leguminous pastures in Canterbury, New Zealand. Journal of Contaminant Hydrology 20: 313-327.

Francis GS, Trimmer LA, Tregurtha CS, Williams PH, Butler RC 2003. Winter nitrate leaching losses from three land uses in the Pukekohe area of New Zealand. New Zealand Journal of Agricultural Research 46(3): 215-224.

Horizons Regional Council, 2007 Nutrient Load Calculation and Nutrient Sources Assessment in Three Catchments of the Manawatu-Wanganui Region [Draft 5th February 2007] Emile Ledein, Olivier Ausseil & Jon Roygard pp67)

Jamieson PD, Zyskowski RF, Sinton SM, Brown HE, Butler RC 2006. The Potato Calculator: A tool for scheduling nitrogen fertilizer applications. Agronomy New Zealand 36: In Press.

Jamieson, R.; Gordon, R.; Joy, D.; Lee, H. (2004). Assessing microbial pollution ofrural surface waters: A review of current watershed scale modeling approaches.*Agricultural Water Management 70*: 1–17.

Meneer, J.C., S.F, Ledgard and A.G. Gillingham 2004 Land use impacts on nitrogen and phosphorus loss and management options for intervention. Environment Bay of Plenty. AgResearch Client Report, June 2004, 52pp

Ministry for the Environment, 2002. Lake Managers' Handbook, Land-Water Interactions, June 2002, Wellington, 75 pp

Monaghan, R.M., de Klein, C.A.M., and Muirhead R.W. 2007. Prioritisation of farm scale remediation efforts for reducing contaminant losses to waterways. A case study of New Zealand dairy farming *Journal of Environmental Management* [in press]

Parminter, I,, Mackay, A., Wharfe, l. and Frazer, A. 2004. Environmental Management Systems –A market driven tool for achieving clean green outcomes? Primary Industry Management Journal Volume **9.** Number 2 9-12

Roygard, J. 2007. A framework for managing non point source and point source nutrient contributions to water quality. Horizons Regional Council, Draft 1 21 May 2007,

van der Velde, M., S.R. Green, G.W. Gee, M. Vanclooster and B.E. Clothier 2005 Evaluation of drainage and water flux measurements with passive suction and non suction flux meters in a volcanic clay soil under tropical conditions *Vadose Zone Journal* 4:1201-1209

Wilcock R 2006 Assessing the Relative Importance of Faecal Pollution Sources in Rural Catchments. NIWA Client Report: HAM2006-104 NIWA Project: EVW06212

Appendix 1: The Upper Manawatu Water Management Zone (UMWMZ)

A.1.1 Above Weber Road

The frequency histogram of dairy farm sizes in this sub-catchment is show in Figure A1. The median farm size of the 44 farms is 118 ha.

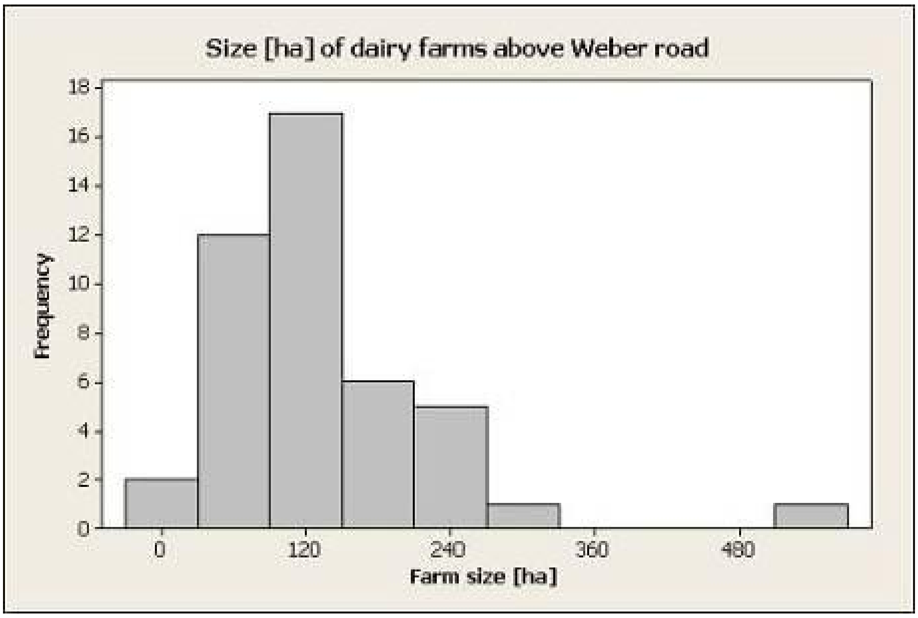

Figure A1. The frequency distribution of dairy farm sizes above Weber Road

The frequency distribution for the number of cows per farm for these 44 farms is shown in Figure A2, from which can be calculated that the median density is 319 cows per farm. We used a non-parametric means to estimate the average stock density on dairy farms above Weber Road to be 16 stock units (SU) per ha (Table A1)

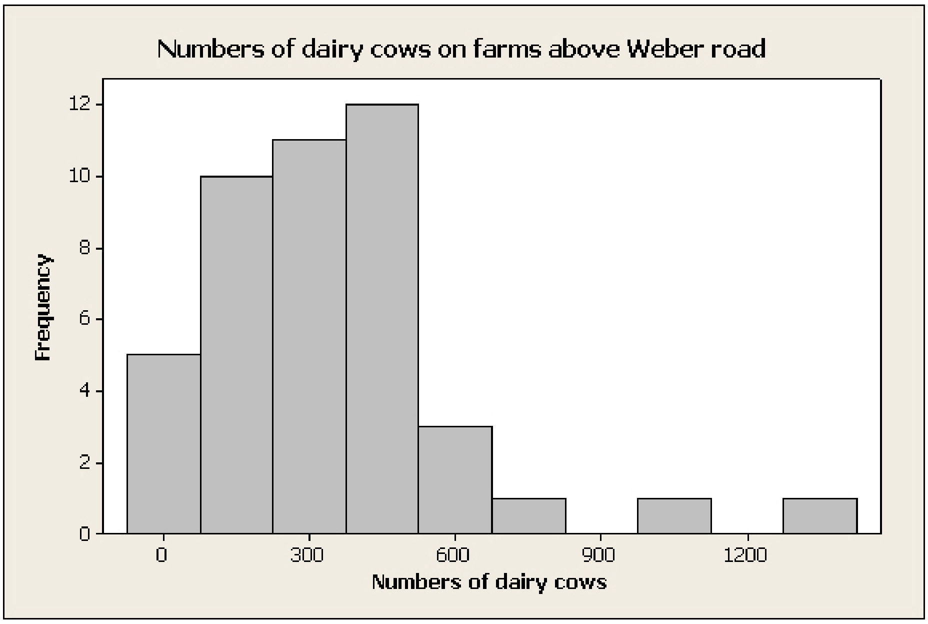

Figure A2. The frequency histogram of dairy cows per farm for the subcatchment above Weber Road

For the 235 sheep/beef farms in the Weber Road sub-catchment of the UMWMZ, the frequency distribution of farm sizes is given in Figure A3. The median farm size is 149.3 ha.

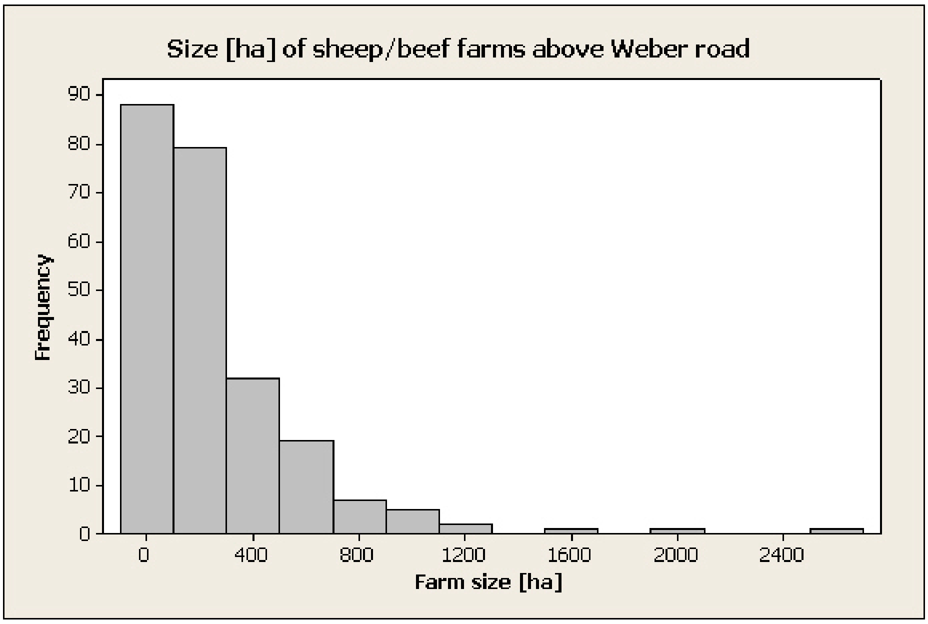

Figure A3. The frequency distribution of farm sizes for sheep/beef units above Weber Road

For these sheep/beef farms, the frequency histogram of animals per farm is given in Figure A4, and we find that the median number of animals per farm is 924. Sheep comprise 91% of the animals in this class. The density of animals on these farms is 9 SU ha^{-1} (Table A1).**Figure A4. The frequency distribution of the number of animals per farm on sheep/beef units above Weber Road.**

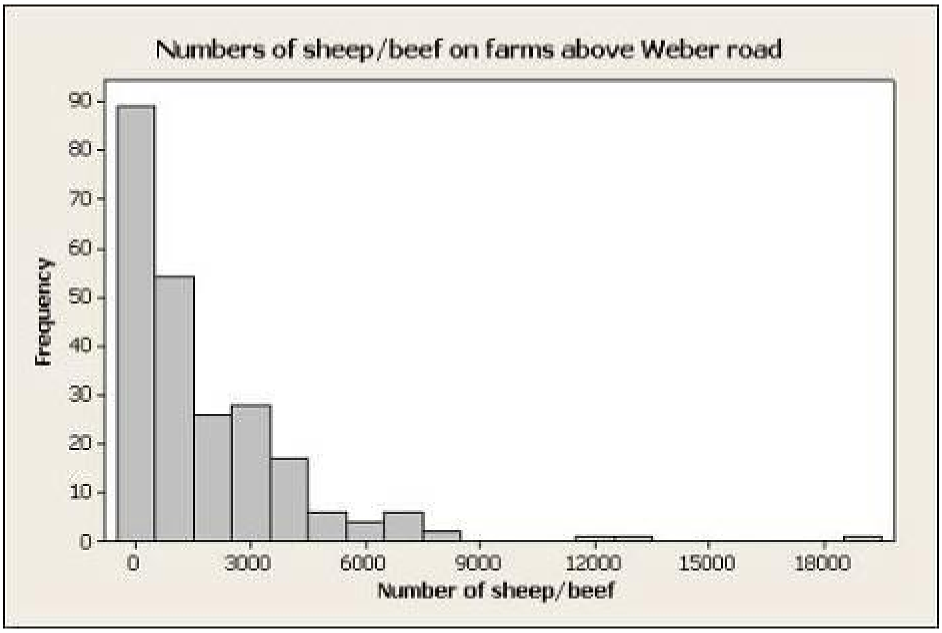

Table A1. Stocking density for dairy and sheep/beef farms above both Weber Road, and Hopelands in stock units (SU) per ha. We used the su-figures of sheep =1.0 SU, beef=4.84 SU, and dairy cows =6.43 SU (updated from MAF (1992) by Harry Clark, AgResearch, *pers. comm.*, and based on an annual dry matter intake of 550 kg SU^{-1}. The principles of this are used in Overseer®). The areas in Table 1 are not the same as those in this Table A1 due to incomplete Agribase™ data.

Area averaged stocking rates [SU/ha]	**Above Weber road**	**Above Hopelands**
Sheep/beef	9 (60,891 ha)	10 (28,692 ha)
Dairy	16 (6,020 ha)	16 (16,384 ha)
Both	9.6 (66,911 ha)	12.2 (45,076 ha)

A.1.2 Above Hopelands

We now present similar data for the sub-catchment above Hopelands, where we only consider the area upstream from Hopelands, and not extending past Weber Road.

There are 112 dairy farms in this Hopelands sub-catchment, and their median size is 115 ha (Figure A5). Although the distribution is positively skewed, it did test as being Gaussian. The distribution in the number of cows per farm (Figure A6) reveals that the median density of animals is 317 cows per farm. Both the farm sizes and stocking density are nearly identical to those found above Weber Road.

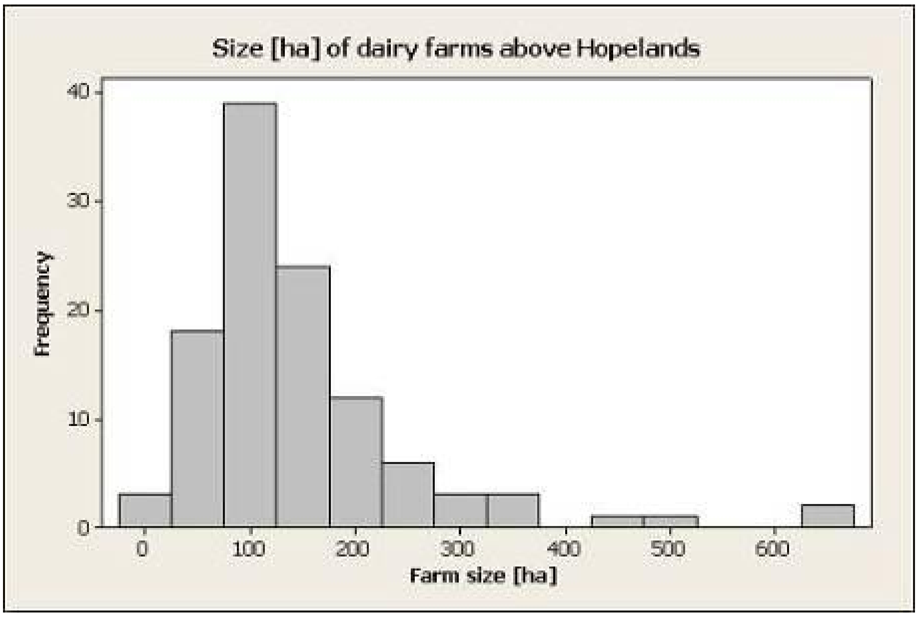

Figure A5. The frequency distribution of dairy farm sizes in the Hopelands sub-catchment.

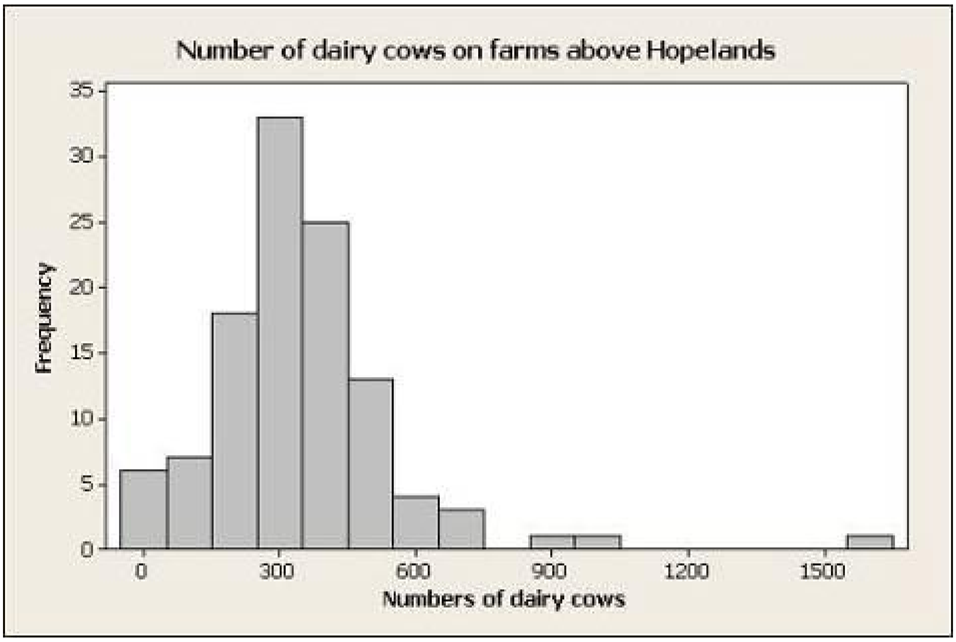

Figure A6. The frequency histogram of cow numbers per dairy farm in the sub-catchment above Hopelands.

Our non-parametric estimate of the average stocking rate of cows on these dairy farms is again 16 SU ha^{-1} (Table A1). In this Hopelands sub-catchment there are 160 sheep/beef units which have the frequency distribution shown in Figure A7. The median farm size is now just 61 ha, which is less than half that of the Weber Road sub-catchment. The distribution of animals per farm for these sheep/beef units is shown in Figure A8, and the median stocking rate is just 250 animals per farm, well down on the figure of 924 above Weber Road. However, when an estimate is made of the average stocking rate (Table A1), the density is 10 su ha^{-1}.

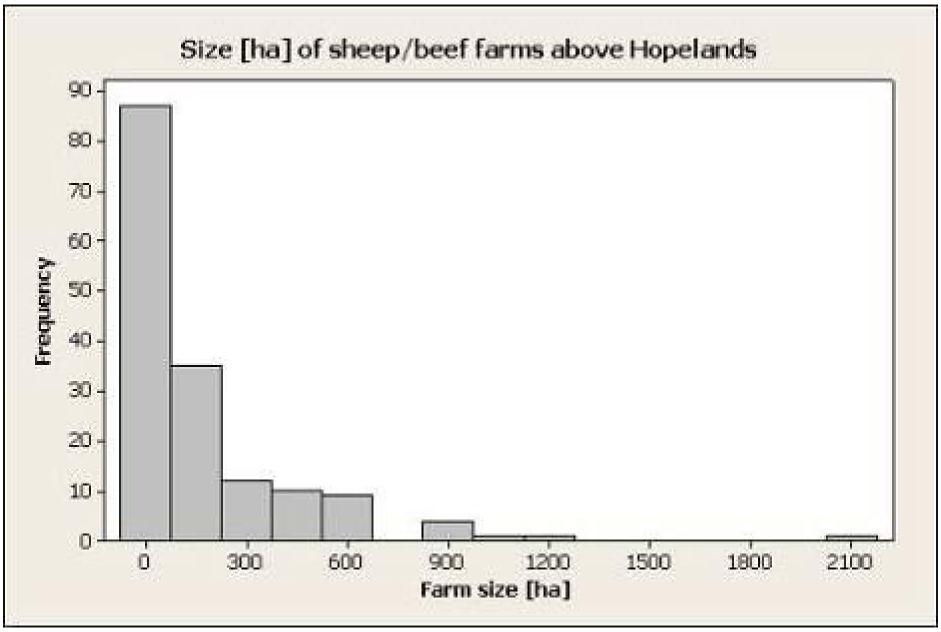

Figure A7. The frequency distribution of farm sizes for sheep/beef units above Hopelands.

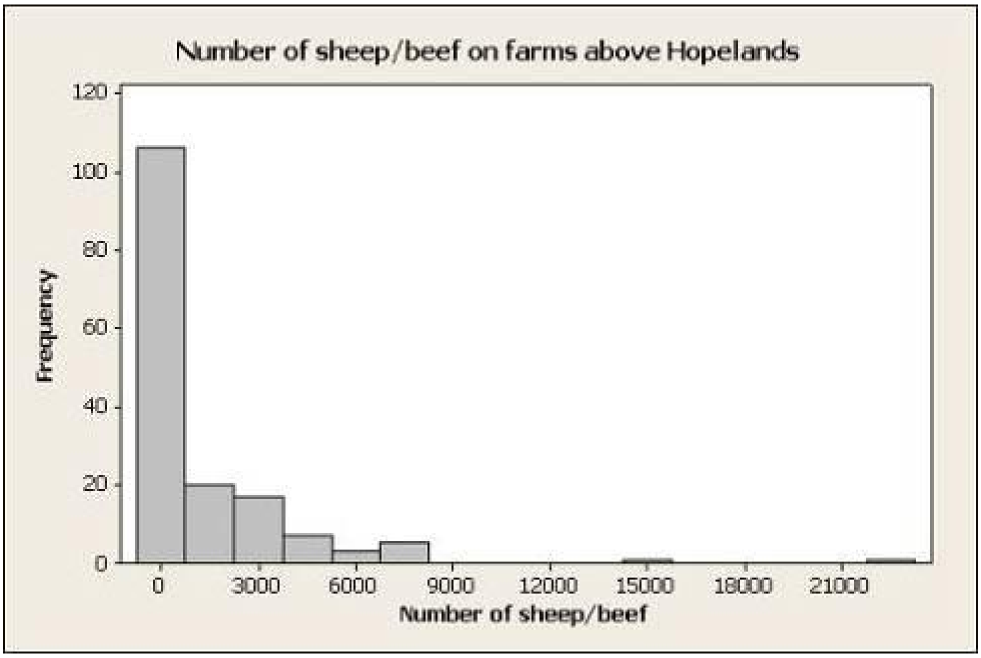

Figure A8. The frequency histogram of the number of animals per sheep/beef farm in the sub-catchment above Hopelands.

Appendix 2: Using Eq [5] Diagnostically and Predictively

An equation of the form of Eq [5] can be used diagnostically to explore the impact, in the river, of changes in landuse practices, and changes to the areas of various landuses.

Consider a hypothetical catchment of area *A* comprising only the landuses of dairying and sheep/beef:

$$A = A_d + A_{sb} \qquad [6]$$

Therefore the annual loading of N in the river, using mass balance will be

$$Q = q_d A_d + q_{sb} A_{sb} \qquad [7]$$

or when using transmission factors in a transfer-function scheme

$$Q = \Re_d \; q^*{}_d \; A_d + \Re_{sb} \; q^*{}_{sb} \; A_{sb} \quad . \qquad [8]$$

The fluxes q^* are obtained from Overseer® calculations (Eq. 3) so that

$$Q = \Re_d \; O^{-1}(L_d) \, A_d + \Re_{sb} \; O^{-1}(L_{sb}) \, A_{sb} \quad . \qquad [9]$$

This equation provides us with a diagnostic means to use Overseer® calculations to explore the implications on river water quality using our transfer-function approach, and the derived values of the transmission factors $\Re$.

A.2.1 Changing dairy practices

If the only change in a catchment were to on-farm practices in dairying, and that these resulted in changed losses predicted by the Overseer® calculations at 60 cm, q^*, then the change in loading in the river, *Q*, we would expect could be found from interrogation of Overseer® by using the partially differentiated form of Eq. [9]:

$$\frac{\partial Q}{\partial q^*} = \Re_d \; A_d \; \frac{\partial O^{-1}(L_d)}{\partial q^*} \qquad [10]$$

where the term on the right of the right-hand side of Eq [10] could be found from Overseer® for the appropriate scenario. This necessarily assumes that the transmission factor, $\Re_d$, is unaffected by the change in farm practice. This highlights a limitation of the transfer-function approach, for it is non-mechanistic. But, with additional data, understanding could be gained as to how changes might affect $\Re_d$, if at all.

Here the differentiation was simply with respect to dairying practices, however, in a general sense it can be carried out in sum for changes in the practices for all the land-use types

A.2.2 Changing the area of either dairying, or sheep/beef in a catchment

A.2.2.1 Changing the area in dairying

In this simple case, we consider that there are only two landuses, dairying and sheep/beef, in this hypothetical catchment. By using Eq. [6], Eq. [9] can be re-written to eliminate explicitly the area in sheep/beef, as

$$Q = \left[\Re_d \; O^{-1}(L_d) - \Re_{sb} \; O^{-1}(L_{sb})\right] A_d + \Re_{sb} \; O^{-1}(L_{sb}) \, A \quad . \qquad [11]$$

So, the impact in the river, Q, of a change in the area under dairying, A_d, without any change in farm management, would be obtained by partial differentiation of Eq. [9]:

$$\frac{\partial Q}{\partial A_d} = \Re_d \; O^{-1}(L_d) - \Re_{sb} \; O^{-1}(L_{sb}) \qquad [12]$$

As with Eq. [10], the right-hand side can here be calculated using Overseer®, again by assuming that the changed configuration of dairy farms has not altered $\Re_d$.

A.2.2.2 Changing the area in sheep/beef

In this simple case, the complement of the case above, we again consider that there are only two landuses, dairying and sheep/beef, in this hypothetical catchment. By using Eq. [6], Eq. [9] can, this time, be re-written to exclude explicit reference to the area in dairying, as

$$Q = \left[\Re_{sb} \; O^{-1}(L_{sb}) - \Re_d \; O^{-1}(L_d)\right] A_{sb} + \Re_d \; O^{-1}(L_d) \, A \quad . \qquad [13]$$

So, the impact in the river, Q, of a change in the area under sheep/beef, A_{sb}, without any change in farm management, would be obtained by partial differentiation of Eq. [9]:

$$\frac{\partial Q}{\partial A_{sb}} = \Re_{sb} \; O^{-1}(L_{sb}) - \Re_d \; O^{-1}(L_d) \qquad [14]$$

As with Eq. [10], the right-hand side can here be calculated using Overseer®, again by assuming that the changed configuration of dairy farms has not altered $\Re_{sb}$.

There is, not surprisingly given that there are only two complementary farm types in this hypothetical catchment, a symmetry between Eqs 12] and [14]. For the UMWMZ, the values of the right-hand sides of Eqs [12] and [14] are given in the left-hand column of Table 3: $\Re_d$ $O^{-1}(L_d)$ =15.4 kg-N ha^{-1} yr^{-1}, and $\Re_{sb}$ $O^{-1}(L_{sb})$ = 3.9 kg-N ha^{-1} yr^{-1}. So because of the greater N-leakiness of dairy systems (Table 5), an increase in the area of dairying in the UMWMZ, will degrade river-water quality by 11.5 (*i.e.* 15.4-3.9) kg-N yr^{-1} for every hectare converted from sheep/beef. Conversely, because sheep/beef farms are found to be less leaky, every hectare of dairying converted into sheep/beef in the UMWMZ will improve river-water quality by -11.5 (*i.e.* 3.9-15.4) kg-N yr^{-1}. We have carried out scenario analyses using this approach this in Section 2.7.3.

As noted in the section above, here the differentiation has been carried out for just dairying and sheep/beef, but it can be done for the mix and mosaic of all landuses.

A.2.3 Conclusions

This transfer-function approach provides:

- Incentive to collect data so that transmission factors can be calculated for various landuse types.
- A means for Overseer® calculations of farm losses to be linked to river water quality.
- A diagnostic tool to explore future impacts of changes in land use, and changes in farm management practices.

Appendix 3: Monitoring Devices – An option

We have suggested BMPs that are predicted by Overseer® to achieve a level of leachate loading at 600 mm in the soil to meet water quality standards in the river. It would, we consider, be prudent to try to monitor directly the loss of nutrients from the rootzone, even just to corroborate Overseer® predictions. New fluxmeters have, as a research tool made this possible. Van der Velde *et al*. (2005) recently described the use of fluxmeters on Tongatapu to monitor the loss of nutrients and pesticides from the soil to the fresh water lens under this raised coral atoll (Figure A9)

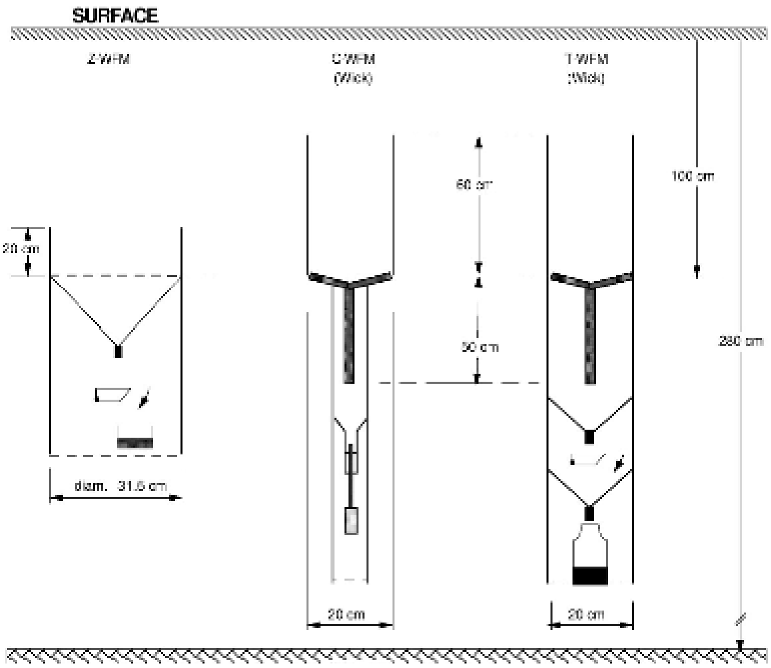

Figure A9. The three types of fluxmeters used by van der Velde *et al.* (2005) on Tongatapu to monitor the losses of nutrients and pesticides to groundwater

Figure A10. Examples of simple fluxmeters for collecting leachate (left), and their installation in an experiment (right) with soil of the row (upper 2) and inter-row of an orchard (lower 2.

We have also been using simple fluxmeters to monitor the losses of nutrients under a range of crops and pastures in New Zealand. The simple versions, without the tipping bucket to monitor the shape of the drainage 'hydrograph', can be constructed for about $500 per unit. HortResearch have been carrying out experiments of N leaching under blueberries in the Taupo catchment using these devices. The land-owner is also a dairy farmer, and he has ordered 45 of these instruments so that he can install them himself, and monitor losses from his dairying operation. We understand that a fertiliser company will be used to analyse the leachate concentrations.

The total drainage, and its average solute concentration, can be recorded on, say, a monthly basis. This monitoring would provide a check on the Overseer® calculations, and could possibly even be used to refine further, in the field, best management practices, especially at times when leachate loss might be critical. It would be necessary to determine appropriate devices and sample numbers required if this approach was to be used for farm scale monitoring.

Appendix 4: Consultants reports

8 February 2007

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Dear Alec,

Re: The Average Sheep & Beef Farm

Further to our discussion yesterday I make the following notes:

With respect to the average sheep and beef farm, you are referring to those that feed into the Manawatu river catchment above (North) of the Hopelands bridge.

Generally speaking, this takes in an area bounded by the Waewaepa range in the east, Whetukura (north east), Norsewood to the north and the Ruahine range in the west.

Farm sizes vary considerably in this catchment from small (150-200ha) intensively farmed units to the much more extensive stations (2500-3000ha) in size).

In reviewing our Profit Check database and calling on my experience and clientele as a Farm Management Consultant, I believe the average sheep and beef farm in this region would be something like:

• **Total area**	425ha		
• **Effective area**	400ha		
• **Carrying capacity**	4000su (10su/ha)		
• **Sheep:cattle ratio**	70:30		
• **Lambing percentage**	115% MA ewes 20% ewe hoggets		
• **Lamb weaning weight**	27.5kg		
• Average lamb sale weight	31kg (early March)		
• Wool production	5.5kg/ssu		
• **Calving percentage**	88% MA cows 85% R2yr heifers		
• **Calf weaning weight**	210kg (mid April)		
• **Soil fertility**	Olsen P	14	
	Potassium	8	
	Calcium	8-10	
	Magnesium	}	have not really taken
	Sodium	}	much notice of these
	pH	5.6	

- **Fertiliser use** — Predominately superphosphate 180-200kg/ha (16-18kgP/ha) On average 7kgN/ha.
- **Rainfall** — Average 1200ml (range 900ml at Hopelands to 1800ml; under Ruahine Range).
- **Soil type** — Generally derived from sedimentary parent material. Soils are stronger/better structured on Limestone and Greywacke parent material.
- **Livestock policies** — **Sheep:** Romney base breeding and some lamb finishing. **Cattle:** Breeding cows with some steer and bull beef finishing.
- **Stock reconciliation**

MA Ewes	2250
Ewe Hoggets	660
Rams	30
Sheep Stock Units	**2800**
MA Cows	100
R2yr Heifers	25
R1yr Heifers	30
R1yr Steers/Bulls	75
Cattle Stock Units	**1200**
Total Stock Units	**4000**

I trust this précis of the "average" farm helps. If you require further information please feel free to call me.

Yours sincerely,

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DAIRY FARM IN THE UPPER MANAWATU (DANNEVIRKE DISTRICT)

My experience with this district comes from:

1. Working in the district as the Dexcel Consulting Officer from 1997 to 2004, facilitating 3 farmer Discussion Groups that covered approximately 50 dairy farms, and met about 8 times per year. Regular annual analysis of financial and physical data was collected from about 25% of these participants. The 2003/04 data was the last I collected.
2. Working as a private Farm Consultant since Feb 2006 on a monthly individual visit basis. I have 7 clients within the direct catchment's concerned (between Hopelands and Weber Road bridges) and a further 6 clients in the Norsewood and Woodville areas, which are still Manawatu River catchment. I have yet to complete a full dairy season with any of these clients but have some good indications what the statistics will be.

My brief is to describe the average dairy farm in the district, based on the above experience. There is considerable variation between the approx 80 farms so there is some professional guesswork in the following answers.

Farm Size:

About 390 cows milked at peak (Oct/Nov) on 138 hectares (effective in pasture). That is a stocking rate of 2.83 cows/hectare and would require a greater winter/calving number of about 410 cows.

Present Fonterra Fencepost data has 3.06 cows/ha as the stocking rate for district, but that is based on farmers' estimated numbers in winter, prior to calving, which has always overstated cow numbers.

There has been a significant number of split-calving winter milking dairyfarms in the Dannevirke district for about 20 years (more than 15 of the 80 farms in 2004) but most have switched to spring-calving only, seasonal supply as the Fonterra pricing premium is reduced. 1 of my clients still winter milks, and intends to cease within 2 winters.

All but 2 of my present clients have support land (runoffs), which average 40 hectares. About two thirds of these are within the district. This land usually grazes some replacement youngstock and dry cows, as well as providing silage to the milking area.

Milksolids Production:
In recent years these farms are averaging milksolids production (sold to the factory) about 360-370 kg/cow or 1000-1050 kg/hectare.

Imported Feeds:
While the farm systems are primarily pasture grazing, utilizing 11-12 tonne DM/ha/year, other feeds like maize silage, grass silage or concentrates have increased in contribution throughout the last decade. Such imports average about 1200 kgDM/ha annually. Most farms feed these and home made supplements on pasture. One third of my clients do have feedpad facilities, but I think that would be well above the district average.

An additional 1000 kgDM/ha as dry cow grazing is sourced away from the milking platform in winter (June/July). It is unusual to see all dry cows away, with maybe 1 cow/ha remaining grazing pasture at home during the dry period.

Most dairyfarms have no replacement youngstock "at home" after early December, another 2000 kgDM/ha sourced elsewhere.

I have no records how much of these feeds involve their own runoffs, but guess it may be half of it.

Soils & Soil Fertility:
About two thirds of the farms are on primarily free draining, shallow loam type soils over shingle subsoils. The remainder are on heavier soils, primarily the Matamau Silt loams. Soil tests would usually show levels of Olsen P 30, MAF K 6-8, Mg 10, and Ca 12.

Fertiliser inputs:
Annual fertilizer inputs typically would be 35kgP, 40kgK and 45 kgS per hectare per year as one dressing usually in late spring early summer. Fertiliser N has been about 120kg/ha/yr.

Effluent Disposal:
Most of these farms spray effluent onto pasture daily while milking, with traveling irrigators. The regulation is 4 hectares per 100 cows and I think many would cover a slightly greater number of hectares.

I trust this information is of assistance to you.
Yours Faithfully
John Simmonds

Appendix 5: The Nitrogen Reports from the Overseer® for leaching predictions

The information is contained in a separate file called Appendix 5.pdf

Appendix 6: Defining nutrient (nitrogen) loss limits within a water management zone on the basis of the natural capital of soil

The information is contained in a separate file called Appendix 6.pdf