BEFORE THE INDEPENDENT COMMISSIONERS

UNDER the Resource Management Act 1991

AND

IN THE MATTER of the proposed Canterbury Land and Water Regional Plan

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STATEMENT OF EVIDENCE OF ROBERT JOHN WILCOCK ON BEHALF OF NGĀ RŪNANGA OF CANTERBURY, TE RŪNANGA O NGĀI TAHU AND NGĀI TAHU PROPERTY LIMITED

4 February 2013

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1. INTRODUCTION

1.1 My name is Robert John Wilcock.

1.2 I am currently employed by the National Institute of Water and Atmospheric Research (NIWA) as a Principal Scientist. My present position at NIWA is Programme Leader, Causes and Effects of Water Quality Degradation, Freshwater and Estuaries National Science Centre.

Qualifications and Experience

1.3 My qualifications are: BSc (Hons) in chemistry; PhD in physical chemistry, both from the University of Canterbury. I am a Fellow of the NZ Institute of Chemistry; a Fellow of the International Union of Pure and Applied Chemistry; a Member of the NZ Freshwater Sciences Society; and a corporate Member of the International Water Association (IWA).

1.4 My work experience includes two years as a post-doctoral fellow at Wright State University, Dayton, Ohio, and five years in the Water Section of Chemistry Division, DSIR, Wellington. I joined the Hamilton Science Centre, Ministry of Work and Development (MWD) in 1980 and subsequently became Group Leader of the Catchments Group. I have been in Hamilton since 1980; during which time MWD was disestablished and the Centre incorporated into DSIR Marine and Freshwater in 1987, and then NIWA in 1992. My research and expertise has been in the areas of water chemistry, gas exchange across the air-water interface, interactions between aquatic plants and water quality in freshwaters, contaminant chemistry, land use effects on water quality and diurnal changes in the physico-chemical properties of natural waters (viz., pH, dissolved oxygen and temperature). During the past 20 years my research has focused on ways of making intensive dairy farming more environmentally sustainable through implementation of good management practices.

1.5 I have written about 100 scientific publications (papers, book chapters and conference proceedings), as well as 94 technical reports. I have been on several scientific management groups, such as the South Pacific Regional Environment Programme on marine pollution (SPREP

POL); National Representative for Commission on Soil and Water Chemistry (International Union of Pure and Applied Chemistry (IUPAC), the Patea dam expert panel and the Waituna Catchment Management Group.

1.6 I have given evidence as an expert witness to several resource management hearings, the Environment Court and the High Court. Most recently I presented expert evidence for the Horizons Regional Council's One Plan and the Otago Regional Council's Proposed Plan Change 6A (Water Quality).

1.7 I am familiar with the Code of Conduct for Expert Witnesses in the Environment Court Practice Note and I agree to comply with the Code. This evidence is within my area of expertise except where I state that I am relying on information provided by another party. I have not knowingly omitted to consider material facts known to me that might alter or detract from the opinions expressed.

Scope of Evidence

1.8 I have been asked by Te Rūnanga o Ngāi Tahu to prepare evidence in relation to water quality management aspects of the proposed Land and Water Regional Plan (pLWRP), including: the value of catchment-specific water quality targets and management; the role of contaminant limits in managing water quality and the cumulative effects of contaminants; the value of using periphyton indicators as a target or outcome for managing water quality; and the efficacy of good on farm practices in addressing effects on water quality.

1.9 In preparing this evidence I have reviewed:

a. Volume 1 of the pLWRP

b. Section 32 Report on the pLWRP

c. Hayward, S.; Meredith, A.; Stevenson, M, (2009). Review of proposed NRRP water quality objectives and standards for rivers and lakes in the Canterbury region. Report No. R09/16 ISBN 978-1-86937-932-2. Environment Canterbury.

d. Memorandum to DairyNZ - Review of LWRP in Submission on Proposed Canterbury Land & Water Regional Plan by DairyNZ (submitter number 0315).

e. Section 42A report - Volume 1 Appendix 1 Memorandum by Adrian Meredith, 7 January 2013.

Summary of Findings

1.10 Catchment-based water quality management enables the linking together of land use, hydrology and water quality so that specific objectives and targets can be based on a biophysical understanding of the underlying science.

1.11 Water quality issues vary between catchments depending upon the sensitivities of waters to different pollutants (nitrogen, phosphorus, sediment and faecal organisms).

1.12 Land use intensification is the major cause of change in water quality, with intensive agriculture (viz. dairying) having the biggest adverse impact on surface and groundwater quality.

1.13 Management zones that are not based on catchment boundaries or that result in catchments being divided among different zones can create problems that may prevent water quality outcomes being achieved.

1.14 There are some anomalies in the classification of nutrient allocation zones.

1.15 The in-house expert panel process used to define water quality nutrient status and define allocation zones is not transparent and seems not to have been peer-reviewed.

1.16 The water quality outcomes approach seems reasonable, although more reactive than a procedure based on concentration limits for nutrients, sediment and faecal indicator organisms.

1.17 Care should be taken in determining point and non-point (diffuse) pollution in order that pollutants are managed effectively in order to meet the water quality outcomes.

1.18 Nutrient management of farms is based on managing nitrogen leaching as calculated by the Overseer model. Workshop findings show that: soil drainage characteristics have a huge bearing (light v heavy soils) on leaching rates; land uses with leaching rates below 20 kg N/ha/yr are unlikely to have concentrations of nitrate-N that exceed the drinking water guideline; increased N leaching rates, either as a result of more intensive farming following irrigation (other than for medium-heavy soils), or irrigated farming of any sort on highly permeable, light-very light soils, will cause high concentrations of nitrate-N to be leached.

1.19 Nutrient-loss management based on modelled N leaching will not provide adequate management for other pollutants (viz. phosphorus, sediment and faecal microbes). These will require a suite of good management practices (GMPs) to be deployed according to catchment objectives and designed to mitigate each pollutant according its biogeochemical properties. There is ample literature describing the efficacy and the cost-effectiveness of a large number of GMPs for use in New Zealand.

2. CATCHMENT MANAGEMENT AND NUTRIENT ALLOCATION ZONES

2.1 Catchment-based management is a widely accepted way of ensuring that the effects of land uses on water quality are understood and able to be managed. Research has shown that integrated catchment management is the best way to achieve a balance between the competing demands of agricultural production and water quality standards (Dodd et al. 2009). An understanding of soil properties, climate and topography can be integrated with land use data to provide catchment-specific rules and to identify key sources of water pollution and good practices for mitigating their effects. For example, contribution source areas (CSAs) are wet soils having a high degree of connectivity with streams and other water bodies. A good management practice (GMP) is to not apply fertilisers like superphosphate near CSAs and thereby avoid unwanted inputs of phosphorus. Riparian wetlands can provide nitrogen removal via the process of denitrification and it is good practice to protect this function by excluding livestock with permanent fences, and by not draining wetlands. The focus on catchment management by Environment Canterbury (ECan) in the plan is therefore supported.

2.2 Water quality degradation of sensitive coastal lakes and wetlands (e.g. Te Waihora/Lake Ellesmere and Wainono Lagoon) is usually best remedied by managing land use in the catchment to reduce pollutant loads. Coastal marine waters (notably estuaries and lagoons) are especially sensitive to nitrogen (N), whereas most freshwater lakes are more sensitive to inputs of phosphorus (P), with respect to eutrophication. In other waters, sediment or faecal matter may be the key pollutants that degrade water quality and limit their uses. The Waikakahi Stream is an example of a lowland stream that has been affected by excessive sedimentation (Meredith et al. 2003; Monaghan et al. 2009). Waters in coastal areas near river mouths used for bathing may be affected by the risk of infection caused by faecal pollution that derives from agricultural sources (Ross and Donnison 2003). Managing the quality of lowland and coastal waters is best achieved by managing activities in their catchments and, where necessary, developing catchment plans that relate land use to a range of water quality targets. These usually include managing N, P, sediment and faecal indicator organisms (in order to manage risk of infection by pathogens).

2.3 Water used for irrigation often affects water quality downstream. The simple mechanism here is that irrigation promotes more intensive land use with increased leaching and runoff losses of potential contaminants. For pastoral agriculture (e.g. intensive dairying) these contaminants are N, P, sediment and faecal microbes. Arable farming may yield increased amounts of sediment and nutrients. Research and experience shows that receiving water quality is best managed by minimising the amount of water used for irrigation. This can be done either by increasing the efficiency of irrigation (i.e. reducing wastage) or by reusing water so that the total volume of water leaving irrigation areas is as little as is practicable (Wilcock et al. 2011). Furthermore, loads entering lakes and coastal lagoons that are sensitive to eutrophication and other pollution may occur in flood flows (viz. P, sediment and faecal microbes). Nitrogen losses from pastoral agriculture are highly seasonal. Summer stream flows have low N concentrations because there is little leaching from dry soils at that time, and because aquatic plants (viz. periphyton) readily take up available N. As soils become wetter in autumn and winter, leaching of N increases and streams in pastoral catchments have characteristically high concentrations of N forms (viz. nitrate) during July-September, and decline with the onset of spring. Concentrations of contaminants are of greatest importance for river and groundwater quality (stimulate periphyton growth, breach drinking water and bathing standards), whereas loads are more important for lentic waters, like lakes and lagoons that are prone to eutrophication. In both cases it is important to have an understanding of flows (water quantity) in order to calculate likely dilutions (concentrations) and loads (concentration X flow). Flows will vary between catchments because of area, and geoclimatic factors that affect rainfall-runoff relationships. Thus, a water quality management is best done by catchments, with an understanding of land use and water quantity (hydrology).

2.4 Not all of the management zones in the pLWRP are strictly along catchment boundaries and some large rivers (e.g. the Waimakariri) have been split into more than one zone. While there are some practical reasons for doing this, owing to the size of the catchment and the distinction between the mountain headwaters and the lowland reach, it does not favour integrated management. Thus, lowland tributaries having water quality outcomes not being met will be treated separately from waters of the same river, where upstream water quality is good.

2.5 In the case of the Waimakariri River, the lower reaches are used for recreational activities (viz. boating and fishing) and should be managed by consideration of land uses throughout the catchment. For example, lowland farming activities should be managed in the lower catchments to prevent the occurrence of nitrate concentrations that are harmful to aquatic life (viz. salmonids) (Camargo et al. 2005; ECan 2009). In order to maintain contact recreation standards in the lower Waimakariri and other similarly large rivers it will be necessary to manage the risk of infection by pathogens (e.g. *Salmonella*, *Campylobacter*) by ensuring cattle are fenced out of riparian zones and other areas with high connectivity to water bodies. Given that the dominant land use may be dairy farming with groundwater nitrate leaching rates of 30 or more kg

N/ha/yr and high levels of faecal indicator organisms in runoff, there should be a focus on managing lower catchment zones where water quality outcomes are not met so that use of the lower Waimakariri River is not impaired.

2.6 It may be possible for a discharge within a zone that is not fully allocated for nutrients (i.e. a green zone or orange zone on the Nutrient Zone map on p.4-8 of the proposed plan) to adversely affect water quality in a fully or over-allocated (red) zone.

2.7 A major feature of the proposed pLWRP is managing and mitigating runoff from irrigated intensive agricultural activities, including dairy farming. In order to maintain water quality in the region it would be helpful to have some soundly based principles (high-level rules) that ensure that water quality will not be degraded in the region. These would give overarching guidance to the sub-regional plan process and resource consents process to make their decisions on the sensitivity of the receiving waters. A possible approach would be that adopted in the Horizons Regional Council One Plan where water values were defined and water quality standards derived to protect those values. Waters with high recreational and aesthetic values, for example, are managed to minimise the extent of periphyton blooms by setting N and P objectives (concentrations) that are in turn used to define appropriate land use limits within the relevant catchments (consistent with recommendations of the Land and Water Forum 2012).

2.8 It would be useful to adopt some high-level guidelines that protect waters already not meeting water quality outcomes but located within zones that have higher potential nutrient allocation from further degradation, by requiring some initial monitoring of water quality and land use as for the over-allocated (red) zones. One approach might be to set concentration standards for N, P, suspended sediment (or visual clarity or turbidity) for each catchment, based on guidelines, State-of-the Environment monitoring by ECan and consideration by an expert panel of what reasonable targets might be, in an open and transparent way with appropriate peer review.

2.9 Nutrients in the PLWRP are to be managed in Nutrient Allocation Zones where general rules apply. The status of these zones (outlined in

Appendix 6 of the Section 32 report) originates from recommendations made by an internal ECan panel that based their decision on "expert opinion of perceived nutrient state of the management units". The findings of this panel do not appear to have been peer-reviewed. I agree with the comment made by Shirley Hayward (Memorandum to DairyNZ in submission C12C/116563) that there is insufficient detail in Appendix 6 to enable close examination of how nutrient status was assigned for each zone, or the uncertainties resulting from the process. It would be helpful to know the ranges of water quality variables that were used to assess each zone and the degree of overlap between zones having a different nutrient status, as well as the spatial variations within zones.

2.10 In Appendix 6 of the Section 32 Report, the risk of having a broad brush approach to zone management is justified as acceptable because it will ultimately be superceded as more detailed sub-regional plans are developed. Ms McIntyre will comment on the planning merits of this sort of approach. From a scientific point of view I have some concerns – not the least of which is ensuring that any of the more detailed sub-regional plans are developed using accurate scientific information on the state of water quality in each catchment and correct information on causes and effects. I also question how the effects of land uses on water quality in each of these zones will be appropriately managed in the interim if the base scientific information used to classify the zones is not transparent or robust.

2.11 The process for defining management units outlined in Appendix 6 is hard to follow. The authors say that zone boundaries were defined primarily by an understanding of nutrient transport and source-sink relationships, rather than just relying on net water movement. I take that to mean that water quality outcomes will be met by considering all connected surface and groundwater catchment areas, rather than just the surface catchment. Is it known where all the contributing groundwater originates from, in order to manage land use to meet water quality outcomes? If so, it would be helpful to have supporting documentation.

2.12 The authors of Appendix 6 made the decision not to apply standards, such as the periphyton guidelines (MfE 2000) and the ANZECC (2000) guidelines that were deemed to be too limiting for further land use development. There is a need for greater transparency about how the Nutrient Allocation Zone boundaries were determined and why the guidelines were rejected other than being too "conservative and unrealistic". This appears to be a value-based assumption that the conventional water standards approach limited resource use too much.

2.13 A useful summary of some of the methods reviewed is given in Table 1 of Appendix 6 but raises questions about why some of the methods cited were not developed further. For example, it is well known that plant biomass in macrophyte-dominated lowland streams is relatively insensitive to changes in nutrient management but does respond to riparian shade (Wilcock et al. 2002).

2.14 Receiving water sensitivity is referred to but not defined in Appendix 6 in relation to the management zones. Again, reference to supporting documentation, preferably peer-approved, would be helpful in understanding how the nutrient status approach will provide protection for waters in increasingly developed catchments.

2.15 The Waikakahi catchment is shown in the Nutrient Allocation Zone map (Appendix 6, Section 32 report) as 'red' (water quality outcomes not met) whereas surrounding catchments are shown as 'green' (meeting water quality outcomes). These catchments are in the lower Waitaki River valley and some (viz. the Waikakahi) are within the Morven-Glenavy-Ikawai irrigation scheme and would be expected to have similar water quality. The scheme comprises a mix of border dyke and spray irrigation that mostly supports intensive dairy farming. The Waikakahi Stream has been studied by ECan and others since 1995 and has high concentrations of N, P and faecal microbes during the irrigation season and previously had very large inputs of sediment originating from heavily stocked paddocks (Meredith et al. 2003; Monaghan et al. 2009). It is highly likely that other streams in neighbouring catchments, also having irrigated dairying as their dominant land use, will have similarly affected water quality but have simply not been monitored as extensively. Shirley Hayward (DairyNZ in submission C12C/116563) points out that Whitneys Creek, in a catchment adjacent to the Waikakahi Stream catchment, has particularly elevated concentrations of dissolved P but 'meets water quality outcomes'. Both Whitneys Creek and Waikakahi

Stream have similar nitrate N concentrations that are lower than areas classified only as ‘at risk’. Both streams are in catchments with similar land uses (predominantly irrigated dairy farming) but it is not clear why they are treated differently with respect to nutrient allocation zoning.

3. WATER QUALITY OUTCOMES AND STANDARDS

3.1 Tables 1a, 1b and 1c of the proposed PLWRP (Volume 1) list outcomes for rivers, lakes and aquifers in Canterbury. These outcomes are a mix of water quality variables (e.g. minimum dissolved oxygen, maximum temperature), indices and observations (e.g. QMCI, TLI, % macrophyte cover) and narrative standards (e.g. suitability for contact recreation). This approach obviates having a large number of numerical standards based on water concentration for many catchments having a range of sensitivities. It is reactive in that it is based upon outcomes.

3.2 For example, a major periphyton bloom (of filamentous algae) in a particular river might signal an increase in inputs of N and P. By contrast, stipulating concentration standards might be more proactive in alerting Environment Canterbury to the likelihood of a periphyton bloom occurring. But, this would depend on timing of measurements and observations. The numerical values given in Tables 1a to 1c seem to confer reasonable protection for waters in each of the management classes.

3.3 The choice of the % macrophyte cover criterion in Table 1a (p4-1, volume 1) is novel and not one that I am familiar with for evaluating river conditions. It is commonly used as an approximate way of assessing plant biomass. I am assuming that the macrophytes referred to are exotic, nuisance plants like *Egeria densa* and *Lagarosiphon* that thrive in open, well-lit locations with elevated sediment nutrient concentrations (Barko and Smart 1983; Wilcock et al. 2002). These nuisance macrophytes tend not to respond to changes in N and P concentrations in agriculturally developed catchments because uptake by the plants is mostly from enriched sediments. Plant vigour and growth is more likely to be controlled by physical variables like available sunlight and frequency of freshes and floods, and seasonal growth patterns. Thus a weedy reach of a river may stay that way no matter what controls are placed on N and P, but will lessen in extent if riparian shade plants are established. The effectiveness of shading in controlling unwanted water weed growth depends on the height of the riparian shade plants and the width of the stream channel (Collier et al. 1995).

3.4 I concur with Shirley Hayward's assessment (DairyNZ in submission C12C/116563) of the outcome criteria (Tables 1a-c) that the method is pragmatic and integrative and provides a useful basis for evaluating community aspirations, but that some indicators will need to be re-evaluated in future. For example, the QMCI index for evaluating stream health by assessing the range and numbers of invertebrate species is one of many such methods and there is no consensus about which is best. Agreement between assessment methods is not always good.

3.5 Point-source pollution management is covered by the water standards in Schedules 4 and 5. Point-source pollution is generally very much less than diffuse (nonpoint) source pollution, overall, but often has significant localised impacts. Some authorities regard diffuse sources according to the origins so that, for example, land drainage over a wide area would be regarded as being diffuse source even though it may enter a stream drain. Others regard point sources as any input to a water body from a single location, so that a farm drain would be considered a point-source by that definition. Surface and subsurface drains may receive large inputs of farm dairy effluent and be highly polluting to receiving surface waters (Ross and Donnison 2003; Monaghan et al. 2007) but be regarded as diffuse sources and not be regulated according to Schedules 4 and 5.

3.6 Receiving water standards for waters not classified as NATURAL are given in Schedule 5 and are based on median values taken from a report by Hayward et al. (2009). The maximum permissible DIN value of 1.5 mg/L is consistent with streams in an irrigated dairy farming landscape rather than less intensive land uses. DIN (dissolve inorganic nitrogen) nearly all comprises nitrate-N and the Schedule 5 DIN standard for spring-fed plains streams is close to the ECan chronic exposure guideline of 1.7 mg/L for 95% protection of aquatic species (ECan 2009; Wilcock et al. 2011). It was not clear if Schedule 5 refers to median concentrations or some higher percentile but it is quite possible that there may be protracted periods when DIN concentrations are close to or exceed the toxicity guideline used by ECan.

3.7 The microbial concentrations in Schedule 5 are also consistent with dairy farming as the dominant land use and are close to limits for contact recreation (95% of samples to have *E .coli* concentrations not greater than 550 per 100 ml). They may be inconsistent with the aspirational outcomes in Section 4 of the pLWRP. Concentrations in five dairy catchments monitored over 7-12 years had median concentrations of 400-1200 and mean concentrations of 1000-2700 *E. coli* per 100 ml (Wilcock et al. 2007). The receiving water standards in Schedule 5 are consistent with typical water quality in intensively farmed catchments rather than seeking to have improved water quality in the region.

4. NUTRIENT MANAGEMENT AND GOOD PRACTICE

4.1 Nutrient management is based on nitrate leaching rates (kg N/ha/yr) calculated using the Overseer model. A series of workshops were held in Christchurch in 2008-09 to address ways of estimating nitrate-N leaching rates in rural Canterbury.

4.2 The report summarising the workshop findings (Lilburne et al. 2010) concluded that:

a. There are many difficult issues in estimating nitrate-N leaching rates for the main land uses on different soils and rainfall zones, including the rarity of good long term measured data, which means that models cannot be reliability calibrated for Canterbury conditions.

b. An expert approach was used to extend the Lincoln University Dairy Farm data to a range of soils, climates and other land uses. More data on both drainage and nitrate-N leaching rates is required, particularly on the shallow and stony soils. This will contribute to improvements in models such as Overseer® and Spasmo.

c. In the meantime, the values in this report are a reasonable starting point to gain an understanding of the regional implications of land use in relation to nitrate-N leaching.

d. An important point that was raised and agreed by participants at the Caucus Workshop was that while these values are suitable for exploration of regional or large catchment scale land use scenarios and for screening the effects of proposed changes in land uses, they are not suitable for use at the farm scale (e.g. in a consent process) as these values are simple long term annual estimates that do not take into account the many management practices that can minimise or add to the actual leaching. Also the extrapolation does not take into account the feasibility of some of the soil/climate/land use combinations.

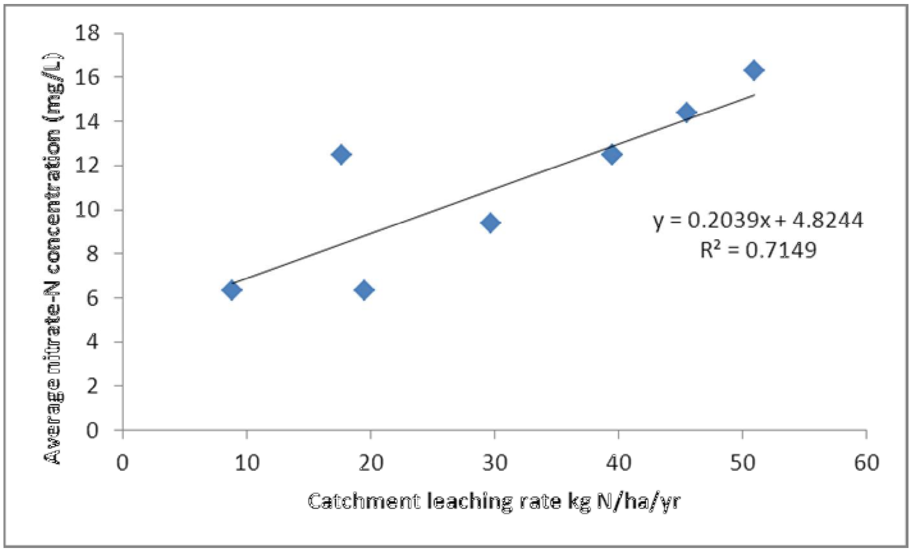
4.3 Differences between soil types have a major bearing on leaching rates, as shown in Table 1 (below) for three regions in Canterbury. It is worth noting that all the modelled nitrate-N leachate concentrations exceed the Table 1c (desired) outcomes average of 'not more than 5.6 mg/L for shallow groundwater predominantly recharged by soil drainage (p4-4, volume 1).

Table 1. Summary of modelled nitrate leaching rates in Canterbury (from ECan Report R10/127). Leaching rates are in kg N/ha/yr and range from medium-heavy soils (minimum rates) to extremely light soils (maximum rates).

Land use	Irrigation	Lincoln	Darfield	Hororata	Conc. (mg N/L)
Dairy 3 cows/ha	Spray irrigation				
winter off		14-38	17-42	20-47	9.4
winter on		19-50	23-56	26-63	12.5
Dairy 4 cows/ha	Spray irrigation				
winter off		19-50	23-56	26-63	12.5
winter on		24-65	29-73	34-81	16.3
Dairy 5 cows/ha	Spray irrigation				
winter off		22-58	26-65	30-72	14.4
100% beef	Dryland	10-20	13-23	15-25	12.5
	Spray irrigation	19-50	23-56	26-63	12.5
100% sheep	Dryland	5-10	6-11	8-13	6.3
	Spray irrigation	9-25	11-28	13-31	6.3

4.4 The modelling predicts that the land uses with average N leaching rates not greater than 20 kg N/ha/yr are: un-irrigated (dryland) sheep, deer and beef farming; spray irrigated sheep farming and irrigated dairy farming on medium-heavy soils where cows are wintered off and average grazing rates are up to 4 cows/ha. Those land uses with leaching rates that are well over the 20 kg N/ha/yr rate are: irrigated dairying, sheep and beef farming on light-very light soils.

4.5 The relationship between modelled N leaching rates and average concentration of nitrate-N leached from Table 1 is shown in Figure 1, where mid-points of each leaching rate range have been plotted against concentration.



The model results in Figure 1 show that a groundwater nitrate-N concentration of about 11.3 mg/L, as specified in Table 1c of the PLWRP volume 1, corresponds to a leaching rate of about 30 kg N/ha/yr. Because the graphed results in Figure 1 are the mid-points of ranges in Table 1, there is quite a spread of uncertainty in the relation between concentration and leaching rate. Nonetheless, the modelling results in ECan Report R10/127 (Lilburne et al. 2010) and the trend of increasing nitrate-N concentration with N leaching rate enable some generalisations to be made about the relationship between land use and nitrate concentrations in leachate. Land uses that with leaching rates less than 20 kg N/ha/yr are unlikely to have concentrations of nitrate-N that exceed the drinking water guideline of 11.3 mg N/L but may exceed the requirement in Table 1c that the average is not greater than 5.6 mg/L. Leaching rates of 30 or more kg N/ha/yr will on average concentrations exceed outcome values for shallow groundwaters. Increased N leaching rates, either as a result of more intensive farming following irrigation (other than for medium-heavy soils), or irrigated farming of any sort of highly permeable, light-very light soils, will cause high concentrations of nitrate-N to be leached.

4.6 The approach of managing nutrient losses by managing nitrate relies on the assumption that ‘good management practices’ (to manage diffuse source inputs of nitrate) will effectively limit inputs of the other major agricultural pollutants (P, sediment and faecal matter). Some good management practices (GMPs) are described in Activity and Resource

Policies of the PLWRP, including stock exclusion from waterbodies and wetlands. There is a substantial amount of literature on ways of mitigating the effects of different kinds of agriculture on water quality degradation. These can be considered as comprising three broad classes: those that treat the problem at source (stock management, effluent disposal etc.), those that intercept contaminants along hydrological pathways that connect land with water (e.g. riparian management zones) and those that remedy problems in receiving waters (e.g. lake sediment capping to prevent P recirculation, bottom-of-catchment wetlands for trapping and removing pollutants). A discussion of the efficacy and the cost-effectiveness of a large number of GMPs for use in New Zealand is given by McKergow et al. (2007).

Dr Bob Wilcock

4 February 2013

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