IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of the proposed Variation 2 to the Proposed Canterbury Land and Water Regional Plan - Section 13 Ashburton

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STATEMENT OF PRIMARY EVIDENCE OF SHIRLEY ANN HAYWARD FOR FONTERRA CO-OPERATIVE GROUP LIMITED AND DAIRYNZ LIMITED

15 MAY 2015

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CONTENTS

1. EXECUTIVE SUMMARY 3

SUMMARY OF KEY DIFFERENCES BETWEEN ENVIRONMENT CANTERBURY MODELLED SOLUTION (VARIATION 2) AND DAIRYNZ/FONTERRA SOLUTION 4

2. INTRODUCTION....5

3. SCOPE OF EVIDENCE 7

4. OBJECTIVES OF WATER QUALITY RULES....7

5. ENVIRONMENT CANTERBURY'S MODEL - OUTCOMES AND DEFICIENCIES....16

6. DAIRYNZ/FONTERRA'S MODEL - OUTCOMES AND BENEFITS 20

7. TECHNICAL EVIDENCE IN SUPPORT OF ALTERNATE STAGING OF REDUCTIONS 26

8. GIVING EFFECT TO THE PROPOSED NUTRIENT MANAGEMENT APPROACH 27

1. EXECUTIVE SUMMARY

1.1 I broadly agree with the water quality outcomes and objectives sought for the Hinds/Hekeao Plains Area. I agree with the specific nitrate targets set for groundwater and surface water quality as long-term targets, providing appropriate reviews are undertaken at regular intervals (at least by 10 year intervals).

1.2 In my view the nitrogen load limit proposed in Variation 2 (as notified) is not appropriate because it is based on a model that greatly underestimates current farming nitrogen losses, and, therefore, the reductions from existing land uses that would be required to achieve 3,400 tonnes of nitrogen are considerably greater than that considered by the Ashburton Zone Committee.

1.3 Using the updated estimates of nitrogen losses, I have explored scenarios that provide for a combination of realistic irrigation development, flexibility for low emitters and significant reductions from high emitters. I consider that the reductions in groundwater nitrate concentrations sought in the Ashburton ZIP Addendum can still be achieved with the proposed DairyNZ/Fonterra solution and therefore, the related water quality outcomes can also be achieved assuming other components of Variation 2 and relevant recommendations in the Ashburton ZIP Addendum are implemented The target nitrogen load for the Lower Hinds/Hekeao Plains Area that achieves these outcomes is likely to be in the range of 3,800 to 4,500 tonnes of nitrogen.

1.4 I have set out in the table below a summary of how, in my opinion, the DairyNZ/Fonterra solution can achieve the target of 9.2 mg/L root zone nitrate nitrogen concentration by the same time as that required by Environment Canterbury.

SUMMARY OF KEY DIFFERENCES BETWEEN ENVIRONMENT CANTERBURY MODELLED SOLUTION (VARIATION 2) AND DAIRYNZ/FONTERRA SOLUTION

Environment Canterbury - Variation 2						
ECan's 2011 land use data Scott 2014 model			**ECan's Variation 2 provisions Scott 2014 model**			
	Area (hectares)	Load (tonnes nitrogen)		Area (hectares)	Load (tonnes nitrogen)	**Change in N load or N concentration**
Existing land use not earmarked for development	97,000	3,928	Existing land use subject to GMP and further reductions	97,000	2,701	-1,227 t N -31%
			Reductions required: 45% dairy and 25% for dairy support down to 20 kgN/ha/yr			
Drylandand earmarked for irrigation conversion	30,000	596	Land earmarked for irrigation conversion - baseload	30,000	596	0
			Load allocated for conversion to irrigated dairy/dairy support/arable		214	+214 t N
Total	**127,000**	**4,524**	**Total**	**127,000**	**3,511**	**-1,013 t N -22%**
Predicted groundwater concentrations			**Predicted groundwater concentrations**			
Drainage volume	Mm^3/yr	364	Drainage volume	Mm^3/yr	350	
Root zone nitrate concentration	mg/L	12.4	Root zone nitrate concentration	mg/L	10.0	-19%
Predicted average nitrate concentrations in shallow groundwater	mg/L	12.4	Predicted nitrate concentrations in shallow groundwater	mg/L	9.2	-26%
DairyNZ/Fonterra proposed solution						
DairyNZ - 2013 land use using DNZ/Overseer 6.2 model			**DairyNZ/Fonterra solution -using DNZ/Overseer 6.2 model**			
	Area (hectares)	Load (tonnes nitrogen)		Area (hectares)	Load (tonnes nitrogen)	
Current land use - not earmarked for development	82,535	5,772	Existing land use subject to GMP and further reductions	82,535	3,639	-2,142 t N -37%
			Reductions required: 36% for all properties > 20 kgN/ha/yr down to 20 kgN/ha/yr			
Area earmarked for irrigation conversion	15,000	339	Area earmarked for irrigation conversion	15,000	461	+122t N
Low N farmland (<20 kgN/ha/yr) (assumed not going to irrigation development)	29,465	397	Low N farmland (<20 kgN/ha/yr) (assumed not going to irrigation development) PA flex to 15 kgN, RDA flex to 20 kgN (limit 17t N)	29,465	479	+82 t N
Total	127,000	6,508	**Total**	127,000	4,579	-1,929 t N -30%
Drainage volumes and nitrate concentrations			**Drainage volumes and nitrate concentrations**			
Drainage volume	Mm^3/yr	469	Drainage volume	Mm^3/yr	469	
Root zone NO_3N concentrations from DNZ/Aqualinc and DNZ/Overseer 6.2 models	mg/L	11.2-13.9	Root zone NO_3N concentrations from DNZ/Aqualinc and DNZ/Overseer 6.2 models	mg/L	8.1-9.7	-28 to -30%
Predicted average nitrate concentrations in shallow groundwater	mg/L	13.2	Predicted average nitrate concentrations in shallow groundwater (assuming no changes to drainage inputs)	mg/L	9.2	-30%

2. INTRODUCTION

2.1 My full name is Shirley Ann Hayward. I hold the qualifications of Bachelor of Science in Plant and Microbial Sciences and Master of Science in Environmental Science. I am a member of the New Zealand Freshwater Sciences Society. I am currently employed as a Water Quality Specialist for DairyNZ Limited ("**DairyNZ**").

2.2 In my current employment with DairyNZ I provide technical expertise on water quality issues relating to the impacts of dairy farming, and provide input into various regional council policy and planning processes. I was co-leader of the science team for the Land Use and Water Quality Hurunui pilot limit-setting project, in which the science team provided technical analysis of catchment water quality, hydrological and ecological issues and options for input into stakeholder and governance group deliberations. I am currently leading a study on five Otago dairy farms that investigate their ability to comply with the Plan Change 6A Schedule 16 water quality discharge thresholds.

2.3 I was previously employed by the Canterbury Regional Council for 16 years in a succession of roles including Microbiologist, Groundwater Quality Officer, Environmental Quality Analyst and Surface Water Quality Scientist. Over an 11 year period with Environment Canterbury I was involved with, and managed, groundwater quality, river and lake water quality and ecological monitoring programmes and investigations. I have authored numerous peer reviewed technical reports on groundwater quality, river and lake water quality and aquatic ecosystem health.

2.4 During my time as a Surface Water Quality Scientist I was the project manager for the coastal lakes water quality monitoring programme and managed several studies relating to water quality and ecology of Te Waihora/Lake Ellesmere. I was also involved with developing a set of recommendations to the Panel hearing submissions on the Natural Resources Regional Plan in relation to river and lake management units and indicators and numeric criteria for water quality objectives and discharge standards.

2.5 I was also employed as a consultant with Pattle Delamore Partners in 2012/13, during which time I managed investigations into the impacts of the Christchurch earthquakes on the hydrological and ecological

functioning of the Wairarapa Stream in Christchurch, and completed a review of regional groundwater quality for the Horizons Regional Council.

2.6 My relevant experience also involves the preparation of evidence for hearings in relation to aquatic ecology and water quality matters in respect of the Proposed Canterbury Land and Water Plan ("**CLWP**") and the Proposed Variation 1 to the CLWP.

Background

2.7 My involvement in the proposed Variation 2 to the CLWP - Section 13 Ashburton ("**Variation 2**") commenced in July 2013 when I became involved in providing technical advice to the Hinds Plains Land and Water Partnership as well as undertaking a technical review of the water quality issues in the Hinds/Hekeao Plains Area for DairyNZ. I managed DairyNZ's contracts for the farm economic and nutrient analysis described by Mr Neal, catchment scale economic analysis described by Dr Bell and Dr Fairgray, and catchment nutrient modelling described by Dr Brown. I have undertaken water quality sampling of several of the Hinds drains in order to assist the Hinds Drains Working Party. I provided technical input to DairyNZ's and Fonterra's submissions and further submissions on Variation 2.

2.8 I am familiar with the provisions of Variation 2 to which these proceedings relate. In preparing my evidence I have reviewed the relevant parts of the section 32 report and the section 42A report.

2.9 I have also read the evidence of Mr Neal, Dr Fairgray, Dr Bell, Dr Brown and Mr Willis.

Code of Conduct

2.10 I have read the Code of Conduct for expert witnesses contained in the Environment Court's Practice Note as updated in 2014 and agree to comply with it. In that regard, I confirm that this evidence is within my area of expertise, except where I state that I am relying on the evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in this evidence. In respect of paragraph 7.2(b) of the Code of Conduct, I record that I am an employee of DairyNZ.

3. SCOPE OF EVIDENCE

3.1 My evidence is structured as follows:

(a) Objectives of water quality rules;

(b) Environment Canterbury's Nitrogen Load model - Outcomes and Deficiencies;

(c) DairyNZ/Fonterra's Nitrogen Load model - Outcomes and benefits;

(d) Giving effect to proposed nutrient management approach; and

(e) Technical evidence in support of other changes.

4. OBJECTIVES OF WATER QUALITY RULES

4.1 I have been asked to comment on the key water quality issues in the Hinds/Hekeao Plains Area and the relevant water quality objectives and limits proposed in Variation 2

Surface waterways

4.2 The key water quality issues have been described in the section 32 and section 42A reports. I largely agree with those issues identified, namely that nitrate nitrogen (NO_3N) concentrations in both shallow groundwater and groundwater-fed streams and drains are elevated and above relevant guidelines. Furthermore, concentrations have been trending upwards. I provide further details on this issue below. I also agree that other aspects of surface water quality such as concentrations of phosphorus, sediment and *Escherichia coli* (*E. coli*) are variable depending on local conditions, but generally the concentrations of these contaminants are higher than desirable in parts of the Lower Hinds River/Hekeao and coastal waterways.

4.3 I generally agree with comments by Meredith and Lessard (2014) that there has been a decline in habitat and water quality, and in flows in many of the coastal drains and streams. I also agree that despite the highly modified nature of the coastal groundwater-fed streams and drains, many of those waterways still support a range of native aquatic species. I consider a multi-pronged approach that addresses habitat, water quality

and flows is needed to improve the biodiversity and cultural values of the degraded waterways.

4.4 Variation 2 proposes a range of nitrate toxicity limits/targets for the three surface waterbody types listed in Table 13(j). These limits/targets represent levels of protection from chronic (non-lethal) toxicity risks to aquatic fauna based on the Hickey (2013) guidelines. They range from a 99% level of species protection for the very upper tributaries of the Hinds River/Hekeao (Hill-fed Upland), 95% level of species protection for most of the Hinds River/Hekeao and its upper tributaries (Hill-fed Lower) and 90% level of species protection for the coastal streams and drains (Spring-fed Plains).

4.5 The nitrate toxicity levels proposed in Table 13(j) also equate to the Attribute States in the National Policy Statement for Freshwater Management 2014 ("**NPSFM**") of A for the Hill-fed Upland, B for Hill-fed Lower and C for Spring-fed Plains river management units. The proposed nitrate toxicity target for Spring-fed Plains (annual median of 6.9 mg/L and annual 95th percentile of 9.8 mg/L) equate to the NPSFM National Bottom Line.

4.6 With particular focus in Variation 2 on nitrogen, I have further examined the nitrate concentrations in the rivers, streams and drains in comparison to the limits/targets proposed in Table 13(j). These assessments are based on water quality data obtained from Environment Canterbury. A description of the data and analyses along with the results are given in **Appendix 1**. Long-term monitoring data are available for five coastal groundwater-fed streams and drains. Four of these currently do not meet the targets in Table 13(j) and all five sites are showing increasing trends in nitrate nitrogen concentrations. In the case of Greenrock Race, nitrate nitrogen concentrations are lower than the other sites and remain below the annual median target of 6.9 mg/L. I understand this waterway receives significant inputs of low nitrate stock race water, thus diluting the groundwater inputs. This is an effective example of stream augmentation with low nitrate water.

4.7 The overall high nitrate concentrations in the coastal streams and drains reflect the dominant source of flow from nitrate-enriched groundwater. I agree with Dr Scott's conclusion that the concentrations of nitrates found

in many of the coastal lowland streams and drains are in the similar range to those found in the upgradient shallow groundwater (Scott 2013a).

4.8 Nitrate nitrogen concentrations in the Hinds River/Hekeao are lower than that found in the coastal spring-fed waterways. The upper reaches of the Hinds River/Hekeao have very low concentrations, typical of the upper reaches of hill-fed rivers in Canterbury. In contrast, nitrate concentrations in the Lower Hinds/Hekeao Plains Area are much higher than the upper reaches, and indicate a stronger influence of nitrate enriched groundwater inputs. The site at Lower Beach Road shown in **Appendix 1** currently does not meet the target proposed in Variation 2 for nitrate toxicity of 3.6 mg/L, nor does it even meet the target for Spring-fed Plains waterways of 6.9 mg/L.

4.9 While the nitrate toxicity targets proposed in Variation 2 will require considerable effort and lengthy timeframes to achieve, I consider the level of protection set for the three surface waterbody types are appropriate as long term goals for those river types, given their current biodiversity, degree of existing modifications, and potential opportunities for enhancements. Review of the appropriateness of these nitrate targets along with review of habitat and flow related objectives will be necessary at regular intervals (at least at 10 yearly plan review stages).

4.10 In addition to concerns with nitrate concentrations, other aspects of water quality are also important depending on the values sought for waterways. For example, at the request of the Hinds Drains Working Party, I also undertook water quality sampling of two drains (Taylors and Fords Road) to assess their potential to meet water quality expectations for suitability for gathering of mahinga kai (e.g., watercress). The results indicate that critical challenges for ensuring the suitability of these sites for mahinga kai gathering are having adequate water flows and considerable reductions in microbial inputs (most likely the need for stock exclusion and adequate riparian buffer zones for the main waterways), as well as reductions in nitrate concentrations.

Groundwater nitrate target

4.11 In addition to affecting streams, groundwater nitrate concentrations also affect the suitability of the groundwater as a drinking water supply. The Ministry of Health has set in the Drinking Water Standards for New

Zealand ("**DWSNZ**") a maximum acceptable value ("**MAV**") for nitrate nitrogen concentrations of 11.3 mg NO_3N/L for drinking water supplies. This is based on the risks to bottle-fed babies who drink formula made with the water. For this reason, the Ministry of Health has set the MAV based on a short term exposure risk (weeks for bottle-fed infants).

4.12 Because of the short-term risk, and the often highly seasonally nature of nitrate concentrations in shallow groundwater, water quality outcomes/limits set in the CLWP (and other plans) for nitrate concentrations in groundwater are often set as an average or median value at some threshold below the MAV. In the CLWP, this threshold is set at half the DWSNZ MAV of 5.6 mg/L which affords a high level of confidence that in most situations, seasonal peaks in groundwater nitrates would remain below the MAV of 11.3 mg/L.

4.13 The annual average nitrate nitrogen target of 6.9 mg/L proposed in Table 13(k) of Variation 2 is slightly higher than the CLWP, but still provides a moderate level of confidence that if the average groundwater nitrates concentrations achieved 6.9 mg/L (particularly averaged across the shallow groundwater system) then groundwater would still likely comply with drinking water standards MAV most of the time. At this level there would remain some risk that after particularly wet periods, or in localised hotspots, nitrate concentrations may not meet the DWSNZ MAV. It appears the Ashburton Zone Committee considered and accepted this situation in their recommendations (Ashburton ZIP Addendum 2014, section 32 report – section 7.3). Furthermore, achieving the target of an average nitrate concentration of 6.9 mg/L is a considerable improvement on current levels (see later sections for details of current groundwater nitrate concentrations).

4.14 The Ashburton Zone Committee sought a nitrate nitrogen target in the shallow groundwater of 6.9 mg/L to both provide for drinking water purposes and to ensure that in the long term the groundwater fed streams and drains could meet the National Bottom Line for nitrate toxicity. I agree with the reasoning behind the nitrate nitrogen target of 6.9 mg/L in shallow groundwater.

Current state in groundwater nitrates

4.15 I have analysed Environment Canterbury's groundwater quality monitoring data for the Lower Hinds/Hekeao Plains Area. This data is described in **Appendix 2**. Dr Scott used data from 13 wells that were sampled quarterly to determine average shallow groundwater nitrate concentrations (Scott 2013a). Based on Environment Canterbury's monitoring data, it is quite clear that there has been a widespread pattern of elevated (above drinking water standard MAV) and increasing nitrate concentrations in the shallow groundwater system over the past decade (**Appendix 2**). In particular, 13 of the 14 quarterly monitoring wells in the Lower Hinds/Hekeao Plains Area have had at least one sample transgress the drinking water standards MAV. Based on this data, I agree with the general conclusion in the section 32 report that groundwater nitrate concentrations are elevated and increasing.

4.16 One of the key issues is whether the quarterly monitoring wells fairly represent the "average" shallow groundwater nitrate concentrations across the Lower Hinds/Hekeao Plains Area, and whether it is appropriate to compare this data to modelled average nitrate losses.

4.17 Figure 1 below is taken from Dr Brown's evidence. It shows the modelled root zone nitrate concentrations (using the DNZ/Overseer 6.2 approximation method) overlaid with Environment Canterbury's quarterly monitoring wells. I consider that the two wells that are located outside of the Lower Hinds/Hekeao Plains Area should not be used to calculate average concentrations for the area. Of the remaining wells 11 wells, (blue dots on the map below) that were used by Dr Scott, most are located in the areas of high nitrogen losses, while there was a lack of monitoring wells in the less developed or low nitrogen loss areas. Consequently, the overall average concentrations based on these wells are likely to over-estimate the true average of the zone.

4.18 Environment Canterbury has recently revised its quarterly monitoring programme and have ceased monitoring 3 wells (light blue squares in Figure 1) and included three additional wells (green squares in Figure 1) (Dr Scott, pers. comm.). I consider these changes provide a better spatial coverage of the inland plains and coastal areas and overall provide a good representation of average shallow groundwater nitrate concentrations. We only have one complete set of annual data for this

revised set of monitoring wells, which gives an average nitrate nitrogen concentration of 10.9 mg/L for the period July 2013 – June 2014.

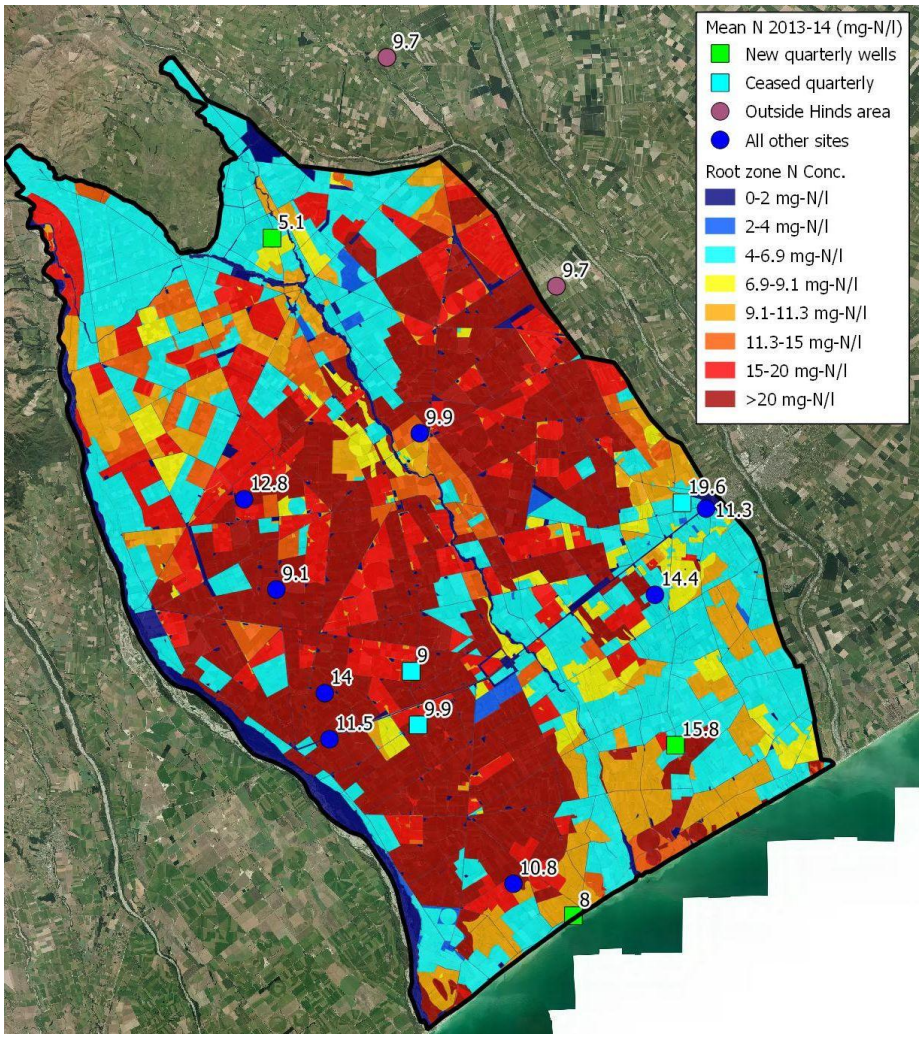


Figure 1 Map showing modelled root zone nitrate nitrogen concentrations and the location of Environment Canterbury's quarterly monitoring wells. The values beside each well location are the average nitrate nitrogen concentrations for 2013/14.

Trends in groundwater nitrates

4.19 I agree with Dr Scott's assessment that up to the early to mid 2000s, many of the long-term monitoring wells show a steady and moderate increase in nitrate concentrations (~0.1 mg NO_3N/L annual rate of increase). During the mid 2000s this annual trend increased markedly in many of the wells, but the point at which the rate of increase changes (point of inflection) varies among wells. Dr Brown reviewed this pattern along with patterns of land use change and changes in irrigation systems. His conclusions were that the lag time for the majority of land surface impacts to be measured in shallow groundwater are at most 3 to 5 years.

4.20 While Dr Scott (2013b) indicated groundwater ages for the shallow groundwater in the range of 10-20 years, I note also that Bower (2014) commented that:

> *The technical team also looked at indirect relationships with time series trends in concentration in groundwater relative to land use changes. That information seemed to suggest a relatively quick response (in order of a few years) to increased nitrogen leaching activities.*

4.21 The comments by Bower (2014) appear consistent with the Dr Brown's assessment based on land use and irrigation changes. I agree with Dr Brown and Bower (2014) assessments that groundwater nitrate concentrations, as measured in the shallow groundwater, responds over a short time period (a few years) to changes in land uses.

4.22 In attempting to assess likely time lags for the transport of nitrates into and within a groundwater system, it is important to understand that the age of groundwater abstracted from a well is an integration of a distribution of water of various ages drawn into the field of abstraction surrounding the well screen. The surrounding groundwater will comprise of waters of different ages due to differing travel paths and mixing processes. Different wells will have different age distributions (Stewart 2006).

4.23 While Dr Brown gives an estimate of the time taken for the majority of changes in nitrogen loss from land uses to be measured in shallow groundwater in the order of 3-5 years, there is likely to be a lingering effect beyond that timeline, where some groundwater flow paths will take longer to reach monitoring wells. At the same time, some flows paths will reach monitoring wells in much shorter timelines (months). The combined effect is that if nothing else changed we would expect the current trend of increasing nitrate concentrations resulting from recent land use and irrigation changes could peak within 3-5 years and that there would be an ongoing trend but at a declining rate.

4.24 Given the current measured average nitrate nitrogen concentration is 10.9 mg/L, the question remains by how much this will increase once the full effects of current land use has travelled through the shallow groundwater system. This is an extremely difficult question to answer without detailed information on changes in nitrate losses and drainage patterns, transport pathways and mixing processes. However, I have

attempted to give an indicative estimate using a simple extrapolation of current trends in concentrations over the 3-5 year time lag suggested by Dr Brown. The purpose of this is to determine the likely reduction in groundwater nitrate concentrations needed to achieve 9.2 mg/L, being the target concentration achieved by reductions in nitrogen losses from agricultural land in the Ashburton ZIP Addendum. The target nitrate nitrogen concentration of 6.9 mg/L in groundwater is expected to be achieved by catchment scale mitigations such as Managed Aquifer Recharge ("**MAR**").

4.25 Figure A4 in **Appendix 3** shows the pattern of increasing annual average nitrate concentrations based on the combined data from the 11 quarterly monitoring wells used by Dr Scott (2013a) (excluding the wells outside the Hinds/Hekeao Plains Area). The overall annual rate of increase in average nitrate concentrations across the monitoring period of July 2005 to June 2014 for those wells is about 0.57 mg NO_3N/L. While this rate of increase is likely an overestimate of the whole area and the trend is not likely continue at the same rate, I have conservatively applied this rate to the average nitrate concentration for the revised quarterly monitoring wells to give an indicative estimate of average concentrations expected from current land uses in Table 1 below.

4.26 This simple analysis suggests that the average measured shallow groundwater nitrate concentration from current land uses could reach up to, and possibly over, 13 mg/L (13.2 mg/L average). This value is within the range predicted in Dr Brown's modelled root zone concentrations for current land use (11.2 – 13.9 mg/L). Given there is likely to be some dilution of root zone nitrate concentrations from drainage from irrigation and stock water races, the predicted peak nitrate concentration of 13.2 mg/L in shallow groundwater is likely to be a worse-case scenario.

4.27 Based on this analysis, a reduction in shallow groundwater nitrate concentrations of 30% from current land use might be needed to achieve the target of 9.2 mg/L. It is assumed that MAR or other catchment scale mitigations will achieve the groundwater nitrate target in Variation 2 of 6.9 mg/L. If MAR or other mitigations were unable to be used, then reductions in groundwater nitrates in the order of 48% would be required to achieve the Variation 2 groundwater nitrate target of 6.9 mg/L. As stated above, being able to quantify and predict the changes in trends and ultimate peak nitrate concentrations is very difficult and highly

uncertain, and therefore, while attempting to do this, I would like to reinforce the uncertain nature of this assessment.

Table 1 - Estimates future measured annual average nitrate concentrations in the shallow groundwater of the Lower Hinds/Hekeao Plains Area. This is based on applying an annual rate of increase of 0.57 mg/L to the 2013/14 average measured values for the revised set of monitoring wells.

	Year	Annual average NO_3N (mg/L)	% reduction to achieve 9.2 mg/L	% reduction to achieve 6.9 mg/L
Measured annual average	2013-2014	**10.9**	**-16%**	**-37%**
	2014-2015	11.5	-20%	-40%
Predicted average based	2015-2016	12.1	-24%	-43%
on an annual increase of	2016-2017	12.6	-27%	-45%
0.57 mg/L	2017-2018	13.2	-30%	-48%
	2018-2019	13.8	-33%	-50%
Average of years 2016/17 to 2018/19		**13.2**	**-30%**	**-48%**

Root zone versus shallow groundwater nitrate target

4.28 In the Ashburton ZIP Addendum (and the section 32 report) the recommended nitrate nitrogen concentration for agricultural losses of 9.2 mg/L is made in reference to lowland water bodies (spring-fed streams), shallow groundwater and soil drainage interchangeably. I interpret this as a broad assumption that the modelled average nitrate concentrations in soil drainage (root zone drainage) is assumed to equal average shallow groundwater concentrations which will result in similar concentrations in the spring-fed (lowland) streams. This is an over-simplification of the relationships between those receiving environments, but is not unreasonable for the purposes of generally describing the intent of the target for agricultural losses and their impacts on the receiving environment.

4.29 An important likely difference in modelled root zone nitrate concentrations and shallow groundwater concentrations (putting modelling uncertainties aside) is the additional input of low nitrate drainage water from irrigation and stock water races as described by Dr Brown. However, it is uncertain whether this volume of drainage (and therefore) dilution will continue as races are upgraded and possibly piped in the future.

4.30 For the purposes of future "freshwater quality accounting" requirements it may be useful to be more specific when referencing target loads and concentrations. In the context of Variation 2, this might mean specifically referencing the targeted nitrate nitrogen concentration from agricultural losses in terms of "modelled root zone nitrate nitrogen concentrations". This approach provides a clear link with the modelled N loads (root zone nitrate concentration is a result of modelled N loads divided by modelled drainage volumes).

4.31 This also means that any dilution and attenuation processes such as drainage from irrigation and stock water races, denitrification enhancements, MAR, instream nutrient processing and targeted stream augmentation ("**TSA**") can be factored separately as part of the influences and mitigations for achieving the target nitrate nitrogen concentration of 6.9 mg/L for shallow groundwater and spring-fed streams.

4.32 For the purposes of my evidence, I have assumed that reductions required for shallow groundwater nitrate concentrations to reach 9.2 mg/L (30%) also applies to reductions required in modelled root zone concentrations. That is despite modelling uncertainty and ranges, if a reduction in root zone nitrate concentrations of 30% is achieved this will achieve an average shallow groundwater nitrate concentration of about 9.2 mg/L, assuming that additional drainage inputs are unchanged.

5. ENVIRONMENT CANTERBURY'S MODEL - OUTCOMES AND DEFICIENCIES

5.1 I have been asked to provide my understanding of how Environment Canterbury modelled the current and target catchment nitrogen loads and root zone nitrate nitrogen concentrations. This is largely based on two documents produced by Dr Scott (Scott 2013a, and Scott 2014).

5.2 Scott (2013a) describes the process of defining land use, based largely on the experience of local farm consultancy, MacFarlane Rural Business ("**MRB**"). Estimates of N losses and drainage values for the land use categories were based on Overseer modelling by MRB (using Overseer 6.0.3), and subsequent extrapolation over the range of soil/climate conditions in the Lower Hinds/Hekeao Plains Area by Dr Scott. As described by Dr Brown, it is now well acknowledged that Overseer

versions 6.0 and 6.1 had considerable shortcomings regarding predictions of drainage (and consequently N load) on irrigated land.

5.3 Tables 13 and 14 of Dr Scott's memorandum dated 3 April 2014 summarise the modelling of nitrogen loads, drainage volumes and drainage nitrate concentrations for the Lower Hinds/Hekeao Plains Area for current, Good Management Practice ("**GMP**"), mitigated and development scenarios. Dr Scott's (2014) memorandum provides updated estimates based on some adjustments to the mitigation strategies employed by MRB, and simplification of the land use categories. Dr Scott usefully provided detailed tables of area, N loads and drainage volumes in her memorandum that enabled replication of her model. Dr Scott's estimated a current load (based on 2011 land uses at GMP) of 4,480 tonnes of nitrogen that would result in an average root zone nitrate concentration of 12.3 mg/L (**Appendix 3**).

5.4 In modelling the solutions package by Dr Scott, it appears the mitigated N loads and drainage values were developed from the application of advanced mitigation ("**AM**") strategies referred to as AM1 and AM2 in the MRB (2014) report, rather than as a fixed percentage reduction. Examining the mitigated scenarios in the Scott (2014) model, the actual percentage reductions that resulted from applying AM1/AM2 to dairy was 51% and from applying AM1 to dairy support was 33% reduction. In addition, it appears Dr Scott's model assumed that the mitigations would apply to all dairy and dairy support farms, regardless of whether their losses were below the proposed 20 kgN/ha/yr permitted activity threshold in Variation 2. Dr Scott also included the additional development of 30,000 ha of land converted from predominantly dryland sheep and beef farms to irrigated dairy, dairy support and arable land uses. This represents an addition of 214 t N as a result of the 30,000 ha of development. I assume this approach was modelled to reflect the solutions package as described in the Ashburton ZIP Addendum, rather than the more specific provisions of Variation 2. This scenario resulted in a total catchment N load of 3,241 tonnes N and a root zone nitrate concentration of 9.3 mg/L, which is a 28% reduction in N load and 23% reduction in root zone nitrate concentration from her 2011 land use model at GMP.

5.5 Using the Scott (2014) model, I calculated the effects of the specific provisions in Variation 2 relating to nitrogen reductions in Table 13(h) and

irrigation expansion and intensification provisions (Rule 13.5.14). That is applying a 45% and 25% reduction to dairy and dairy support N load respectively down to the permitted activity threshold of 20 kgN/ha/yr. I assume based on the provisions in Variation 2 that properties, regardless of their land use, are not required to make reductions below 20 kgN/ha/yr. I also used the same land use development scenario of Dr Scott but limited new irrigation land use to a N load of 27 kgN/ha/yr. I did not assume, however, that drainage volumes would change as a result of load reductions scenarios because, in the Hinds/Hekeao Plains Area, increases in irrigation efficiencies that result in reduced drainage are likely to be counterproductive to achieving groundwater nitrate targets. I did include a small increase in drainage volume as the result of conversion of dryland to irrigated land (increase in ~200 mm drainage - on advice from Dr Brown). The resulting catchment load from applying Variation 2 provisions to Dr Scott's model is a load of 3,511 tonnes N and a root zone nitrate concentration of 9.5 mg/L. This represents a 22% reduction in the catchment load from the current load without development (Environment Canterbury's 2011 land use at GMP), and a 23% reduction in nitrate concentrations from Dr Scott's modelled current concentration of 12.3 mg/L (**Appendix 3**).

5.6 One of the basic concerns with the Scott 2014 model is that it is based on Overseer nitrogen losses and drainage values without any adjustments made for known deficiencies in the irrigation and drainage model as described by Dr Brown. The consequence of this approach is a considerable underestimate of total nitrogen loads and drainage volumes as illustrated in Dr Brown's summary of the differences in N losses and drainage values between models. Despite the differences in load estimates, there is very little difference in modelled root zone nitrate concentrations.

5.7 As a result of using the Scott (2014) model, the target load of 3,400 tonnes of nitrogen in Variation 2 is an underestimate of the load needed to achieve the root zone concentration target of 9.2 mg/L. That is the nitrogen load of 3,400 tonnes is likely to result in a root zone concentration of around 7.2 mg/L (using Dr Brown's more reliable drainage volume of 469 Mm^3/yr). If this nitrogen load is treated as an absolute number, then it is likely that farm scale reductions in the order of 50-55% would be required to meet this load.

5.8 In the section 42A report, a memorandum by Dr Scott and Mr Bower questioned the submission point by DairyNZ and Fonterra that the overall reductions in nitrogen loss indicated in Variation 2 from farming in the Lower Hinds/Hekeao Plains Area was flawed. This submission point was based on the above analysis. The point of difference between myself and Dr Scott and Mr Bower appears to be in defining the starting point. That is they assumed the starting point for determining reductions in nitrogen losses was assuming 2011 land uses plus 30,000 ha of new irrigation development unconstrained by a nitrogen cap. I assume this was on the basis that consents had already been granted for potentially up to 30,000 ha of new irrigation. My understanding of this is that at the time of notification of Variation 2, new irrigation was possible under the water use and land use consents held by Rangitata Diversion Race Management Limited ("**RDRML**") and Barhill Chertsey Irrigation Limited ("**BCIL**"), but this development was constrained by nitrogen limits on their respective land use consents. Because of that, in my opinion it was not appropriate to use an unconstrained development scenario as the starting point for any assessment.

Deficiencies in the broader approach

5.9 During the development of the Ashburton ZIP Addendum and Variation 2, it became apparent that there was a considerable discrepancy between the current and future N loads modelled by Environment Canterbury, and the nitrogen load limits that were included in a recently granted water use consent for RDRML (CRC121664). In the RDRML consent, the calculated average N loss per ha for their existing irrigators was around 3 times higher than that used for the Environment Canterbury catchment load modelling.

5.10 This discrepancy created considerable uncertainty and angst amongst the farming community based on my observations of meetings of the Hinds Plains Land and Water Partnership. Consequently it became apparent that a revised estimate of the current and potential future nitrogen load was needed. Ideally this would be based on a universally consistent approach (protocol) using the anticipated updated version of Overseer (Overseer version 6.2), but this was not available in time for evidence preparation. Instead, as described by Dr Brown, Aqualinc developed an updated estimate of current land use, irrigated area, and ultimately an estimate of the nitrogen load, land drainage volume and root

zone nitrate concentration making adjustments for drainage deficiencies in Overseer.

6. DAIRYNZ/FONTERRA'S MODEL - OUTCOMES AND BENEFITS

DairyNZ/Fonterra's model

6.1 Owing to the concerns raised by the Hinds Plains Land and Water Partnership group and my own review of Environment Canterbury's approach to setting a catchment nitrogen load limit, DairyNZ contracted Aqualinc to assist with developing an updated estimate of current land use, irrigated area, and ultimately an estimate of the nitrogen load, land drainage volume and root zone nitrate concentration for the Lower Hinds/Hekeao Plains Area. Dr Brown describes the approach taken by Aqualinc for this analysis.

6.2 The purpose of this work was to gain an understanding of the likely changes that will result from the anticipated update to Overseer including improvements in the drainage components of the model, and the effect of those changes on the relationships with groundwater nitrate targets. This work was not intended to produce an alternate catchment nitrogen load target for Variation 2. In my view, the development of a catchment N load target that would be linked to land use consents and assessments of nitrogen allocation status requires the development of an agreed set off land use categories, best available land use information and using a consistent version of Overseer with a regionally or nationally agreed input protocol.

6.3 In general the approach developed by Aqualinc is similar to Environment Canterbury's in that it was a GIS based analysis of land use descriptions overlaid with rainfall/soil/irrigation categories that were matched to a nitrogen/drainage look-up table that was established for the Hinds Plains Area.

6.4 As described by Dr Brown, any attempt to assess a catchment nitrogen load and resulting nitrate concentrations will inevitably have a number of associated and often unavoidable uncertainties. These include the specificity of land use information and estimates of N losses and drainage values for the different land uses and intensities across various soil and climatic conditions that exist in the study area

6.5 Dr Brown describes the source of land use information, which includes base land use data provided by Environment Canterbury. While we consider this to be an updated and improved assessment of current land uses in the Lower Hinds/Hekeao Plains Area, it is important to recognise that it is still a relatively coarse assessment of land use. However, it is not easy or practical to significantly improve the spatial or farm system information in the near future. I expect reporting requirements to increase for nutrient losses and for land use consents from agricultural land over the next 5-10 years. This will result in a considerable step up in the quality of land use information that can be used for more accurate catchment assessments and modelling than is possible at present.

6.6 A Hinds specific base look-up table was developed to provide a base input for N load and drainage values for the Aqualinc model. Details of the approach and assumptions used to develop the table of values, and the base 'look-up' table are provided in **Appendix 4**. As with land use information, this remains a coarse assessment of nitrogen losses from agricultural land. Adjustments made by Aqualinc improve this somewhat particularly in respect of estimates of drainage volume, but the overall catchment load estimates inevitably remain uncertain.

6.7 As described by Dr Brown, the Aqualinc/DairyNZ catchment model estimates a much higher current catchment load (ranging from 5,300 to 6,500 tonnes N) and modelled root zone nitrate concentrations in the range of 11.2 to 13.9 mg/L. The nitrogen load is considerably higher (15 to 45% higher) compared to the Scott (2014) estimate of 4,500 tonnes N for 2011 land use. Dr Brown explains these differences. While the differences in N loads appear large, the root zone nitrate concentration estimates are comparable with Scott (2014). Furthermore, my estimate of potential peak nitrate concentrations from current land use falls within the range of root zone nitrate concentrations modelled by Dr Brown.

Modelling effects of Variation 2 and alternative scenarios

6.8 I have been asked to use the data from the Aqualinc models to assess the effect of Variation 2 provisions and alternative scenarios as follows:

(a) Apply an even percentage reduction across all properties with N losses greater than 20 kgN/ha/yr (or reductions down to 20kgN/ha/tr, whichever came first) while maintaining the same

reductions in load as applying the 45% and 25% reductions to dairy and dairy support land (losing more than 20 kgN/ha/yr).

(b) Assuming a more realistic irrigation expansion scenario (15,000 ha of new irrigation) and including flexibility provisions that allow all properties with N losses below 15 kgN/ha/yr to increase to 15 gkN/ha/yr and allow properties with N losses between 15 – 20 kgN to increase up to 20 kgN/ha/yr

(c) Combinations of the above.

6.9 I have used the modelled data to determine the reductions required from properties under the various scenarios in order to achieve a 30% reduction in the average root zone nitrate concentration for each of the scenarios and each of the models. The 30% root zone reduction target is based on my assessment of the likely reductions needed in groundwater nitrates to achieve a concentration of 9.2 mg/L.

6.10 **Appendix 3** summarises this analysis and compares these scenarios to Environment Canterbury's modelled scenarios. I have included the results using both the DNZ/Aqualinc and DNZ/Overseer 6.2 models in **Appendix 3** to give an indication of the range of effects on loads and concentrations. However, I rely on the DNZ/Overseer 6.2 model results to draw my conclusion because it is likely to be more representative of losses using Overseer V6.2.

6.11 In order to determine a realistic irrigation development scenario, I have had to make assumptions about the area of new irrigation and resulting additional load that has been consented and is likely to be used by the two irrigation schemes that currently hold irrigation expansion consents (RDRML and BCIL). From discussion with these companies, I have used an area of 15,000 ha of new irrigation for the purpose of modelling a realistic irrigation development scenario. In addition, I have had to make an assumption about the N load that will result from this new irrigation. From RDRML's consent, they have been allocated a total load of 211 t N for expansion of irrigated area in the Lower Hinds/Hekeao Plains Area. The consent held by BCIL is less explicit about load that will be used in the Lower Hinds/Hekeao Plains Area. Following the discussions with BCIL, I have modelled a total load of 250 t N for their new irrigation. I have had to also infer their additional load as a result of the expansion

based on using a proportion of the total load consented to them compared to the total development load of 810 t N indicated in the Ashburton ZIP Addendum.

6.12 The area of new irrigation that I have modelled (15,000 ha) is within the range of realistic areas of irrigation expansion estimated by Dr Brown. Table 2 summarises my assumptions used for N load modelling purposes from discussions with these companies about the likely area of new irrigation and additional nitrogen loads.

Table 2 - Assumptions used to model realistic irrigation expansion in the Lower Hinds/Hekeao Plains Area *[1] – calculated as 57% times 596 t N (Environment Canterbury base load for development scenario)

Irrigation scheme - expanded irrigation loads (2013 consented expansion)	New irrigation area	Existing load	Consented/ agreed total expansion load (tonnes N)	% of 810 tonnes N	Proportion of 214 'additional' tonnes N (applying % of 810 tonnes N)
RDRML	7,800	unknown	211	26%	56
BCI	7,200	unknown	250	31%	66
Total	**15,000**	**339*[1]**	**461**	57%	**122**

6.13 Table 3 below summarises the modelling of flexibility provisions as described in paragraph 6.8 above. For the nitrogen load modelling I have assumed that all the area that fell below the two flexibility thresholds (except non-farming area) would increase up to the flexibility cap. This is a worse-case scenario, as it is likely that at least some of this land will either not intensify or will convert to irrigation using the irrigation schemes consent provisions. The area assumed to be intensified through these flexibility provisions in the economics modelling was more modest (22,000 ha as described by Mr Neal) so as not to overstate the economic benefits of the flexibility provisions.

Table 3 - Details of the flexibility provisions modelled for the DairyNZ/Fonterra proposed solutions. This data is based on the DNZ/Overseer 6.2 model results.

	Area (ha)	Irrigation	Area (ha)	Current load (~OVS6.2) (tonnes N)	Flexibility cap (kgN/ha/yr)	Load at 2 tiered flexi cap (tonnes N)	Additional load (tonnes N)
farming land at <15 kgN/ha/yr (excl. non	22,058	Dryland	14,643	172	15	220	65
		Irrigated	7,420	94	15	111	
Farming land losing 15-20 kgN/ha/yr	7,402	Dryland	2,400	41	20	48	17
		Irrigated	5,002	90	20	100	
Total low emitter flexibility load (combined)	**29,460**			**397**		**479**	**82**

6.14 In scenarios 1 and 2, I summarise the current N loads and root zone concentrations for the Scott 2014 and DNZ/Aqualinc and DNZ/Overseer 6.2 models as described by Dr Brown. In Scenarios 3 and 4, I include the additional load identified in the Ashburton ZIP Addendum as being available for further development (214 tonnes N additional load). This additional load increases the total current load by 3-4% and root zone nitrate concentrations by 3%.

6.15 In scenario 6, I analysed the effect of achieving a 30% reduction in modelled root zone nitrate concentrations through applying an even reduction (regardless of land use) for properties with losses above 20 kgN/ha/yr. This required a **33% reduction** in N losses for properties losing more than 20kgN/ha/yr.

6.16 Including the effect of the additional 214 tonnes N indicated by the Ashburton Zone Committee for further development results in existing properties needing to make a **36% reduction** in their N load, or reduce to 20 kgN/ha/yr, whichever came first in order to maintain a 30% reduction in root zone nitrate concentrations (Scenario 10).

6.17 Comparing the approach of even reductions of 36% for properties above 20 kgN/ha/yr (Scenario 10) to the approach in Variation 2 of 45% and 25% reductions applying only to dairy and dairy support (down to 20 kgN/ha/yr – Scenario 8) gave a very similar result in N load and both achieved the 30 % reduction in root zone nitrate concentrations.

6.18 Finally I calculated the combination of the following provisions:

(a) constraining new irrigation development to the area likely to be developed by RDRML and BCIL (15,000 ha) resulting in an additional 122 tonnes of N;

(b) including a provision flexibility of low emitters (those emitting less than 15 kgN/ha/yr) in increase their N losses up to 15 kgN/ha/yr; and

(c) including a provision for those emitting between 15 and 20 kgN/ha/yr to increase up to 20 kgN/ha/yr (Scenario 11).

6.19 This resulted in a load of 4,600 tonnes of N (using the DNZ/Overseer 6.2 data), and a predicted root zone nitrate concentration of 9.7 mg/L, which

is a 30% reduction from the modelled concentration for current land uses (i.e, 13.9 mg/L). The predicted root zone nitrate nitrogen concentration of 9.7 mg/L is very similar to that predicted with the Scott (2014) model of Variation 2 provisions (Scenario 7) of 9.5 mg/L, and is a greater relative reduction (30%) in root zone concentrations compared to Scenario 7 (23%).

6.20 This scenario (Scenario 11) is assumed to include the load that has already been consented as further development load to RDRML and BCIL consent holders. Some of which will have been taken up already since their consents were granted in 2013, but of which the remaining consented amount is expected to be taken up over the next few years. In constraining the development provision to half that anticipated in the Ashburton ZIP Addendum, there is capacity to provide low emitters with flexibility to respond to market changes and increase their production without being unfairly constrained (given they contribute overall a small proportion of the catchment N load). While this flexibility may benefit some dairy farmers on heavy soils (with N losses below 20 kgN/ha/yr), it is anticipated this provision will largely benefit non dairy farmers. This combined scenario can be achieved without increasing the reduction burden on those above 20 kgN/ha/yr (still targeting a **36% reduction**) while also achieving a 30% reduction in root zone nitrate concentration.

6.21 Based on this analysis, it appears that the alternative scenario of an even reduction of 36% for properties losing more than 20 kgN/ha/yr (or reduce down to 20 kgN/ha/yr), plus the realistic development scenario for the two irrigation schemes that currently have consents to expand, and flexibility provisions for low emitters will achieve at least the same outcomes in terms of reductions in root zone nitrate concentrations as the provisions in Variation 2 (as notified).

6.22 I consider that the reductions sought in the Ashburton ZIP Addendum groundwater nitrate concentrations can still be achieved with the proposed DairyNZ/Fonterra solution and therefore, the related water quality outcomes can also be achieved assuming other components of Variation 2 and relevant recommendations in the Ashburton ZIP Addendum are implemented. The target nitrogen load for the Lower Hinds/Hekeao Plains Area that achieves these outcomes is likely to be in the range of 3,800 to 4,500 tonnes of nitrogen.

7. TECHNICAL EVIDENCE IN SUPPORT OF ALTERNATE STAGING OF REDUCTIONS

7.1 I was asked to calculate the changes in N load and modelled root zone nitrate concentrations resulting over time from the staging of reduction regimes as described by Mr Neal. Table 4 below shows the changes in nitrogen loads and modelled root zone nitrate concentration for the two different staged regimes proposed by DairyNZ/Fonterra.

7.2 There is a very slight modelled increase in N load and concentration at the 2017 stage of implementation of GMPs because of the likely irrigation development that will be occurring in the intervening period, before the significant reductions regime takes effect. This estimate in N load reductions does not take into account reductions that are likely to occur as a result of widespread implementation of GMP. This is very difficult to quantify, in part because Overseer modelling assumes some degree of GMP, and in part because it is difficult to gauge current levels of implementation of GMP. It is likely to result in at least a few percentage reduction in N losses for many properties, and much greater changes for a few properties. If we conservatively assumed implementation of GMP resulted in an overall 1% reduction against current loads by 2017, the 64 t N reduced would offset the assumed 61 t N of increase load from irrigation expansion.

7.3 Overall, both of the reduction regime stages proposed by DairyNZ/Fonterra will result in a pathway of reducing overall catchment N loads and resulting root zone and groundwater nitrate concentrations.

Table 4 Summary of changes in N load and modelled root zone nitrate concentrations resulting from different staging of the reduction regime proposed by DairyNZ/Fonterra. The DNZ/Overseer 6.2 model version was used for this analysis.

Timeline DairyNZ/Fonterra 4 stage	**2013**	**2017 GMP**	**2020**	**2025**	**2030**	**2035**
Existing land uses (tonnes N)	6,500	6,500	5,938	5,373	4,823	4,375
Reduction regime		GMP	9% for those above 20 kgN/ha/yr	18% for those above 20 kgN/ha/yr	27% for those above 20 kgN/ha/yr	36% for those above 20 kgN/ha/yr
Irrigation development (tonnes N)*[1]		61	100	122	122	122
Flexibility caps (tonnes N)*[2]		none (PA rule from 2017)	25	50	70	82
Total N load (tonnes N/yr)	**6,500**	**6,561**	**6,063**	**5,545**	**5,015**	**4,579**
% change in load		1%	-7%	-15%	-23%	-30%
Modelled root zone nitrate nitrogen concentration	**13.9**	**14.0**	**12.9**	**11.7**	**10.6**	**9.7**
Timeline DairyNZ/Fonterra 3 stage	**2013**	**2017 GMP**		**2025**	**2030**	**2035**
Existing land uses (tonnes N)	6,500	6,500		5,552	4,940	4,375
Reduction regime		GMP		15% for those above 20 kgN/ha/yr	25% for those above 20 kgN/ha/yr	36% for those above 20 kgN/ha/yr
Irrigation development (tonnes N)*[1]		61		122	122	122
Flexibility caps (tonnes N)*[2]		none (PA rule from 2017)		50	70	82
Total N load (tonnes N/yr)	**6,500**	**6,561**		**5,724**	**5,132**	**4,579**
% change in load		1%		-12%	-21%	-30%
Modelled root zone nitrate nitrogen concentration	**13.9**	**14.0**		**12.1**	**10.9**	**9.7**

8. GIVING EFFECT TO THE PROPOSED NUTRIENT MANAGEMENT APPROACH

8.1 I have reviewed the proposed rules prepared by Mr Willis. Based on the analysis described above, I consider Mr Willis's proposed amendments to the policy and rules relating to nutrient management for the Lower Hinds/Hekeao Plains Area, in combination with catchment mitigations such as MAR and TSA will achieve the water quality outcomes sought in the Ashburton ZIP Addendum and in Variation 2. This is specifically related to the effects of nitrogen on the water quality outcomes.

Shirley Ann Hayward

15 May 2015

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Scott (2013b) Lag times in the Hinds catchment. Internal Environment Canterbury memorandum dated 31 July 2013.

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Appendix 1 – Median nitrate nitrogen concentrations in the Hinds River/Hekeao and coastal streams and drains of the Lower Hinds/Hekeao Plains Area

Water quality data was provided by Environment Canterbury from its state of the environment monitoring programme, and from specific water quality investigations in the Hinds/Hekeao Plains Area.

I have focussed on sites with continuous long-term water quality data (>10 years), except for the more recent data collected on the Hinds River/Hekeao, for which routine monitoring only began in 2011. I have calculated the annual median nitrate nitrogen concentration for the July to June annual period for the sites. The frequency of sampling has varied over the long-term monitoring programme, ranging from monthly sampling to quarterly sampling. Furthermore, many sites go dry during some summers, and therefore no samples are collected. Therefore the annual median concentrations are calculated from varying number of samples. While not ideal, this is the most practical way of illustrating broad patterns and trends.

The annual nitrate nitrogen concentrations are shown in Figure A1 below and are graphed and overlaid onto a map of modelled root zone nitrate nitrogen concentrations as described by Dr Brown in his evidence in chief.

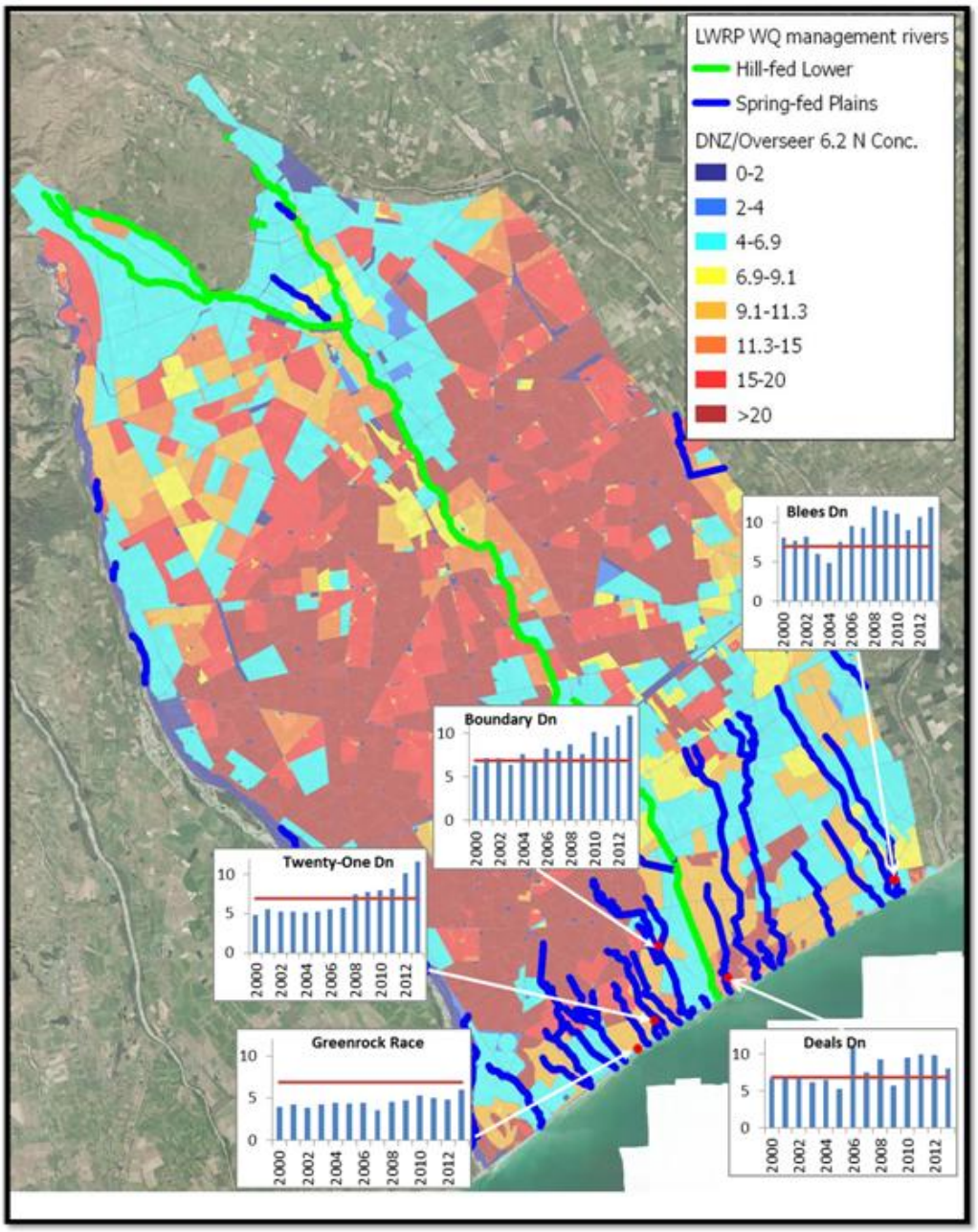


Figure A1 – Graphs of annual median nitrate nitrogen concentrations for five sites in Environment Canterbury's long-term monitoring programme in the Hinds/Hekeao Plains Area. Note: Greenrock Race is not identified on the CLWRP planning maps. The red horizontal line on the graphs show the annual median target of 6.9 mg/L nitrate nitrogen. The background map was provided by Dr Brown, and is comparable to Figure 2 in Dr Brown's evidence.

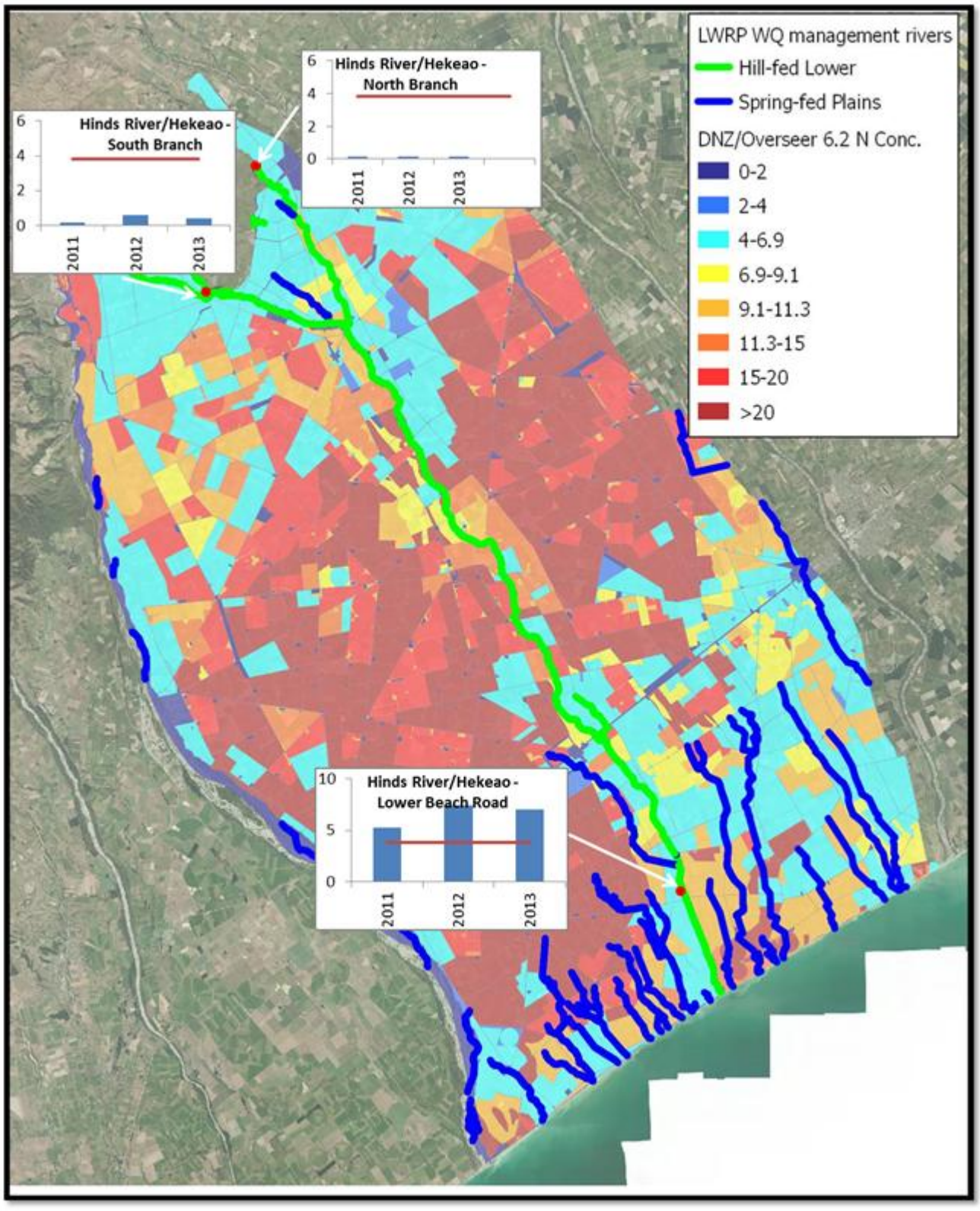


Figure A2 – Graphs of annual median nitrate nitrogen concentrations (mg/L) in the Hinds River/Hekeao. The red horizontal line on the graphs show the annual median target of 3.8 mg/L nitrate nitrogen for Hill-fed Lower rivers.

Appendix 2

Current state and trends in groundwater nitrates

Environment Canterbury has had in place a regional annual groundwater quality monitoring programme for over 20 years. This programme involves monitoring over 200 wells across the region in spring-time when many of the groundwater chemical constituents related to land surface recharge are at their peak concentrations (including nitrate concentrations). More recently Environment Canterbury instigated a region-wide quarterly monitoring programme that reflects seasonal variations in quality and can be used to more accurately assess annual average conditions. The wells in this programme tend to be shallow wells that draw from predominately land surface recharge (Hansen 2012).

Time series plots of nitrate nitrogen concentrations of wells that are included in the quarterly monitoring programme are shown in Figure A3 below. The quarterly monitoring programme began in 2005, and most of these wells were monitored annually prior to this programme. Both the pre-2005 annual data and post 2005 quarterly data are included in the plots.

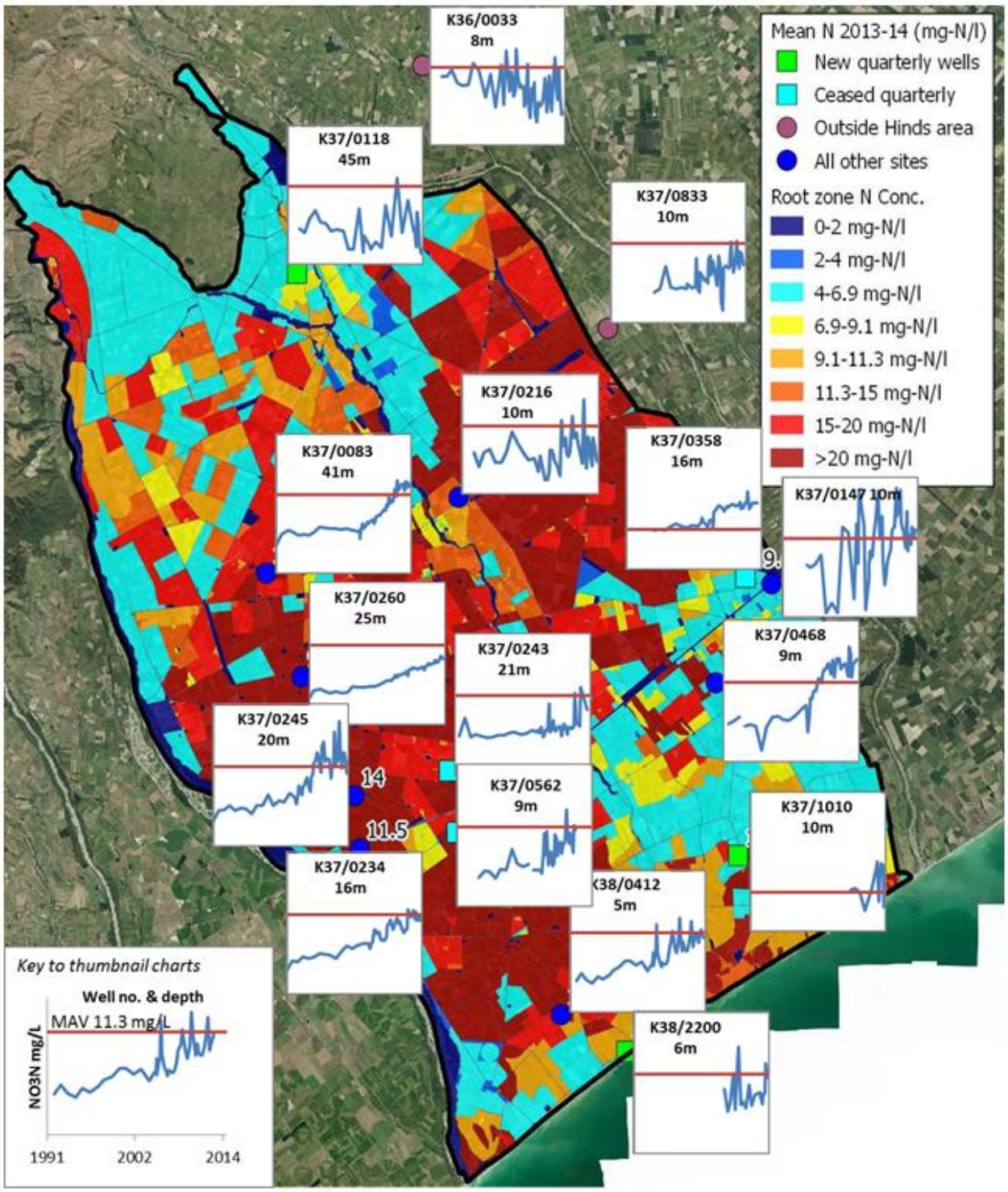


Figure A3 Trends in nitrate concentrations in shallow wells in the Lower Hinds/Hekeao Plains Area and surrounds. Note: all of the x and y axes in the thumbnail charts have the same scales as the example chart in the Key to thumbnail chart. The horizontal red line on the charts is the DWSNZ MAV for nitrate nitrogen.

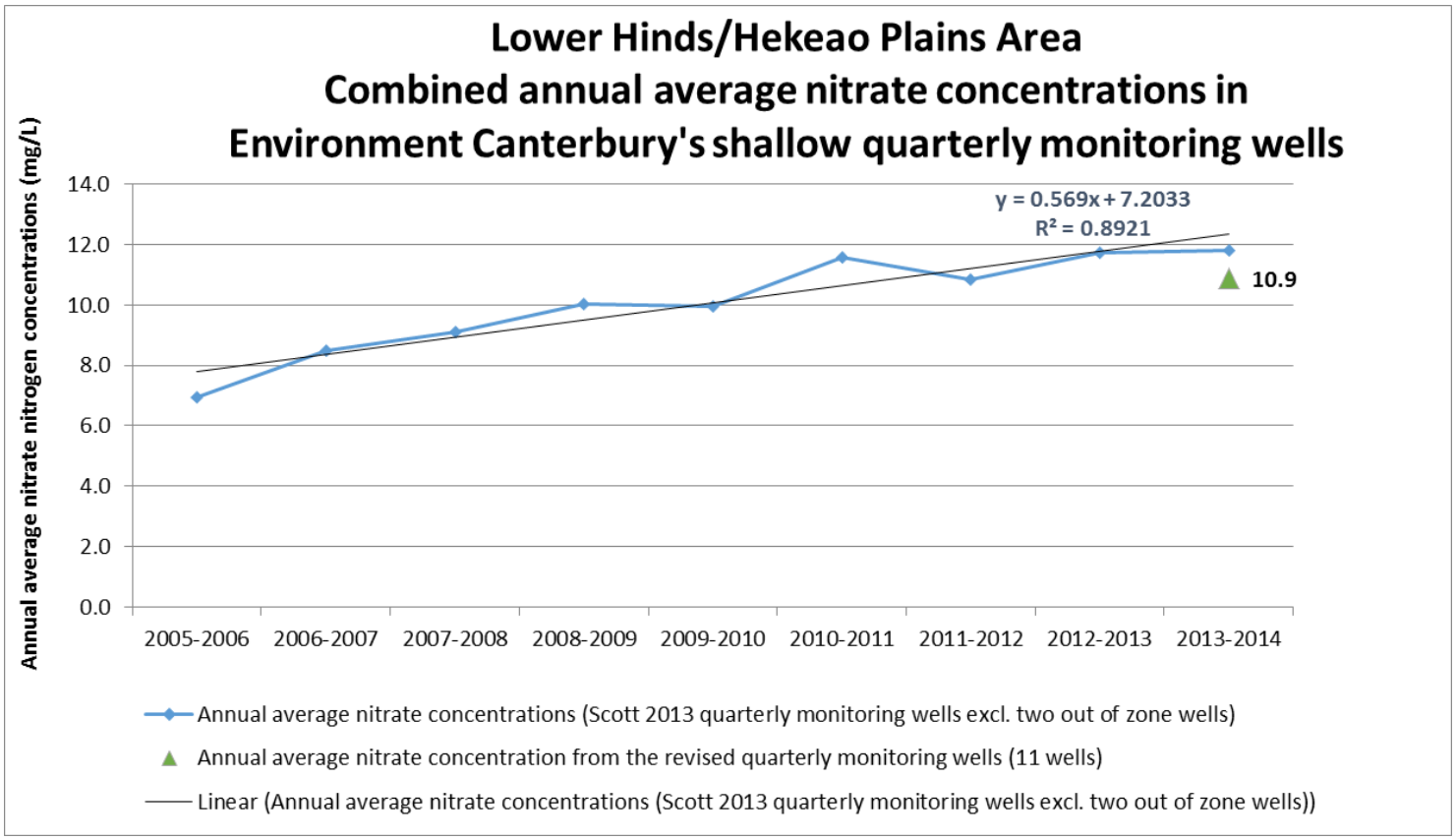


Figure A4 Combined annual average nitrate nitrogen concentrations in 11 quarterly monitoring shallow groundwater well in the Lower Hinds/Hekeao Plains Area.

Appendix 3 – Comparison of nitrogen load models and scenarios

Dr Scott usefully included full details of the updated nitrogen losses, drainage values and land use categories and areas in her memorandum dated 3 April 2014 (Scott, 2014). Using this data I was able to replicate her model and generate the same nitrogen loads, drainage volumes and root zone nitrate concentrations that she reported. Furthermore, I was able to understand the scenarios that she modelled, including the % reductions used in mitigated and development scenarios.

I was also able to use her data to model the effects of Variation 2 provisions regarding nitrogen reductions and development/intensification. The results of this analysis are summarised in Table A1 below.

Dr Brown provided me with the complete set of property level nitrogen loads, drainage values and root zone nitrate concentrations generated by his catchment models. I used this data to examine the different components and options for nitrogen control provisions in Variation 2. I used data from both catchment models, described by Dr Brown as 'DNZ/Aqualinc' and 'DNZ/Overseer 6.2', to provide an indication of the range of likely estimated loads and concentrations. However, I have used the estimates generated from the 'DNZ/Overseer 6.2' model to report findings and draw conclusions. It is important to note that the DNZ/Overseer 6.2 model is an attempt to estimate the nitrogen loads that would be generated by Overseer 6.2. We did not have sufficient time to fully valid this against actual Overseer 6.2 modelled farms at the time of writing this statement of evidence, but preliminary examination of a few of our case study dairy farms modelled in Overseer V6.2.0 gave similar result to those predicted by the DNZ/Overseer 6.2 model.

	Scenario #	Scenario	Reduction regime required	Load calulation method	Total Nitrogen (tonnes N/yr)	% reduction in total nitrogen load from current	Modelled root zone nitrate nitrogen concentration (mg/L)	% change in root zone nitrate nitrogen concentration from current
Current	1	**Environment Canterbury 2011 land use (current at GMP)**		**Scott (2014)**	**4,484**		**12.3**	
	2	DairyNZ/Aqualinc 2013 land use		DNZ/OVS6.2	6,508		13.9	
				DNZ/Aqualinc	5,267		11.2	
	3	**Environment Canterbury 2011 land use + current plus additional load of 214 t N**		**Scott (2014) current land use + 214 tonnes N**	**4,698**	**5%**	**not modelled by Scott (2014)**	
	4	DairyNZ/Aqualinc 2013 land use plus additional load of 214 tN		DNZ/OVS6.2	6,722	3%	14.2	3%
				DNZ/Aqualinc	5,481	4%	11.6	3%
Reductions without development	5	**Environment Canterbury 2011 land use**	**Dairy and dairy support reduce by 45% and 25% respectively, or down to 20 kgN/ha/yr, whichever comes first**	**Calculated using Scott (2014) model**	**3,292**	**-27%**	**9.0**	**-26%**
	6	Applying even reductions to properties above 20kgN/ha/yr, no development, target to achieve 30% reduction in root zone nitrate concentrations	33% reduction for all emitters above 20kgN, or to 20kgN whichever comes first	DNZ/OVS6.2	4,547	-30%	9.7	-30%
			33% reduction for all emitters above 20kgN, or to 20kgN whichever comes first	DNZ/Aqualinc	3,703	-30%	7.9	-30%
Variation 2 N reductions with development	7	**Environment Canterbury 2011 land use- applying Var2 land use provisions, including 214 tN of additional N load, asumming only 15,000 ha of new irrigation**	**Dairy and dairy support reduce by 45% and 25% respectively, or down to 20 kgN/ha/yr, whichever comes first**	**Calculated using Scott (2014) model**	**3,511**	**-22%**	**9.5**	**-23%**
	8	DairyNZ/Aqualinc 2013 land use plus additional load of 214 tN - applying Variation 2 provisions, assuming on 15,000 ha of new irrigation, otherwise unspecified development		DNZ/OVS6.2	4,596	-29%	9.7	-30%
				DNZ/Aqualinc	3,832	-27%	8.1	-28%
ZIP addendum	9	**Environment Canterbury 2011 land use- as modelled by Scott (2014) - development capped at 27 kgN, 51%/33% reductions applied to dairy/dairy support (AM1/AM2), no lower threshold at which reductions cease**		**Scott (2014)**	**3,241**	**-28%**	**9.3**	**-24%**
DairyNZ/Fonterra alternative solution	10	DairyNZ/Aqualinc 2013 land use plus additional load of 214 tN - assumed 15,000 new irrigation, otherwise unspecified development	36% reduction for all emitters above 20kgN, or to 20kgN whichever comes first	DNZ/OVS6.2	4,589	-29%	9.7	-30%
			36% reduction for all emitters above 20kgN, or to 20kgN whichever comes first	DNZ/Aqualinc	3,812	-28%	8.1	-28%
	11	**36% reduction across all farms >20kgN, 122 additional load for existing consented/likely irrigation development over 15,000 ha, 15 kg PA flexibility cap, 15-20 kgN RDA cap**	**36% reduction to 20kgN, flex cap to 15 kgN, 15 to 20 kg allowance**	DNZ/OVS6.2	**4,579**	**-30%**	**9.7**	**-30%**
			36% reduction to 20kgN, flex cap to 15 kgN, 15 to 20 kg allowance	DNZ/Aqualinc	3,822	-27%	8.1	-28%

Table A1 Summary of comparison of catchment models and scenarios

Appendix 4 Development of a specific nitrogen and drainage Hinds base 'look-up' table for the Lower Hinds/Hekeao Plains Area

A specific set of nitrogen load and drainage values for the major land use categories in the Lower Hinds/Hekeao Plains Area was developed using a combination of sources of information and data. This included the MRB (2014) report and values reported from Scott (2014) as well as DairyNZ's own data for dairy and dairy support farms. The assumptions used were that the values would be largely based on either dryland land use and irrigated land use assuming pivot type systems based on Overseer V6.1.3. This approach was taken for the base Hinds look-up tables because Aqualinc would subsequently apply drainage adjustment factors that were more specific based on their irrigation type data, and resultant adjustments in nitrogen loads. Estimates of drainage values and N loads that adjusted for Overseer's drainage and irrigation deficiencies were generated from these base Hinds look-up tables for the combinations of farm type/soil/rainfall/irrigation as described by Dr Brown.

The base Overseer files used by MRB (2014) were provided to DairyNZ by RDRML, and updated to Overseer V6.1.3 by Angela Harvey (Farm and Nutrient Management Specialist employed by DairyNZ). From these files adjustments were made to create dryland or pivot irrigated systems for the specific soil and rainfall categories of the land use categories to create N loads and drainage values for all land uses except dairy and dairy support. N losses and drainage loads for dairy and dairy support farms were based on the case study farms reported by Mr Neal but adjusted to cover the range of soil and rainfall categories used by Aqualinc under advice by Ms Harvey.

Land use categories for the Hinds look-up table were coarsely grouped, similar to Environment Canterbury's approach, with values generated specifically for the major land use/rainfall/soil combinations that generally covered >1,000 ha. Adjustments were applied by Aqualinc to create greater resolution of categories as described by Dr Brown.

Table A2 DairyNZ Base Hinds look-up tables for N loads and drainage values based on Overseer V6.1.3 for the major land use categories

Land use	Rainfall zone (mm)	Soil	Irrigated		Dryland	
			N loss (kg-N/ha)	drainage (mm)	N loss (kg-N/ha)	drainage (mm)
Arable	650	Heavy	10	201	5	121
Arable	650	Light	12	247	-	-
Arable	750	Light	19	417	15	228
Arable	875	Light	20	473	17	292
Dairy	650	Heavy	13	142	-	-
Dairy	650	Light	47	204	-	-
Dairy	750	Heavy	15	177	-	-
Dairy	750	Light	50	240	-	-
Dairy	875	Light	65	344	-	-
Dairy support (not including wintering)	750	Light	-	-	12	208
Dairy support (not including wintering)	875	Light	20	305	13	235
Dairy support including wintering	650	Heavy	36	179	18	121
Dairy support including wintering	650	Light	40	204	-	-
Dairy support including wintering	750	Light	45	277	25	228
Dairy support including wintering	875	Light	60	305	30	279
Dairy wintering as a secondary land use	650	Heavy	40	202	18	121
Dairy wintering as a secondary land use	650	Light	69	247	-	-
Dairy wintering as a secondary land use	750	Light	79	292	39	228
Dairy wintering as a secondary land use	875	Light	115	442	55	292
Deer/Goat/Pig	750	Light	-	-	10	208
Horticulture	650	Heavy	-	-	6	121
Mixed use farms	875	Light	20	305	-	-
Sheep	650	Heavy	6	142	-	-
Sheep	750	Light	14	230	8	208
Sheep	875	Medium	-	-	10	220
Sheep	850	Light	-	-	10	235
Sheep/Beef	650	Light	19	193	-	-
Sheep/Beef	750	Light	17	230	12	208
Sheep/Beef	875	Light	-	-	13	235