IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of the Proposed Canterbury Land and Water Regional Plan

STATEMENT OF EVIDENCE OF SHIRLEY ANN HAYWARD
FOR THE GROUP 2 HEARING

1. INTRODUCTION

1.1 My name is Shirley Ann Hayward. I hold the qualifications and have the experience set out in my statement of evidence for the Group 1 hearing.

1.2 I have read and am familiar with the Code of Conduct for Expert Witnesses outlined in the Environment Court's Practice Note 1 November 2011 and although this is a Regional Council hearing, I have complied with it in preparing this evidence. I also agree to follow the Code when presenting evidence to the Hearing Committee. I confirm that the issues addressed in this brief of evidence are within my area of expertise and I have not omitted to consider material facts known to me that might alter or detract from my expressed opinions.

2. SCOPE OF EVIDENCE

2.1 My evidence will cover a review of the basis for the nutrient allocation zone status and recommendations for amendments to the status of some zones.

3. BACKGROUND

3.1 DairyNZ's submission on the proposed Canterbury Land and Water Regional Plan (proposed plan) highlighted concerns about the robustness and transparency of the rationale for the nutrient allocation zone status. Consequently I have undertaken an analysis to evaluate the nutrient allocation zone status in a consistent manner against the water quality outcomes proposed in Tables 1a, b and c. In the strictest sense, this means utilising data for the main indicators in the outcome tables that are affected by nutrient inputs, which are: periphyton and macrophytes for streams and rivers, Trophic Level Index (TLI) for lakes and nitrate concentrations in groundwater. This evaluation was on the basis the outcomes in Tables 1a, b and c were recognised as region-wide interim outcomes, while sub-regional chapters were progressively being developed.

4. WATER QUALITY OUTCOME TABLE 1A (RIVERS AND STREAMS)

4.1 The indicators in Table 1a (rivers) integrate the effects of a range of factors, with some of the indicators directly and indirectly influenced by nutrients, and others not related to nutrient enrichment effects. Periphyton and macrophytes are the key indicators directly affected by nutrient inputs. Nutrients, along with flows, temperature, shading and substrate determine the frequency and extent of nuisance plant growth. In turn, indicators such as the quantitative macroinvertebrate community index (QMCI) and dissolved oxygen are influenced by the type and abundance of plants present. Therefore, these indicators are indirectly affected by nutrient inputs. Dissolved oxygen is also affected by the flow regime and temperature.

4.2 Based on the data I have available, I have focussed on evaluating those indicators that are directly affected by nutrient status. These are: observations of periphyton (% cover of filamentous algae) and macrophytes.

4.3 Periphyton and macrophyte cover data is collected by Environment Canterbury's field staff using a very simple bank-side visual assessment with a low level of accuracy. Despite this limitation, this data does provide a reasonable indication of the incidence of nuisance growths. Environment Canterbury has also used this data for detailed analyses of macrophyte/nutrients/sediment relationships (probably beyond its original intention of use but out of necessity because of a paucity of more robust data). Unfortunately, there is insufficient region-wide data on periphyton chlorophyll a to allow comparison to Table 1a, which leaves a gap in my ability to evaluate river condition in relation to total periphyton biomass.

4.4 Table 1 and Figures 1 to 3 utilise periphyton (% cover of filamentous algae) and macrophyte cover for the period of data 2008-2012 provided to me by Environment Canterbury. For each site, I calculated the average annual maximum % cover for the 5 year period and compared that value relevant management unit in Table 1a.

4.5 In analysing the data against the criteria in Table 1a, I have used the following criteria to evaluate compliance of each site with Table 1a;

(a) Meets water quality outcomes for relevant indicator – average annual maximum value for the site is less than 85% of the corresponding value in Table 1a

(b) At risk - average annual maximum value for the site is within 15% of the corresponding value in Table 1a

(c) Water quality outcome not met – average annual maximum value for the site is greater than the corresponding value in Table 1a

Periphyton cover (% cover of filamentous algae (=nuisance algae))

4.6 For the hill-fed and alpine-fed rivers, only a few sites do not comply with the periphyton criteria for filamentous algae cover (Figure 1, Table 1). Sites that do not comply occur within both red and orange nutrient allocation zones (NAZ) in the proposed plan. The Waipara zone is notable in that all 3 sites in this zone do not comply with the relevant periphyton criteria. This catchment is one a few in Canterbury that have significant areas of tertiary sedimentary geology which contributes a natural source of phosphorus and other minerals to the waterways. This combined with a hot-dry microclimate means this river is unlikely to routinely comply with the periphyton criteria.

4.7 Most spring-fed streams also met the filamentous algae criteria, except in the Selwyn – Waihora and Upper Waitaki – Ahuriri Arm zones, where filamentous algae cover exceeded relevant criteria.

Macrophyte cover (total plant cover and emergent macrophyte cover)

4.8 Macrophytes (rooted aquatic plants) are the dominant plant form in spring-fed streams with stable flows and fine substrate. They are rarely found in hill-fed or alpine rivers because of coarser substrates and frequent floods. Therefore, macrophyte cover indicator criteria were only set for spring-fed stream types in Table 1a. While nutrient enrichment is a significant factor in excessive macrophyte growth, a recent modelling study of Environment Canterbury's data also indicated that the extent of fine sediment deposition in streams was highly correlated with excessive macrophyte growth (Booker and Snelder 2012). Booker and Snelder (2012) suggested that 'macrophytes could be controlled through management of fine sediment entering rivers as well as (and possibly even more effectively than) setting nutrient limits'.

4.9 Figures 2 and 3 and Table 1 indicate that a few sites do not comply with the emergent macrophyte cover criteria, and most (but not all) of these sites fall within the red zones. However, within the red zones a number of sites also comply.

4.10 The majority of sites across all zones (with adequate data) did not comply with the total macrophyte cover criteria. While this may create problems in some waterways, it is also likely the criteria in Table 1a are too stringent for some river types e.g. inland spring-fed streams.

5. TROPHIC LEVEL INDEX OUTCOMES FOR LAKES– TABLE 1B

5.1 I have focused on data for the coastal lakes and Lake Benmore as these occur in catchments where the lakes are a significant feature in the catchment, and catchment nutrient losses are important drivers of their condition. Table 2 summarises the TLI information for these lakes. The coastal lakes and lagoons generally are at or exceed the TLI criteria in Table 1b. Lake Benmore (Haldon Arm) hovers around the criteria for this lake type.

Table 2 – Trophic level index for selected lakes in Canterbury that had a critical influence on Nutrient Allocation Zones. Trophic Level Index data obtained from Environment Canterbury's website.

	Zone	TLI critera (Table 1b)	TLI 2006	TLI 2010
Coastal lakes				
Te Waihora/Lake Ellesmere	Selwyn-Waihora	6	6.9	7.1
Lake Forsyth/Te Roto O Wairewa	Okana-Lake Forysth	6	7.8	7.9
Coopers Lagoon/Muriwai	Little Rakaia	4	4.5	4.7
Wainono Lagoon	Wainono	6	5.9	6.6
Washdyke Lagoon	Washdyke	6		5.9
Large high country lakes				
Lake Benmore (Haldon Arm)	Upper Waitaki - Ahuriri Arm	2	1.4	2.1

6. GROUNDWATER NITRATE OUTCOMES - TABLE 1C

6.1 Water quality outcomes in Table 1c of the proposed plan refers to three groundwater sub-units; coastal confined aquifer systems, shallow groundwater recharged by soil drainage, and deep groundwater recharged by rivers. For the groundwater management unit 'Coastal Confined Gravel Aquifer System' and the sub-unit 'Unconfined gravel aquifer – deep groundwater predominately recharged by rivers', the outcomes aim to maintain groundwater quality (including nitrates) in the state found for the period 2007- 2010. I have not undertaken any analysis of these outcomes. For the groundwater sub-unit 'Shallow groundwater predominately recharged by soil drainage', the outcomes for nitrates are described as a maximum concentration of 11.3 mg/L of nitrate nitrogen which equates to the Drinking Water Standards for New Zealand (DWSNZ) maximum acceptable value (MAV) and an average of 5.6 mg NO_3N/L which equates to half the drinking water standards MAV. The tables do not describe what is meant by 'maximum' and 'average' groundwater nitrate concentrations. Potentially, the frequency of sampling (monthly, quarterly or annually) may be important, as well as whether the criteria apply to individual wells or an evaluation across an aquifer or zone.

6.2 High concentrations of nitrate in drinking water can pose a health risk for certain people, particularly 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), and therefore, short term peaks in nitrate concentrations are important in evaluation of risks to drinking water supplies.

Data analysis

6.3 I have undertaken an analysis of the nutrient allocation zones in relation to groundwater nitrates based on my interpretation of what might be intended by average and maximum nitrate values. Environment Canterbury has provided me with groundwater nitrate data from their annual and quarterly groundwater quality monitoring programmes. Environment Canterbury's quarterly monitoring programme involves sampling groundwater during each of the four main seasons from 97 wells spread across the Region, and covers the time period from 2006 - 2011.

6.4 The annual groundwater quality monitoring programme involves sampling groundwater from 330 wells spread across the region once during spring months, which generally coincides with highest groundwater levels and greatest influence of land surface recharge on groundwater quality (eg peak nitrate concentrations) (Environment Canterbury 2013). I have used annual data for the 10 year period from 2002 – 2012.

6.5 In evaluating 'average' groundwater nitrate concentrations, data collected quarterly allows more accurate description of annual nitrate concentrations, accounting for seasonal variations, but Environment Canterbury's quarterly monitoring programme does not provide much coverage of the Region, and only few wells per zone (none in many zones) (Figure 4). This means that the quarterly dataset will not be able to describe average nitrate concentrations spatially very well.

6.6 The annual monitoring dataset has better spatial coverage of the Region and of the main zones. Figures 4 and 5 illustrate the patterns in nitrate concentrations based on the quarterly and annual groundwater monitoring programmes respectively, presenting average and maximum concentrations for each well. The broad spatial patterns are similarly illustrated by both datasets, but the greater coverage by the annual groundwater monitoring programme led me to use this dataset for further analyses described below. Furthermore, by using annual spring-time groundwater nitrates, this represents an environmentally conservative approach.

Shallow unconfined groundwater

6.7 I chose to define shallow groundwater as less than 50 m below ground level. This is broadly considered the depth above which land surface recharge can strongly influence groundwater quality in the Region and in particular, the depth above which elevated nitrate concentrations occur (Hanson 2002). However, it is also recognized that in some parts of the Region, the depth of influence from land surface recharge may extend to 150 m below ground level and in other areas may only extend 20-30 m below ground level. I was not able to distinguish groundwater predominately derived from soil drainage from river derived shallow groundwater based on nitrate concentrations alone, nor do I consider this necessary as I recommended in my statement of evidence for the Group1 hearings that shallow groundwater derived from river recharge should be included in the subunit for shallow unconfined groundwater. Groundwater wells abstracting from the coastal confined aquifers were excluded from this analysis.

Average and maximum nitrate concentrations

6.8 Nitrate concentrations in groundwater can vary seasonally and between years. In Canterbury, seasonal peak concentrations typically occur in late winter/spring/early summer after winter recharge (rainfall and snow) results in drainage water transporting stored nitrogen from the soil into the groundwater system. Shallow groundwater sourced from soil drainage typically shows strong seasonal fluctuations in nitrates, while deeper groundwater and river recharged groundwater have less marked fluctuations. Year to year variations are often related to annual recharge variations. Major recharge events (e.g., 1992 snow event and heavy winter rain in 2009) can result in higher than usual peak nitrate concentrations (Hayward, 2002, Hanson 2002).

6.9 A maximum criterion for nitrate concentrations that equals the NZ drinking water standards MAV is aimed at ensuring that all groundwater in the region is suitable for potable water supplies without treatment for nitrate contamination. I assume the reason that an average value of half MAV was included in Table 1c was on the assumption that if average nitrate concentrations (either in an individual well or at a zonal level) are below half MAV, then seasonal and inter-annual peaks concentrations should remain below the MAV.

6.10 This assumption was examined using the annual groundwater quality monitoring data and is summarised in Table 3. This shows that on an individual well basis, if the average nitrate concentrations (even for spring-time sampling) are less than half the MAV, it is unlikely that concentrations will exceed the drinking water standards (assuming no long term trends). If average well concentrations are between half and ¾ MAV, then there is a moderate chance that concentrations above the MAV may occur for some wells (generally after a particularly wet winter period). However, if average nitrate concentrations are above ¾ MAV, it is highly likely that nitrate concentrations will exceed the MAV at times. Based on this analysis, using an average nitrate concentration criteria of half MAV per well could be considered highly protective.

6.11 Nitrate concentrations in shallow groundwater can peak following a significant recharge events for periods of weeks to months. Therefore, consideration of maximum nitrate concentration is important because of the short-term exposure risk to bottle-fed infants.

Table 3 – Summary of average and maximum groundwater nitrate concentrations for wells sampled annually in spring for the period 2002 – 2012 (Wells less than 50 m deep, and excluding wells from the coastal confined aquifers)

Well categories (based on average NO_3N concentrations for each well)	**Number of wells in each category**	**Number of wells in each category with maximum NO_3N concentrations above MAV**
Average NO_3N concentrations below half MAV	139	0
Average NO_3N concentrations between half MAV and ¾ MAV	47	12
Average NO_3N concentrations above MAV and ¾ MAV	48	45

6.12 Table 4 summarises nitrate concentrations in terms of averages across each zone and number of wells within each zone which has had concentrations exceeding the DWSNZ MAV based on the annual spring-time monitoring programme. I have qualitatively assessed each zone considering both the zone average nitrate concentrations and frequency of wells exceeding the MAV.

Table 4 – Summary of shallow, unconfined groundwater nitrate concentrations per zone, based on annual data for the period 2002-2012.

Zone	NAZ status (pLWRP)	Zone average (mg NO3N/L)	Number of wells per zone	Number of wells with maximum NO_3N conc. >MAV	Percent of wells with maximum NO_3N conc. >MAV
Hapuku	Meets Water Quality Outcomes	0.1	1	0	0%
Lower Waitaki	Meets Water Quality Outcomes	1.7	4	0	0%
Morven - Glenavy	Meets Water Quality Outcomes	4.3	4	0	0%
Rakaia	Meets Water Quality Outcomes	0.8	3	0	0%
Rangitata	Meets Water Quality Outcomes	2.7	2	0	0%
Ashburton	At Risk	7.0	5	2	40%
Ashley	At Risk	1.4	3	0	0%
Little Rakaia	At Risk	1.7	5	0	0%
Makikihi	At Risk	2.5	4	0	0%
Opihi	At Risk	4.5	14	2	14%
Orari	At Risk	3.8	5	1	20%
Otaio	At Risk	1.5	2	0	0%
Pareora	At Risk	3.2	5	0	0%
Saltwater Creek	At Risk	0.2	2	0	0%
Upper Waitaki - Haldon Arm	At Risk	0.4	6	0	0%
Washdyke	At Risk	6.4	12	5	42%
Ashburton - Rakaia	Water Quality Outcomes Not Met	10.4	17	9	53%
Ashley-Waimakariri	Water Quality Outcomes Not Met	4.7	18	3	17%
Christchurch - West Melton	Water Quality Outcomes Not Met	2.4	15	0	0%
Kaikoura	Water Quality Outcomes Not Met	0.6	3	0	0%
Rangitata - Orari	Water Quality Outcomes Not Met	7.9	3	2	67%
Selwyn - Waihora	Water Quality Outcomes Not Met	5.8	40	11	28%
Temuka	Water Quality Outcomes Not Met	0.8	2	0	0%
Upper Waitaki - Ahuriri Arm	Water Quality Outcomes Not Met	1.1	1	0	0%
Valetta - Hinds - Mayfield/Hinds	Water Quality Outcomes Not Met	8.4	16	13	81%
Waikakahi	Water Quality Outcomes Not Met	3.9	3	1	33%
Wainono	Water Quality Outcomes Not Met	4.9	8	2	25%
Waipara	Water Quality Outcomes Not Met	8.1	2	0	0%
Amberley	Unclassified	0.1	3	0	0%
Ewelme	Unclassified	3.3	2	0	0%
Kaikoura Peninsula	Unclassified	0.7	1	0	0%
Kowai	Unclassified	7.1	2	1	50%
Hurunui	Refer to Hurunui Waiau River Regional Plan	6.4	9	1	11%
Jed	Refer to Hurunui Waiau River Regional Plan	6.4	4	2	50%
Waiau	Refer to Hurunui Waiau River Regional Plan	3.7	8	2	25%

Colour classification key:

Zone average – red = > half MAV, orange = within 15% of half MAV

Percent of wells with max NO_3N > MAV – orange = 10 – 25%, red=>25%

Colour key for zone names = interpretation of whether the water quality outcomes for shallow unconfined groundwater meet nitrate criteria in Table 1c for nitrates. Blue – insufficient data (2 or less wells), green = meets outcome criteria, orange = at risk, red = does not meet outcome criteria, black = unclassified zones or within Hurunui Waiau River Regional Plan.

7. OVERALL EVALUATION AGAINST WATER QUALITY OUTCOMES

7.1 In undertaking this analysis, the difficulty in applying a quantitative evaluation became apparent, and ultimately this required some subjective and interpretive assessment. It appeared a hierarchy of criteria could be used, whereby if a nutrient sensitive lake, in which its catchment area dominates a zone, has TLI that does not meet the relevant criteria in Table 1b, this becomes an overriding factor in determining the nutrient allocation zone status. Similarly, if it is apparent that widespread exceedence of groundwater nitrate concentration criteria occurs, this also becomes an overriding factor. Because nuisance macrophytes and periphyton occur as a result of a combination of factors (climate, substrate, flow regimes and nutrients) and they are highly variable in space and time, interpretation of the data is more subjective and variable across a zone and ultimately may carry less weighting in an overall assessment of nutrient status of a zone.

7.2 Table 5 summarises my assessment of the overall status of the zones for which I had access to sufficient water quality data. I acknowledge this analysis is limited by data available to me, and may not fully consider all water quality attributes affected (directly or indirectly) by nutrient enrichments (e.g, total periphyton biomass, toxin producing cyanobacteria, QMCI and dissolved oxygen). However I consider it a useful starting point for a framework that could be further refined and expanded. An important aspect of it is the use of available data in a transparent and consistent manner. This is critically important because of the consequences of the nutrient allocation status as used in the proposed plan on agricultural activities.

7.3 This assessment indicates agreement with the nutrient allocation map of the proposed plan for many zones, particularly many of the green and red zones. However, differences in assessment of some red zones occur, and in particular my analysis for some reds zones indicate they are largely indistinguishable from oranges zones in their compliance with the water quality outcomes tables. In particular, the Ashley – Waimakariri, Temuka, and Waikakahi zones could in my view be classified as ‘at risk’ rather than ‘water quality outcome not met’. In these zones, particularly the Ashley – Waimakariri and Temuka zones, water quality is quite variable and the zones have considerable spatial heterogeneity. The data for these zones indicate that there is potential assimilative capacity in areas of these zones that could allow some further development, providing appropriate measures are put in place as would be likely required for a land use change consent in an ‘orange’ zone.

Table 5 – Overall assessment of zones against water quality outcomes (nutrient related) compared to the Nutrient Allocation Zone maps.

ZONE NAME	ZONE CLASS	Lake outcomes	Groundwater nitrates	Periphyton/ Macrophytes
Colour indicates an assessment of the overall status of the zones against the nutrient related criteria of Tables 1a, b and C	pLWRP nutrient allocation zone status	From Table 2	From Table 4	From Table 1
Maerewhenua	Meets Water Quality Outcomes			
Morven - Glenavy	Meets Water Quality Outcomes			
Rakaia	Meets Water Quality Outcomes			
Rangitata	Meets Water Quality Outcomes			
Waimakariri	Meets Water Quality Outcomes			
Ashburton	At Risk		data for only 5 wells	
Ashley	At Risk			
Conway	At Risk			
Hakataramea	At Risk			
Little Rakaia	At Risk	Coopers Lagoon/Muriwai - TLI>4 Catchment area is a subset of the zone		
Makikihi	At Risk			
Opihi	At Risk			
Orari	At Risk			
Pareora	At Risk			
Upper Waitaki - Haldon Arm	At Risk	Lake Benmore (Haldon Arm) at TLI criteria		
Waihao	At Risk			
Washdyke	At Risk	Washdyke Lagoon - close to TLI criteria		
Ashburton-Rakaia	Water Quality Outcomes Not Met			
Ashley-Waimakariri	Water Quality Outcomes Not Met			
Christchurch - West Melton	Water Quality Outcomes Not Met			
Kaikoura	Water Quality Outcomes Not Met			
Ohapi Creek	Water Quality Outcomes Not Met			
Okana - Lake Forsyth	Water Quality Outcomes Not Met	Lake Forsyth/Te Roto O Wairewa - TLI > 6 Catchment area dominates zone		
Selwyn - Waihora	Water Quality Outcomes Not Met	Te Waihora/Lake Ellesmere - TLI >6 Catchment area dominates zone		
Temuka	Water Quality Outcomes Not Met			
Upper Waitaki - Ahuriri Arm	Water Quality Outcomes Not Met	Lake Bemore (Ahuririr Arm) - unknown TLI but reportedly more vulnerable to nutreint		
Valetta - Hinds - Mayfield/Hinds	Water Quality Outcomes Not Met			
Waikakahi	Water Quality Outcomes Not Met			
Wainono	Water Quality Outcomes Not Met	Wainono Lagoon - TLI>6 Catchment area most of zone		
Waipara	Water Quality Outcomes Not Met			

7.4 The potential constraints on any further land use changes in the Temuka and Ashley-Waimakariri zones are significant. Appendix 1 summarises estimates of current irrigated land in the these zones, and area currently in dairying. This indicates that there is a considerable area of dryland in the Ashley-Waimakariri zone (~49,000 ha), some of which could be irrigated without compromising the ability of the zone to meet the water quality outcomes. In the Temuka zone, there is potential irrigated land that could be converted to dairying in areas while maintaining water quality outcomes, provided appropriate farm management measures are put in place.

8. CONCLUSIONS:

8.1 I have undertaken an assessment of the nutrient allocation zone status by using available data in a consistent framework. This analysis has illustrated the difficulty in quantitatively evaluating the overall status of zones in relation to the water quality outcomes in Tables 1a, b and c for nutrient related indicators. However, such an approach provides a transparent framework that could be used for refining the allocation status of the some zones and for evaluating the effects of activities against the tables.

8.2 While there were agreement between this analysis and the nutrient allocation status as proposed in the plan for many zones, there were some differences. In particular, the data for Temuka and Ashley-Waimakariri zones indicate these zones should be classified as 'at risk – orange' rather than 'not meeting water quality outcomes –red'.

9. REFERENCES

Booker, D., Snelder, T. 2012: Development of nutrient criteria for managing macrophytes in lowland and spring-fed Canterbury streams. Environment Canterbury report R12/29.

Dodson M., Aitchison-Earl P., Scott L. 2012: Ashley-Waimakariri groundwater resources investigation. Environment Canterbury report R12/69

Environment Canterbury 2013: Canterbury Water - The Regional Context. Supporting the Canterbury Water Management Strategy. Environment Canterbury report

Environment Canterbury 2013: Annual groundwater quality survey 2011: Environment Canterbury Report number R13/13

Hanson, C., 2002. Nitrate concentrations in Canterbury groundwater – a review of existing data. Environment Canterbury technical report R02/17.

Hayward, S., 2002. Christchurch-West Melton Groundwater Quality: A review of groundwater quality monitoring data from January 1986 to March 2002. Environment Canterbury Technical Report U02/47.

Shirley Hayward

28 March 2012

Table 1 – Evaluation of observations of nuisance periphyton and macrophyte growths against water quality outcome criteria.

Zones (color indicates interpretation of overall compliance with Table 1a for periphyton and macrophytes)	pLWRP zone classification	Periphyton - long filaments (average of annual maximum)	Macrophytes - emergent (average of annual maximum)	Macrophytes - total (average of annual maximum)
Ashburton	at risk			
Hill-fed lower (average of sites)		**2**		
Ashburton R at North Branch - Digby's Bridge		0		
Ashburton R at North Branch -SH72		6		
Ashburton R at SHI Bridge		0		
Ashburton R at South Branch - Hills Road		0		
Ashburton R at South Branch - SH72		2		
Spring-fed plains				
Wheatstone Drain at Croys Rd		25	56	77
Ashley	at risk			
Hill-fed lower				
Ashley R at SH1 bridge		7		
Hill-fed upland				
Ashley R at Gorge bge		10		
Spring-fed plains (average of sites)		**16**	**28**	**65**
Little Ashley Stm at SH1 Bridge		27	38	88
Taranaki Ck - Gressons Rd Bridge		18	24	68
Taranaki Ck at Preeces Rd, Main Trib		10	41	72
Waikuku Stm at SH1 Bridge		11	8	30
Ashley-Waimakariri	not met			
Hill-fed lower				
Cust Main Drain at Skewbridge		3		
Spring-fed plains (average of sites)		**5**	**11**	**68**
Cam R at Bramleys Rd Bridge		7	13	27
Kaiapoi R at Island Rd Bridge		7	11	90
Ohoka Stm at Island Rd Bridge		1	8	86
Conway	at risk			
Hill-fed lower				
Conway At S.H.1		30		
Hakataramea	at risk			
Spring-fed lower basin (average of sites)		**9**	**24**	**36**
Cattle Ck Morland Settlement Road		6	2	2
Deadman Stm Hakataramea Valley Road		14	12	14
Kirkliston Stm Hakataramea Valley Road		14	51	85
Padkins Stm Hakataramea Valley Road		8	0	0
Rocky Point Stm Hakataramea Valley Road		3	57	77
Hill-fed lower				
Hakataramea River at SH82		25		
Kaikoura	not met			
Spring-fed plains (average of sites)		**25**	**37**	**49**
Lyell Ck at Mill Road		12	22	44
Lyell Ck at Nth Branch at Mt Fyffe Rd		7	82	88
Lyell Ck at SH1		9	0	5
Lyell Ck Sth Branch at Mt Fyffe Rd		15	51	64
Middle Ck at Beach Rd		70	13	24
Middle Ck at Mt Fyffe Rd		36	67	79
Warren Ck at Rorrisons Rd		26	24	37
Little Rakaia	at risk			
Spring-fed plains (average of sites)		**6**	**11**	**68**
Jollies Brook at Bullocks Rd		0	11	45
Lee R at Bridge On Brooklands Farm		13	10	91
Ohapi Creek	not met			
Spring-fed plains (average of sites)		**4**	**7**	**55**
North Ohapi Ck at Guild Road		0	10	70
Ohapi Ck at Guild Road		1	4	32
South Ohapi Ck at Guild Road		12	6	61
Opihi	at risk			
Hill-fed lower (average of sites)		**6**		
Opihi R at Allandale		0		
Opihi R at Rockwood Bridge		6		
Opihi R at Saleyards Bridge		2		
Opihi R at SH1		8		
Opihi R at Waipopo		3		
Opuha R at Skipton Bridge		20		
Tengawhai R at Pleasant point bridge		5		
Hill-fed upland				
Opihi R at Burkes Pass		6		
Spring-fed plains				
Orakipaoa Ck at Milford Lagoon Road		9	13	73
Orari	at risk			
Hill-fed lower (average of sites)		**9**		
Orari R at Parke Rd		11		
Orari R at Thatchers Road ACCESS		7		
Spring-fed lower basin				
Coopers Ck at SH72		0	18	20
Spring-fed plains (average of sites)		**16**	**14**	**56**
Ohapi Ck at above Orari confluence		0	5	45
Orari R Mouth Reserve		37	5	44
Rhodes Stm at Parke Rd		12	31	78
Pareora	at risk			
Hill-fed lower (average of sites)		**4**		
Pareora R - SH1 BRIDGE		5		
Pareora R at Brassells Bridge		4		
Pareora R at Evans Crossing		2		
Rakaia	met			
Alpine - lower				
Rakaia R at SH1		9		
Alpine - upland				
Rakaia R at Gorge Bridge		0		
Rangitata	met			
Alpine - lower (average of sites)		**4**		
Rangitata R at Mouth		2		
Rangitata R at SH1		5		
Alpine - upland (average of sites)		**2**		
Black Birch Ck near access track		0		
Bush Stm at bridge		2		
Forest Ck at bridge		2		
Rangitata R at Arundel Bridge		5		
Rangitata R below Coal Ck		1		
Hill-fed upland (average of sites)		**3**		
Deep Stm at access rd		0		
Scour Stm at bridge		5		
Spring-fed plains				
McKinnons Ck at Wallaces Bridge		2	60	74
Selwyn - Waihora	not met			
Banks Peninsula				
Kaituna Stm at recorder		21		
Hill-fed lower (average of sites)		**50**		
Hawkins R above Bridge Deans Road		61		
Selwyn R at Coes Ford		40		
Spring-fed plains (average of sites)		**33**	**38**	**70**
Boggy Ck at Lake Rd		47	26	39
Doyleston Dn at Lake Rd		69	58	71
Halswell R at McCartneys Bridge		3	13	56
Hanmer Rd Dn at Lake Rd		36	52	58
Harts Ck at Lower Lake Rd Site		3	17	65
Irwell R at Lake Rd		57	56	78
LII Stm at Pannetts Rd bge		8	11	95
Waikewai Ck at Gullivers Rd		42	69	100
Temuka	not met			
Hill-fed lower (average of sites)		**10**		
Kakahu Stm at Earls Road		36		
Te Moana R at Goodwin Road		2		
Temuka R at SH1		7		
Waihi R at SH72		5		
Waihi R at Te Awa Bridge		0		
Hill-fed upland (average of sites)		**6**		
Te Moana R at Glentohi		3		
Waihi R at Waimarie		8		
Spring-fed lower basin				
Raukapuka Ck at Coach Road		0	17	82
Spring-fed plains (average of sites)		**1**	**14**	**58**
Dobies Ck at SH72		0	3	29
Smithfield Ck at Te Awa Rd		2	21	94
Taumatakahu Stm at Grange Settlement Rd				
Upper Waitaki - Ahuriri Arm	not met			
Spring-fed upland basin (average of sites)		**18**	**15**	**48**
Quailburn Henburn Road		26	0	0
Sutherlands Ck Ben Omar Road		26	22	58
Willowburn Quailburn Road Bridge		1	24	85
Upper Waitaki - Haldon Arm	at risk			
Alpine - upland		**10**		
Fork Stm at SH8 Tekapo Military Camp		2		
Fraser Stm at Aoraki/Mount Cook Lookout		7		
Twizel R at SH8		22		
Hill-fed upland				
Wairepo Ck at Arm Outlet		31		
Spring-fed upland basin (average of sites)		**6**	**3**	**9**
Bendrose Stm at SH8		1	2	3
Irishman Ck at SH8 Windy Ridges		10	0	1
Maryburn R at SH8 Bridge		7	8	22
Valetta - Hinds - Mayfield/Hinds	not met			
Spring-fed plains (average of sites)		**8**	**30**	**65**
Blees Drain at Lower Beach Rd		6	4	47
Boundary Drain at Trigpole Rd		8	8	54
Deals Drain at Lower Beach Rd		5	22	80
Greenrock Rc at Lower Beach Rd		13	72	83
Twenty one Drain at Twenty-one Dn Rd		9	46	60
Waihao	at risk			
Hill-fed lower (average of sites)		**17**		
Waihao R at Bradshaws Bridge		9		
Waihao R at McCullochs Bridge		25		
Waikakahi	not met			
Spring-fed plains (average of sites)		**2**	**21**	**72**
Waikakahi Stm at Cock & Hen Road		0	39	80
Waikakahi Stm at Te Maihora Road		3	3	64
Waimakariri	met	**0**		
Alpine - lower (average of sites)		**0**		
Waimakariri R at above south branch		0		
Waimakariri R at Stewarts Gully Yacht Club		0		
Alpine - upland (average of sites)		**0**		
Waimakariri R at Bealy Bridge		0		
Waimakariri R at Gorge above bridge		0		
Wainono	not met			
Hill-fed lower (average of sites)		**19**		
Hook R at Hook Beach Rd		12		
Hook R Waimate Hunter Road		26		
Spring-fed plains (average of sites)		**16**	**44**	**95**
Buchanans Ck at Above Waihao Confluence		14	21	90
Hook Drain at Hook Beach Rd		3	73	99
Sir Charles Ck at End Haymans Road		31	39	96
Waipara	not met	**57**		
Hill-fed lower (average of sites)		**57**		
Waipara R at Laidmore Rd		53		
Waipara R at Omihi Stm		68		
Waipara R at Teviotdale Bridge		50		

Figure 1 Compliance of observations of filamentous green algae with criteria in Table 1a

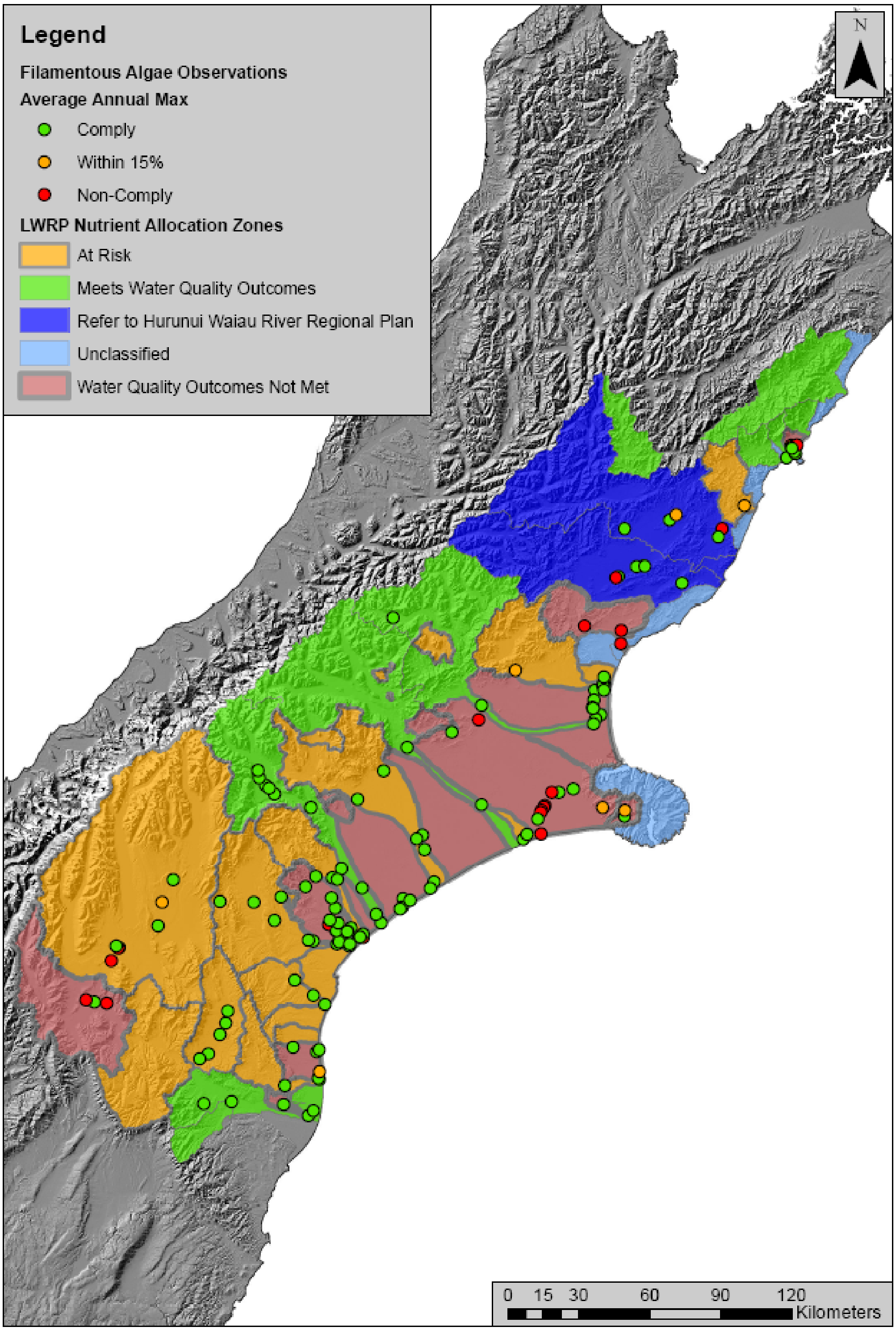


Figure 2 Compliance of observations of emergent macrophyte cover with criteria in Table 1a

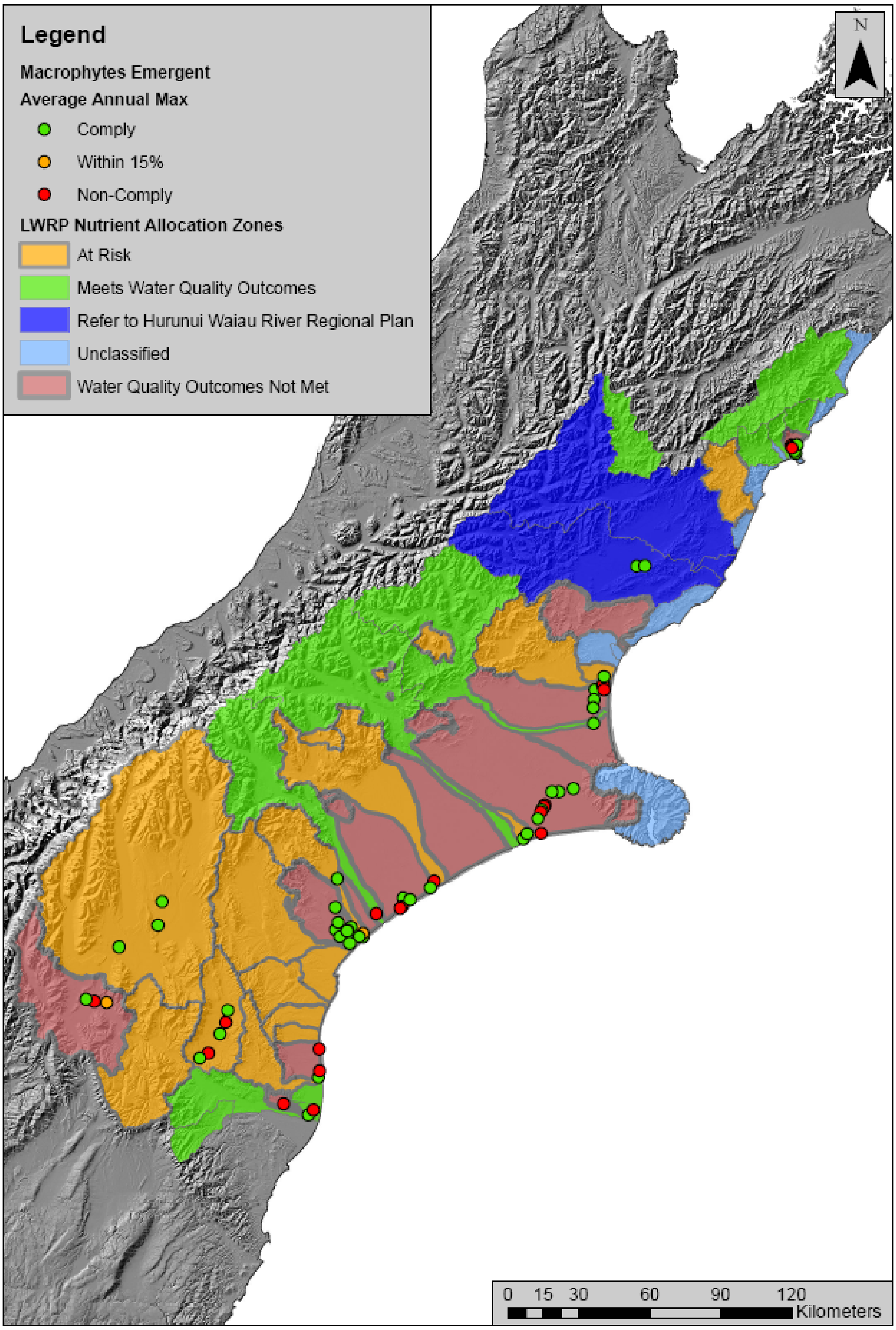


Figure 3 Compliance of observations of total macrophyte cover with criteria in Table 1a

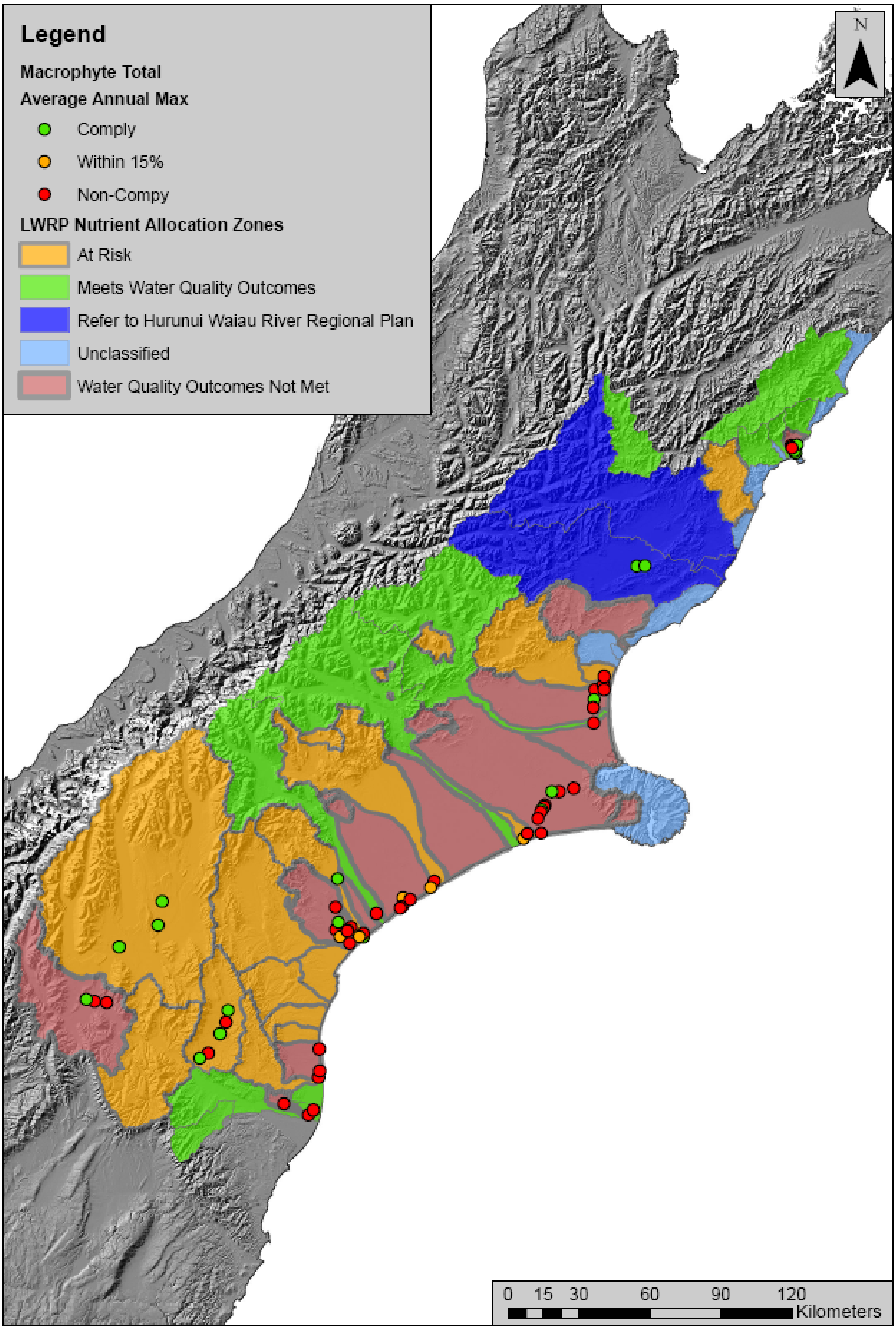


Figure 4 Average and maximum nitrate concentrations in wells sampled quarterly

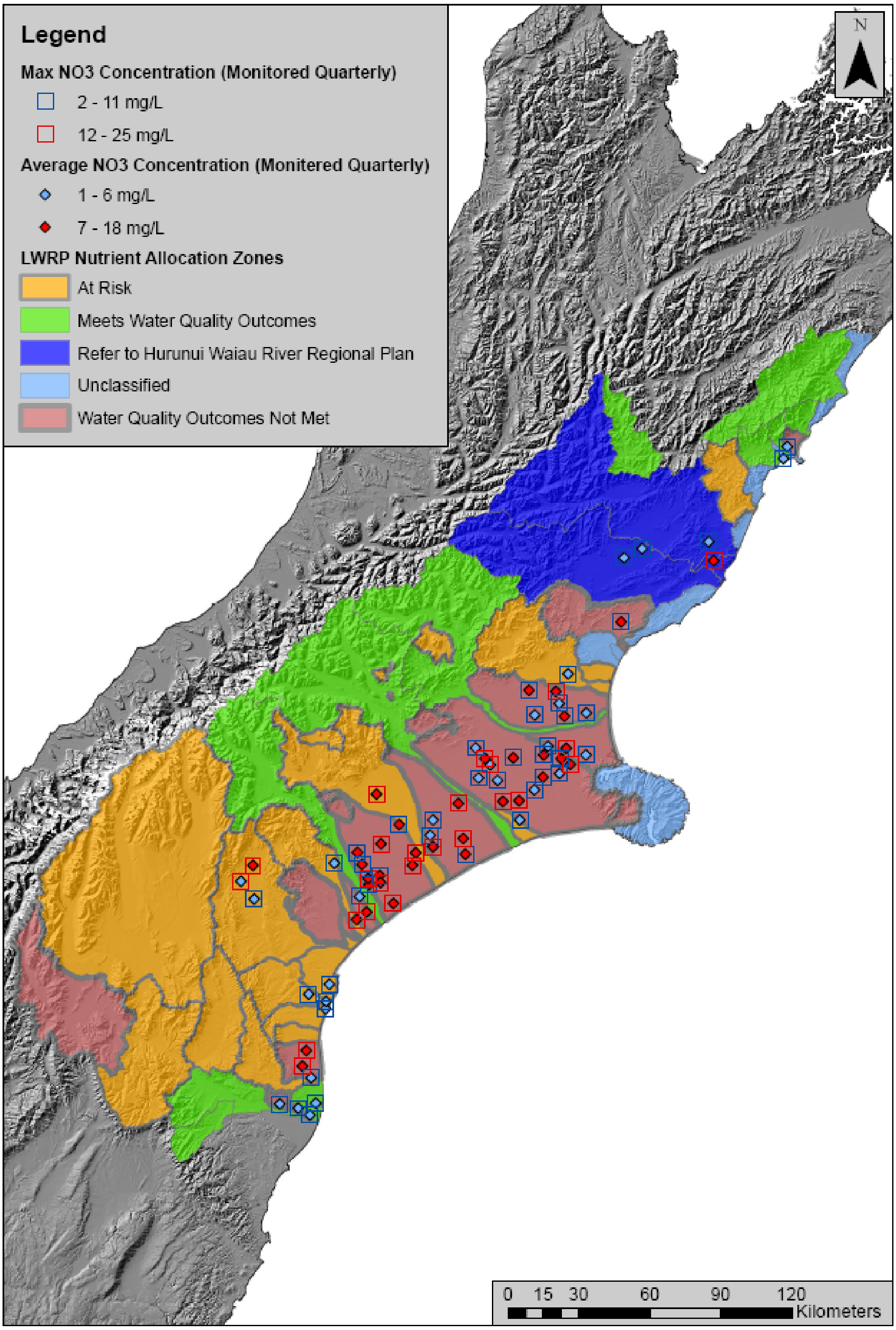
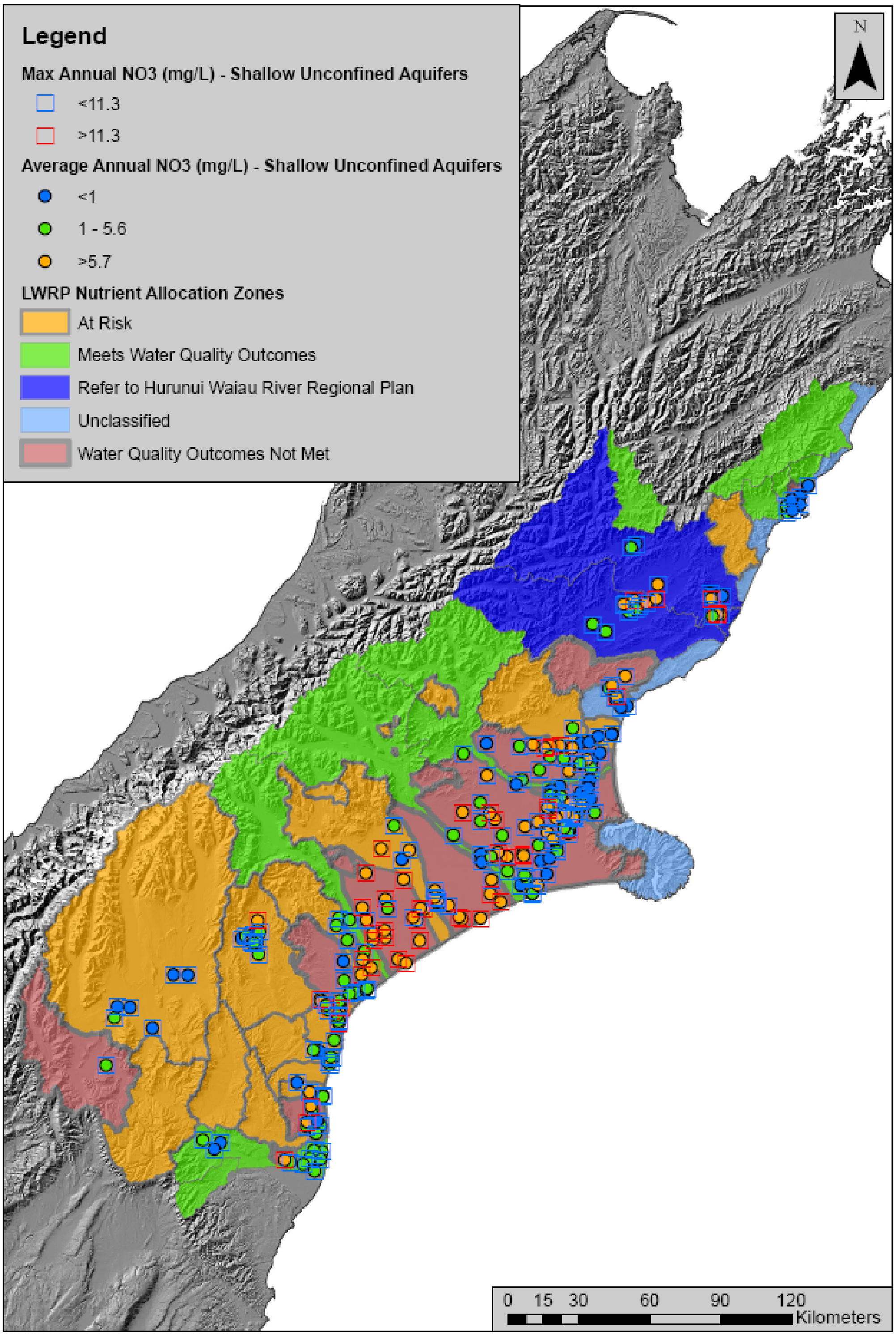


Figure 5 Average and maximum nitrate concentrations in wells sampled annually during spring



APPENDIX 1 LAND AREA IN TEMUKA AND ASHLEY-WAIMAKARIRI ZONES

Table 6 Estimates of land area available for further irrigation in the Temuka and Ashley-Waimakariri zones

	Temuka zone	Ashley-Waimakariri zone
Total area of zone (ha)	57,129	95,483
Irrigable area of zone - flat land (ha)	27,000	85,000
Estimate of total irrigated area (ha)	22000[a]	36000[b]
Area irrigated by surface water schemes (ha)	3200[C]	18000[d]
Area irrigated by individual surface water and groundwater takes (ha)	18,800	18,000
Estimate of irrigable area in dryland (ha)	5,000	49,000
Estimate of current area in dairying (ha)[e]	8,600	13,600

a - estimated from Ecan 2012
b - Dobson et al. 2013
c- Kakahu and Opuha schemes
d - Waimakariri Irrigation Limited
e - estimated from number of active farm dairy effluent consents in each zone