IN THE MATTER OF	the Resource Management Act 1991
AND	
IN THE MATTER OF	resource consent applications by various parties to take and use water from rivers, streams, canals and lakes in the Upper Waitaki Catchment..

JOINT STATEMENT OF EVIDENCE OF JOHN CHARLES BRIGHT AND MELISSA CLARE ROBSON

1.1 This is a joint statement of evidence prepared by John Charles Bright and Melissa Clare Robson. Dr Robson was one of the key authors of the Water Quality Study ("**WQS**"). Dr Bright undertook a peer review role in terms of the preparation of the WQS.

1.2 Dr Bright is a Water Resources Engineer with 30 years' experience. His relevant qualifications are B.Sc. (Physics, 1975), B.E. (Hons) (Agricultural, 1978), and Ph.D. (Agricultural Engineering, 1986). He is a member of the American Society of Civil Engineers. Dr Bright is the Managing Director of Aqualinc Research Ltd. A summary of his relevant expertise and experience is set out in his CV in **Appendix A**.

1.3 Dr Robson is an environmental scientist who has held her current role in the Waterways and Coastal Group of GHD Limited for 18 months. She holds a Bachelor of Science (Honours) in Tropical Environmental Science conferred by the University of Aberdeen, a Masters of Science in Integrated Water Management and Advanced Irrigation conferred by Cranfield Institute of Water Management at Silsoe, and a Doctorate in Plant and Soil Science conferred by the University of Aberdeen, the Aberdeen Centre for Organic Agriculture and the Scottish Agricultural College. A summary of Dr Robson's relevant expertise and experience is set out in her CV in **Appendix A**.

1.4 Dr Bright and Dr Robson confirm that they have read the Environment Court's Practice Note dated 31 March 2005. They confirm they have complied with it when preparing my written evidence and agree to comply with it when giving this oral evidence. This evidence is within their areas of expertise outlined above.

2. SCOPE OF EVIDENCE

2.1 This joint statement addresses the following matters:

- the methods used in the WQS to estimate nutrient concentrations in surface water and groundwater in the Mackenzie Basin under current and proposed land-uses;
- the thresholds selected in terms of the appropriate maximum nutrient concentrations in surface water and groundwater;
- the outcomes of WQS in terms of current and proposed nutrient loadings; and
- The mechanisms for ensuring that the nutrient thresholds are met.

3. EXEC SUMMARY

3.1 The WQS approach to managing water quality in Lake Benmore, and in the rivers, streams and groundwater that feed into it is comprehensive and robust.

3.2 In scope it:

(a) Identifies surface water and groundwater values potentially affected by land-uses enabled by irrigation.

(b) Determines which parameters, such as nutrient concentration, to measure to determine if values are being affected.

(c) Identifies where in the catchment to make such measurements to monitor the full cumulative effects of the proposed irrigation.

(d) Specifies thresholds to delineate between acceptable and unacceptable levels of effects.

(e) Quantifies the expected effects of the proposed activities in terms of measurable parameters, such as nutrient concentrations, and on indicators related to values such as the appearance of the lake or river.

(f) Determines from the expected effects and the specified thresholds a Nutrient Discharge Allowance (NDA) for each farm. Providing the farming activity does not result in the NDA being exceeded that farm will not adversely affect the aquatic environment.

(g) Specifies farm-scale and catchment-scale monitoring and corrective action programmes designed to ensure the proposed activities remain environmentally sustainable.

3.3 In our opinion the methods used in delivering on this scope of work are fit for purpose and have been competently applied. The results obtained can be relied upon for sustainably managing water quality in the Upper Waitaki catchment.

3.4 The WQS has found that an additional 25,000 hectares (approximately) of agricultural land in the Upper Waitaki can be irrigated without significant adverse effect on the aquatic environment, providing the proposed farm activities do not exceed the NDA's specified by the study.

4. REVIEW OF DOCUMENTS

4.1 In preparing this evidence, we have both reviewed the following documents:

- WQS reports (August 2009)
- MfE Hydrology Reports prepared for the Waitaki Water Allocation Plan development process.
- The evidence of Ian McIndoe, Dr Melissa Robson, Dr Val Snow, and Mr Brian Coffey.

5. OVERVIEW OF THE WATER QUALITY STUDY

5.1 Set out below is our overview of the WQS. The outcome of the WQS is essentially a "water quality management plan" which, when applied to all applicants for acquisition consents, will ensure that an appropriate level of water quality is maintained in the Mackenzie Basin.

5.2 The information presented in this overview has been taken from GHD(2009a, 2009b, 2009c), unless otherwise stated.

6. WATER QUALITY STUDY APPROACH

6.1 The purpose of the WQS is to ensure catchment-scale nutrient management that constrains the cumulative effects of agriculture on water quality within acceptable limits. However, it also translates catchment-scale nutrient discharge constraints into farm-scale constraints so that the impacts of individual farming operations can be managed.

6.2 The WQS approach can be summarised as follows.

(a) Identify node points (locations) within the Mackenzie Basin where nutrient concentrations can be measured and monitored to ensure that specified environmental quality standards are met throughout the Basin.

(b) Develop proposed nutrient concentration thresholds for each node point to ensure appropriate water quality is maintained.

(c) For each node point, identify the land which contributes nutrients to the water whose quality is monitored at that node point. In the WQS these contributing areas are variously referred to as basins, surface water sub-catchments and groundwater sub-catchments.

(d) Determine the current nutrient loadings (inputs to) groundwater and surface water and nutrient concentrations at node points, reflecting past and present land-use activities, and develop methods for predicting current nutrient concentrations given current land-uses.

(e) Predict, using the methods specific to the sub-catchments, the nutrient concentrations expected to result from the irrigation development proposed by consent applicants, assuming land-uses as specified in the consent applications and assuming that land-use is managed according to Good Agricultural Practice.

(f) Calculate the reductions in nutrient loss rates, relative to those under Good Agricultural Practice, that are required in each node points contributing area in order to meet the nutrient thresholds specified for each node point.

(g) Verify that such nutrient loss rates are feasible.

(h) Design monitoring and corrective action programmes that assure that the specified environmental performance standards will be met. If monitoring reveals a threshold has been, or is likely to be exceeded, corrective action is initiated to avoid exceeding the threshold.

6.3 The WQS approach is equivalent to the Total Maximum Daily Load approach used for managing diffuse source pollutants in the USA, and the approach used in some EU countries to meet EU Water Directives. As such it has become orthodox in other countries, but not yet in NZ. Similar approaches that have been or are being applied in NZ to manage lake water quality are Lake Taupo (operative) and the Rotorua Lakes (under development).

6.4 The WQS approach is a comprehensive implementation of the contaminant management concept independently proposed by Bright et al (2008) for the New Zealand Business Council for Sustainable Development.

6.5 We support the WQS approach to managing water quality in Lake Benmore, and in the rivers, streams and groundwater that flow into it.

Definition of node points

6.6 In order to manage the impacts of land-use on water quality it is necessary to define what the potential impacts may be, where they may arise, what needs to be monitored or predicted and managed, and where the monitoring should take place.

6.7 The WQS identified water appearance as the primary attributes of Lake Benmore that is subject to change as a result of land-use change in the Mackenzie Basin. A change in appearance would be driven by increased Nitrogen (‘N’) and Phosphorous (‘P’) flowing into the Lake, leading to increase biological productivity within the Lake. Trophic Level Index was determined to be the most appropriate indicator of the productivity of the Lake, and therefore of a change in water clarity. The WQS further identified the high probability of spatial variation in lake clarity due to the very different inflow volumes into each arm of Lake Benmore. Consequently three node points were specified for the Lake – Northern Arm, Ahuriri Arm, upstream of the dam – for the purposes of predicting and monitoring the effects of land-use change on the Lake.

6.8 The valued river and stream attributes considered in the WQS to be the most sensitive to changes in land-use are visual appearance and aquatic ecosystem health. Visual appearance could be adversely affected if periphyton biomass increases significantly, due to increased N and P concentrations in streams. Aquatic ecosystem health may be adversely affected by an increase in N concentration.

6.9 Convenient access to a potable water source is considered to be the sole groundwater use that may be degraded by an increase in N concentration due to land-use change.

6.10 The locations in the Mackenzie Basin where the change in nutrient concentrations due to the cumulative effects of land-use change are expected to be greatest, or where there is potential for a significant environmental effect to accrue, are at the outlets of the sub-catchments in which the change in land-use that irrigation enables would increase nutrient supply.

6.11 The location of points defined in the WQS for quantifying the current and potential effects of land-use change in the Mackenzie Basin are shown in Figure 1 (**Appendix B**). Throughout this statement we refer to these points as node points. They are simply locations in the water flow network where it is feasible to monitor contaminant concentrations and where the full cumulative effects of land-use in a sub-catchment can reasonably be expected to be observable.

6.12 Node points are also the points of obligation in the WQS approach to managing water quality – the locations for which water quality standards are set, and where compliance with those standards is monitored.

6.13 In our opinion the number and location of the node points is appropriate for the task of managing impacts on water quality and of equitably sharing any obligations associated with keeping nutrient losses below specified limits. Collectively they form a comprehensive and robust structure for monitoring and managing water quality in the Mackenzie Basin.

Identify the boundary of each node point’s contributing area

6.14 Up-gradient of each Node Point is an area of land which contributes the water and nutrients that flow past the Node Point.

6.15 The boundary of the contributing area for node points on rivers and streams was defined by river sub-catchment boundaries. All sub-catchments that flow to a river node point were aggregated into one to form that node points contributing area. Fifteen such contributing areas were identified, as shown in Figure 2 (**Appendix B**).

6.16 The contributing areas for the 11 groundwater node points were primarily defined by surface water sub-catchments. The contributing areas for groundwater and surface water node points therefore generally coincide. The node points typically represent the outlet from a sub-catchment.

6.17 The contributing area of a down-stream node point contains the contributing areas of all node points upstream of it. The contributing area of the Lake Benmore node, for example, contains the whole of the upper Waitaki Catchment, and therefore all of the contributing areas of all node points upstream of the dam. The contributing area of the node point located where the Ahuriri River discharges into the Ahuriri Arm of Lake Benmore contains all contributing areas for node points upstream of the Ahuriri river node point, but not the contributing area for the node point located where the Tekapo River discharges into the Northern Arm of Lake Benmore.

Propose nutrient concentration thresholds at each node point

6.18 Within streams, rivers and lakes there is a natural capacity to assimilate nutrients without there being a significant adverse water quality effect. The magnitude of this capacity varies from catchment to catchment.

6.19 The WQS proposes that nutrient concentration thresholds be set for node points located throughout the catchment and in Lake Benmore to contain the effects of land-use intensification within acceptable limits. The nutrient concentration thresholds are set at the level at which the natural capacity to assimilate nutrients without significant adverse effect is exhausted.

6.20 The breaching of a concentration threshold initiates a requirement for corrective action, as described in Section 11 of this evidence.

6.21 The setting of nutrient concentration thresholds is described in GHD(2009a,2009b,2009c). In summary, thresholds have been recommended throughout the catchment to maintain:

- Groundwater quality (N concentration);
- River and stream quality (N and P concentration and periphyton biomass);
- Lake quality (Trophic Level Index, and corresponding N and P concentrations).

6.22 These thresholds are described in the following sections.

Groundwater thresholds

6.23 The nitrate-N concentration in groundwater in this area, under extensive pastoral farming, typically ranges up to 1 mg/L. The concentration threshold proposed by the WQS is therefore 1 mg/L nitrate-N. This threshold was proposed by the WQS because it was seen to correspond with the qualitative standard for groundwater described in the NRRP.

6.24 We are unaware of any valued attribute that is intrinsic to the groundwater system in the Mackenzie basin that justifies the use of this concentration limit.

6.25 The drinking water standard of 11.3 mg/L nitrate-N is an appropriate standard because it directly relates to a groundwater attribute or use that is valued.

Thresholds for rivers and streams

6.26 The ANZECC (2000) guideline values are recognised as New Zealand's only nationally adopted guidelines for toxicants. The ANZECC thresholds have been adopted for the purposes of the WQS. We support their use because of their standing nationally.

6.27 The ANZECC (2000) values that are appropriate for rivers and streams in the Upper Waitaki Catchment (Upland streams > 150 m) are given below, ***Table 1***.

Table 1 Trigger values for New Zealand upland rivers (Davies-Colley, 2000)

	Total phosphorus mg/L	**Dissolved reactive phosphorus mg/L**	**Total nitrogen mg/L**	**Nitrate-N mg/L**	**Ammonia-N mg/L**
Upland sites, >150 m	0.026	0.009	0.295	0.167	0.010

6.28 The rivers and streams periphyton threshold proposed for each sub-catchment is based on a 25 percent increase of calculated periphyton biomass above existing conditions at the sub-catchments node point(s).

6.29 Justification for adopting this threshold is in evidence to be presented by Dr Coffey. In essence the effect of a 25 percent increase threshold, in Dr Coffey’s opinion, would not be perceptible to casual users, nor constitute a significant adverse change from current conditions. We note that Dr Ryder agrees with the rationale behind the limit recommended by Dr Coffey.

6.30 The 25 percent increase has been translated into changes in nitrogen and phosphorus concentration, assuming the nitrogen and phosphorous are in balance. Staying below the periphyton threshold therefore does not rely on one nutrient being limiting. Control of both nitrogen and phosphorus gives additional security to the maintenance of maximum annual periphyton biomass below the recommended thresholds. Further justification of this approach is provided by Dr Coffey.

Lakes

6.31 Lake Benmore was used in the WQS as a key location for assessing cumulative effects because this is the first location at which all of the cumulative effects of the proposed activities occur. Lakes Pukaki, Ohau and Tekapo lie above almost all of the proposed activities and thus are not expected to be effected by the intensification that could follow the proposed irrigation in the Mackenzie Basin. Changes in the water quality of Lakes Aviemore and Waitaki can be expected to follow those of Lake Benmore.

6.32 There are no national guidelines for lake nutrient concentrations. However, trophic level designations from Burns *et al*. (2000), while not guidelines, can be used to set thresholds for desirable and acceptable lake condition. We support this approach for the Upper Waitaki lakes.

6.33 In consultation with lake scientists and ecologists from within New Zealand and internationally, the Oligotrophic state was recommended as a suitable threshold for Lake Benmore. Oligotrophic lakes contain very low concentrations of those nutrients required for plant growth and thus the overall productivity of these lakes is low.

6.34 The threshold has been set below the boundary between the Oligotrophic and Mesotrophic states – 20% below the boundary for total nitrogen and 15 % below the boundary for total phosphorus.

6.35 The maintenance of the whole lake at or below an Oligotrophic state ensures a high quality, low nutrient water source leaving the catchment.

Determine current nutrient concentrations at each Node Point

6.36 There are two main methods for determining current nutrient concentration values at each node point.

6.37 These are:

- Measure water quality at each node point periodically over a twelve month time frame and calculate from these measurements a statistic, such as the mean or median, to represent the current nutrient status of the water.
- Estimate the current nutrient status by modelling the effects of land-use activities on water quality.

6.38 The WQS reports current nutrient concentrations at node points based on both existing measurements and modelling. This provides an assessment of the current state of the system based on measured data, and an assessment of the potential effects based on modelling that has been calibrated using the measured current state data. This provides greater reliability than basing all assessments on modelling alone.

6.39 The following section of evidence describes, in summary form, the application of each method and the results obtained.

Nutrient concentration measurements

6.40 The nodes, and their respective sub-catchments, at which measured nutrient concentration data were obtained are shown in Figure 1 (Appendix B). In addition, nutrient concentrations in groundwater have been measured at various sites and depths throughout the Mackenzie Basin.

6.41 Measurement data were obtained from ECan, the Upper Waitaki Water Quality Trust (UWWQT), individual farm data, and through targeted water quality sampling undertaken as part the WQS project.

6.42 Full details of the data available are presented in GHD (2009a, 2009b, 2009c). In summary the available data comprises:

- Groundwater quality information from a total of 90 monitoring sites. The well numbers, locations and nitrate-N concentrations are given in GHD (2009c) .
- River/stream nitrogen and/or phosphorous data at 17 key sites, including all node points. The locations, number of samples and sample date range is summarised in Table 4.1 below. All data is presented in GHD (2009a, Appendix AA).
- Lake water quality data at multiple sites in Lakes Benmore, Tekapo, Pukaki, Ohau and Ruataniwha in January and April 2008.

Table 4.1 Overview of river water quality sampling at Node Points

Node Point	Number of Samples	Sample Date Range
Greys River	8	17Apr07 – 22Jan09
Stony River	15	17Apr84 – 22Jan09 (5 since Jan08)
Ahuriri River @ L Benmore	19	3Oct90 – 22Jan09 (5 since Jan08)
Quail Burn	13	15Dec04 – 22Jan09 (5 since Jan08)
Hen Burn	5	15Dec04 – 18Apr05
Mary Burn	9	17Apr07 – 22Jan09
Tekapo River above Pukaki River confluence	3	18Dec08 – 22Jan09
Twizel River above Ohau river confluence	9	10Oct07 – 22Jan09
Wairepo Creek	56	19Feb01 – 22Jan09 (9 since Jan08)
Omarama Stream @ SH8	39	3Oct90 – 22Jan09 (9 since Jan08)
Willow Burn	41	15Dec04 – 22Jan09 (11 Since Jan08)

6.43 The frequency and spread of samples over the twelve month period Jan 08 to Jan 09 is fit for the purpose of providing an average annual snapshot of the current nutrient status of the water ways.

7. MODELLED NUTRIENT CONCENTRATION

Overall approach

7.1 The WQS's overall approach to modelling nutrient concentration in groundwater, streams, rivers and lakes was to model the generation of stream flow, groundwater flow and nutrient loading on a sub-catchment basis and, starting with the most upstream sub-catchments, route the water and nutrients down through a sequence of sub-catchments to Lake Benmore.

7.2 The system was modelled as being in steady-state and conveying the average annual water flow and nutrient load from the head waters down to Lake Benmore.

7.3 Surface and groundwater flow through a catchment was modelled as coming from three distinct sources:

(a) Rain on the highlands of the sub-catchment – areas that are, and are expected to remain, essentially unaffected by land-use in terms of nutrients mobilised.

(b) Rain on the part of the sub-catchment that is subject to land-use change (the WQS refer to such areas as Basins).

(c) Inflows from other sub-catchments, such as canal, river, stream or groundwater flow.

7.4 Rain on the highlands was partitioned into water lost through evapotranspiration, water draining to regional groundwater, and stream flow. The methods used have been applied by others in the Wanaka Catchment. The methods used are the most practical option to use when there is a limited amount of measured flow data, as is the case here.

7.5 Rain on the Basins was partitioned into water lost through evapotranspiration and water draining below the root zone by using water balance modelling methods to be described in evidence by Mr Ian McIndoe. This was a straightforward application of well established methodology using good input data.

7.6 Inflows from Lake Tekapo, Pukaki and Ohau were the measured average annual canal flows over the period 1996-2007, plus measured spill flows from Lake Ohau. Data on other spill flows was not available and had to be estimated. The unavailability of data on all measured water inputs from the Lakes, and the lack of data at sub-catchment level that was suitable for validating the flow models meant that no direct model validation was possible.

7.7 However the model of the system as a whole was able to be calibrated successfully to measured average annual flow past Benmore Dam over the period 1996-2007. Consequently the data provided by the model is robust.

7.8 Nitrogen inputs to the sub-catchments were modelled as being sourced only from Basin areas, which we consider to be appropriate given that the highland areas are essentially unaffected by land-use in terms of nutrients mobilised. Phosphorous losses from the whole of each sub-catchment were estimated. The methods used to estimate nutrient loads for agricultural land-uses will be described in evidence by Dr Val Snow. In essence they involve the straightforward application of the same nutrient balance models used elsewhere in New Zealand for similar purposes – notably for establishing nutrient management regimes for Lake Taupo and the Rotorua Lakes.

7.9 Not all of the catchment is used for agricultural purposes. The nature and distribution of all land-use types were identified using the New Zealand Land Cover DataBase v2. Irrigated areas, both current and proposed, were superimposed onto the land cover database. Estimates of nutrient losses from non-agricultural land-uses were obtained from published literature. The sources of such data and the manner in which the data were used are very appropriate for a study of this type.

7.10 The modelled nutrient loads into Lake Benmore matched well with the estimated nutrient discharge past Benmore Dam, this estimate being based on measured total discharge and lake nutrient concentration. This supports the validity of the methods and data used, and assumptions made, to estimate nutrient loads from current land-uses, and the use of this approach to estimate the nutrient load expected from the proposed land-uses.

7.11 A spreadsheet model, based on the conservation of mass, was used on a sub-catchment by sub-catchment basis to route water and nutrients down through a sequence of sub-catchment and node points to Lake Benmore.

7.12 The spreadsheet model treats surface water flows and regional groundwater flows as distinct, but connected, flow paths. Drainage water, and the nutrients it carries, is partitioned between surface water flow and regional groundwater flow on the basis of measured surface water flow gains and losses, from and to shallow groundwater. All water gained in a stream reach is assumed to come from drainage water, to the extent there is sufficient drainage volume. If not the balance is taken from regional groundwater. The assumption that all gaining water is taken from drainage water, and the nutrients contained in it, implicitly assumes that the draining water is held up by shallow low permeability soil layers and moves laterally across the top of the low permeability layer to the stream. There is observational information, from test pits, that this occurs in this area. The implication is that the gaining reach of a stream is subject to loading from the most highly contaminated water in the sub-catchment. It is our opinion that these assumptions will lead to a conservative (high) estimate of the impact of land-use on nutrient concentrations in streams and rivers.

7.13 The spreadsheet model assumes full mixing of all surface water flows in the sub-catchment before surface water is discharged into the next sub-catchment. It makes the same assumptions in regard to groundwater flow.

7.14 At each node point the concentration of nutrients in surface water and groundwater are calculated, as is the nutrient load placed on the next downstream sub-catchment by the upstream sub-catchment. The nutrient load placed on surface water and groundwater by leaching through the soil profile is also quantified.

7.15 Modelled nutrient concentrations were compared to measured concentrations at surface water and groundwater node points. The model was calibrated by making adjustments to model parameters, where possible, to bring the modelled values into closer agreement with measured values.

Current agricultural land-use

7.16 Land use in the Upper Waitaki is predominantly extensive, un-irrigated pastoral farming. The climate is harsh and the potential growing season is shortened by both extreme heat and cold as well as water stress that curtails pasture production at different times of the year. Pasture production is highly variable, both inter-annually and intra-annually. The only common feature is the almost complete lack of pasture production for three months over winter.

7.17 With no irrigation or artificial fertiliser, pasture production is estimated to be approximately 2.8-3.0 t DM/ha/yr. Production from irrigated and fertilised pasture increases production but does not completely eliminate year-to-year variability (King, 2008).

7.18 The main livestock are sheep and beef, although some stations have deer as well. The majority of the catchment has a stocking rate of less than 1 su/ha. Through the area of proposed development, current average stocking rates are in the region of 1-2 su/ha. With irrigation the stocking rate will typically be 12-15 su/ha (Snow *et al*., 2008a; Snow *et al*., 2008b).

7.19 The main forage crops grown are ryecorn and lucerne, with some turnips and rape. Occasionally a farmer will plant wheat, get one grazing off it and then harvest the grain for on-farm use. Forage crops are not commonly grown under irrigation in the Basin because larger and more reliable yields are achieved under pasture (Trolove, 2008).

7.20 Not all of the catchment is used for agricultural purposes. The nature and distribution of all land-use types has been analysed, mapped, and is made available as the New Zealand Land Cover DataBase v2. The information contained in this database was used to determine the nature and area of each land-use activity present in each sub-catchment.

Current Irrigation

7.21 The majority of existing irrigation in the basin is either border dyke or centre pivot, although there are some other spray systems such as K-line and some less regulated flood irrigation systems. Current irrigated areas have been estimated from satellite imagery taken in January 2007, consented irrigation takes, local knowledge (Aqualinc, 2008) and from information derived from farmer questionnaires. A total of 8,990 ha was identified; 4,378 ha of surface irrigation and 4,612 ha of spray irrigation. Figure 3 (**Appendix B**) shows the area of consented and existing irrigation.

Modelled Nutrient Losses from Key Agricultural Land-Use Activities

7.22 The current average nutrient losses from farms in the Upper Waitaki Catchment are low. Leaching losses at a block level ranged from less than 3 to 26 kg N /ha with higher losses coming from dairy units, farms with high stocking rates and farms with a high percentage dedicated to forage or arable crops. Extrapolated phosphorus losses ranged from 0.01 to 1.1 kg P /ha with higher losses associated with border dyke irrigation, hill country and deer. Modelled losses from actual on-farm modelling from seven stations in the catchments are shown in ***Table 2***.

Table 2 Nitrogen (through leaching) and phosphorus loss by block type

Block Type	**Count**	**N loss (kg N /ha)**			**P loss (kg P /ha)**		
		Range	Average	Median	Range	Average	Median
Pasture	27	2 - 4	2.6	3.0	0.0 - 1.0	0.14	0.00
Forage	6	30 - 54	43.3	45.5	0.5 - 0.5	0.50	0.50
Grain	1		28.0			1.00	
Irrigated	5	6 - 12	9.0	9.0	0.2 - 1.9	0.68	0.40

7.23 At a block level, nutrient losses as modelled by AgResearch, were strongly influenced by usage. Losses were particularly high from forage crop blocks and were higher from irrigated than un-irrigated pasture blocks. The high losses associated with forage crops are largely due to their management. As is apparent from ***Table 2***, for irrigated pasture (non-dairy), the N losses were 2-3 times the losses from un-irrigated pasture.

7.24 Details of the data and methods used will be described in evidence by Dr Val Snow and Dr Ross Monaghan.

Overall assessment of the WQS modelling approach

7.25 In summary, in our view the overall modelling approach adopted in the WQS is orthodox and robustly applied. The quantification of flows, concentrations and loads as average annual values is appropriate, given the limited amount of information available on the hydrology and hydrogeology of sub-catchment.

7.26 In our opinion the methods used to complete the WQS are appropriate, robust and comprehensive. The methods have been competently applied.

8. EXISTING ENVIRONMENT - NUTRIENT CONCENTRATION

Groundwater at Node Points: Nitrate concentrations

8.1 The measured and model estimates of groundwater nitrate concentrations are given in ***Table 3***.

The low concentration of nitrate is likely due to a combination of the existing land practices and dilution from low nutrient status regional groundwater flows.

Table 3 Estimated and observed mean groundwater N concentrations and loads at all Node Points

Node	Estimated N Loss to Groundwater kg/year	Estimated N concentration mg/L	Measured Mean N mg/L	Range of Observed N
Greys River	80900	0.58	0.62	0.1 – 1.6
Stony River	17522	0.20	0.3	0 – 0.5
Ahuriri River @ SH8	14679	0.07	no data	
Ahuriri River @ Benmore	118547	0.35	no data	
Quail Burn	21791	1.16	no data	
Hen Burn	11204	0.47	0.57	
Mary Burn	133799	0.56	0.5	0 – 0.6
Tekapo River	1717	0.77	no data	
Twizel River	93080	0.40	0.21	0 – 0.6
Pukaki River @ Lake Benmore	213606	0.77	no data	

Wairepo Creek	59546	1.13	0.4	0.01 - 0.72
Omarama Stream	32417	0.21	0.37	0.1 – 0.6
Willow Burn	10341	3.26	no data	
Chain Hill	26447	1.60	0.9	0.4 – 1.2
Ohau River	9499	0.42	No data	

8.2 The model estimates are similar to the measurements obtained for the Greys River, Mary Burn and Hen Burn nodes. Observed N concentrations are higher than estimated for Stony River and Omarama Stream nodes, however, the estimated N concentrations are within the range of observed concentrations. Estimated N concentrations are approximately twice observed concentrations for the Wairepo Creek, Chain Hill and Twizel nodes, but within the observed range for the Twizel node. Where irrigation has only recently started, such as the Wairepo Creek sub-catchment, the full impacts may not have yet been manifested in the measured groundwater quality. The modelling approach assumes that the full impacts are immediately apparent. Hence the modelling may be indicating the N concentration that will eventually be reached as a result of recent land-use change.

8.3 In summary, model estimates of N concentration in groundwater are acceptably close to measured values. Where the model estimates differ significantly from measured values they tend to be over estimates and thus apply a degree of conservatism to this aspect of the WQS.

Surface water at Node Points - Phosphorus concentrations

8.4 Phosphorus loads in streams were estimated at the nodes and are set out in Table 4.

Table 4 Estimated and observed average total phosphorus and dissolved reactive phosphorus concentrations in streams at mean flow at node points

Node	Estimated Total Phosphorus mg/L	Estimated Dissolved Reactive Phosphorus mg/L	Observed Mean Total Phosphorus (Median in parentheses) mg/L	Range of Observed Total Phosphorus concentration mg/L	Observed Mean Dissolved Reactive Phosphorus (Median in parentheses) mg/L	Range of Observed Dissolved Reactive Phosphorus concentration mg/L
Greys River Node	0.029	0.014	0.015 (0.015)	0.008-0.028	0.007 (0.007)	<0.004-0.011
Stony River Node	0.075	0.041	0.064 (0.060)	0.027-0.11	0.035 (0.034)	0.009-0.066
Ahuriri River Node	0.009	0.004	0.006 (0.008)	<0.004-0.009	0.003 (0.003)	0.001-0.005
Quail Burn Node	0.039	0.015	0.012 (0.010)	0.008-0.014	0.004 (0.004)	0.002-0.007
Hen Burn Node	0.019	0.007	0.020 (0.015)	0.012-0.025	0.006 (0.007)	0.004-0.008
Mary Burn Node	0.016	0.006	0.010 (0.008)	<0.008-0.02	0.004 (0.004)	<0.004-0.006
Tekapo Node	0.050	0.012	0.006 (0.006)	<0.004-0.009	<0.004 (<0.004)	<0.004
Twizel River Node	0.037	0.018	<0.008 (<0.008)	<0.008	0.004 (0.004)	<0.004-0.006
Pukaki River Node	0.025	0.009	0.005 (0.008)	0.001-0.008	0.001 (0.001)	0.001-0.002
Upper Wairepo Creek Node	0.014	0.004	0.015 (0.016)	0.009-0.02	<0.004 (<0.004)	<0.004
Wairepo Creek Node	0.026	0.006	0.017 (0.011)	0.008-0.066	0.004 (0.003)	0.001-0.023
Inlet to Lake Ruataniwha	0.002	<0.002	<0.004 (<0.004)	<0.004	<0.004 (<0.004)	<0.004
Omarama Stream Node	0.04	0.017	0.02 (0.016)	0.008-0.034	0.01 (0.007)	<0.004-0.016
Willow Burn Node	0.04	0.01	0.03 (0.03)	0.011-0.051	0.01 (0.01)	0.005-0.87
Lower Ohau River	0.003	<0.003	<0.004 (<0.004)	<0.004	<0.004 (<0.004)	<0.004

Blue highlights indicate where concentrations exceed ANZECC (2000) guideline trigger values.

8.5 The WQS methodology assumed that all phosphorus lost from the land would be captured in the surface water flow. This led to an over estimation of the expected concentrations of phosphorus in the streams compared to observed concentrations.

8.6 The overall P mass balance for the catchment shows a good relationship between modelled losses from land (i.e. the P input to the hydrological system) and observed losses from Lake Benmore (the measured P loss from the hydrological system above the dam).

Surface water at Node Points - Nitrate concentrations

8.7 The modelled and observed stream nitrate concentrations at sub-catchment nodes are shown in Table 5. There is a reasonable relationship between measured and modelled nitrate concentrations. Modelled concentrations fall within the measured range and are generally in agreement with the mean of the observed data.

Table 5 Estimated and observed nitrate-N concentrations in streams at sub-catchment nodes

Node	No of Observations	Estimated nitrate-N @ Mean Flow (mg/L)	Observed Mean nitrate-N (mg/L)	Median	Range of Observed nitrate-N (mg/L)	
Greys River	7	0.034	0.03	0.029	0.007	0.12
Stony River	15	0.17	0.44	0.33	0.1	0.81
Ahuriri River	8	0.019	0.02	0.016	0.007	0.056
Quail Burn	8	0.014	0.02	0.016	0.002	0.032
Hen Burn	5	0.023	0.09	0.082	0.014	0.18
Mary Burn	9	0.018	0.07	0.012	0.012	0.15
Tekapo River	3	0.024	0.003	0.0023	0.002	0.005
Twizel River	4	0.034	0.02	0.0038	0.002	0.063
Wairepo Creek	26	0.019	0.051	0.017	0.002	0.16
Upper Wairepo	3	0.086	0.004	0.002	0.002	0.008
Omarama Stream	11	0.14	0.1	0.18	0.005	0.26
Willow Burn	44	0.69	0.33	0.33	0.005	0.87

Blue highlights indicate where concentrations exceed ANZECC (2000) guideline trigger values.

Lake Benmore

8.8 The range of measured nitrogen and phosphorous concentrations in Lake Benmore are presented in summary form in Figure 4 (**Appendix B**).

8.9 Under current conditions the average annual nitrogen and phosphorous concentrations in both arms of Lake Benmore sit below the WQS thresholds. This means there is capacity for the lake to assimilate nutrients from additional irrigated area without exceeding these thresholds.

Lake Ruataniwha and Wairepo Arm/Kelland Pond

8.10 Total N and P concentrations have been used to estimate the existing trophic status of Lake Ruataniwha. The total nitrogen concentrations are below detection level and so the trophic level can’t be calculated. However, the nutrient concentrations indicate that it will be Oligotrophic or better.

8.11 Total N and P concentrations have also been used to estimate the existing trophic status of the Wairepo Arm/Kelland Pond, which is calculated to be in a Mesotrophic state.

9. SUMMARY OF CURRENT NUTRIENT STATUS RELATIVE TO NUTRIENT THRESHOLDS AT NODE POINTS

Groundwater

9.1 The above results show that in many sub-catchments, the mean of the measured nitrate concentration in groundwater is below 1 mg/L nitrate-N. This means that, with respect to this threshold, there is unused nitrogen discharge allowance. Additional irrigation could therefore occur without transgressing the groundwater nitrate threshold.

9.2 The modelled mean nitrate concentration is below the 1 mg/L nitrate-N threshold for all sub-catchments, except the Wairepo Creek, the Quail Burn, the Willow Burn and Chain Hills. For two of these node points there are no measurements with which to compare the estimates. For the other two nodes the mean of the measurements is less than modelled. This may mean that the model is simply overestimating the effects of land-use on nitrates in groundwater, or it may mean that the full effects of recent land-use change have not yet developed. To be conservative the modelled results have been used to quantify current status.

Surface water

9.3 The mean of the measured total phosphorous concentrations under current land-uses is less than the threshold for all but the Stony River and the Willow Burn. With respect to dissolved reactive phosphorous these nodes also exceed the threshold, along with the Omarama Stream.

9.4 The means of the measured and modelled nitrate concentrations exceed the threshold for Stony Creek and Willow Burn, only.

9.5 With respect to the threshold, there is unused nutrient discharge allowance in all other sub-catchments, which means additional irrigation could occur without transgressing these thresholds. No additional irrigation is proposed in the Stony Creek sub-catchment. A small amount of additional irrigation is proposed in the Willow Burn. A reduction in nutrient loss from existing properties in the Willow Burn would be necessary to create scope for additional irrigation without exceeding the surface water nutrient threshold.

Lake Benmore

9.6 Lake Benmore is currently classified by ECan as Microtrophic to Oligotrophic (Meredith and Wilks, 2006). Norton *et al*. (2009) classify the existing state of Lake Benmore as Oligotrophic. It currently lies within the thresholds proposed.

9.7 The Northern Arm has been measured in both the Microtrophic and sometimes in the Ultra-microtrophic state and the Ahuriri Arm has been measured in the Oligotrophic state, Figure 4. The TLI levels of Lake Benmore have not shown any significant change from 2002 to 2008. Both arms of the lake lie within the thresholds proposed.

10. PREDICTED NUTRIENT STATUS RELATIVE TO NUTRIENT THRESHOLDS GIVEN EXISTING AND PROPOSED IRRIGATION

The Scenarios

10.1 A series of scenarios were designed to assess the impact of future development of irrigated land. The impacts have been assessed assuming that Good Agricultural Practices are applied on all new irrigated land, and on irrigated land for which consents are being renewed. The need for and magnitude of any mitigation required to reduce nutrient concentrations to below nutrient thresholds was thus identified and quantified by comparing predicted nutrient concentrations under the development scenarios with nutrient thresholds specified at node points.

10.2 The scenarios are set out below.

10.3 **Scenario 1** involved modelling the current land use and provides the baseline for comparative assessment.

10.4 **Scenario 2** existing irrigated area plus an additional 26,755 ha of new irrigation. This scenario includes areas proposed to be developed for irrigation by the current consent applicants, areas for which consents are already held but are not yet irrigated, and tranching irrigation (irrigated area for which water is available, but which has not yet been applied for), giving a total of 26,755 ha additional irrigation and a total of 35,755 ha irrigation.

10.5 The nutrient budget modelling for current land uses and Scenario 2 has assumed that soils are developing, with a build up in organic matter due to the intensified agriculture.

10.6 Eventually soils develop to a point where nitrogen immobilisation reaches a steady state. These soils are classified for modelling purposes as 'highly developed'. Nutrient loss estimates made assuming 'highly developed' soils provide an upper limit estimate of nitrogen losses from a farm. The highly developed status has no impact on phosphorus losses.

10.7 Two further scenarios were assessed to determine the effects of highly developed soils:

- Scenario **3** Existing irrigated area, assuming soils are highly developed.
- Scenario **4** Existing irrigated area plus an additional 26,755 ha of new irrigation, assuming soils are highly developed.

Irrigated Area

10.8 The proposed irrigation area was determined principally through the resource consent applications lodged with ECan (as determined by Aqualinc, 2008). However, where direct communication from farmers generated differing information, this information took precedence. Consents applications have been made for the irrigation of an extra approximately 17,000 ha of the 26,755 ha of proposed irrigated area.

10.9 For the purposes of estimating the cumulative effects of irrigating the whole 26,755ha, the remaining area has been distributed as per the MEL/MIC tranching regime, and it was assumed that the remaining land would be used for sheep and beef farming. Figure 5 (**Appendix B**) shows a map of the proposed irrigated areas including the consented but not operative irrigation and the assigned irrigation as per the tranching agreement. A table of current and proposed irrigated area by sub-catchment is shown in ***Table 6***.

Table 6 Proposed irrigation areas by sub-catchment in the Upper Waitaki Catchment

Sub-catchment	Existing Irrigation Area (ha)			Proposed Irrigation Area (ha)				Allocated Irrigation Area (ha)				Tranching Irrigation Area (ha)				
	Spray	Borderdyke	**Total**	Spray	Borderdyke	K-Line	**Total**	Spray	Borderdyke	K-Line	**Total**	Spray	Borderdyke	K-Line	**Total**	**Grand Total ha**
Ahuriri	192.0	697.6	889.7	1769.7			1769.7		90.0		90.0	470.4			470.4	3219.7
Direct to Bemore catchment	425.1	472.8	897.9	815.0			815.0				0.0	370.8			370.8	2083.8
Greys	86.4	177.4	263.8	771.2	80.4		851.6				0.0	829.6			829.6	1945.0
Hen Burn	124.4	6.2	130.6	136.6			136.6				0.0	908.3			908.3	1175.5
Mary Burn	312.4	782.8	1095.2	1104.1			1104.1				0.0	500.00			500.0	2699.4
Ohau River	106.4	417.0	523.4	956.5			956.5	464.1			464.1	3707.0			3707.0	5186.8
Omarama Stream	168.8	1018.3	1187.1	402.2			402.2				0.0	246.6			246.6	1835.9
Pukaki	149.4	122.1	271.6	986.5			986.5				0.0	243.7			243.7	1501.8
Quail Burn	384.4	7.4	391.7	1142.0		256.1	1398.0				0.0	79.5			79.5	1869.3
Stony River	58.2	389.6	447.7				0.0				0.0				0.0	447.7
Tekapo River	145.2	47.8	192.9	103.3			103.3				0.0	483.2			483.2	779.5
Pukaki	159.6		159.6	5269.3			5269.3				0.0	336.2			336.2	5765.2
Wairepo Creek	1201.1	98.4	1299.6	2769.3		160.2	2929.5	1463.5			1463.5				0.0	5692.6
Willow Burn	1098.8		1098.8	131.1			131.1				0.0	173.2			173.2	1403.2
Grand Total (ha)	4612.4	4237.3	8849.7	16356.7	80.4	416.3	16853.4	1927.6	90.0	0.0	2017.	8348.6	0.0	0.0	8348.6	35605.2

Predicted Effects of the Proposed Irrigation and the Nutrient Loss Reductions Required to Avoid Breaching Nutrient Thresholds at Node Points

10.10 The predicted effects of the proposed irrigation on nutrient loads at node points are summarised in the Section 6 of GHD (2009a).

10.11 In general, nutrient management associated with the proposed irrigation, and irrigation renewals, will have to be to a higher standard than Good Agricultural Practice in all sub-catchments if the proposed nutrient thresholds are to be met and all of the proposed irrigated area is to be irrigated.

10.12 The following tables set out the size of the nutrient loss reductions that would be required, relative to losses under Good Agricultural Practice, to avoid breaching nutrient thresholds at node points. The reductions in nutrient load, where expressed in terms of mass per unit area, have been calculated based on the assumption that the reduction required is distributed uniformly over the proposed and re-consenting irrigated area. This is only one example of how the reduction could be allocated, but it is one we understand all of the Applicants have accepted. These set the nutrient discharge allowance (NDA) for individual applicants.

Groundwater

10.13 Only two groundwater sub-catchments have nitrate concentrations that are predicted to exceed the 1 mg/L nitrate-N threshold where they are currently modelled to be below it – the Pukaki and Ohau groundwater sub-catchments.

10.14 The required nutrient reductions for these sub-catchments are shown in ***Table 7***.

Table 7 Required changes in nitrate loads to groundwater in groundwater sub-catchments

Ground water sub-catchment	**New & Existing irrigation (expressed in hectares)**	**Environmental Threshold (expressed in kg N per year)**	**Environmental Threshold (expressed in kg P per year)**	**Total N change (expressed in Kg N per year) to achieve Environmental Threshold**	**Total P change (expressed in Kg P per year) to achieve Environmental Threshold**	**Total N change (expressed in Kg of nitrate-N per hectare per year) to achieve Environmental Threshold**	**Total P change (expressed in Kg P per hectare per year) to achieve Environmental Threshold**
Pukaki Groundwater sub-catchment	8,910	364,303	nd	-27,500	Nd	-3.1	Nd
Ohau Groundwater sub-catchment	2464	16941	nd	-39,681	Nd	-17.4	Nd

10.15 In the sub-catchments where modelled (but not measured) nitrate concentrations exceed the threshold the excess nitrate-N concentration has not been considered to be an adverse effect. However, if the excess in nitrate-N in the groundwater caused a threshold to be breached at another downstream node point, the activities that caused the excess in nitrate-N would need to reduce their nitrogen discharges to the point where all downstream thresholds were met. This is the case in the Wairepo sub-catchment.

10.16 Increases in groundwater nutrient concentrations in the Wairepo sub-catchment are predicted to impact on the water quality of the Wairepo Arm/Kelland Pond. To maintain the Wairepo Arm/Kelland Pond in its current Mesotrophic state, nutrient losses from the proposed irrigated area will have to be 16.4 kg N/ha and 0.7 kg P/ha less than is estimated to occur under Good Agricultural Practice, as shown in Table 11.

Streams and Rivers – ANZECC(2000)

10.17 Under proposed Scenario 2, phosphorus concentrations in the Stony River, Quail Burn, Omarama Stream, Wairepo Creek, and Willow Burn are predicted to exceed ANZECC (2000) guideline values at node points.

10.18 Nitrate concentrations in the Stony River, Wairepo Creek and the Willow Burn are also predicted to exceed ANZECC (2000) values.

10.19 The nutrient loss reductions required for these sub-catchments to meet ANZECC (2000) guidelines is shown in ***Table 8*** below. Where water quality at sub-catchment nodes was already found to exceed the triggers under current land-uses, the nutrient mitigation requirement has been divided amongst the whole sub-catchment on a per hectare basis.

Table 8 Required changes in nutrient losses in contributing areas to meet ANZECC (2000) trigger guidelines at node points

Node Point	New & Existing irrigation (expressed in hectares) upstream of the Sub-catchment Node	Environmental Threshold (expressed in kg nitrate-N per year)	Environmental Threshold (expressed in kg TP per year)	Total N change (expressed in Kg nitrate-N per year) to achieve Environmental Threshold	Total P change (expressed in Kg TP per year) to achieve Environmental Threshold	Total N change (expressed in Kg of nitrate-N per hectare per year) to achieve Environmental Threshold	Total P change (expressed in Kg P per hectare per year) to achieve Environmental Threshold
Stony River Node	447	5,793	1032	-104	-2982	-0.1	-0.1
Omarama Stream Node	1835	12,108	5327	1,088	-4078	0.1	-0.1
Quail Burn Node	1569	4,635	2294	3,627	-746	2.3	-0.5
Willow Burn	1403	572	28.4	-2,639	-236.5	-0.7	-0.1
Wairepo Lower	4449	1279	68.9	-8667	-4781.1	-1.9	-1.0

Red highlight indicate where trigger guidelines are exceeded under current conditions and mitigation requirements have been shared across the whole sub-catchment.

Rivers and Streams: Periphyton

10.20 The reductions in nutrient losses, relative to those predicted to occur under Good Agricultural Practice, that are required to limit periphyton growth to less than a 25 percent increase are presented in ***Table 9***.

Table 9 Required changes in nutrient loads at sub-catchment nodes for a 25% increase in periphyton biomass

Sub-catchment Node	New & Existing irrigation (expressed in hectares) upstream of the Sub-catchment Node	Environmental Threshold (expressed in kg nitrate-N per year)	Environmental Threshold (expressed in kg TP per year)	Total N change (expressed in Kg nitrate-N per year) to achieve Environmental Threshold	Total P change (expressed in Kg TP per year) to achieve Environmental Threshold	Total N change (expressed in Kg of nitrate-N per hectare per year) to achieve Environmental Threshold	Total P change (expressed in Kg P per hectare per year) to achieve Environmental Threshold
Stony River Node	0	9,175	1980	3,278	-228	No new or renewing irrigation	
Greys River Node	1664	4,760	1191	1,704	-240	1.0	-0.1
Tekapo Node	3420	7,520	4516	1,389	1250	0.4	0.4
Mary Burn Node	1152	4,850	1385	1,731	-642	1.5	-0.6
Twizel River Node	1230	3,440	953	1,226	9	1.0	0.0
Ahuriri River Node @ Benmore	6696	27,000	5400	9,684	-6213	1.1	-0.9
Omarama Stream Node	961	15,800	5857	4,780	1862	5.0	1.9
Quail Burn Node	1573	1,565	509	558	-503	0.4	-0.3
Pukaki @ Benmore	10156	23,150	5,131	1,050	2057	0.5	0.4

1 Assumes N and P are balanced. 2 Existing irrigation comprises the areas where an application for renewal has been lodged to be heard at same time as new applications for those farmers that have subscribed to the MWRL Water Quality Study.

Lakes

10.21 Although there is a single standard recommended for Lake Benmore, the inherent difference between the Northern Arm and the Ahuriri Arm, and the difference in irrigation in their respective catchments, are such that the Ahuriri Arm is at greater risk of exceeding the recommended standard than the Northern Arm.

10.22 The reduction in nitrogen and phosphorus losses, relative to those under Good Agricultural Practice, that are required to maintain the two arms of Lake Benmore in an Oligotrophic state are show in ***Table 10***.

10.23 For the Northern Arm of Lake Benmore to remain at or below Oligotrophic, no on–farm nutrient loss reductions are required. Note, however, that mitigation may be required to protect other receiving environments (streams, rivers and groundwater).

Table 10 Required changes in nutrient loads to maintain the Ahuriri Arm of Lake Benmore in an Oligotrophic state

	New & Existing irrigation (expressed in hectares)	Environmental Threshold (expressed in kg N per year)	Environmental Threshold (expressed in kg P per year)	Total N change (expressed in Kg N per year) to achieve Environmental Threshold	Total P change (expressed in Kg P per year) to achieve Environmental Threshold	Total N change (expressed in Kg of N per hectare per year) to achieve Environmental Threshold	Total P change (expressed in Kg P per hectare per year) to achieve Environmental Threshold
Ahuriri Arm	7,282	154185	9391	-77584	-7674	-10.7	-1.1

1 Existing irrigation comprises the areas where an application for renewal has been lodged to be heard at same time as new applications for those farmers that have subscribed to the MWRL Water Quality Study.

10.24 For the Ahuriri Arm of Lake Benmore to remain Oligotrophic, nutrient losses must be reduced by 10.7 kg N and 1.1 kg P for every hectare of proposed or renewed irrigation in the catchments that drains to the Ahuriri Arm, as shown in ***Table 10***

10.25 Norton *et al*. (2009) in their report on Lake Benmore water quality also found that the Ahuriri Arm was more vulnerable to nutrient increases than the Northern Arm. Their detailed modelling work predicted a similar threshold for total nitrogen for the Ahuriri Arm at 173,000 kg for the boundary of the Oligotrophic/Mesotrophic states, and a greater threshold for phosphorus at 24,000 kg for the boundary of the Oligotrophic/Mesotrophic states.

Table 11 Required changes in nutrient loads for no increase in trophic state in the Wairepo Arm of Lake Ruataniwha

Secondary receiving environment	New & Existing irrigation (expressed in hectares)	Environmental Threshold (expressed in kg N per year)	Environmental Threshold (expressed in kg P per year)	Total N change (expressed in Kg N per year) to achieve Environmental Threshold	Total P change (expressed in Kg P per year) to achieve Environmental Threshold	Total N change (expressed in Kg of nitrate-N per hectare per year) to achieve Environmental Threshold	Total P change (expressed in Kg P per hectare per year) to achieve Environmental Threshold
Wairepo Creek	3642	59484	2534	-59728	-2427	-16.4	-0.7

1 Existing irrigation comprises the areas where an application for renewal has been lodged to be heard at same time as new applications for those farmers that have subscribed to the MWRL Water Quality Study.

The feasibility of achieving the required degree of nutrient discharge reduction

10.26 The feasibility of achieving the required degree of nutrient discharge reduction is briefly illustrated by the following examples. Both examples are in sub-catchments that drain to the Ahuriri Arm of Lake Benmore. This arm requires more stringent nutrient thresholds than does the Northern Arm. In one example the more difficult threshold to meet is the P loss, whilst in the other example nitrogen is the principle constraint. In both examples the proposed farm type is dairy farming.

10.27 The first example is a proposed 1200 hectare dairy farm in the Ahuriri sub-catchment for which the maximum allowable nitrogen loss per year, as determined by the WQS, is 26 kg/ha and the maximum phosphorous loss per year is 0.37 kg/ha.

10.28 The proposed farm system involves housing the dairy herd in cubicle stables full time for 8 months per year, and 12 hours per day for the remaining 4 months. Feed will be mainly cut and carried to the cows. All effluent from the cubicle stables, milking platform, feed storage area and solid effluent storage area will be collected, undergo solids separation and stored for application during the growing season. Liquid effluent will be applied using centre pivots during the irrigation season. Solids will either be applied uniformly to land or sold off the property.

10.29 The nitrogen and phosphorous losses per year have been estimated, using Overseer, to be 14.7 kg/ha and 0.37 kg/ha respectively. One of the keys in redesigning this dairy operation to comply with the nutrient loss thresholds was the capture of the bulk of the urine and faeces produced by the cows so that its application to land could be carefully managed to achieve a high degree of uniformity and to match nutrient input rates with the rate of nutrient uptake by pasture during the growing season.

10.30 The second example is a proposed 2100 hectare diary farm in the Wairepo sub-catchment for which the maximum allowable nitrogen loss per year, as determined by the WQS, is 14.8 kg/ha and the maximum allowable phosphorous loss is 0.76 kg/ha.

10.31 The proposed farm system is conceptually the same as described in paragraph 11.27 above, but on a slightly larger scale. The nutrient losses estimated by Overseer for the proposed operation of this farm are 14.7 kg/ha of nitrogen and 0.76 kg/ha of phosphorous.

10.32 Both of these farms are feasible farm systems, and are patterned on the growing number of dairy farms designed around the use of cubicle stables in South Canterbury and Southland. Each has been designed to meet the environmental standards set by the WQS.

11. FARM SCALE AND CATCHMENT SCALE MONITORING AND CORRECTIVE ACTION PROGRAMME

11.1 Maintaining, at an acceptably low level, the risk of nutrient thresholds being exceeded requires all consent applicants to have a Nutrient Discharge Allowance (NDA) for their farm, and to maintain nutrient losses from their farms below that NDA. Nutrient losses from farms will need to be monitored to verify that the required performance is being delivered.

11.2 To verify that the allowed nutrient losses from each farm collectively result in nutrient concentrations remaining below the nutrient thresholds specified for each node point, it is necessary to monitor nutrient concentrations throughout the Mackenzie Basin.

11.3 Monitoring at both farm-scale and catchment-scale are thus required.

11.4 Corrective action programmes applicable at farm-scale and at catchment scale are also required in the event that farm practice does not maintain nutrient losses below a specified level, and in the event that catchment scale monitoring demonstrates that nutrient thresholds at node points are being exceeded, or can be expected, on reasonable grounds, to be exceeded within a defined period of time. Mr Kyle will present a suite of propose consent conditions that encapsulate this approach, which he terms “adaptive management”.

Farm Scale Monitoring and Corrective Action Programme

11.5 The WQS has shown that the proposed irrigation development can take place in the Upper Waitaki, without significant adverse effects, providing nutrient losses from each farm are maintained below the NDA specified for each farm.

11.6 To assure compliance with the NDA it is our view that a three component monitoring programme is required for each farm. The three components are:

- Development of an approved Farm Environmental Management Plan (FEMP)
- Monitoring compliance with the FEMP
- Monitoring compliance with the NDA

11.7 The nature of the FEMP’s that are required, in our view, will be described in separate brief of evidence to be presented by Dr. Robson.

11.8 In our opinion a farm manager will need to maintain a farm management diary that records sufficient details to demonstrate compliance with the FEMP.

11.9 Monitoring compliance with the NDA can be achieved by either:

1. Annual use of Overseer, or approved equivalent, with relevant details from the farm management diary, to estimate annual nutrient losses; or
2. Continuous monitoring of nutrient losses using approved monitoring methods (eg lysimeters) and annual analysis of the data to calculate the annual nutrient loss at farm scale.

11.10 It is our view that the estimated or calculated annual nutrient loss should be filed with ECan annually.

11.11 If monitoring shows that the NDA is exceeded a review of the FEMP will be required to identify the further steps that are to be taken to reduce nutrient losses so that they do not exceed the NDA. A review of the consent conditions relating to compliance with the nodal and property NDA's is also enabled by the conditions recommended by Mr Kyle.

Catchment Scale Monitoring and Corrective Action Programme

11.12 The following catchment scale monitoring programme is proposed.

Stream, river and lake monitoring

11.13 Node points were defined by GHD (2009a) for the purpose of quantifying nutrient concentrations in water ways resulting from existing land uses, and for quantifying the expected effects of the proposed development.

11.14 The WQS proposes that routine monitoring of nutrient concentrations and periphyton biomass at these nodes be undertaken to verify that WQS thresholds are not being exceeded. A map of the recommended monitoring sites and a description of the surface water monitoring programme can be found in Figure 6 (**Appendix B**) and Table 12.

Water flows

11.15 Flow measurements should be taken at the same time as water quality sampling so that nutrient loading on downstream sub-catchments can be quantified.

11.16 **Groundwater monitoring**

11.17 Figure 6 (**Appendix B**) shows a map of well locations that are recommended for monitoring groundwater quality. Where no suitable well exists, a suggested location is given. A description of the groundwater monitoring programme can be found in ***Table 12***.

Corrective Action

11.18 It is our view that if monitoring reveals that a nutrient threshold is consistently being breached, or that the rate of increase in nutrient concentration gives reasonable grounds for expecting a nutrient threshold to be breached within two years, the following actions should occur:

(a) The entity responsible for the monitoring immediately informs Environment Canterbury of the situation.

(b) The nutrient thresholds in the affected sub-catchment(s) are reduced by a set quantum; this reduction to come into effect 12 months after Environment Canterbury is notified of the situation and remain in effect until the formal review described below is completed.

(c) All consent holders work with Environment Canterbury to design and implement an investigation programme that determines the nature and degree of any changes required to the environmental standards currently in effect, and to the nutrient discharge allowances.

(d) Should changes in the nutrient discharge allowances be shown to be required, all affected Farm Environmental Management Plans must be reviewed and altered where necessary to demonstrate that the new discharge allowances can be met.

11.19 In our opinion the monitoring and corrective action programme is sufficiently comprehensive and robust to manage the water quality effects of the propose land-uses with acceptable limits. It places the costs of meeting water quality standards on the consent applicants and they carry a substantial proportion of the risks if standards are not met. Mr Kyle has recommended a suite of consent conditions that robustly encapsulate this concept and are, in our opinion, both robust and appropiate in the context provided by the Basin and the nature of the proposals being advanced.

11.20 It is our understanding that this approach is more comprehensive and rigorous than other water quality management programmes currently in use in New Zealand.

Table 12 Recommended Catchment Scale monitoring programme for the Upper Waitaki

	Monitoring Type	**Parameter to be measured**	**Sites to be monitored**	**Frequency of monitoring**	**Reporting**
Ground-water	Quality	Total nitrogen, nitrate, ammonia, total Kjeldahl nitrogen, total phosphorus, dissolved reactive phosphorus	All groundwater monitoring bores	Quarterly. If after 2 years there is consistency between the quarterly samples, this can be reduced to twice a year	Reported annually to ECan and MIC in an annual water quality report
Surface water	Quality	Total nitrogen, nitrate, ammonia, total Kjeldahl nitrogen, total phosphorus, dissolved reactive phosphorus, suspended solids, pH, temperature	All sub-catchment nodes	Monthly	Reported annually to ECan and MIC in an annual water quality report
	Quantity	Flow assessed when sampled	All sub-catchment nodes	Monthly with sampling	Reported annually to ECan and MIC in an annual water quality report
	Flushing Flows (FRE3)	Flow	Stony River, Wairepo Creek, Tekapo River, Greys River	Continuous until FRE3 has been confidently determined	Reported to ECan
	Establish that FRE3 is sufficient to remove nuisance algal growths	Periphyton biomass before and after a FRE3 flow event	All sub-catchment nodes	One off	Reported to ECan
	Ecology	Benthic invertebrates, macrophytes, epiphytes and macroinvertebrates.		Annually	Reported annually to ECan and MIC in an annual water quality report

	Monitoring Type	**Parameter to be measured**	**Sites to be monitored**	**Frequency of monitoring**	**Reporting**
Lakes Tekapo, Pukaki and Ohau	Quality	Vertical profile of temperature, dissolved oxygen, pH, total nitrogen, total phosphorus, ammonia, nitrate, nitrite, total Kjeldahl nitrogen, dissolved reactive phosphorus, Secchi depth, Chlorophyll-a	Lake Tekapo, Lake Pukaki and Lake Ohau	Quarterly	Reported annually to ECan and MIC in an annual water quality report
	Lake Sediment	Total nitrogen, total phosphorus		Every 3 years	Reported every 3 years to ECan and MIC in an annual water quality report
	Ecology	Benthic invertebrates, macrophytes, epiphytes and macroinvertebrates		Annually	Reported annually to ECan and MIC
Lake Benmore, Lake Ruataniwha and Wairepo Arm	Quality	Vertical profile of temperature, dissolved oxygen, pH, total nitrogen, total phosphorus, ammonia, nitrate, nitrite, total Kjeldahl nitrogen, dissolved reactive phosphorus, Secchi depth, Chlorophyll-a	Lake Benmore, Ahuriri Arm, Northern Arm and near Benmore Dam, Lake Ruataniwha and Wairepo Arm of Lake Ruataniwha	Monthly	Reported annually to ECan and MIC in an annual water quality report
	Lake Sediment	Total nitrogen, total phosphorus		Every 3 years	Reported every 3 years to ECan and MIC
	Ecology	Benthic invertebrates, macrophytes, epiphytes and macroinvertebrates		Annually	Reported annually to ECan and MIC in an annual water quality report
Lake Aviemore and Lake Waitaki	Quality	Vertical profile of temperature, dissolved oxygen, pH, total nitrogen, total phosphorus, ammonia, nitrate, nitrite, total Kjeldahl nitrogen, dissolved reactive phosphorus, Secchi depth, Chlorophyll-a	Lake Aviemore near dam and Lake Waitaki near dam	Quarterly	Reported annually to ECan and MIC in an annual water quality report
	Lake Sediment	Total nitrogen, total phosphorus		Every 3 years	Reported every 3 years to ECan and MIC
	Ecology	Benthic invertebrates, macrophytes, epiphytes and macroinvertebrates		Annually	Reported annually to ECan and MIC in an annual water quality report

12. SUMMARY

12.1 The WQS approach to managing water quality in Lake Benmore, and in the rivers, streams and groundwater that feed into it is comprehensive and robust.

12.2 In our opinion the methods used in delivering on the WQS approach, as outlined in Section 6, are fit for purpose and have been competently applied. The results obtained can be relied upon for sustainably managing water quality in the Upper Waitaki catchment.

12.3 The WQS has found that an additional 25,000 hectares (approximately) of agricultural land in the Upper Waitaki can be irrigated without significant adverse effect on the aquatic environment, providing the proposed farm activities do not exceed the NDA's specified by the study.

13. REFERENCES

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Appendix A: CV’s

Appendix B: Maps

Figure 1: Map of nodes and sub-catchments in Upper Waitaki Catchment

Figure 2: River sub-catchments and surface water node sub-catchments in the Upper Waitaki Catchment

Figure 3: Current irrigation areas in the Upper Waitaki Catchment

Figure 4: Current range of total nitrogen and phosphorous concentrations in Lake Benmore

Figure 5: Location of proposed irrigation area in Upper Waitaki Catchment

Figure 6: Proposed locations for Upper Waitaki Catchment monitoring