in the matter of: the Resource Management Act 1991

and

in the matter of: a number of applications to take and use water from the Upper Waitaki catchment

Brief of evidence of Donna Lee Sutherland

Dated: 16 September 2009

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BRIEF OF EVIDENCE OF DONNA LEE SUTHERLAND

INTRODUCTION

1 My full name is Donna Lee Sutherland

2 I am a scientist in Freshwater Ecology at the National Institute of Water and Atmospheric Research (NIWA). For the past 11 years I have worked on New Zealand lake ecosystems focusing on algal and macrophyte response to anthropogenic impacts and the taxonomy and ecology of New Zealand and Antarctic algae and New Zealand freshwater macrophytes. I have worked on over 150 lake systems in New Zealand and Antarctica. Over the past 5 years I have undertaken a number of consultancy studies on the invasive alga *Didymosphenia geminata* (didymo) and its implications for stakeholders and their activities. I have authored or co-authored 11 scientific publications, numerous presentations and popular articles and over 50 commercial consultancy reports. I have also authored a taxonomic guide to common benthic cyanobacteria.

3 I have a Bachelor of Science and Masters of Science (Hons) from the University of Canterbury, specialising in plant and algal sciences.

4 I am also a member of New Zealand Freshwater Sciences Society, Australasian Society for Phycology and Aquatic Botany, and the New Zealand Plant Conservation Network.

5 I confirm that I have read the Environment Court's Code of Conduct for expert witnesses and this evidence has been prepared in accordance with that code. I agree to comply with the code's terms. In that regard, I confirm that the statements made in this evidence are within my area of expertise (unless I state otherwise) and I also confirm that I have not omitted to consider material facts which might alter the opinions stated in this evidence.

6 I have been involved in the following work that is relevant to the current resource consent applications to take and use water for irrigation in the Upper Waitaki Catchment and the cumulative water quality assessment by Mackenzie Water Research Limited (MWRL):

- Champion, P.; Sutherland, D.; Kelly, G. (2006) Canterbury high country lakes aquatic survey and recommendations to manage the risk of pest plant invasion. NIWA Client Report HAM2006-002;
- Sutherland, D. (2008) Synopsis of the invasive freshwater diatom 'Didymo'. NIWA Client Report 2008-040;
- Snelder, T., Spigel, B, Sutherland, D. and Norton, N. (2005) Assessment of effects of increased nutrient concentrations in

streams and lakes of the Upper Waitaki Basin due to catchment land use changes. NIWA Client Report: CHC2005-003;

- Sutherland, D.; Kelly, G.; Dumas, J.; Spigel, B.; Norton, N. (2009) Water quality parameters in the Upper Waitaki Basin December 2008 – April 2009. NIWA Client Report CHC2009-112;
- Norton, N., Spigel, B.; Sutherland, D.; Trolle, D.; Plew, D. (2009) Lake Benmore Water Quality: a modelling method to assist with assessments for nutrient loadings. NIWA Client Report CHC2009-091; and
- A number of client reports on the potential implications of macrophytes and periphyton growth in the Upper Waitaki Catchment.

7 In preparing this evidence I have reviewed:

7.1 Cumulative Water Quality Effects of Nutrients from Agricultural Intensification in the Upper Waitaki Catchment – Summary Report, August 2009. GHD;

7.2 Cumulative Water Quality Effects of Nutrients from Agricultural Intensification in the Upper Waitaki Basin – Rivers and Lakes Report Final August 2009. GHD;

7.3 Upper Waitaki Basin – Accumulated Effects of Nutrient Runoff: Selected Stream Survey, April 2008. Brian T. Coffey and Associates Limited; and

7.4 Upper Waitaki Basin – Follow-up Stream Surveys to assess the effects of irrigation on nutrient run-off to waterways. April 2009. Brian T Coffey and Associates Limited.

7.5 The evidence of Dr Griffiths, Mr Potts, Mr Callander, and Dr Snelder.

7.6 The evidence of John Bright and Dr Melissa Robson (joint statement), Dr Brian Coffey, Dr Greg Ryder and Ian McIndoe.

7.7 Section 42A Officers Report – Limnology. Dr Marc Schallenberg.

SCOPE OF EVIDENCE

8 I have been asked by Meridian Energy Limited (Meridian) to prepare evidence in relation to the current resource consent applications to take and use water for irrigation in the Upper Waitaki Catchment and the MWRL assessment in respect of the cumulative water

quality effects report prepared by GHD and others. My evidence includes a discussion of:

8.1 An overall summary of the existing environment of the hydro-canals and Lakes Benmore, Ruataniwha and the Wairepo Arm;

8.2 The potential effects of increased nutrient concentrations on these water bodies; and

8.3 My opinion on deficiencies in the assessment of cumulative water quality effects relating to these waterbodies, including the monitoring proposed by MWRL.

EXISTING ENVIRONMENT OF LAKE BENMORE

9 The two arms of Lake Benmore have measurably different water quality. The Haldon Arm has lower major nutrients, nitrogen (N) and phosphorus (P), and lower phytoplankton (free-floating algae) productivity than the Ahuriri Arm (Table 1). Based on the data I collected in 2008-09, it appears that the two Arms would be classified as 'oligotrophic'. This means relatively high water quality, with low nutrients, highly valued colour and clarity and limited phytoplankton productivity[1].

Table 1. Measured means of chlorophyll *a*, total phosphorus (TP) and total nitrogen (TN) for the upper 15 m of water column in each Arm sampled from December 2008 to April 2009[2].

	TLI	Chl a, ug/L	TP, ug/L	TN, ug/L
Haldon Arm	2.4	0.7	9.8	83.4
Ahuriri Arm	2.9	1.4	11.5	127.1

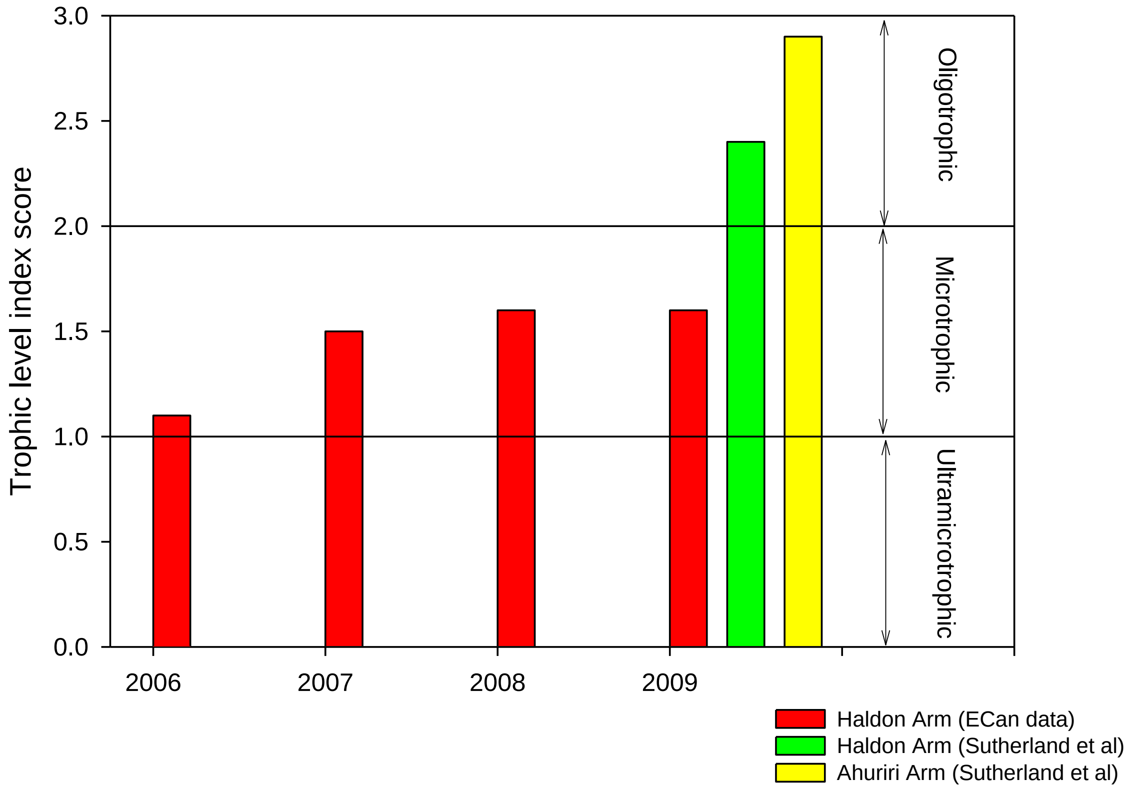
10 The trophic state can be further classified according to the trophic level index (TLI). The trophic level index is a measurable index that uses total N, total P, chlorophyll *a* (a measure of phytoplankton biomass) and secchi depth (a measure of water clarity) to rank a lake along a trophic scale and can be used to measure change. To calculate the TLI, measurements of each parameter must be taken

[1] Burns et al. 2000, Davies-Colley et al. 1993

[2] Note: Secchi depth was excluded from TLI calculation due to the highly reflective glacial flour of the Haldon Arm.

over an entire year[3]. There have been no annual water quality measurements taken in either Arm of Lake Benmore but estimates of TLI have been calculated for both Arms based on summer sampling. Environment Canterbury (ECan) has sampled the surface waters of the Haldon Arm since 2006[4], while I sampled throughout the water column in both Arms from December 2008 to April 2009. Estimated TLI for each Arm are shown in Figure 1

Figure 1. Nominal trophic level index (TLI) scores for the Haldon and Ahuriri Arms of Lake Benmore. Environment Canterbury TLI derived from summer surface water measurements in the Haldon Arm. Sutherland et al TLI derived from measured data over the first 15 m of the water column.



11 The TLI scores from the ECan data are lower than those I derived from my data. My calculations are based on measurements of the first 15m of the water column for each Arm, while ECan only measured the upper 1-2m. Sampling only the upper surface water

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[3] Burns et al. 2000

[4] The TLI for the Haldon Arm has been calculated excluding Secchi depth measurements. This is due to the high level of glacial flour giving an artificially high extinction co-efficient, or how quickly the light is absorbed in the water column.

column will underestimate the phytoplankton biomass and nutrient concentrations, which are often depleted in the surface waters in summer, resulting in an underestimation of the TLI.

12 In large oligotrophic lakes phytoplankton often aggregate into a layer known as the deep chlorophyll maximum. This layer occurs in subsurface waters, often in the metalimnion[5]. In the protocols developed for determining TLI, Burns et al (2000) specify sampling strategies which include integrated depth sampling through the water column. In my opinion, the TLI scores, calculated from my measurements, of 2.4 for the Haldon Arm and 2.9 for the Ahuriri Arm, most realistically represent the current summer trophic state of the two Arms of Lake Benmore.

13 In their analysis, GHD measured water quality parameters in the two Arms of Lake Benmore once in January 2008 and again in April 2008. Sampling stations were in a different location on each sampling occasion. Data presented in Appendices J to K of the GHD River and Lakes report show that total N, total P and chlorophyll *a* were only measured down to a depth of 6.7 m in the Ahuriri Arm and 5 m in Haldon Arm. They concluded that the Ahuriri Arm was oligotrophic and the Haldon Arm was microtrophic based on these surface water samples. As with the ECan measurements, this is likely to lead to an underestimation of the TLI of the lake.

14 Surface water samples were collected quarterly in the Lower Benmore Basin by Meridian from August 2002 to May 2004. Annual average TLI, based on quarterly measurements of TN, TP and chlorophyll *a*, was 2.1. This is comparable to the summer-time TLI of 2.2 calculated from my sampling of the Lower Benmore Basin in 2008-2009.

15 A comparison of the nutrient concentrations and chlorophyll *a* that I measured in the Haldon and Ahuriri Arms of Lake Benmore against the values of variables that define the boundaries of the trophic levels is shown in Table 2. For both Arms, total phosphorus concentrations are at mesotrophic levels and total nitrogen was at oligotrophic levels. Chlorophyll *a* values were oligotrophic for the Ahuriri Arm and Microtrophic for the Haldon Arm.

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[5] The metalimnion (often termed thermocline) is a thin but distinct layer in a lake in which temperature changes more rapidly with depth than it does in the layers above or below. The thermocline may be thought of as an invisible blanket which separates the upper mixed layer (epilimnion) from the calm deep water below (hypolimnion).

Table 2. Comparison of measured variables of TLI (excluding Secchi depth), shown in the first set, against values of variables for each trophic state defined by Burns et al (2000), shown in the second set. Measured data derived from Sutherland et al (2009).

	TLI	Chl a, ug/L	TP, ug/L	TN, ug/L
Haldon Arm	2.4	0.7	9.8	83.4
Ahuriri Arm	2.9	1.4	11.5	127.1

Lake Type	TLI	Chl a, ug/L	TP, ug/L	TN, ug/L
Ultra-microtrophic	0 - 1	0.13 - 0.33	0.84 - 1.8	16 - 34
Microtrophic	1 - 2	0.33 - 0.82	1.8 -4.1	34 - 73
Oligotrophic	2 - 3	0.82 - 2.0	4.1 - 9.0	73 - 157
Mesotrophic	3 - 4	2.0 - 5.0	9.0 – 20	157 - 337
Eutrophic	4 - 5	5.0 - 12	20 – 43	337 - 725
Supertrophic	5 - 6	12 - 31	43 – 96	725 - 1558
Hypertrophic	6 - 7	> 31	> 96	> 1558

16 However, with recent development in the catchment, such as the approximately 1000 ha increase in actual irrigated area since 2008[6], in-lake nutrient concentrations will not be in equilibrium with current land-use. This is due to the lag response for nutrients, particularly via groundwater, to arrive at the lake. In his evidence, **Mr Callander** estimates that there could be up to 10-20 years to see the full migration of nutrients through the system.

17 The Haldon Arm and lower basin (where the two Arms meet) of Lake Benmore have a distinctly milky blue colouration owing to the 'glacial flour' suspended in the water column. The glacial flour originates from Lake Pukaki, via the Ohau Canal. This suspended sediment restricts the depth to which light can penetrate and thus compresses the littoral zone. The littoral zone is the interface between the catchment and the open water of lakes and the flora in

[6] Evidence in Chief of Ian McIndoe, September 2009.

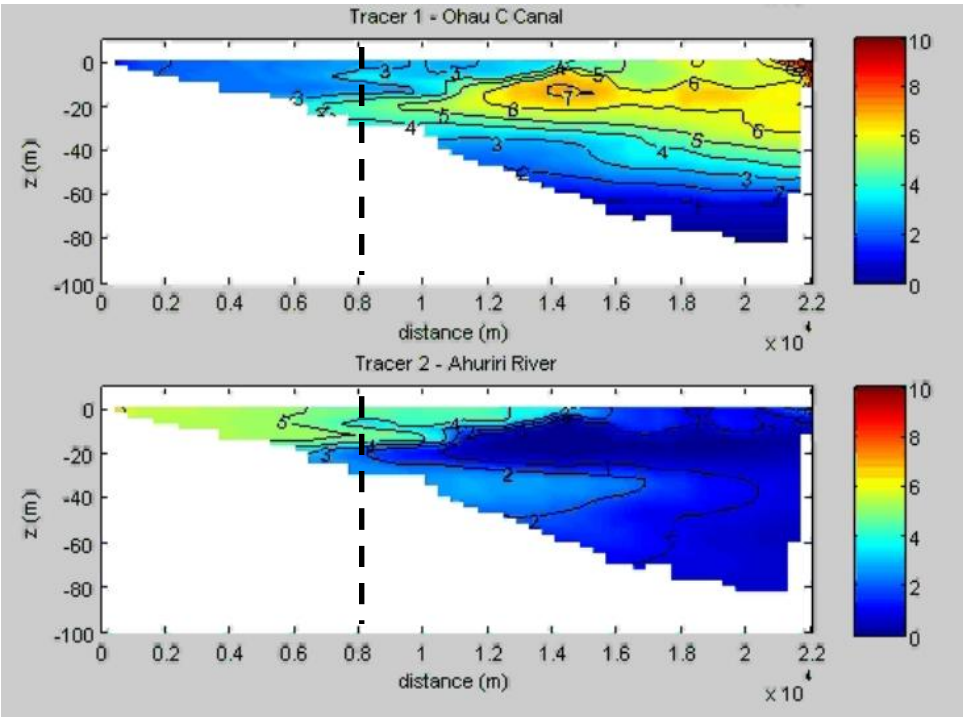
this compressed zone may contribute to the whole lake productivity to an extent far greater than its area would suggest in these low nutrient waters. The Ahuriri Arm does not receive 'glacial flour' inputs from the river inflows, but does receive sediment inputs from the Ahuriri River, which, during flood periods, reduces clarity in the Arm. However, 'glacial flour' does enter the Ahuriri Arm during periods when the Haldon Arm water pushes up through 'The Neck' into the Ahuriri Arm.

18 Measured and modelled variables show extensive water exchange occurs between the two Arms that vary in strength and at varying depths at different times of the year[7]. These water exchanges influence sediment, nutrients and dissolved oxygen in the respective Arms. These hydrodynamic exchanges had previously been predicted on the basis of temperature and suspended sediment data[8]. An example of the exchange of water between the two Arms is shown in Figure 2.

[7] Norton et al 2009

[8] Pickrill and Irwin 1986

Figure 2. Vertical transect through the Ahuriri Arm from the Ahuriri River delta (left hand side) to the Benmore Dam showing water exchange between the two Arms on a given day. An inert tracer represents how much water is being contributed by each Arm. For example, a value of 10 means that 100% of the water is derived from that particular Arm, while a value of 0 means no water is derived from that Arm. Top figure shows water from the Ohau C Canal (via the Haldon Arm) entering the Ahuriri Arm, while the bottom figure shows water arriving from Ahuriri River entering the Ahuriri Arm. Dotted line indicates entrance of 'The Neck'.



19 There are three types of primary producers in Lake Benmore. Phytoplankton are free-floating algae that are found in the water column. Periphyton are benthic algae that live attached to a surface, such as on plants (termed epiphytic), on rocks (termed epilithic) or on sediments (termed epipelic). Both phytoplankton and periphyton are comprised of a number of groups of algae, such as diatoms, cyanobacteria and green algae. Toxic and nuisance species are present in each algal group. The third type of primary producer is aquatic plants (macrophytes) and macroalgae (characeans).

20 A comprehensive study on the phytoplankton periodicity between 1975-1980 found that diatoms dominated the community in Lake Benmore, although green algae occasionally developed[9]. Recently, I

[9] Duthie & Stout 1986

found that during summer, cyanobacteria and green algae were more numerically dominant in the Ahuriri Arm and the lower basin of Lake Benmore.

21 There are no known studies of periphyton, including epiphytes in Lake Benmore, either published or in the grey literature (such as technical reports and databases). I have made taxonomic observations of the algal diversity of the periphyton community in Lakes Benmore, Ruataniwha and all of the hydro-electricity canals. The community in both the lakes and canals are similar and is dominated by cyanobacteria and diatoms (including the invasive, unwanted *Didymosphenia geminata* (didymo) confirmed in the Tekapo and Ohau B - C Canals, & Lake Benmore), with filamentous greens dominant near river inflows. Similarly, there are no known studies on the macroinvertebrates in either of the lakes or hydro-electricity canals.

22 There is no spatial or temporal information available for periphyton (including algae, fungi and bacteria) and macroinvertebrates in the hydro-canals or lakes.

23 The macrophyte community in the littoral zone of the Haldon Arm is dominated by native characeans (macroalgae), pondweeds and milfoils. The exotic weed elodea (*Elodea canadensis*) inhabits sheltered bays, such as Richard’s Bay, throughout the Haldon Arm and lower basin. The macrophyte community in the Ahuriri Arm is dominated by the invasive weed, lagarosiphon, with pondweeds, milfoils and elodea also present. Characeans dominate at depths below 6 m[10]. Lagarosiphon now occupies a large proportion of the Ahuriri Delta, with large, monospecific, surface reaching stands up to 6 km wide (Plate 1). Control measures, including the aquatic herbicide diaquat, are currently being implemented. This is discussed in the evidence of **Mr Turner**.

[10] NIWA Aquatic plant database

Plate 1. Large, monospecific, surface-reaching stands of the oxygen weed lagarosiphon growing in the Ahuriri Arm, Lake Benmore.

24 The lower Benmore basin of Lake Benmore supplies the majority of inflows to Lake Aviemore, at a mean annual flow of 340 m^3/s. In turn, Lake Aviemore supplies the major inflows to Lake Waitaki and subsequently the lower Waitaki River. Maintaining water quality in the lower Benmore Basin therefore offers a high level of protection for the water quality of the lakes and river downstream of Lake Benmore.

EXISTING ENVIRONMENT OF LAKE RUATANIWHA AND WAIREPO ARM

25 Less is understood about the existing environment of Lake Ruataniwha and the Wairepo Arm compared to Lake Benmore. There is no spatial or temporal water quality data for Lake Ruataniwha. A single measurement by GHD in January 2008 indicated that TP and TN were within the range of microtrophic. This seems appropriate given the microtrophic status of Lakes Pukaki and Ohau, where Lake Ruataniwha water originates.

26 There is virtually no data for water quality in the main body of the Wairepo Arm. ECan have measured water quality in the inlet of Wairepo Arm, where Wairepo Creek enters, since 2003. Averaged water quality results from the 33 sampling occasions shows that the TN and TP are mesotrophic, although there is a large amount of variability in the data. TP has varied from oligotrophic to supertrophic, with the higher concentrations mainly occurring in the summer period.

27 In December 2008 – January 2009, GHD measured TN on two occasions and TP on three occasions at their Wairepo Creek Node. TN was eutrophic at the time of sampling while TP varied from mesotrophic to eutrophic. For consistency of other TLI measurements that have been presented so far, I have used summer-time (in this case mid November – mid March) nutrient concentrations to determine the mean TLI over the past three years (excluding chlorophyll *a*) for the Wairepo Arm inlet. 3-yearly average TLI is consistent with the TLI protocol[11] .The summer-time mean TLI is 3.7, towards the upper end of mesotrophic scale. TP is 3.95, at the boundary between mesotrophic and eutrophic, while TN was 3.45, or in the middle of the mesotrophic range. **Dr Robson** stated that the mean TLI for the Wairepo inlet was 3.18 at present based on her assessment of the data[12].

28 Chlorophyll *a* has not been determined for the Wairepo Arm.

29 Macrophytes in Lake Ruataniwha grow to a depth of 4.5m below median lake level. In the shallows, the community is dominated by low growing turf plants, including the rare plants, *Pilularia novae-hollandiae* and *Crassula sinclairii*. The oxygen weed elodea (*Elodea canadensis*) dominates the macrophytes, with the native milfoils and pondweeds in low abundance.

EXISTING ENVIRONMENT OF HYDRO-ELECTRICITY CANALS.

30 The hydro-electricity canals receive water, and therefore nutrient inputs, from Lakes Ohau, Pukaki and Tekapo. Further details on the hydrological arrangements of the Waitaki Power Scheme have been provided in the evidence of **Ms Moss**. In addition to this, the Ohau B - C Canal receives nutrient inputs from the Wairepo Arm, Kelland Ponds and Lake Ruataniwha.

31 Species diversity of periphyton and macrophyte communities are similar to Lakes Ruataniwha and Benmore, with the exception of lagarosiphon, which, to date, is not known to be present in any of

[11] Burns et al 2000

[12] Dr Robson personal communication to Mr Turner (e-mail)

the hydro-electricity canals. A large biomass of elodea has recently caused problems for hydro generation in the Ohau B - C Canal, as explained in **Mr Turner's** evidence. Elodea often forms dense, tall beds in many habitats, including lakes, ponds, rivers and streams. It is a relatively brittle plant, with a velocity tolerance of up to ~ 0.8 m/s. It grows well in a range of nutrient concentrations but is readily displaced by more aggressively growing weed species, such as lagarosiphon, egeria and hornwort.

32 Didymo was first recorded in the Ohau B - C Canal in April 2007. Benthic sampling in November 2007 confirmed that didymo cells were present throughout the length of the canal. Growth was observed at the Benmore Salmon farm situated in the canal, particularly on nets, float barrels and ropes, as well as on boulders and cobbles elsewhere in the canal. More recently, didymo has begun to rapidly increase biomass in the canal. As of May 2009, there were distinct trends of biomass accrual in the canal. The highest biomass of didymo occurs on, and just downstream of, the salmon farm. It is likely that the release of nitrogen based nutrients from the salmon farm is stimulating the growth of didymo. Didymo has become the dominant alga in the periphyton community and continues to proliferate in the Ohau B - C Canal, but has not yet reached maximum biomass. Didymo has also recently (June 2009) been detected in the Tekapo Canal, where it is undergoing rapid growth in the vicinity of the Mt Cook Salmon Farm.

IMPLICATIONS OF INCREASED NUTRIENTS

33 Increased nutrient loads to Lake Benmore from the intensification of land use activities will stimulate algal (both phytoplankton and periphyton) growth. Lab and field based nutrient addition experiments for the lakes have demonstrated that the phytoplankton communities are both nitrogen and phosphorus limited. As discussed in the evidence of **Dr Snelder**, periphyton in the streams (including didymo), were either nitrogen, phosphorus or nitrogen and phosphorus limited. Nutrient limitation means that growth of the alga is limited by a particular nutrient and once that nutrient supply increases growth will continue until some other growth factor becomes limiting.

34 Increases in chlorophyll *a* were modelled in response to increased nutrients in both Arms of Lake Benmore[13]. At the time of the model setup and running, the only information available on future nutrient loads was contained in the 2004-2005 reports[14]. The 2004-2005 reports did not provide a consistent set of loads or concentrations that were suitable for the lake model but did give an indication of the relative increases that could be expected over the range of scenarios. These

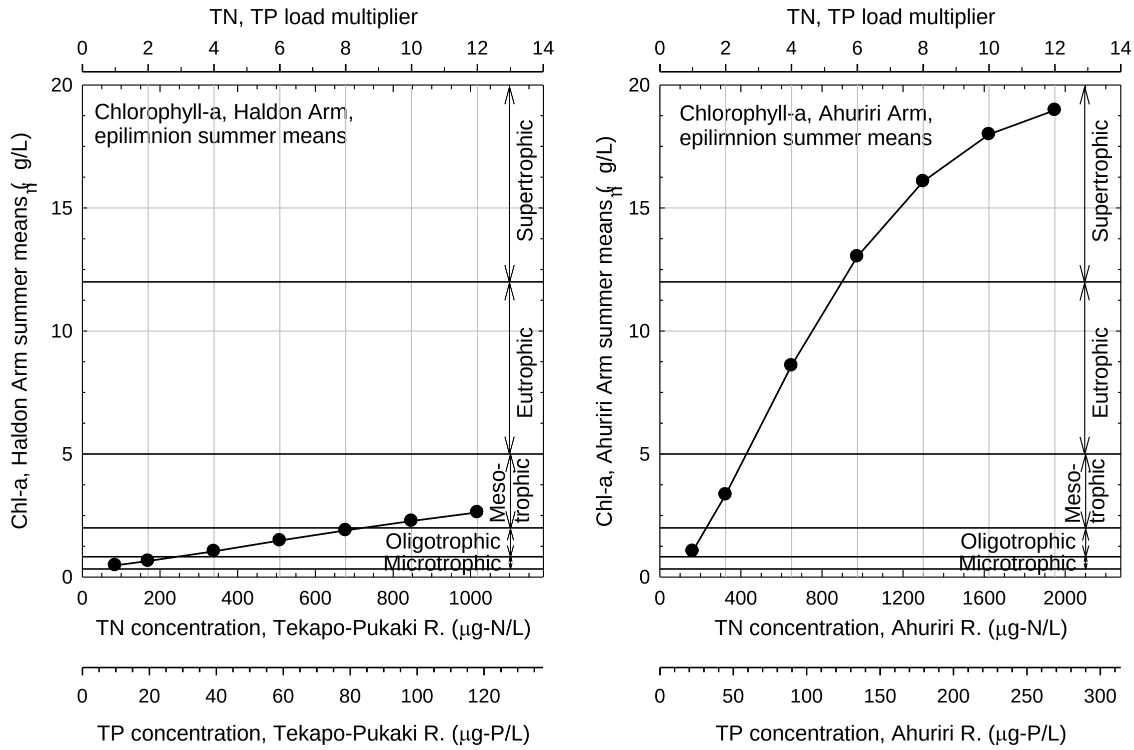
[13] Norton et al. 2009

[14] Reports of GNS (White et al. 2004), HortResearch (Green, 2005), AgResearch (McDowell 2004) and NIWA (Snelder et al. 2005).

relative increases suggested a maximum of a 12 times increase in current loads for both nitrogen and phosphorus could be possible under the most highly developed scenario.

35 In the Lake Benmore model, phytoplankton blooms were shown to develop in the Ahuriri Arm during summer, with the duration and extent of the bloom intensifying as nutrient concentrations increased (Figure 3). The model showed that at 1.6 times the existing measured nutrient concentrations (this did not include nutrient run-off from current development yet to arrive at the lake, termed lag effect) chlorophyll *a* concentrations had reached mesotrophic levels in the Ahuriri Arm. Chlorophyll *a* reached eutrophic levels at 3.2 times existing concentrations.

Figure 3. Modelled chlorophyll *a* concentrations (Chl *a* µg/L) averaged through the epilimnion during the summer period in the Haldon Arm (left), Ahuriri Arm (right)

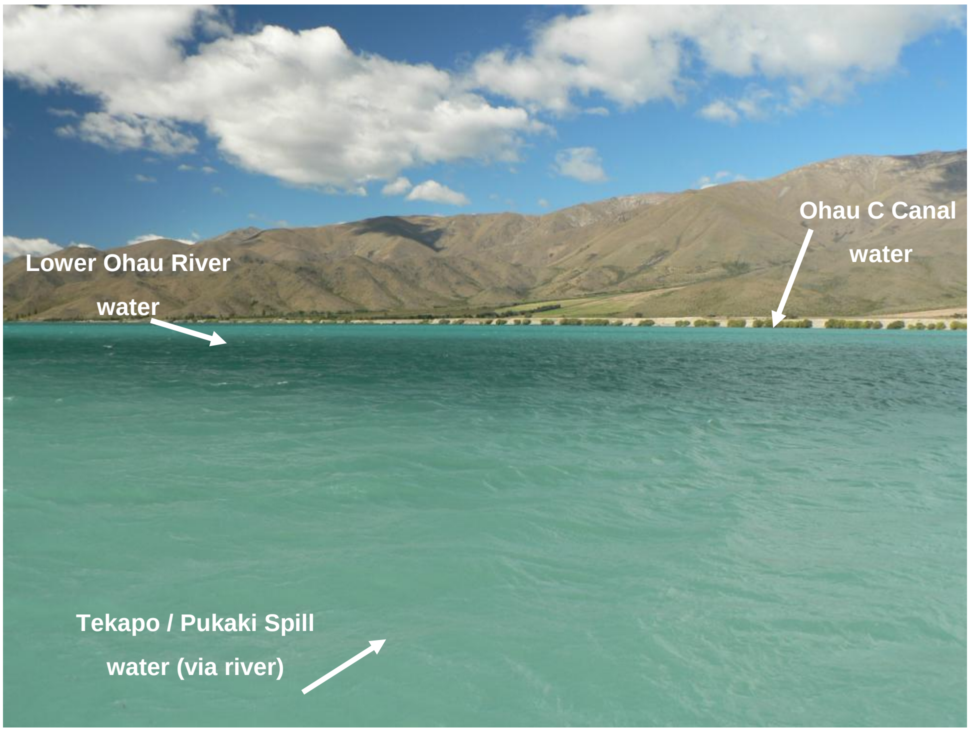


36 The Ahuriri Arm is particularly sensitive to increases in nutrient concentrations due to the small volume of water entering the Arm from the Ahuriri Catchment and the longer residence time (that is, the time a

water molecule remains in the Arm) of 75 days compared to the Haldon Arm, which has a residence time of 57 days and receives higher volume, low nutrient inflows from the Ohau C tailrace, that act to flush the Arm.

37 While the Haldon Arm is less sensitive to increased nutrient loads, due to the flushing effect of the Ohau C Canal water, localised effects at the river mouths may occur. During sampling visits I observed that an area approximately $1km^2$ at the Tekapo-Pukaki and Ohau River mouths does not mix with inflows received from the Ohau C Canal (Plate 2). As the Tekapo-Pukaki Rivers are anticipated to receive the majority of increased nutrient loading from the Haldon Arm catchment, it is possible that algal blooms could occur within this $1km^2$ region. This may cause localised impacts to biota, including foraging fish, and have consequences for recreational fishing, as described in the evidence of **Mr Greenaway.**

Plate 2. View of the distinct surface waters from the Ohau C Canal, Lower Ohau and Tekapo-Pukaki Rivers entering the Haldon Arm, during spilling from Tekapo-Pukaki Canals, January 2009.



38 As described in paragraph 16, the two Arms are hydrodynamically connected, with large volumes of water exchanged between the two. Increased nutrient loads to the Haldon Arm may negatively impact

on the water quality in the Ahuriri Arm and lead to an increase in TLI if the Ahuriri Arm is already close to a trophic level threshold.

39 The Lake Benmore model[15] clearly demonstrated the range that exists between summer maxima and winter minima of chlorophyll *a* in all three basins of Lake Benmore. This was particularly marked in the Ahuriri Arm and lower Benmore Basin and has an effect on the TLI of these basins. Comparisons between the modelled summer and annual average TLI showed that shifts in trophic levels were achieved at lower nutrient loads in the summer compared with averages across the year. In my opinion, summer TLI is more appropriate for assessing nutrient loads to Lake Benmore as summer TLI will determine the impacts on lake values.

40 Lake periphyton at, or near, the river and groundwater inflows will be the first community to respond to increased nutrient loads as the periphyton can intercept and rapidly assimilate nutrients that enter the lake[16].

41 Epilithon and epiphyton rely mainly on nutrients from the surrounding water and can be expected to respond most rapidly to increased nutrients in the water inflows, while epipelon relies on nutrients from interstitial water (water in the sediment) and will grow in response to increased nutrient loads via groundwater. Increases in biomass can negatively impact aesthetic and recreational values and may impact on the feeding and breeding habitat for organisms such as invertebrates and fish.

42 Community composition is also influenced by nutrient concentrations. Toxic and nuisance phytoplankton blooms become more prevalent as nutrient concentrations increase in lakes. Phytoplankton blooms already occur at low incidences in the Ahuriri Arm. *Volvox aureus*, a colonial green alga embedded in a hollow gelatinous sphere, is the dominant species in these blooms (Plate 3). *Volvox* species respond to nutrient-rich conditions and are more frequent in eutrophic lakes and during very stable phases in large river-fed basins and storage reservoirs[17]. In my opinion there will be increased growth and prevalence of *Volvox aureus* under increased nutrient loads. Issues associated with blooms of *Volvox aureus* are discussed in the evidence of **Mr Turner**.

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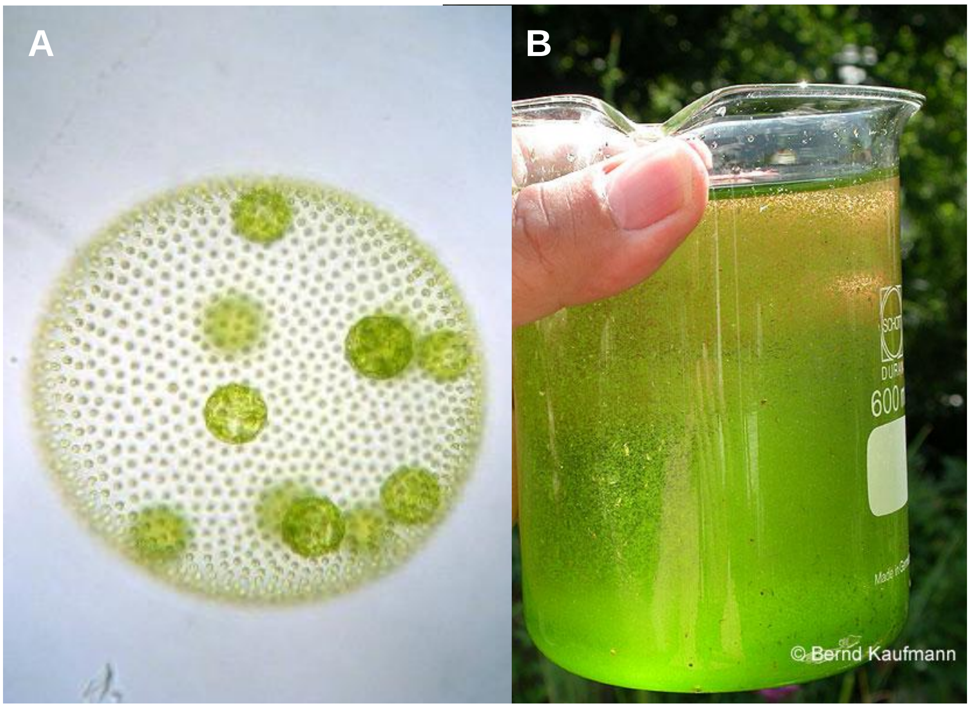
[15] Norton et al 2009.

[16] Goldman, 1988; Hadwen & Bunn, 2005

[17] Reynolds et al 2002

Plate 3. A). Cells of the colonial green alga *Volvox aureus* embedded in a gelatinous sphere; B) Water sample showing *Volvox aureus* bloom.



43 Cyanobacterial blooms become more frequent as nutrient concentrations increase, and typify eutrophic waters. In North Island eutrophic lakes, cyanobacterial blooms are more frequently becoming toxic, affecting water quality and biota. Species of cyanobacteria are already present in the phytoplankton community in the Waitaki Lakes. It is reasonable to expect that blooms will occur in these lakes with increased nutrients, as typified by other lakes throughout the world.

44 For periphyton, filamentous green algal growth is associated with elevated nutrients in lakes and is frequently associated with shorelines near river mouths, where nutrient concentrations are typically higher. Filamentous green algae will also increase in the canals as a result of nutrient additions.

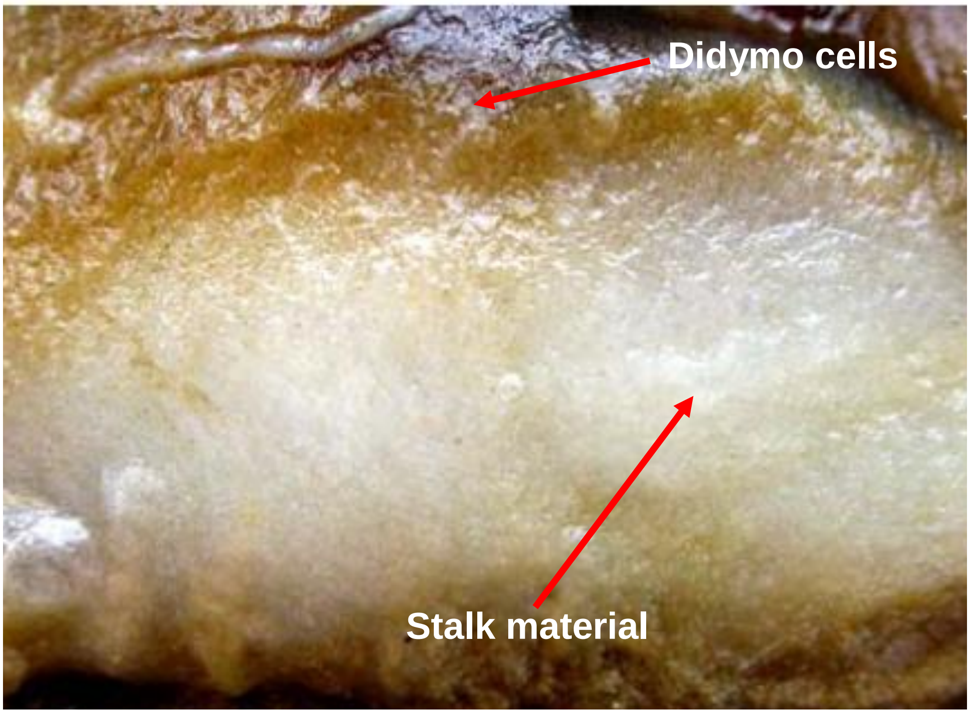
45 Changes in species composition to less desirable species, such as filamentous green algae and didymo are likely to occur in Lake Benmore, around the shorelines associated with nutrient inflows, through groundwater or rivers. Basic knowledge of didymo ecology and growth dynamics in New Zealand lakes is lacking. However, didymo is presently growing extensively along the shorelines of some South Island lakes, including Lake Ohau. Didymo has been shown to be nutrient limited in the Ahuriri River[18] and it would most

[18] Larned et al 2006

probably be nutrient limited in lakes and canals as well. NIWA in-house studies of the response of didymo to nutrients have shown that didymo only requires small increases of the limiting nutrient to bloom and proliferate. This is also apparent in rivers in Southland where didymo biomass increase downstream as nutrient concentrations increased.

46 Didymo growth is expected to be most prolific in the canals due to the stable flows and extensive suitable substrate. Small increases in nutrients arising from the Wairepo Arm are likely to have the most stimulating effect on biomass production in the canals. Under microtrophic to oligotrophic concentrations, such as the range that could be expected in the canals from nutrient additions from the Wairepo Arm, didymo produces the greatest biomass, comprised mostly of thick fibrous stalk material (Plate 4).

Plate 4. A cross section view of a didymo colony growing attached to a rock. Golden-brown cells of didymo sit at the top of the colony attached to thick, white, fibrous stalk material.



47 Increases in nutrient concentrations can affect macrophytes in two ways. For aggressively growing weed plants, such as lagarosiphon, egeria and hornwort, growth can be favourable under increased nutrient concentrations as the plant is able to sequester nutrients from both sediment and water. Dense weed beds can prevent diffusion and mixing of oxygen through the water column. Under

such conditions benthic respiration can lead to benthic anoxia[19], which can result in release of nutrients from the sediments.

48 Released nutrients from the sediment under anoxic conditions can be substantially high. In Lake Rotorua, it has been estimated that just four days of anoxic conditions over the sediments would produce the same amount of nitrogen and phosphorus that are brought into the lake by all the external sources for an entire year[20]. This release of nutrients from the sediments further stimulates phytoplankton blooms. When modelled, anoxia did not occur over the whole basin of the Ahuriri Arm even at the highest nutrient loads (most likely due to the complex mixing of waters derived from the Haldon Arm). However, with the extensive (>6km^2), dense weed beds in the Ahuriri Delta, localised anoxia may occur as a result of poor water exchange inside and outside of the bed. If this occurred substantial additional nutrients would be released from the sediment.

49 Recycling of nutrients can be critical for maintaining primary production in lakes. For many lakes, primary producers obtain more of their phosphorus from recycling than from inputs. Recycling of nutrients from sediments stabilises eutrophication thus making any management measures more difficult to effectively implement.

50 Macrophyte growth rates can be negatively affected by increased epiphyte and phytoplankton growth under high nutrient concentrations. As both types of algae increase, the amount of light that reaches the surface of the plant decreases. This, in turn, can lead to declining health of macrophyte beds and ultimately lead to a collapse of the macrophyte bed resulting in loss of habitat and biodiversity. As these beds decay, nutrients are released that further stimulate algal blooms. Loss of macrophytes leads to a process termed flipping lakes, where the lake shifts from a macrophyte dominated system to a phytoplankton dominated system.

51 Water quality in the lower Benmore Basin is most vulnerable to any impacts on the water quality in the Ahuriri Arm. Changes in water quality in the lower Benmore Basin also impacts on the water quality of the lakes and river system below the Benmore Dam.

52 Localised impacts around the shorelines of Lakes Tekapo, Ohau and Ruataniwha are likely to occur from increased land-use intensification. Proliferations of periphyton, particularly didymo and filamentous greens can be expected to occur around the shorelines where nutrient run-off from land arrives at the lake. Didymo is

[19] Champion & Burns 2001

[20] Howard-Williams and Kelly 2003

presently growing along the southern shoreline of Lake Ohau but is presently absent from the northern shoreline (Plate 5).

Plate 5. Didymo growing along the Southern shoreline 0.25 m below medium water level in Lake Ohau. Rock has been removed from water for photo.

53 The implications of undesirable growths of plants and algae to Meridian's operations are detailed in the evidence of **Mr Turner**.

DEFICIENCIES IN THE ASSESSMENT OF THE CUMULATIVE WATER QUALITY EFFECTS.

54 Predicting the response of algae and macrophytes in the canals and lakes to increased nutrient loads is reliant on accurate calculations of water flows including surface and ground water, nutrient inputs to the rivers and nutrient cycling processes such as denitrification. A number of issues concerning the predictions of these processes by MWRL have been raised in the evidence of **Dr Griffiths**, **Dr Ryan**, **Mr Ford / Mr Harris**, **Dr Snelder**, **Mr Callander** and **Mr Potts**. **Dr Griffiths'** evidence has pointed out uncertainties with the water balance and calculation of flow, which directly affects the modelled nutrient loads, while **Mr Callander's** evidence showed deficiencies in phosphorus assessment through the groundwater. **Dr Snelder** has raised concerns regarding the appropriateness of the periphyton guidelines as a means for determining nutrient loads to the stream and river nodes. Concerns raised by all these experts ultimately impact on the reliability of the nutrient loads to the rivers, the Wairepo Arm, Lake Benmore and canals.

55 There is a large discrepancy between the current nutrient loads to the two Arms in Lake Benmore in the reports of GHD[21] and Norton et al[22].These differences are shown in Table 3.

[21] GHD, 2009

[22] Norton et al. 2009

Table 3. Annual loads of total nitrogen and total phosphorus (tonnes per year) to the Ahuriri and Haldon Arms, under calculated baseline (Norton et al and GHD) and under proposed Scenarios (GHD). Data derived from Norton et al 2009 and GHD 2009.

Estimated annual loads	Norton et al. Estimated existing loads based on mean flows 1994-2008	GHD Estimated existing	GHD Scenario 2	GHD Scenario 3	GHD Scenario 4
Ahuriri Arm					
Total Nitrogen (tonnes N/yr)	167.5	153.4	231.6	314.4	364.7
Total Phosphorus (tonnes P/yr)	23.1	9.8	17	9.8	17
Haldon Arm					
Total Nitrogen (tonnes N/yr)	658.4	499.4	592.6	639.8	943.7
Total Phosphorus (tonnes P/yr)	69.3	40.5	67.6	40.5	67.6

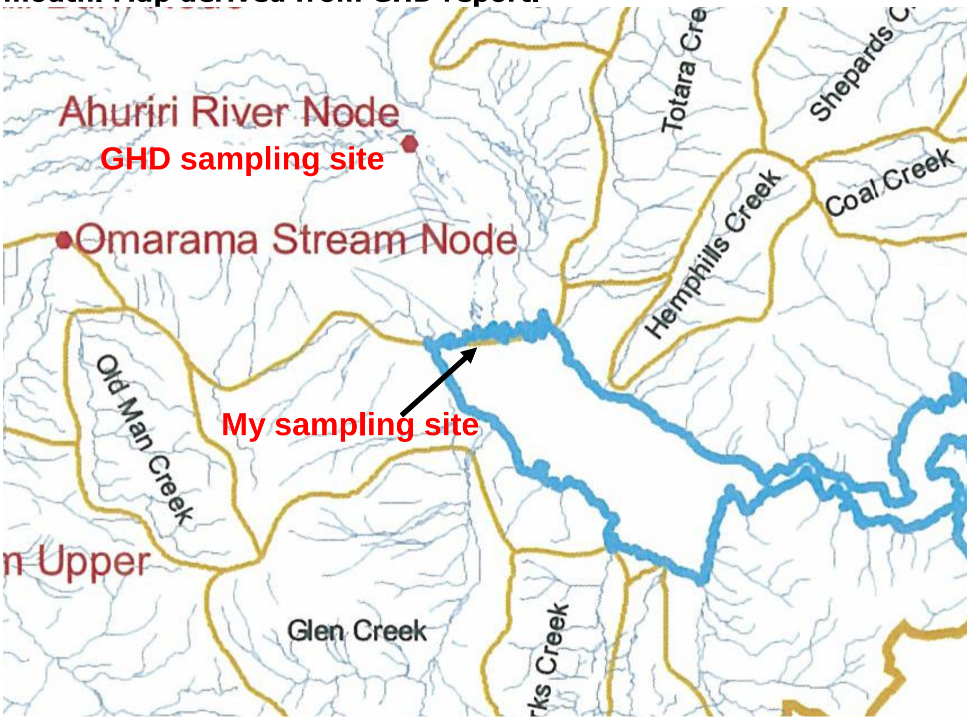
56 Of particular concern is the estimated total phosphorus loads to the lake, especially the Ahuriri Arm. Under even the most intensive development the estimated total phosphorus loads to the Ahuriri Arm are approximately 30% less than the current estimated baseline reported by Norton et al (2009)[23]. GHD's Scenario 2 – highly developed with no additional mitigation measures- estimates 17 tonnes P/yr compared with Norton et al's estimated existing load of 23.1.

57 In both cases, summer-time measured nutrient concentrations have been used for calculating annual loads. However, Norton et al used water quality parameters that I had sampled at the river mouth as it enters the Ahuriri Arm. In contrast, GHD sampled approximately 5 km upstream at their Ahuriri River node (Figure 4). Sampling at the

[23] Norton et al. 2009

river mouth, as it enters the Arm, is the most appropriate sampling location to measure loads to the lake from the river. The river mouth represents the sum total of nutrient loads to the river.

Figure 4. Map showing the location of GHD sampling site at the Ahuriri River Node and my sampling site at the Ahuriri River mouth. Map derived from GHD report.



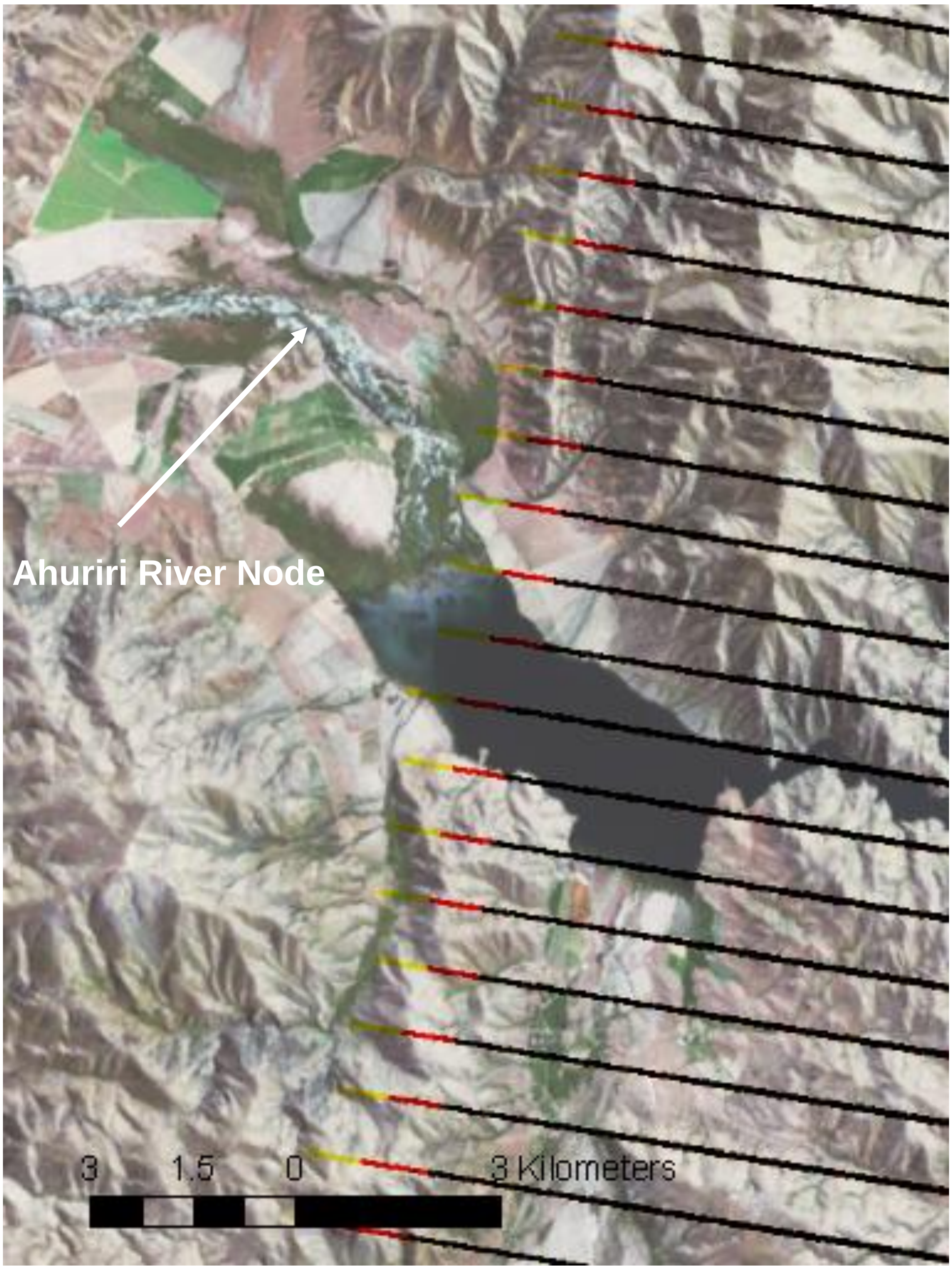
58 On the two occasions in January 2009 where my sampling coincided with GHD's, TP was two to three times higher at the river mouth site than the node site (Table 4).

Table 4. Total phosphorus (TP, µ/L) measurements at the Ahuriri Node site and the Ahuriri River mouth during January 2009. Data from Ahuriri Node from GHD (2009), data from Ahuriri River mouth from Sutherland et al (2009).

	Ahuriri River Node - GHD	Ahuriri River Mouth - NIWA
7-8 January 2009	5	9
21-22 January 2009	4	12

59 There is a large amount of irrigation presently occurring downstream of the Ahuriri River sampling node (Plate 6). Run-off from this irrigation as well as phosphorus re-charging from groundwater below the node site may explain the differences between TP concentrations and may account for some of the discrepancies between the load calculations.

Plate 6. Satellite image taken 2 February 2009 showing the irrigated area directly above the Ahuriri Arm.



60 As discussed in **Dr Griffiths** evidence, GHD have estimated the mean concentration of TP based on samples from low flows. **Dr Griffiths** states that most of the nutrient load is carried by flows about five times mean flow and as a consequence, phosphorous loads could easily be underestimated by 50% or more. On one occasion (18 Dec 2008) GHD did measure TP at their Ahuriri Node during flows ~ 2 x mean flow, following a period of flood flows. Their measured TP was 110 µg/L but this was excluded from Table 12 of their report[24], with no explanation.

61 During my sampling in 2008 – 2009, TP concentrations ranged from 6 -50 µg/L at the river mouth and from 6.7 – 39 µg/L in the first 10 m of the water column in the Ahuriri Arm (sampling station located at the deepest point of the Arm, near the entrance to 'The Neck').

62 For the Haldon Arm, GHD have estimated much lower existing loads from the Ohau C Canal but much higher from the Haldon Arm catchment compared to Norton's study. It is unclear from their flow data and nutrient concentration measurements how they have derived annual loads, particularly for TN arriving from the Ohau C Canal.

63 In Figure 23 of the GHD Rivers and Lakes report[25] TN loads from the Ohau C Canal to the Haldon Arm are estimated to be 60.145 tonnes/yr under the existing status. However, when I calculated TN loads based on their measured concentrations during December 2008 – January 2009, this gave an estimate of 1011.56 tonnes/yr (calculation is shown below).

123.3 mg/m^3 x 1g/1000 mg x 1kg/1000g x 1 tonne/1000kg x 259.9 m^3/s x 86400 sec/day x 365.25 days/yr.

123.3 mg/m^3 based on mean TN concentrations derived from Appendix N, Rivers and Lakes Report (2009).

259.9 m^3/s is the mean flow in the Ohau C Canal (1 Jan 1994 – 31 Dec 2008)[26].

64 Based on the concentrations I measured at the point where the Ohau C Canal enters the Haldon Arm, annual TN loads to the Haldon Arm are estimated to be 505.5 tonnes/yr.

65 In my opinion the understanding of the temporal trends in water quality of the inflows to Lake Benmore is currently poor. There is a lack of understanding of the system during high and flood flows

[24] Range of observed Total Phosphorus concentration (mg/L).

[25] GHD, 2009

[26] Ohau C Canal mean flow data supplied by Mr Stead, Meridian.

throughout the year, or even low and mean flows outside of the summer period. This is highlighted in the disparity between the two reports, particularly for phosphorus in the Ahuriri Arm and nitrogen in the Ohau C Canal. In order to have some confidence in nutrient load calculations, the minimum information needed would be for 12-18 months of water quality and physio-chemical measurements taken on at least fortnightly intervals at the lake inflow sites and in the three main basins of the lake, as well as vulnerable sites such as Wairepo Arm. This will ensure that seasonal flow-mediated trends can be determined.

66 On page 15 of the GHD Rivers and Lakes report it is stated that:

> *"Subsequently, groundwater monitoring has shown significant phosphorus concentrations in some areas, suggesting that not all phosphorus lost from farms is transported via surface water, however the ultimate receptor remains Lake Benmore. Therefore the proportion of measured to predicted loads observed in the existing scenario was used to scale phosphorus load estimations to surface water under proposed Scenario 2".*

While it may seem appropriate to assign phosphorus to the surface waters when estimating nutrient loads under different scenarios, in practise a significant proportion of phosphorus will move through the system via groundwater, with not all of this re-charging to the surface waters before reaching either Lake Benmore, or the Wairepo Arm. Any phosphorus entering the lake below the river mouth, via interstitial waters, is unaccounted for in any of the proposed monitoring programmes. This could result in a substantial amount of phosphorus accumulating in the bottom waters and just below the surface sediment, which could serve to further stimulate weed growth. Internal nutrient cycling could lead to a rapid release of high concentrations of phosphorus that could result in a sudden change in trophic status.

67 Caution also needs to be exercised when calculating current loads from current observed water quality data against existing land-use as there is an unknown lag period between intensification of land and nutrients arriving at the lake, particularly via groundwater and groundwater recharge to rivers. It is unlikely, given the recent land-use intensification that measured nutrient concentrations in the rivers or at the river mouth are in equilibrium with current development. In his evidence, **Mr Callander** discusses difficulties associated with determining the lag effects in this system. The lag effect is also a concern as development continues, from current consented levels, as effects will not become apparent for some time after implementation of irrigation, as discussed by **Mr Potts** in his evidence.

68 The Haldon Arm has a greater capacity for nutrient loads than the Ahuriri Arm. As such, MWRL has suggested that no mitigation is required for the Haldon Arm to maintain a trophic level at or below oligotrophic. Hydrological interactions between the two Arms and the implications of increased nutrient loads in the Haldon Arm on the water quality and TLI in the Ahuriri Arm have not been addressed by MWRL. Coupled hydro-dynamic – ecosystem models, such as those used by Norton et al (2009) may help aid predictions of impacts of Haldon nutrient loads on the Ahuriri Arm.

69 MWRL have relied heavily on using nutrient ranges defined by the trophic level index for nitrogen and phosphorus for estimating nutrient load caps to the lake. Chlorophyll *a* is a fundamental determinant of TLI as it is a direct measure of biological response to changes within the lake. With the exclusion of Secchi depth, chlorophyll *a* makes up a third of the TLI value. During algal blooms, there will be frequent breaches of the TLI proposed by MWRL. The exclusion of chlorophyll *a* dismisses relationships between nutrient inputs and ecological responses, such as increase in algal growth, increase in frequency and duration of algal blooms and changes in composition to toxic and / or nuisance species. Biological response does not necessarily respond on the same linear scale as nutrient loading.

70 In my opinion, MWRL have applied the TLI index inappropriately to determine their nutrient loads to the lake. The TLI index was created to define ranges of measureable water quality parameters that may best describe trophic status of lakes. It was never the intention of the developers of the TLI that it be used to calculate nutrient loadings. Nutrient ranges expressed in the TLI are the in-lake water concentrations that are a product of external nutrient inputs, biological uptake, biological release, internal nutrient loading and recycling and remineralisation.

71 In the Lake Benmore model[27] nutrient loads were applied to the lake over a one year period under different scenarios. The model simulated in-lake biological, physical, geochemical and hydrological processes over this period resulting in an output of in-lake nutrient concentrations of N and P and chlorophyll *a*, (among other parameters) throughout the water column. Annual-average and summer-average values of these parameters over the epilimnion were then used to derive the anticipated TLI under the specified nutrient loads.

72 Lakes tend to respond to increased nutrient loads in a non-linear manner. As nutrient loads increase, small changes may be observed initially in the lake, but at some tipping point, large changes in the

[27] Norton et al. 2009

trophic status can occur rapidly[28]. However, when nutrient loads are reduced, the trophic state may not revert back at the same rate. A study examining 35 long-term lake re-oligotrophication studies around the world found that a time lag of 10-15 years was typical before lakes respond positively to substantial reductions in external nutrient loadings[29]. Recovery was delayed by internal nutrient loadings which continuously replenished nutrient supplies to the water column. Restoration of degraded lakes is not always feasible.

73 MWRL have proposed to maintain Lake Benmore at a threshold below the oligo-meso trophic boundary, comprising of TN at 20% below and TP at 15% below the boundary for a TLI of 2.75. The summer-average TLI of the Ahuriri Arm is already 2.9. This would imply that nutrient mitigation would be needed under existing loads presently arriving at the Ahuriri Arm (excluding any lag effect and consented but unimplemented irrigation development) if a summer-average TLI was used. However, as noted above, the proposed threshold does not take chlorophyll *a* into consideration.

74 MWRL do not state if it is their intention to use annual-average TLI or a summer-average TLI. As stated in paragraph 39, a summer-average TLI would be more appropriate for Lake Benmore for assessing nutrient loads, as summer TLI will determine the impacts on the lake values. Based on the Lake Benmore model output, annual average TLI would mean that during summer the trophic state would increase to mesotrophic and the frequency and duration of algal blooms and unwanted periphyton / macrophyte growth would increase.

75 MWRL propose to increase the mean TLI of TN and TP to 3.75 in the Wairepo Arm[30]. However, as discussed in paragraph 27, the 3-yearly summer-time average TLI is already at 3.7, with TP at 3.95.

RESPONSE TO MWRL EVIDENCE

Dr John Bright and Dr Melissa Robson, 2 September 2009

76 At paragraph 8.9 **Dr Bright** and **Dr Robson** state that under current conditions the average annual nitrogen and phosphorus concentrations in both arms of Lake Benmore sit below the WQS threshold.

77 Annual average concentrations of nitrogen and phosphorus have not been determined for either Arm of Lake Benmore. There has been

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[28] Carpenter 2000

[29] Jeppesen et al. 2005

[30] Dr Robson personal communications to Mr Turner (e-mail)

limited summer-time sampling to date by GHD, ECan and myself. In paragraphs 11-13 of my evidence I outline the deficiencies in the surface water sampling that has been carried out by both GHD and ECan. In my opinion, summer-time nutrient concentrations are already above the proposed WQS threshold, without accounting for lag effect from recent development.

78 At paragraph 8.11 **Dr Bright** and **Dr Robson** state that 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.

79 As stated in paragraph 27 of my evidence, summer-time 3-yearly mean TLI is 3.7, with TP at 3.95, or at the boundary of mesotrophic/eutrophic. Summer-time measurements were used in the calculation to be consistent with the Lake Benmore calculations, based on available data. However, in determining the TLI (both in my calculations and GHD), chlorophyll *a* has been excluded. Given that nutrient concentrations in the Wairepo Arm are well outside of oligotrophic levels chlorophyll *a* will be at levels to significantly influence TLI and therefore, need to be included.

80 At paragraph 10.16 **Dr Bright** and **Dr Robson** state that 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.

81 However, as presented in paragraphs 27 and 75 of my evidence, summer-time mean nutrient concentrations are already at the threshold level proposed by MWRL, with mean total phosphorus at the boundary between mesotrophic and eutrophic. Water quality in the Wairepo Arm appears to be degrading under the existing land-use intensification.

82 At paragraph 9.7 **Dr Bright** and **Dr Robson** state that the TLI levels of Lake Benmore have not shown any significant change from 2002 to 2008.

83 It is unclear what TLI values **Dr Bright** and **Dr Robson** are referring to. Data has not been presented to show the TLI over the period of 2002 to 2008. I am not aware of water quality data for the Haldon or Ahuriri Arm preceding ECan's water quality monitoring that commenced in 2006. Meridian's water quality data for 2002-2004 was for the Lower Benmore Basin. ECan's TLI data (as presented in Figure 1 of my evidence), showed a significant increase in the TLI from 1.1 in 2006 to 1.5 in 2007, and it remains at 1.6 in 2008. However, as discussed in my evidence, ECan's surface water sampling is likely to significantly underestimate TLI. In addition to this, the lag effect of nutrient run-off arriving at the lake will mean

that changes in the TLI as a result of recent development will not be noticed for some time to come.

84 At paragraph 10.25 **Dr Bright** and **Dr Robson** state that 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 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.

85 **Dr Bright** and **Dr Robson** incorrectly reported on the findings of Norton et al (2009). The estimated existing annual loads to the Ahuriri Arm, based on measured concentrations at the Ahuriri River mouth, were calculated to be 173,000 kg of TN and 24,000 kg for TP (as shown in Table 3 of my evidence). This does give a summer-average TLI of 2.9 (at the boundary of oligotrophic / mesotrophic) but is the existing environment and not a prediction of threshold limits under any increased nutrient loads. If **Dr Bright** and **Dr Robson's** threshold limits of 154,185 kg of TN and 9,391 kg of TP are to be applied then considerable mitigation of nutrient run-off will need to be applied for existing irrigation.

86 At paragraph 11.18 **Dr Bright** and **Dr Robson** state 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, that certain actions should occur.

87 It is unclear on how they define 'consistently being breached'. There is not enough baseline information in which to assess both inter- and intra-annual variability in the system. Nor is it possible to assess rate of increase in nutrient concentrations to predict a breach within two years. Nutrient loads do not arrive at a constant rate to the lake, varying within and between years.

88 As stated in paragraph 71 of my evidence, lakes tend to respond in a non-linear manner to increased nutrient loads. That is, small changes may be observed initially in the lake, particularly in the biological community, but large changes in trophic state can occur rapidly at some tipping point. While nutrient loads and in-lake concentrations may increase linearly biological processes will respond on an exponential scale, with rapid growth occurring once that tipping point is reached. The trophic state may not revert back at the same rate as internal nutrient loads continue to replenish nutrients in the water column.

Dr Brian Coffey, 2 September 2009

89 At paragraph 6.5 **Dr Coffey** states that on the assumption there is no internal cycling of nutrients in Lake Benmore, it is possible therefore to calculate an existing nutrient budget for the lake and to nominate a maximum increase in nitrogen and phosphorus load.

Internal nutrient recycling is an integral part of any lake's nutrient budget. For many systems the internal nutrient recycling contributes substantially to the nutrient budget. In resource-limited environments, such as large oligotrophic lakes, the plankton dynamics depends mostly on the internal processes in the food web that act to recycle the nutrient many times over within the surface waters. This recycling takes on added significance when nutrient concentrations and rates of external supply are low. In my opinion it is of fundamental importance to include internal nutrient cycling for any assessment of proposed nutrient loads to Lake Benmore. The hydrological-ecosystem models used for the Lake Benmore modelling by Norton et al (2009) are complex, process-based models that simulate coupled hydrodynamic, water quality and biogeochemical cycles in aquatic ecosystems. These models have the ability to explicitly represent the physical, chemical and biological processes that control trophic state, and to resolve these processes spatially and temporally to account for the complexity of the Lake Benmore ecosystem.

Dr Gregory Ryder, 2 September 2009

90 At paragraph 6.3 **Dr Ryder** states that the WQS has been undertaken on a scale and with a level effort that to his knowledge has not been previously attempted in the South Island.

91 The WQS only sampled Lake Benmore on 2 occasions, once in January 2008 and again in April 2008. As discussed in my paragraph 13, water sampling procedures were inconsistent with protocols developed for determining TLI (Burns et al. 2000). There was no attempt to sample water quality parameters at river mouths in order to assess what is currently entering the lake, instead relying on measurements taken some distance upstream. Most water quality sampling at node points have occurred during low flows thus do not reflect nutrient loads carried through the system during high flow events, as discussed in paragraph 57 (above) and in the evidence of **Dr Griffiths**.

92 I consider that the WQS is sub-standard to other sampling programmes in the South Island and inadequate for defining current baseline.

RESPONSE TO SECTION 42A REPORTS

Section 42A Officer's report - Dr Marc Schallenberg.

93 I agree with **Dr Schallenberg's** conclusions he has drawn from his evaluation of the cumulative water quality effects of nutrients from agricultural intensification in the Upper Waitaki Catchment – summary report and appendices. Of particular note is **Dr Schallenberg's** summary statement. He concludes that few background data are available and the level of analysis of potential impacts on the lakes is insufficient to allow him to judge if the provided assessment is reliable. In my evidence I have outlined areas of concern with MWRL's assessment and in my opinion I do not consider their assessment is reliable.

94 **Dr Schallenberg** also notes that on the basis of the information available there is a significant risk that the adverse effects could be greater than predicted in the MWRL report and are certainly likely to be more widespread that impacts on TN and TP. I agree with this statement and support **Dr Schallenberg's** concluding remark that a comprehensive assessment of such risks would require a more in depth analysis of the present state of the lakes and future scenarios than the current analyses presented in the MWRL reports provide.

RECOMMENDATIONS

95 MWRL has not established a baseline of nutrient concentrations and aquatic biota on which to measure future monitoring against. As a minimum, a baseline of at least 18 months of water quality, physio-chemical parameters and biological data needs to be established for the lakes, canals and Wairepo Arm. This data should be collected at least fortnightly in the summer months and monthly in the winter. The 18 months should span two summer periods. Full water column profiles need to be measured at the deepest part of each basin in the lake.

96 Sufficient sampling will help clarify and confirm the actual existing TLI for Lake Benmore and the Wairepo Arm.

97 Given the uncertainty surrounding how measurements below detection limits were handled, I recommend that further water quality analyses is conducted by a laboratory that has lower detection limits. There are a number of water quality laboratories in New Zealand that are capable of measuring the low nutrient concentrations that are found in the Upper Waitaki Lakes.

98 Differences between Norton et al's and GHD's estimated current annual loads to the Haldon Arm, from the catchment and Ohau C Canal, and the Ahuriri Arm need to be rectified in order to

accurately calculate projected nutrient loads under the various scenarios.

99 Nodes at each of the river mouths (including Ohau C Canal) need to be established as monitoring sites. Both the Ahuriri River and Tekapo River nodes are a considerable distance upstream from the mouth and, as such, I do not consider these to be adequate for the purpose of monitoring nutrients entering the lake from surface waters.

100 A detailed assessment of increased nutrient loads to periphyton, including didymo, and lagarosiphon needs to be undertaken for Lake Benmore, Wairepo Arm and the hydro-electricity canals. This may include small-scale nutrient addition experiments.

101 When setting an environmental criterion for Lake Benmore and the Wairepo Arm a biological parameter, such as chlorophyll *a* must be included. Phytoplankton blooms can occur, resulting in a breach of TLI, even when nutrients are maintained at the defined target levels. Nutrients are only one of many drivers of phytoplankton growth.

102 MWRL's assessment is based around not breaching their target TLI at any time. However, I consider that their monitoring programme of monthly water quality sampling, which is reported on an annual basis, does not meet this objective. Furthermore, monitoring of benthic biological response has only been proposed on an annual basis, although I note at the exclusion of periphyton other than epiphytes. A key monitoring objective should be to verify biological response to nutrient loads, thus ensuring that increases in nutrient concentrations is not compromising biological processes. Biological response to nutrient loads is most likely to occur in an exponential manner. The greater the uncertainly around the risk of the proposed nutrient loads, that is, without strong baseline data the more frequent the monitoring and reporting should be.

103 As the Wairepo Arm is already vulnerable to increased nutrient loads, and indeed, reaches eutrophic and hypertrophic levels on occasions, without better understanding of the Arm and seasonal responses monthly monitoring of water quality may not be frequent enough during summer months. The Wairepo Arm is close to, if not already at, a tipping point between mesotrophic and eutrophic conditions and as such, needs to be closely monitored given the risk to this Arm and the associated hydro-electricity canals.

104 I consider that there is not sufficient information pertaining to the mitigation actions, and the associated timeframe for implementation, that would need to be put in place should monitoring indicate a decline in the water quality of the lakes. Annual reporting means that there could be substantial delay before

any mitigation was implemented. Given the possible 10-20 year lag in the system, changes in surface and groundwater nutrient loads would not be effective for some time. Further delay in recovery will occur as internal nutrient loadings will continuously replenish nutrient supplies to the water column for extended periods.

CONCLUSION

105 The existing baseline for Lake Benmore, the hydro-electricity canals and the Wairepo Arm have not been adequately established. It is important to understand these systems in their present state before implementing any additional nutrient loads to them. Interactions between basins in Lake Benmore and between the Wairepo Arm and canals needs to be carefully considered before setting nutrient load limits.

106 Biological response to increased nutrient loads in the Wairepo Arm, and associated canals, and in the lakes needs to be carefully assessed. The biological community will most probably respond disproportionately to increased nutrient loads. That is, while nutrient loads may increase linearly, biological productivity will respond exponentially thus increasing the risk of threshold breaches occurring.

107 As Lake Benmore is the end reciprocal for processes in the upper catchment, it is my opinion that there needs to be a greater level of certainty for nutrient processes above the lake before there can be certainty with calculated nutrient loads arriving at the lake, either in surface flows or via groundwater. Uncertainties associated with MWRL's assessment of the sources of nutrients and the processes that transform and transport these nutrients to the lake have been presented in the evidence of **Dr Griffith**, **Mr Potts** and **Mr Callander.**

108 I do not have confidence in the MWRL assessment of acceptable nutrient loads to Lake Benmore, or the Wairepo Arm. This conclusion is based on the misinterpretation of the TLI and its application. Taking the simplistic approach of selecting a TLI then calculating the loads to achieve the in-lake nutrient concentrations is fundamentally flawed as they have not considered biological and geochemical processes that occur in the lake and influence nutrients. I suggest that a more appropriate approach is to base nutrient load limits around biological responses, such as nuisance growths and higher organism interactions, and physio-chemical processes, such as dissolved oxygen from which acceptable thresholds could then be determined.

Dated: 16 September 2009

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Donna Lee Sutherland

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