BEFORE THE CANTERBURY REGIONAL COUNCIL

IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of Proposed Plan Change 5 to the Canterbury Land and Water Regional Plan

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STATEMENT OF EVIDENCE MARK JAMES ON BEHALF OF MERIDIAN ENERGY LIMITED

22 JULY 2016

ANDERSON LLOYD
LAWYERS
DUNEDIN

Solicitor: S W Christensen
(stephen.christensen@andersonlloyd.co.nz)

Level 10, Otago House
Cnr Moray Place & Princes Street,
Private Bag 1959,
DUNEDIN 9054
DX YX 10107
Tel 03 477 3973
Fax 03 477 3184

INTRODUCTION

Qualifications and Experience

1. My name is Mark Richard James.

2. I am an aquatic ecologist holding the following degrees, BSc Victoria University, Wellington; BSc (Hons) Victoria University, Wellington and PhD (Aquatic Biology), University of Otago, Dunedin.

3. I have a background in basic and applied research in marine and freshwater ecology and biology with over 36 years' experience including research, consulting and management of science organisations.

4. Following two years with the Institute of Nuclear Sciences, Department of Scientific & Industrial Research (DSIR) I was employed in 1982 by the Taupo Research Laboratory, DSIR, and became involved in ecological research in marine, river and lake environments. From 1982 until 1992 I specialised in researching the ecology of aquatic systems.

5. With the restructuring of DSIR I moved to Christchurch in 1992 as a scientist with the National Institute of Water & Atmospheric Research (NIWA). In 1994 I was appointed as a Project Director and led large multi-disciplinary Foundation for Research, Science & Technology (FRST) funded programmes on fresh water and marine ecosystems. In 2000 I moved to Hamilton to take up the position of Regional Manager with NIWA and in 2002 was appointed as NIWA's Director Operations. In 2008 I retired from this position taking up a brief position as Chief Scientist for Environmental Information before leaving NIWA in late 2008 and setting up as a private environmental consultant and ecotour operator.

6. Since 1982 I have been involved in research on the ecology of freshwater and marine systems. These studies aimed to gain a better understanding of ecological processes in lakes, rivers, coastal and open ocean systems. I have worked in New Zealand, Finland, Denmark, Australia and in Antarctica. My research has been published in over 45 papers in scientific journals and books. These publications have included scientific papers in international journals and book chapters on the ecology of freshwater and marine invertebrates, freshwater management, coastal sustainability as well as the effects of sediments, lake level management, and other anthropogenic activities on aquatic ecosystems.

7. During my 36 years' experience I have been involved with Regional Councils, government departments and industry in establishing guidelines for ecological assessments, providing descriptions of freshwater and marine communities and assessments of potential ecological effects for a wide range of projects throughout New Zealand.

8. I have led a number of large multidisciplinary ecological projects including studies on lake ecosystems, management of lake, river and coastal systems, effects of dredging and hydro-development, and effects of discharges into lake, river and coastal systems.

9. I carried out research on the Waitaki lakes while working for DSIR and NIWA and since mid-2011 have been working on the Waitaki system as an independent consultant to Meridian Energy Ltd providing advice, managing science projects and carrying out aquatic investigations.

10. In preparing my evidence I have reviewed the code of conduct for expert witnesses contained in part 5 of the consolidated Environment Court Practice Note 2011. I have complied with it in preparing my evidence. I confirm that the issues addressed in this statement of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

11. In preparing my evidence I have reviewed:

- Evidence of Donna Sutherland, Peter Callander, Barry Biggs and Antonius Snelder to the resource consent applications to take and use water from the Upper Waitaki Catchment (Sept, 2009 hearing);

- 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;

- Sutherland, D. (2012). Water quality in the Upper Waitaki Catchment – current state and potential impacts of increased nutrient concentrations as a result of land use intensification. NIWA Report CHCH2012-14. Prepared for Meridian Energy Ltd;

- Sutherland, D.; Kelly, G.; McDermott, H.; Hawke, L. (2012). Upper Waitaki interim water quality monitoring data December 2011 to April 2012. NIWA Report CHCH2012-080. Prepared for Meridian Energy Ltd.

- Plan Change 5 to the Canterbury Land and Water Regional Plan. Prepared by Environment Canterbury Regional Council, February 2016;

- Clarke, G. (2014). Memo to Upper Waitaki Zone Committee, Discrepancies in TLI estimates for Lake Benmore

- Clarke, G. (2015). The current water quality state of lakes in the Waitaki catchment. ECan Report No. R15/157.

- Clarke, G. (2015a). Upper Waitaki limit setting process, Predicting consequences of future scenarios: Lake water quality. ECan Report No. R15/156

- Gray, D. (2015). Upper Waitaki catchment flows, water quality and ecology: state and trend. ECan Report No. R15/57.

- Meridian Energy Ltd's submission on the Proposed Plan Change 5 (PC5) to the Canterbury Land and Water Regional Plan;

- A number of client reports to Meridian since 2000 on water quality, macrophytes and periphyton growth in the Waitaki Catchment;

- Appendix G (Shaw et al) Waitaki Technical Analysis in CWLP Plan Change 5 Section 42A Report. ECan Report No. R16/23.

SCOPE OF EVIDENCE

12. In my evidence I have been asked by Meridian Energy Limited (*Meridian*) to address the following:

- An overview of the existing environment in the Upper Waitaki Catchment (UWC), specifically as this relates to water quality and existing aquatic values.

- Water quality and aquatic values as relevant in the Upper Waitaki catchment and in particular Lakes Ruataniwha, Kellands Pond and Wairepo Arm.

- Meridian's relief sought on PC5 to the Canterbury Land and Water Regional Plan, as it relates to water quality, including amendments to definitions and related policies, appropriateness of Trophic Lake Index (TLI) and relevance of indicators.

SUMMARY

13. The Upper Waitaki Catchment (UWC) is highly regarded for its aesthetics and recreational values, and its freshwater ecological values, largely related to its alpine ecosystems and habitats of braided rivers, natural high country lakes, tarns and associated wetlands. The braided river habitats are of international significance and along with associated wetlands and springs are home to a number of threatened birds, fish and other taxa.

14. The UWC rivers above Lakes Tekapo, Pukaki and Ohau have been largely untouched by modifications through farming and hydro-development and have high water quality. Below these lakes however water quality is in danger of continuing to decline with increasing pressure from developments such as land-use intensification (including farming, dairy farm conversions), salmon farming and other activities.

15. The aspects of PC5 that are of primary interest to Meridian and relevant to my expertise are the establishment of appropriate and comprehensive water quality outcomes and limits that recognise naturally occurring processes and variation, while protecting the overall health of the water bodies, and the mechanisms for ensuring that Waitaki Nitrogen Load Limits are not exceeded.

16. There has been considerable discussion involving ECan and various stakeholders about the appropriate TLI for the upper lakes and Lake Benmore as the major receiving water body in the catchment. While there has been debate about the actual TLI numbers for the lakes all agree that the outcome for the lakes should be to retain their existing state and that they should not be allowed to deteriorate further. A TLI limit is appropriate but my concern is that because the trophic scale for TLI is a continuum, if the lakes are managed so that increased levels of nutrients can be added up to a limit, even allowing for a buffer, there is a heightened risk that the lakes will reach a tipping point.

17. A major concern I have is that with lags which could be 10-20 years between nutrients entering groundwater and reaching surface water bodies, the full implications of existing intensification are yet to be realised. PC5 now proposes water quality outcomes to protect these values take into account potential lags, which is commendable. This addresses my earlier concerns and will help prevent further deterioration of lake health. However, protection of the existing trophic state (oligotrophic or mesotrophic) for Lake Ruataniwha, Kellands Pond and the Wairepo Arm needs to managed carefully.

18. I support the relief sought by Meridian to address these issues. In particular I support:

- The strengthening of rules to ensure that Total Nitrogen Loading and nitrogen limits specified in Policy 15B (Tables 15B (a-f) for the

Haldon and Mid-Catchment Zones and any Headroom allowed for are not exceeded, taking into account the cumulative impacts of all activities including existing and future consents that may be granted.

- Recognition that there are particular natural features of the UWC (especially glacial flour and didymo) that exist at present and should be recognised in the setting of outcomes and limits.

- Lake Ruataniwha is the link between the upper lakes (Pukaki and Ohau) and Lake Benmore. It is an artificial lake within a modified river environment. Outcomes and limits for Lake Ruataniwha should be at least the same as the Haldon Arm (2.7) into which the water discharges but recognising the high quality of the feeder lakes which have a TLI limit of 1.7.

- Kellands Pond and Wairepo Arm are important water bodies and also have direct hydrological linkages to Lake Benmore and in my opinion this means at a minimum appropriate outcomes and limits should be applied to these water bodies to protect these key water bodies. Limits are provided in Meridian's submission and my evidence.

EXISTING ECOLOGICAL VALUES IN THE UPPER WAITAKI CATCHMENT

19. In this section I provide an overview of the existing environment as it relates to water quality and aquatic ecosystem values. This is based on earlier evidence I presented to the hearing in 2013 on the proposed CLWRP, recent technical ECan reports which assess the existing state and trends for rivers and lakes in the Upper Waitaki Catchment between 2009 and2014, and new information that has become available.

20. From the mid-1800s the UWC has been significantly modified through burning, clearing and drainage of wetlands for farming and hydro-electric development. Forty percent of wetlands have been drained for farming since 1850. Historically most of the catchment has been low intensity, dryland sheep farming. In recent years there has been a shift to more intensive land-use and conversion to dairying. Recent Council hearings have considered a number of consent applications to take, use and discharge water in the UWC. The impact of further land use intensification was a key concern at these hearings for a number of submitters, including Meridian, because of its potential to significantly affect water quality and existing aquatic values.

21. The development of the Waitaki Power Scheme between the 1920s and end of the 1980s resulted in the inundation of some 7400 ha of open braided river bed, 3,900 ha of swamp wetland and 2000 ha of flush type and mosaic wetland (Wilson 2000). An additional 22,250 ha of

open water was created through the development of hydro-reservoirs and expansion of existing lakes. With the development of the hydro-canals in the 1970s stretches of the Tekapo River, all the Pukaki River and parts of the Ohau River were effectively dewatered and most of the braided river bed and associated wetlands were lost.

22. The UWC above the upper lakes (Tekapo, Pukaki and Ohau) has been left largely untouched by these modifications and the lakes, and the rivers which feed these lakes, are essentially still in a natural state from a water quality perspective. The water quality below these lakes however has and is coming under increasing pressure for a range of developments including land intensification, salmon farms, sewage discharge and other activities.

23. The most significant freshwater ecological and biodiversity values in the UWC are related to alpine ecosystems and habitats of braided rivers, natural high country lakes, tarns and associated wetlands and include a number of threatened fish and bird species.

24. Today the rivers of the UWC, including the modified mid-catchment rivers (eg. Tekapo and Ahuriri), still contain some of the best examples of braided river habitat in New Zealand. These are of international significance as such systems are uncommon world-wide, are considered rare ecosystems in New Zealand, have high biodiversity, and along with associated wetlands and springs are home to a number of threatened birds, fish and other taxa.

Water quality

25. Water quality data is relatively sparse for parts of the UWC. There is some water quality data from ECan monitoring of rivers and streams over the last 20 years and comprehensive monitoring was undertaken for Meridian by NIWA in December-April 2008/09 to support the development of an ecosystem model for Lake Benmore and then more recently in 2011-13 when 12-14 months of monthly data was collected from a number of river and lake sites. Recent reports by ECan have provided very good descriptions of the present state of rivers and lakes in the UWC based on data collected 5 years (2009-2014) by ECan, NIWA and others. (See **Figure 1** for a map of sites on rivers that are monitored). ECan continues to collect data that will add to our understanding of how the lakes and rivers are changing over time.

26. The rivers feeding into the upper lakes are mostly glacial and snow melt in origin and contain large amounts of glacial flour that give them their characteristic milky-blue colour and low clarity. The lakes that these rivers feed into have similar biological and chemical characteristics as the upper headwaters with low concentrations of nutrients and phytoplankton (algae) and low abundance of secondary producers (zooplankton, fish). The upper lakes (Tekapo, Pukaki and

Ohau), though turbid due to glacial flour, are classified as microtrophic to oligotrophic because of the otherwise high water quality (Burns and Bryers 2000) (see **Table 1** for trophic state characteristics).

27. The rivers and canals connecting the upper lakes to Lake Benmore generally reflect the high quality and low nutrient state of the lakes with some also influenced by naturally high turbidity due to glacial flour. However some of the streams and tributaries and lower parts of the major rivers are receiving increased nutrient inputs directly and indirectly from activities such as land-use intensification and aquaculture. The consequence is that the quality of these water bodies is deteriorating. Streams close to land use intensification, such as the Ahuriri River at SH8, Wairepo Creek and Willow Burn in particular have poorer water quality as a result of this intensification with higher levels of dissolved inorganic nitrogen and phosphorus and extensive filamentous algal growths (Coffey evidence to the 2009 Upper Waitaki Water Consent Hearing, Gray 2015).

28. There is no ongoing water quality monitoring at sites in the upper Ohau River however Meridian has started collecting data on water clarity, suspended solids (SS), settled sediments and periphyton. The limited data to date shows that SS can be very high with water quality likely to reflect the conditions in Lake Ohau where the water is naturally turbid (as a result of glacial flour) and low in nutrients.

29. The recent assessment of state and trends in water quality of the rivers in the UWC (Gray 2015) note that the lower Ahuriri, Wairepo River and lower parts of the Tekapo River, in particular, are at risk and are showing evidence of the negative impacts of land-use intensification, increasing levels of nutrients and/or may show signs of stress. This classification (“at risk”) was based on an expert panel of Environment Canterbury ecologists.

30. Also of major concern in these rivers is the presence of didymo which proliferates in lake fed rivers and other rivers with stable flow. Didymo especially prefers low nutrient, cold rivers. Didymo is a significant issue in the lower Tekapo, Twizel and Ohau Rivers.

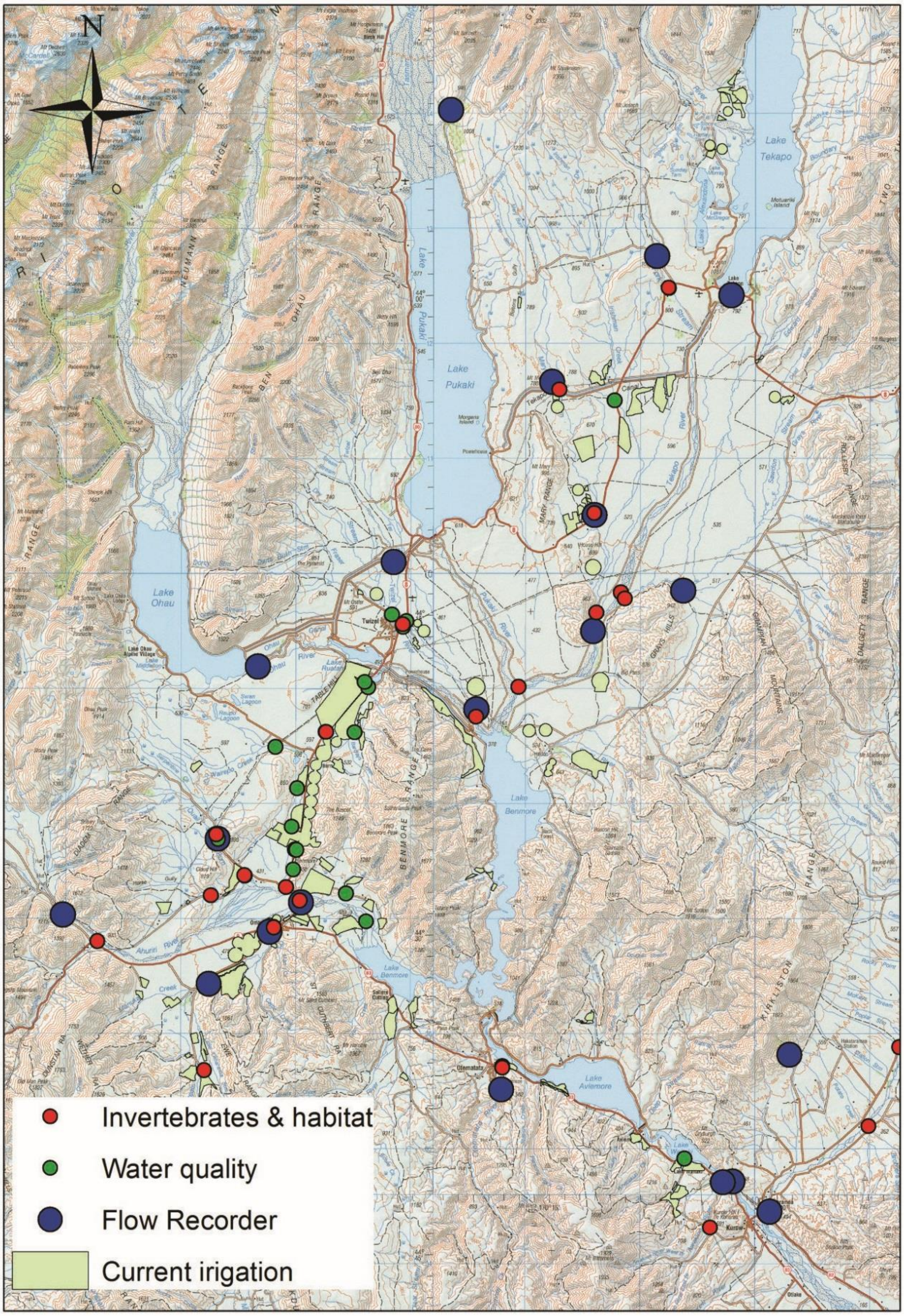

Figure 1. Location of data collection stations and the current extent of irrigated land in the Upper Waitaki catchment (Gray 2015).

31. During hearings and submissions on the CLWRP there has been much discussion over the TLI for Lake Benmore and the other lakes. The TLI uses measures of chlorophyll *a* (Chl *a*, an indicator of phytoplankton biomass), total nitrogen (TN), total phosphorus (TP) and water clarity (secchi disc) to rank lakes according to their trophic state. The TLI uses a combination of measures as they tend to vary together as water quality declines. In the case of the Waitaki catchment, secchi disc is not used because the presence of glacial flour confounds this.

32. There has been no long-term time series or spatially-resolved water quality data collected for Lake Ruataniwha. The few measurements of total nitrogen (TN) and total phosphorus (TP) taken in Lake Ruataniwha by GHD in 2008 indicated the lake is microtrophic (see **Table 1** for definitions of Trophic state), consistent with having a short residence time and receiving most of its water from the upper lakes. Limited measurements in 2011/12 by NIWA recorded TN of 92 ug/L and TP 5.6 ug/L which would place Lake Ruataniwha in the oligotrophic category (TLI 2-3).

Table 1. Environmental characteristics of lakes with different trophic states (from Norton et al. 2009)**.**

Microtrophic – clear water, no risk of obvious algal blooms, healthy macrophyte beds, no risk of toxic blooms, healthy invertebrate and fish communities, high biodiversity value. TLI 1-2 Oligotrophic - clear water, very low risk of obvious algal blooms, healthy macrophyte beds, no risk of toxic blooms, healthy invertebrate and fish communities, low-moderate periphyton growth on beds, high biodiversity value. TLI 2-3 Mesotrophic - clear but tending green water, moderate risk of obvious algal blooms, increased stress on macrophyte beds, some risk of toxic blooms, potential shift in phytoplankton community, increased productivity of some of the invertebrate and fish communities, moderate periphyton growth on beds, good biodiversity value. TLI 3-4 Eutrophic - turbid green water, high risk of sustained algal blooms, high risk of macrophyte bed collapse, moderate risk of toxic blooms, phytoplankton dominated system, shifts in the invertebrate and fish community composition, low-moderate periphyton growth on beds, compromised biodiversity value. TLI 4-5

33. Kellands Pond is a small man-made pond largely influenced by groundwater from the surrounding farmland and is linked by a culvert to the Wairepo Arm. The recent ECan report (Clarke 2015) notes that nitrate and nitrite concentrations increased on average by 45% per year between 2003 and 2013 and placed the Pond in the upper

eutrophic range. However, TP and chlorophyll a (indicator of algal biomass) are still relatively low. TLI_2[1] has ranged from 2.2-3.8 between 2003 and 2013 at the edge of the Pond, but in the centre was 3.0 and 3.2 in 2011/12 and summer of 2013.

34. Data on TN and TP for samples from the Wairepo Arm Inlet between 2006 and 2009 over summer indicated a TLI_2 of 3.7 i.e towards the upper end of the mesotrophic scale (Sutherland evidence to 2009 Upper Waitaki Water Consent Hearing). Measurements by ECan since 2003 in the Wairepo Arm indicated the water body is mesotrophic but with large variability in the data. Wairepo Arm is much smaller than Lake Ruataniwha, is not directly fed by the large upstream lakes, and a significant proportion of its immediate catchment is irrigated agricultural land. The most recent indication of the present trophic state of the Wairepo Arm is based on measurements of TN and TP by NIWA in 2011/12 from which Wairepo Arm has been assessed as being mesotrophic-oligotrophic with a TLI of 3.0-3.2. I note however that this is based on only a few measurements and could vary between years depending on the relative importance of water from the Wairepo catchment versus lower nutrient water from Lake Ruataniwha to the Wairepo Arm.

35. Lake Benmore, through the Haldon and Ahuriri Arms, is the receiving water body for most of the upper catchment. The Haldon Arm receives water directly, or indirectly from the upper lakes (Ohau, Pukaki, Tekapo) and local tributaries, while the Ahuriri Arm is fed by the Ahuriri River. Agricultural intensification through irrigation has occurred in the catchments of both arms. The present water quality in the Haldon Arm and Lakes Aviemore and Waitaki, which are downstream of Benmore, reflects that of the upper lakes and rivers with well oxygenated, low nutrient water (but increasing) with relatively high natural turbidity. The Ahuriri River draining into the Ahuriri Arm of Benmore has a higher nutrient concentration than inputs to the Haldon Arm resulting in lower water quality in the Ahuriri Arm. It has higher nutrient concentrations than the Haldon Arm, higher phytoplankton biomass, but lower turbidity due to the absence of glacial flour (Sutherland et al. 2009, Gray 2015).

36. Based on the NIWA data that has been collected according to the protocols set by Burns and Bryers (2000), and excluding secchi disc from the calculations because of natural turbidity, the TLI in summer 2008/09 for Lake Benmore was 2.84 in the Ahuriri Arm (Sutherland et al. 2009). In 2010-11 the TLI in the Ahuriri Arm had slightly increased to 2.94 (Sutherland et al. 2012). Such a small increase is unlikely to be ecologically significant, given the inherent variability of natural systems, but it is notable that both values place the Ahuriri Arm towards the upper limit (of 3.0) for oligotrophic waters. Data collected by ECan from 2009-2014 shows that the TLI in the Ahuriri Arm has

[1] TLI based on TN and TP only

ranged from 2.1-3.0 (NIWA data 2.8-3.3) and above the dam 1.3-2.2 (NIWA data 2.2-2.6) and NIWA data for the Haldon Arm 2.4-2.7. The discrepancy in the data has been assessed as most likely due to different sampling points. ECan has recognised this and has subsequently adopted NIWA's sampling locations (Clarke 2014). However both sets of data up to 2014 indicated the Ahuriri Arm was close to, if not already exceeding, 3.0 and the main body of the lake up to 2.7.

37. I understand more recent data collected by ECan has found TLIs of 1.8 and 1.7 for the Haldon Arm and 2.6 and 2.1 for the Ahuriri Arm in 2014/15 and 2015/16 based on collections at the NIWA sites and using an integrated sample. Differences between years is expected because of variability in rainfall, climate and other factors and it is more the range over several years that is important. I haven't seen the chlorophyll a, TN or TP data on which the latest TLI is based but this information may provide some explanation for the lower values in the last few years.

Periphyton, macrophytes and phytoplankton

38. Periphyton is the collective term given to the matrix of benthic algae, cyanobacteria, bacteria, fungi and protozoa which are found on hard substrates in most rivers and the littoral zone of lakes. While it is often the basis for the food web it can also reach nuisance levels, particularly filamentous green algae in rivers. The range of species found in the UWC rivers is similar to other New Zealand rivers, and is composed mostly of diatoms. There was little information on the present status of periphyton in the UWC catchment until the benthic diatom *Didymosphenia geminata* (didymo) was first recorded in the UWC in 2006. Didymo has now been recorded from the Ahuriri River, Tekapo River, Twizel River, Omarama Stream and upper and lower Ohau River. By 2009 it was present in all the canals.

39. Periphyton growth in rivers and streams depends on a number of factors including nutrient supply, temperature, light levels, presence of grazers (invertebrates) and stability of flows. Biomass is often determined by the rate at which development occurs between significant flood events that scour out and re-set the community. Stable flows and favourable growth conditions promote high biomass. Bioassay experiments by NIWA have demonstrated that most stream reaches in the UWC are nutrient limited and thus periphyton growth is likely to respond to increased nutrients. Many streams in the catchment also have relatively stable flows with few floods, lack shading and increased concentrations of N and/or P will likely to result in proliferation of nuisance algal growth.

40. Didymo is a special case as unlike other species it can proliferate, reaching high biomass in nutrient poor, cold waters. It can be especially prolific in stable lake-fed rivers. Low phosphorus concentrations in particular are thought to be a requirement for its presence and abundance in rivers.

41. In terms of the health of the rivers, the upper part of the rivers connecting the upper lakes to Lake Benmore reflect the high quality and low nutrient state of the upper lakes and have nutrient concentrations similar or below periphyton guidelines for the protection of benthic diversity, trout angling and habitat (Biggs 2000). However, some of the streams and tributaries, and lower parts of the major rivers are receiving increased nutrient inputs directly and indirectly from activities, such as land-use intensification and aquaculture and would breach these guidelines. A periphyton cover of 120 mg chl/m^2 or less for filamentous periphyton during summer is required for aesthetic and recreation values while < 50 mg chl/m^2, as has been set for alpine rivers (in draft PC5 of CLWRP), will be characterised by sensitive invertebrate taxa.

42. The macrophyte communities in many water bodies of the UWC still contain good populations of native species. The littoral zone of the Haldon Arm is dominated by native characeans, pondweeds and milfoils. Lake Ruataniwha has a shallow community of turf species (including some rare species), the introduced *Elodea*, native milfoils and pondweed. Because of the natural high turbidity and water level variability in Lake Pukaki there are no macrophyte beds in the littoral zone but native communities as well as *Elodea* are found around the edge of Lake Tekapo, Lake Ohau and Lakes Aviemore and Waitaki.

43. The introduced species *Elodea* has been in the UWC for decades but it is only recently that it has caused problems, mostly in the hydro canals Ohau B-C. *Elodea* is also found in sheltered bays in the Haldon Arm and the lower basin of Benmore (NIWA Plant Database). The major nuisance weed is *Lagarosiphon* which forms dense stands in the Ahuriri Arm where it has displaced native species. Lagarosiphon is a relatively recent invader to the UWC and despite considerable effort to contain this species it is gradually expanding with fragments having recently been found in the mid-Haldon Arm at Goose Neck Island (D. Sutherland, NIWA, pers.comm). I am advised by Meridian that through the combined LINZ and Meridian management programme, currently Lagarosiphon has been pushed back into and up the Ahuriri Arm. New Zealand's most aggressive and deleterious invasive species, *Ceratophyllum* (hornwort) and *Egeria*, are now present in the South Island and their potential spread into the UWC is of major concern for both the native communities and industries such as hydro-electric production. The applicability of Lake SPI for assessing macrophytre communities and lake health is discussed later in my evidence.

44. The lakes are also likely to be nutrient limited (along with light because of glacial flour). In terms of phytoplankton in the lakes Clarke (2015b) provides a useful assessment of the nutrient status of the lakes and shows that the lakes tend to be more P limited than other catchments. As the catchments become more intensively farmed they are likely to become progressively nitrogen enriched and phosphorus limited thus both need to be considered carefully. The N:P ratio for Kellands pond and Ahuriri Arm of Benmore indicate P limitation while the Haldon Arm and upper lakes are more likely to be N and P limited (Clarke 2015b). There is likely to be some seasonal changes as well.

MERIDIAN'S INTEREST IN WATER QUALITY AND AQUATIC VALUES

45. A number of water bodies in the UWC are already showing signs of deteriorating water quality. Areas of greatest concern at this point are the Ahuriri Arm of Benmore, Wairepo Creek/Arm and streams such as the Willow Burn and Stony River. Land-use intensification that results in an increase in nutrient loss, sewage and waste discharge and increased activities such as salmon farming can be expected to cause further deterioration.

Landuse intensification and water quality

46. Land-use intensification will have an impact on water quality in the Waitaki system, where it results in changes to nutrient loading, sediment or water flux. Effects will be most obvious in Lake Benmore, as the major receiving water body in the catchment, with the severity of impact depending on the area of increased irrigation, location of intensification and farming practices (Snelder et al. 2005, Sutherland et al.2008).

47. The major threat to water quality in the UWC is therefore enhanced nutrient runoff to surface and groundwaters from agricultural land-use intensification and other activities such as salmon farms. Deteriorating water quality will have a number of actual and potential adverse effects on Meridian's Waitaki Power Scheme and interests as described in **Mr Page's** evidence. Increased nutrient loadings to nutrient-limited systems will result in enhanced algal productivity, decreased water clarity, increased risk of algal blooms in rivers (periphyton) and lakes (phytoplankton), and growth of nuisance plants (macrophytes). These will all have flow-on effects to the biological communities that rely on these components, including threatened species of fish and birds, as well as aesthetics and recreational values.

Phytoplankton

48. Bioassays of water from Lake Benmore have found phytoplankton (algae) growth to be limited by both N and P (Clarke 2015b). As noted above the Ahuriri Arm is close to the upper bound for oligotrophy, and

blooms of the colonial green *Volvox aureus,* which is characteristic of more eutrophic conditions, are already occurring. Increased nutrient loadings would lead to greater risks of transition to mesotrophic status, with the risk of toxic and nuisance algal blooms becoming greater as trophic state declines.

49. Norton et al (2009) presented results from modelling the effects of increased nutrient loadings to the two arms of Lake Benmore. The models predicted that chlorophyll *a* concentrations would reach mesotrophic levels in the Ahuriri Arm at 1.6 times existing nutrient inputs. I note that these models were based on sampling during the 2008-09 year and did not allow for any nutrients released to groundwater by recent land use intensification but yet to reach surface water bodies. The Ahuriri Arm is particularly sensitive to nutrient-induced algal blooms because of its longer residence time and smaller volume relative to the Haldon Arm. As noted above, the Ahuriri Arm is also very close to the upper TLI threshold for oligotrophic status currently.

50. The 2009 modelling has now been updated in a NIWA study for ECan (Spigel et al. 2015) based on improved model calibration and nutrient inputs as well as new land-use scenarios. The results of this latest modelling show that there would be an increase in TLI from 2.59 for Scenario 2a to 2.71 and 2.72 for 2b in the Haldon Arm (current 2.38) and 2.91 for Scenario 1a to 3.25 for Scenario 2b for the Ahuriri Arm (current 2.85) which would significantly exceed the TLI in PC5 of 2.9 for the Ahuriri Arm and 2.7 for Haldon Arm. Scenario 1a, 2a and 2b represent an increase in N load to Lake Benmore of 13.2, 26.1 and 26.37% for N and 12, 19.2 and 22.5% for P. Although there are lots of assumptions with these models they demonstrate the importance of considering all potential nutrient inputs to the waterways, both existing and potentially future consented inputs, as well as cumulative impacts from smaller developments.

51. The inflows to the Haldon Arm from the canals and rivers provide flushing and dilution of nutrients in the Arm but because mixing is not uniform across the Arm there are areas close to these inflows where mixing may be slow and thus would be more susceptible to localised algal blooms. This could cause localised impacts on ecosystem health and food webs.

Periphyton

52. Snelder et al. (2005) estimated that for most streams in the Waitaki Basin the severity and frequency of exceedance of algal biomass guidelines would increase by a factor between 1.5 to 3, depending on the land use scenario from earlier modelling. Similar effects would be predicted for the Tekapo, Pukaki and Ohau Rivers. Increased nutrient levels and resulting periphyton biomass would also be predicted in the canals below salmon farms and where there was groundwater input.

Periphyton mats have already been observed downstream of salmon farms (Sutherland 2012b).

53. While excessive growths of any periphyton taxa would be a concern to Meridian, it is the benthic diatom didymo that is likely to have the most impact on its operations. Didymo generally does best in cooler, low nutrient waters. Filamentous green algae tend to dominate the periphyton community at higher nutrient levels. Studies have shown that didymo cell division is controlled by levels of dissolved reactive phosphorus but only at concentrations of up to 2 ug/l. At higher concentrations other species tend to dominate (Kilroy and Bothwell 2012). Concentrations in the canals and most of the water ways in the UWC are currently low in phosphorus (<1 ug/l) so a small increase in phosphorus loading would be expected to lead to increased levels of didymo.

54. High biomass of didymo results in poor river health, including an invertebrate community dominated by taxa (worms, chironomid larvae and snails) that have low QMCI values and have low values for a range of fish and bird species, including threatened species discussed earlier. In addition to impacts on the food web, didymo tends to thrive under stable flow conditions which are found in a number of tributaries and rivers as well as canals in the UWC, particularly during summer. Mats of periphyton are already observed in some of the canals and could resut in blockage at intake structures (Sutherland 2012b).

55. Although Meridian did not introduce didymo to the system, Meridian and Genesis control the flows in a number of rivers in the catchment including the lower Waitaki, Tekapo and Ohau and thus potentially some of the management options for reducing didymo. If didymo was to spread further and to nuisance proportions in the UWC river systems then there could be pressure on Meridian to provide flushing flows targeted to clean out didymo with associated economic and energy supply implications as discussed by **Mr Page**.

Macrophyte growth

56. As discussed above, the nuisance weed lagarosiphon, along with potential invasion by hornwort and egeria, poses a significant threat to Meridian’s operations. Recent increases in elodea are also of concern and have already caused management responses at Ohau B and C to avoid the blockage of intakes. In response, Meridian is currently investigating new and refurbished intake screens. This is discussed in **Mr Page'**s evidence.

57. There is already concern that lagarosiphon is spreading throughout the Haldon Arm and regular surveillance and control programmes are in place through Land Information New Zealand at high risk areas like the delta at the top of Benmore and around boat ramps. Macrophyte proliferation is largely a result of cumulative impacts and changes.

While permitted changes to waterway configurations, such as the creation of hydro impoundments, have increased the area potentially available for macrophyte growth, it is the introduction of nuisance species through other activities that has realised the threat. Increased plant growth in response to nutrient loadings to the water ways feeding into Lake Benmore and the lower lakes would cause a further escalation of the weed problem that would adversely affect Meridian.

58. In summary the potential for increased periphyton growths and increased biomass and spread of nuisance weed species is of major concern to Meridian. It is critical that existing water quality is maintained and where possible improved if these issues are to be avoided. Thus it is important that there are adequate provisions in PC5 to manage activities which may result in an increase in nutrient loads and thus have an effect on water quality of the UWC lakes.

Trophic lake index

59. As discussed above the TLI was developed as a way to rank lakes according to their trophic state. It is encouraging to see that the outcomes in PC5 ensure lakes never actually reach a lower trophic level. This is important for 2 reasons. Firstly the index is a continuum and is prone to natural variation in the three sub-indices in response to changes in other variables. The expectation that responses to land use change can be precisely modelled and managed is also unrealistic and there are likely to be tipping points when TLI-related changes would occur more rapidly for a given change in nutrient load. The exact tipping points are not known but changes could be rapid as they are approached.

60. Secondly there are lag times or delays between when nutrients enter groundwater and when they reach downstream water bodies. It is possible that the full implications of land use intensification in the UWC are yet to show up. This is supported by observations of Kellands Pond which drains into the Wairepo Arm. After intensification nearby ECan have only recently observed the start of degradation of water quality in this water body. In his evidence presented at the 2009 hearing (for a number of applications to take and use water from the upper Waitaki Catchment) Mr Callander stated that it could be 10-20 years before we see the full effects of present land-use changes. Recent data collated by ECan (Clarke 2015a) show that concentrations of nitrate and nitrite in Kellands Pond increased dramatically from 2009. Thus in my opinion a cautious approach should be taken to allowing for any future increase in nutrient levels arising from future land use changes, taking into account the lags before nutrients from existing land use changes reach surface waters.

61. It is also worth noting that the Natural Resources Regional Plan (NRRP) required that Benmore be "maintained at the boundary of oligotrophic and mesotrophic condition or better". Mesotrophic conditions will mean

greater risk of nuisance periphyton and weed growth in Lake Benmore and the lower lakes as well as deteriorating general river and lake health.

62. In order to be effective there must be management of nutrient loads. PC5 allows for this and I support this. Although arbitrary, 2.7 has been accepted as a suitable TLI for management for Haldon Arm and Benmore Dam and 2.9 for the Ahuriri Arm. The Ahuriri Arm is already past this point in some years (latest reading is 2.94 in 2010/11) thus further increase in loadings is expected to lead to a deterioration in lake health and the lake can be expected in the near future to exceed the target TLI. Experience with Lake Taupo and the Rotorua lakes shows that improving the trophic state of a lake is extremely expensive, difficult and not achievable in the short to medium term (10-20 years). Thus any form of management needs to be carefully assessed and the need for significant additional management interventions avoided.

COMMENTS ON MERIDIAN SUBMISSIONS AND ON THE SECTION 42A REPORT

63. There are a number of policies, rules and outcomes documented that will ensure the long-term sustainability of aquatic resources. I will not go into these aspects but instead focus on areas of concern.

64. As discussed earlier cumulative nitrogen and phosphorus loads entering the waterways could very easily move Lake Benmore, as the major receiving water body for the UWC, into the next trophic level. This, along with the increased risk of aquatic macrophyte growths in the likes of Lake Benmore emphasises the importance of considering all nutrient inputs cumulatively and for all major water bodies. In my opinion this provides a sound basis for considering nitrogen and phosphorus limits for Kellands Pond and the Wairepo Arm.

65. The purpose of Table 15B (a-d) in defining outcomes and limits is generally supported. Several changes have been made to address some inconsistencies and there are improved outcomes and limits based on various submissions. The recognition that to ensure lakes do not deteriorate to a lower trophic state requires effective water quality outcomes and limits, is particularly noteworthy and fully supported. However I still have concerns around the application of outcomes and limits that do not take into account the special attributes of many of the UWC water bodies namely:

- Glacial flour which impacts on aesthetics, optical properties, phytoplankton, macrophytes and periphyton, and sediment cover.

- Didymo which has spread throughout the Waitaki with resulting impacts on periphyton biomass and macroinvertebrate populations.

66. An example is the Meridian resource consent requirement for the discharge of natural flood water from Lake Ohau into the upper Ohau River. This discharge constitutes the full flow of the river. Based on recent measurements of sediment cover in the Ohau River, which has a minimum flow condition, the water in the existing Ohau River would not always meet the fine sediment standard in Table 15b(a) for lake-fed rivers in the Upper Waitaki at present, due to its natural glacial flour. This would also be the case if the full flow was released under flood conditions. Based on **Ms Dawson's** evidence, Policy 4.2 could be interpreted as requiring the management of the upper Ohau river (by way of this discharge consent) to achieve, or at least assist in achieving, the freshwater outcomes, including for fine sediment. From my understanding, such management would not be possible.

67. As identified by other Meridian witnesses I also have concerns about the potential artificial differentiation between outcomes and limits. In her evidence **Ms Dawson** states that there are examples of freshwater outcomes being implemented directly through conditions of consent in connection with irrigation in the upper Waitaki. Several of these include environmental trigger conditions which refer to the TLI in the Wairepo arm. This attribute is only included in Table 15b(b) as a freshwater outcome, and not in Table 15b(d) as a water quality limit. Similarly, other irrigation consents include environmental triggers relating to chlorophyll a (periphyton) in downstream rivers (only specified as an outcome for rivers), and the discharge consent for Mt Cook Alpine Salmon includes a requirement for a macrophyte management plan for Lake Benmore (more aligned with the lake outcomes than the limits). In my view, it is appropriate for consents to manage through conditions some of the outcome attributes to achieve the desired water quality results. If only the limit tables are used then management of the likes of periphyton in rivers will rely on the nutrient limits alone rather than the manifestation of these which is periphyton growth. It is periphyton growth that affects the river values such as recreation and macroinvertebrate communities thus there should be a limit for this as well (and guidelines are well developed and in the NPS-FM). This gets particularly complicated when didymo is present which can grow at lower P levels but not higher levels.

Nitrogen loads

68. The major remaining issue with nitrogen loads is the potential for cumulative inputs to exceed the Nitrogen Load Limit. Cautionary limits and early warning triggers for TLI have been set for most of the water bodies through individual consent processes. My main concern with a over reliance on an adaptive management approach without managing to outcomes and limits is that the links between inputs on land to groundwater and then to surface water bodies are not well established and the impact of lag time makes responses to exceedances of trigger levels very difficult to manage. Thus it is critical to set appropriately cautionary outcomes and limits and take a suitable cautionary and

common approach to all consents to ensure the health of the water bodies never reaches critical levels.

Lake Ruataniwha

69. Lake Ruataniwha is a critical link between Lakes Ohau, Pukaki and Tekapo, and Lake Benmore and the lower lakes. It is important that its water quality is maintained to a high level that reflects the high quality of waters entering the lake from the rivers and hydro canals. There are no limits or outcomes for the lake proposed in PC5. Meridian submitted that the TLI in the lake should reflect the high water quality of the inputs with a TLI of 1.7 and that Ruataniwha be included as an "Artificial lake-on river".

70. Lake Ruataniwha is under pressure from nutrient inputs. In the scenario assessment report by Clarke (2015b), it is noteworthy that even under Scenario 1a large proportional increases in annual nitrogen and phosphorous loads to Lake Ruataniwha are predicted (pg. 7), driving a predicted 8% increase in TLI (pg. 10). Under Scenario 2a, (which I understand to be the scenario relevant to Lake Ruataniwha because it falls with the Haldon Arm (orange) zone), large increases in the nitrogen and phosphorus loading of Lake Ruataniwha are reported (pg. 8) driving a 9% predicted change in TLI (pg. 10).

71. The Section 42A report agrees that the generic TLI of 4 for artificial lakes would not be appropriate. The recommendation from that report is that routine monitoring should be carried out but there is still no commitment to establishing a water quality index for this lake. In my view, Clarke's (2015b) assessment of Lake Ruataniwha is largely correct. The TLI of Lake Ruataniwha is likely to be microtrophic, with a similar TLI to that of Lakes Tekapo, Pukaki and Ohau, being approximately 1.7 (pg. 15). I am aware of the Mount Cook Alpine Salmon farm located in the Ohau Canal (above Ohau A Powerstation) and Meridian advises me that this is in the process of being relocated (except perhaps for 1 fingerling raft associated with the adjacent land-based hatchery) for canal infrastructure management reasons.

72. In my view, a provisional TLI should be applied while more sampling is carried out. My recommendation is a TLI of 2.7 or less to protect Lake Benmore. My concern is that without a provisional TLI for Lake Ruataniwha the cumulative inputs from land-use intensification and aquaculture may not be appropriately managed to ensure the health of water bodies further down the Waitaki.

Kellands Pond and Wairepo Arm

73. Kellands Pond has no surface tributary inflows and is thought to be fed by groundwater inflows from a drainage area of 1,591 ha, some of which is subject to further land use intensification. Kellands Pond flows

into the Wairepo Arm along with inflows from the Wairepo Creek and drains a catchment of over 21,000 ha.

74. In PC5 the TLI for Kellands Pond and the Wairepo Arm are set at 4 (Artificial lakes other) with the Section 42A report recommending a change for Kellands Pond to 3.7. Meridian submitted that these should be changed to a maximum TLI of 3.2 or better and TN should be <350 ug/L or better. I consider a TLI of 3.2 to be appropriate for both water bodies to help ensure no further deterioration in water quality to water bodies downstream.

75. Clarke (2015b) predicts a TLI outcome of 3.2 for Wairepo Arm, noting that this would indicate lake trophic status quo, but unrealised effects from recent development would indicate otherwise (pg. 16). For Kellands Pond the TLI prediction is "in excess of 3.7" with Clarke noting rapidly increasing nitrogen levels have been observed and that the Pond is phosphorous limited (pg. 16).

76. While the Section 42A report has recommended a reduction from the existing TLI for Kellands Pond of 4.0 to 3.7 this is not considered appropriate or precautionary enough for the following reason. The ECan report provides estimates of TLI for Kellands Pond of 3-3.2 for samples from the centre of the lake for data from 2009 to 2014. The 3.7 referred to by the Section 42A report reflects the maximum for samples taken at the edge of Kellands Pond. I do not consider that samples taken at the edge will reflect the existing conditions for the main body of water and thus 3.2 would be the appropriate level for the main body of the Pond.

77. It should also be acknowledged that even 3.2 breaches the overall TLI objective of 3 under the CLWRP (as noted by the ECan Clarke 2015a report). Maintaining the existing state as a minimum is a key outcome in the CLWRP.

78. With a TLI of 4 for Wairepo Arm there would be an increased risk of the waterbody becoming further degraded than it is at present, particularly as it is the direct receiving environment for the Wairepo Creek. Thus in practical terms, because the Arm is already mesotrophic and should not be allowed to get to eutrophic, allowing for some uncertainty this water body should not receive any increase in nutrient loadings.

Didymo

79. The benthic diatom *Didymosphemia geminata* was first introduced in 2006 to the UWC and has now spread throughout including the Ahuriri River, Tekapo River, Twizel River, and upper and lower Ohau River. There is no acknowledgement in Tables 15B (a,c) of the presence of didymo or in the Officers Report's comments on the tables. However, I do support the statement in the Officers Report that 120 mg/m^2 of

periphyton, which Fish and Game wanted applied to hill-fed lower and lake-fed rivers would be prohibitive for rivers dominated by diatomaceaous algae.

"Will meet"

80. The requirement that "Lakes, rivers ... will meet the freshwater outcomes..." in Strategic policy 4.1 of the CLWRP would be very difficult to achieve in dynamic river and lake systems such as those in the UWC. Examples are:

- A temperature maximum of 19°C for lakes and 20 °C for rivers. In the middle of a dry hot summer these could be exceeded naturally. An example is the Ahuriri River mouth which in Dec 2011-Feb 2012 was over 21 °C on at least three occasions (Sutherland et al. 2012).

- The same would apply to changes in natural colour which need to take account of natural variation and the effects of variable glacial flour concentrations, which I predict could be more than 5 Munsell units at times. There is no real basis for its application to rivers influenced by glacial flour.

- Similarly Lake SPI is not applicable and the ECan report (Clarke 2015a) acknowledges the index "may not be particularly relevant in lakes with naturally low water clarity. This is because macrophyte condition cannot be used to determine ecological health of naturally low productive lakes with of low natural light penetration. In such environments, native macrophyte diversity and extent will be low (as will invasive macrophytes). Lake Pukaki doesn't have any macrophytes for this reason.

81. Some of the outcomes and limits still do not recognise the different "natural" character and inter-connectedness of the waters in the upper Waitaki. Lakes Tekapo, Pukaki and Ohau all receive varying amounts of glacial flour with Pukaki being the most turbid (secchi disc[2] <1 m, cf. Tekapo 5 m and Ohau 10 m, - Stout 1978). The past and existing environments include significant movement of water between different water bodies through the canal system and rivers and there have been changes to source inputs e.g. there is no flow from Lake Pukaki into the lower Tekapo now but in the past the waters were mixed. Because some of the sources have such different characteristics the receiving water could change, but due to natural differences in water clarity.

82. The outcomes in Tables 15B (a-b) appear to be derived from a variety of sources while the actual limits in Tables 15B (c-d) for rivers and lakes are based on data and thus reflect natural variability. Outcomes

[2] Secchi disc is a measure of water clarity based on the depth that a dinner plate size disc can be seen in the water body.

for attributes such as chlorophyll a, QMCI, temperature and fine sediment cover for rivers (Table 15B (a)) and visual quality, temperature, Lake SPI for lakes (Table 15B (b)) are not relevant for some rivers and lakes because of natural variability and this needs to be acknowledged, at least where there are special characteristics which apply to much of the catchment (glacial flour which affects fine sediment cover and visual quality and didymo which affects periphyton cover and QMCI). I consider these special conditions are significant enough to be incorporated into the application of attributes for the upper Waitaki.

83. In summary it will be essential for the best management outcome and to protect the health of the water bodies in the upper UWC that PC5 and any changes to it provide for the existing environment and in particular the existing variability in a number of parameters while providing for:

- maintenance and improvement (where appropriate) in water quality in the catchment by managing farming activities (and aquaculture);
- management of nutrient loadings to lakes, to manage the potential for periphyton and weed growth in lakes;
- ensuring that outcomes and limits for connecting waterways recognise that the health of these water bodies will influence the health of other water bodies downstream, including Lake Benmore, and that outcomes and limits be set accordingly.

MERIDIAN RELIEF SOUGHT

84. The relief sought by Meridian to address major concerns as noted above is supported. In particular:

- Strengthening rules to ensure that Total Nitrogen Loading is managed within the prescribed limits.
- Within the Waitaki sub-region Freshwater Management Units, when implementing Policies 4.1 and 4.2 recognise that the existing freshwater quality in the lakes and rivers is influenced by naturally occurring processes, including the glacial origin of the water, and natural variation. Water bodies which receive significant inputs of glacial flour or have significant didymo populations must recognise these special characteristics when limits and outcomes (Tables 15 (a-d) are applied.
- Lake Ruataniwha is the link between the upper lakes (Pukaki and Ohau) and Lake Benmore and is an artificial lake-on river. Limits

should reflect this and be at least equivalent to those of the Haldon Arm (2.7), but more appropriately currently TLI estimated as approximately 1.7 into which the water discharges but recognising the high quality of the feeder lakes for TLI, to be measured near the outlet (thus accounts for attenuation within the lake). The annual median and maximum chlorophyll *a* of <2 and <10 mg/m^3 should apply to reflect the influence on the Haldon Arm.

- Kellands Pond and Wairepo Arm are also intrinsically linked to Lake Benmore and thus limits and outcomes should be set in Tables 15(b) and (d) to protect the Pond and Arm as well as Lake Benmore. Limits are provided in Meridians' submission. These should be set at the existing TLI of 3.2, TP <10 mg/m^3 and annual median and maximum chlorophyll *a* of <2 and <10 mg/m^3whcih is consistent with other 'Artificial lakes – other".

Dated: 22 July 2016

Mark Richard James

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