Before the Hearings Commissioners
at Christchurch

in the matter of: a submission and further submission on the proposed Canterbury Land and Water Regional Plan under the Resource Management Act 1991

to: **Environment Canterbury**

submitter **Meridian Energy Limited**

Statement of evidence of Mark Richard James

Date: 4 February 2012

COUNSEL: AR Galbraith QC (argalbraith@shortlandchambers.co.nz)

Chapman Tripp
T: +64 3 353 4130
F: +64 3 365 4587

245 Blenheim Road
PO Box 2510, Christchurch 8140
New Zealand

www.chapmantripp.com
Auckland, Wellington,
Christchurch

CHAPMAN TRIPP

STATEMENT OF EVIDENCE OF MARK RICHARD JAMES

INTRODUCTION

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 30 years experience in 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 "Lake Ecosystems" and "Sustainability of Cultured and Coastal Shellfisheries". 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 33 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:

    11.1. Proposed Canterbury Land and Water Regional Plan. Prepared by Environment Canterbury Regional Council, August 2012;

    11.2. Meridian Energy Ltd's submission on the proposed Canterbury Land and Water Regional Plan;

    11.3. Evidence of Donna Sutherland, Nimal Priyantha Dodampe Gamage, 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);

    11.4. 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;

    11.5. 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;

    11.6. 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;

    11.7. 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;

11.8. 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.

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

SCOPE OF EVIDENCE

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

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

12.2. Meridian's interest in water quality and aquatic values as relevant in the Upper Waitaki catchment.

12.3. Meridian's relief sought on the proposed Canterbury Land and Water Regional Plan (*the Proposed Plan*) as it relates to water quality including amendments to definitions and related policies, appropriateness of TLI and relevance of indicators.

SUMMARY

13. The Upper Waitaki Catchment is highly regarded for 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 above the lakes (Tekapo, Pukaki and Ohau) has 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. Lake Benmore through the Haldon and Ahuriri Arms is the receiving water body for most of the catchment. The water quality sampling that has been carried out to date indicates that Lake Benmore is towards the upper end of the oligotrophic trophic state and at least parts of the

lake are in danger of becoming mesotrophic if water quality declines further. Based on total nitrogen (TN) and total phosphorus (TP) the TLI of the Wairepo Arm would place it as mesotrophic and at least eutrophic on occasions and is likely to be close to the tipping point to eutrophic. Thus any net increase in loadings to the Wairepo Arm would be of concern.

16. Meridian's major concerns with water quality and aquatic values are the impacts on its operations through declining water quality and cumulative impacts that may impact on biodiversity and conservation values. Enhanced nutrient runoff from agricultural land-use intensification and other activities are a major threat to water quality in the UWC. Increased growth of nuisance weeds and algae as a result of declining water quality will impact directly on Meridian's operations by increasing potential build up of macrophytes and algae on screens causing loss of operational efficiency. Meridian is also concerned that should land-use intensification not be well managed that it may become the de-facto agent responsible for management of water bodies through provision of flushing flows. Thus it is important that Meridian ensure there are provisions in the Proposed Plan to manage activities which may impact on water quality.

17. There has been considerable discussion about the trophic lake index (TLI) for Lake Benmore as the major receiving water body in the catchment. While there has been debate about the actual TLI number all agree that the outcome for the lake should be to retain its oligotrophic state. A target of 3.0 thus seems appropriate but the concern is that the trophic scale is a continuum and managing up to a threshold risks getting closer to a tipping point. Secondly with lags between nutrients entering groundwater and reaching surface water bodies the full implications of existing intensification are yet to be realised. There should be a buffer to protect these values and prevent further deterioration of lake health.

18. A number of objectives, policies and rules in the Proposed Plan are at odds with the existing situation or would appear to be unattainable. Ones of particular concern from an ecological perspective are:

    18.1. Objective 3.10 - There has already been considerable modification of the natural systems, processes and inter-connectedness of water bodies in the UWC. While there should be protection of the existing natural systems and processes, there needs to be recognition that a number of ecological effects, such as barriers to fish passage, are historical and that Meridian has implemented programmes to mitigate these effects. Natural processes and continuity of rivers, as identified as an objective in the Proposed Plan, is at odds with the existing consented situation.

    18.2. The outcomes in Table 1a and b are generally supported but there needs to be greater clarity and realism around defining terms and compliance. 100% compliance for the outcomes stated is unrealistic for some environmental parameters and some sort of percentile compliance is recommended. An example is temperature in rivers where some may exceed the outcome of 20 ^{0}C naturally in very hot summers. Similar comments would apply to periphyton growth and water colour which varies considerably in this catchment, depending on the origin of the water (also applies to Activity Policy 4.52).

18.3. Enabling of a 10% increase in the loss of nitrogen before farming intensification is considered to be a "change in farming" (for the purposes of the Proposed Plan rules – see Definitions Section 2.10) is of concern. This has the potential to cumulatively result in significant further degradation in water quality within at risk and sensitive lake catchments.

18.4. Provisions in the Proposed Plan are focussed on nitrogen but phosphorus can also be a limiting nutrient for plant growth and can impact on growth of nuisance algae and weeds. Thus phosphorus losses and effects need to be captured.

18.5. Policy 4.80 refers to offsetting of significant effects in the same wetland. Wider biodiversity benefits may be achieved from restoring, enhancing or creating habitat in a different location or habitat type. This is the basis for the successful Project River Recovery.

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

19.1. Removal of 10% increase as the definition for a "change" in farming.

19.2. Include both nitrogen and phosphorus in assessments using models of nutrient inputs and effects.

19.3. Clarify in a number of places that the baseline is the existing environment not historical natural processes. In some cases processes may still be changing as new equilibriums are reached eg lake-side erosion.

19.4. Removal of 100% compliance for outcomes and more realistic percentiles for compliance be included. Other outcomes should relate to "significant" change not "any" change.

19.5. The classification of water bodies into water quality classes needs to be clarified on the planning maps.

19.6. Provide flexibility for mitigation and off-setting to allow for best biodiversity outcomes.

EXISTING ECOLOGICAL VALUES IN THE UPPER WAITAKI CATCHMENT

20. In this section I provide an overview of the existing environment as it relates to water quality and aquatic ecosystem values.

21. From the mid-1800s the Waitaki system 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 included hearing evidence and considering 104 consent applications to take, use and discharge water in the UWC. The impact of further intensification was a key concern at these hearings for a number of submitters, including Meridian, because of its potential significant effect on water quality and existing aquatic values.

22. 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.

23. 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.

24. The most significant freshwater ecological values in the UWC are related to its alpine ecosystems and habitats of braided rivers, natural high country lakes, tarns and associated wetlands. The significant values and resources in each of these habitats has been summarised in a number of reports including Mitchell and Davis-Te-Maire (1993), Burrell and Fergusson (2004), Chadderton et al. (2004), Daly (2004), Elkington and Charteris (2005), O'Donnell (2000), Benn (2011), and the New Zealand Freshwater Fish Database (NZFFD).

25. Today the rivers of the UWC, including the modified mid-rivers (eg. Tekapo, Ahuriri, Twizel and Ohau), 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

26. Water quality data is relatively sparse for most parts of the UWC. There is some water quality data from ECan monitoring of rivers and streams over the last 20 years, although sampling has been sporadic at times, and GDH took some samples on three occasions in December 2008 and January 2009. The most comprehensive monitoring to date was undertaken for Meridian by NIWA in December-April 2008/09 in support of development of an ecosystem model for Lake Benmore and more recently 2011-13 when 12-14 months of data was collected monthly from a number of river and lake sites.

27. 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).

28. 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, reflect that of the upper lakes and rivers with well oxygenated, low nutrient water though with relatively high natural turbidity. The Ahuriri River draining into the Ahuriri Arm of Benmore has a higher nutrient concentration and this results 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.

29. During the recent hearing into applications for the UWC consents to take water for irrigation there was much debate over the Trophic Lake Index (TLI) for Lake Benmore. 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, secchi disc is not used because the presence of glacial flour confounds this. The TLI gives an index along a continuous scale and based on a large dataset and international standards, certain TLI values have been assigned to specific trophic states (Table 1). The environmental characteristics for lakes of different trophic state are shown in Table 2. The index does only give one measure of lake health and does not include degree of oxygenation, and proliferation of nuisance plants which can also have a strong influence on ecosystem health.

Table 1. Trophic state defined by Burns and Bryers (2000).

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

Table 2. 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.

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.

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.

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.

30. 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 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 (Table 3).

Table 3. Measured variables of TLI (excluding Secchi depth) measured in the Haldon and Ahuriri Arms of Lake Benmore. Data from Sutherland et al. 2009, 2012. TLI and mean concentrations calculated over Dec-April each year.

	TLI	Chl a, ug/L	TP, ug/L	TN, ug/L
Mid-Haldon Arm				
2008/09	2.65	0.86	13.2	100
2011/12	2.51	1.6	5	109
Lower Haldon Arm				
2008/09	2.19	0.87	6.3	71
2011/12	2.52	1.6	5	112
Ahuriri Arm				
2008/09	2.84	1.3	11	129
2011/12	2.94	2.24	7.5	151

31. In the Haldon Arm, two sites were sampled, one above and one below the confluence with the Ahuriri Arm. Overall summer TLI was lower than in the Ahuriri Arm, towards the middle of the oligotrophic range

(Table 3). In 2011-12 both sampling sites in the Haldon Arm showed similar TLI values, whereas in 2008-09 the site below the confluence had lower mean concentrations of TP and TN, resulting in a low TLI. Variation in TLI values for lakes between years is normal. TLI uses dynamic variables, and the climatic and other conditions prevailing from year to year affect in lake processes that determining how these variables behave. P, N and phytoplankton all respond to the dynamics of variables differently.

32. There has been no time series or spatially-resolved water quality data collected for Lake Ruataniwha or the Wairepo Arm. The few measurements of TN and TP taken in Ruataniwha by GHD in 2008 indicated the lake is microtrophic, consistent with having a short residence time and receiving most of its water from the upper lakes. Measurements by ECan since 2003 in the Wairepo Arm indicate the water body is mesotrophic but with large variability in the data. Wairepo Arm is much smaller than Ruataniwha, is not directly fed by the large upstream lakes and has a significant proportion of irrigated agricultural land in its immediate catchment. Limited measurements in 2008/09 by GHD indicated the Wairepo Creek that drains into this Arm was mesotrophic to eutrophic. The best indication of the trophic state of the Wairepo Arm is based on measurements of TN and TP, (Sutherland evidence to the 2009 Upper Waitaki Water Consent Hearing) from which Wairepo Arm has been assessed as being mesotrophic with a TLI of 3.7. The Arm already reaches at least eutrophic levels on occasions and is likely to be close to the tipping point to eutrophic. The Commissioners in the Upper Waitaki consents also concluded, based on the evidence presented, that the Wairepo Arm is close to the mesotrophic-eutrophic boundary and no net increase in nutrient load should be permitted.

33. The rivers and canals which connect the upper lakes with the Haldon Arm of Lake Benmore generally still have high quality water. However, streams close to land use intensification, such as Stony River, Wairepo Creek and Willow Burn have poorer water quality with higher levels of dissolved inorganic nitrogen and phosphorus and extensive filamentous algal growths (Coffey evidence to the 2009 Upper Waitaki Water Consent Hearing). A summary of data collected by ECan over the last 20 years is shown in **Appendix 1**.

34. Current water quality in the lower Waitaki i.e below Waitaki Dam is generally classed as good with most parameters meeting the Australian and New Zealand Environmental and Conservation Council (ANZECC) guidelines. There are some locations, particularly in the lower river and where tributaries enter the main stem and certain times when some parameters do not meet the guidelines. Generally nitrate, ammonium and dissolved reactive phosphorus (DRP) increase in the Waitaki with distance downstream of the Waitaki Dam (Larned and Norton 2006).

Wetlands

35. As discussed earlier there has been significant modification of wetlands and braided river habitat in the UWC through development of farming and the hydro-electricity scheme. Up to 40% of particular wetland types having been lost through catchment development (Wilson 2000) but high value wetlands still exist in various parts of the catchment, mostly around and above Lakes Tekapo, Pukaki and Ohau and in the Ahuriri catchment.

36. The largest intact alluvial wetlands in the UWC are found from Watson Stream to Ben Avon on the Ahuriri River, around the confluence of the Hopkins River with the Dobson River and the Ohau delta region (Woolmore 2011, Robertson 2012). These areas are distinctive for their high biodiversity and presence of threatened fish and plant species. Large parts of the mid-Ahuriri are now protected and managed by Department of Conservation as a result of purchase through the Nature Heritage Fund. The Ohau moraines provide a complex of wetlands including tarns, tussock grasslands, sedge and rush swamps which in turn provide important habitat for waders and water fowl (including threatened black stilt, wrybill and biittern). Unprotected wetlands in these areas are threatened by land intensification, grazing, drainage and weeds. The lower Ahuriri and Ahuriri delta provide important wetland habitat for kaki, bittern and marsh crake as well as the threatened lowland longjaw galaxias (Robertson 2012).

37. The largest area of existing wetlands in the UWC is in the Tekapo catchment. The large wetlands are primarily associated with the Godley and Cass Rivers and along the sides of Lakes Tekapo and Pukaki. The lakes and lagoons along the west side of Tekapo provide high value habitat for a range of birds and aquatic life including threatened bird (crested grebe, kaki and bittern) and fish species. The Glenmore Tarns have been identified by DoC as the most outstanding kettlehole tarns in the South Island. These tarns are naturally rare ecosystems and also provide important habitat for a range of birds and aquatic life. Again the main threat to these habitats is from intensification of land-use, grazing and weeds.

38. The area of wetland ranked the highest by WONI (Waters Of National Importance) in the UWC is on the lateral moraines to the west of Lake Tekapo. This area labelled the Braemar Road Tussock – Maryburn complex includes tussock grassland, meandering streams and tarns. Other high value wetlands are found associated with the Fork Stream (good populations of native fish), Wolds Stream, Maryburn and Grays River.

Periphyton and macrophytes

39. 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. While it is often the basis for the food web it can also reach nuisance levels, particularly filamentous green algae. 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 and in the Ohau Canal in 2007. It has now been recorded from the Ahuriri River, Tekapo River, Twizel River, Omarama Stream and lower Ohau River. By 2009 it was present in all the canals. The range of species found in the Waitaki Rivers is similar to other New Zealand rivers, and is composed mostly of diatoms. The lower Waitaki River periphyton community is diverse. However filamentous green algae do occasionally bloom, particularly in slow-flowing side braids and some tributaries.

40. 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 Waitaki 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 P likely to result in proliferation of nuisance algal growth.

41. The macrophyte community 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.

42. Of 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 found in these canals, but also in sheltered bays in the Haldon Arm and 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). 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.

Macroinvertebrates

43. Very little is known about the aquatic invertebrate communities in water bodies of the UWC. Where there is suitable water flow in the rivers draining the upper lakes there is likely to be a community dominated by mayflies, stoneflies, elmid beetles, caddisflies, craneflies and chironomid larvae. In areas that are dewatered and there are residual flows and pools or have constant low flows the community is likely to be dominated by snails, chironomid larvae and worms. These environments would be particularly susceptible to increased nutrient loadings and changes to communities characteristic of poor quality waters.

Fish

44. Of the 26 freshwater fish species found in the UWC, six are threatened species. The lowland longjaw galaxias which is found in clear high quality spring fed streams and river margins is classified as nationally critical and is only known from one location outside the UWC. The bignose galaxias is endemic to the Waitaki and found in similar environments. The Waitaki River marks the southern boundary of the Canterbury mudfish which is nationally endangered.

45. The UWC supports a significant trout population and it is the most commonly found fish in the Waitaki. Chinook salmon are found mostly below the Waitaki Dam and along with brown and rainbow trout make up an important sports fishery in the catchment. Sockeye salmon are found occasionally below Lake Ruataniwha but the best habitat for them is Lake Ohau, the Upper Ohau River and Pukaki Canal.

46. Longfin eels are still common and a widespread native fish in the UWC. However the fishery is now largely depleted as a result of the installation of structures on the Waitaki River. Results of a 1993 survey indicated there had been no recruitment of elvers or juvenile eels above Aviemore Dam since the dams were built (Mitchell and Davis-Te Maire 1993). Since 2000 Meridian has undertaken a trap and transfer of elvers into lakes of the upper catchment and of migrants down to the lower Waitaki.

Birds

47. The remaining wetlands and braided rivers, particularly the Tekapo and Ohau Rivers, provide important habitat for a range of wading birds and water fowl and are considered by DoC to be regionally and nationally

significant. Over 26 species of waterbirds are found in the UWC with a number of endemic birds breeding in the catchment, predominantly on braided rivers. These endemic species include the wrybill, black stilt, banded dotterel, South Island Pied Oystercatcher, black-fronted tern and black-billed gull.

48. At least five threatened bird species are known to occur in the UWC. The black stilt, black-fronted tern and wrybill are acutely threatened and the black-billed gull and banded dotterel are chronically threatened (Hitchmough et al. 2007). The black-fronted tern and wrybill, both classified as Nationally vulnerable, feed on invertebrates in the rivers and breed on islands in the braided rivers of the Waitaki. An estimated 15% of all wrybills and 60% of all black-fronted terns are found in the UWC (Maloney et al. 1997). The black stilt (kaki) is one of the most threatened species in New Zealand with fewer than 200 birds now in captivity and the wild. These birds feed and breed on the braided rivers and deltas. In 1981, prior to the restoration efforts of the kaki recovery programme and Project River Recovery funded by Meridian and Genesis, there were only 23 individuals left. These birds rely on habitats with high quality water and associated food webs.

MERIDIAN'S INTEREST IN WATER QUALITY AND AQUATIC VALUES

49. I understand Meridian's major concerns with water quality and aquatic values are the direct and indirect impacts on its operations through declining water quality and cumulative impacts of other activities that may reduce biodiversity and conservation values in the UWC. Direct impacts on Meridian's operations will be through increased growth of nuisance algae and macrophytes. This would increase the need for aquatic weed surveillance and management and add costs associated with preventing build up of weeds on screens. Indirect effects will be through pressure on Meridian to mitigate increased periphyton growth downstream of control structures by providing flushing flows, most likely to be needed at times when water flow is naturally low. Meridian is concerned that, should agricultural intensification not be carefully managed it may become the *de-facto* agent responsible for mitigation of low water quality in water bodies.

50. 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, sewage and waste discharge and increased activities such as salmon farming can be expected to cause further deterioration.

Landuse intensification and water quality

51. 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 are most immediate at 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).

52. 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. 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. Of particular concern to Meridian's operations are the effects on phytoplankton, periphyton and macrophyte growth.

Phytoplankton

53. Bioassays of water from Lake Benmore have found phytoplankton (algae) growth to be limited by both N and P. 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, already occurring. Increased nutrient loadings would lead to greater risks of transition to mesotrophic status; the risk of toxic and nuisance algal blooms becomes greater as trophic state declines.

54. Norton et al (2009) present results from modelling of 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. Note that these models were based on sampling during the 2008-09 year and does 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.

55. The inflows to the Haldon Arm from the canals and rivers provide flushing and dilution of nutrients in the Arm but 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 the ecosystem health and food webs.

Periphyton

56. 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. 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.

57. 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.

58. High biomass of didymo results in poor river health, including an invertebrate community dominated by invertebrates (worms, chironomid larvae and snails) that 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 result in blockage at intake structures.

59. Although Meridian did not introduce didymo to the system, they control the flows in a number of rivers in the catchment including the lower Waitaki, Tekapo, Ohau and Pukaki and thus potentially some of the management options for reducing didymo. Trials in other catchments have shown that flushing flows can assist in managing didymo growth. 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 with associated economic and energy supply implications.

Macrophyte growth

60. As discussed above, the nuisance weed lagarosiphon is slowly spreading from the Ahuriri Arm and, 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 outages at Ohau B and C through blockage of intakes.

61. There is already concern that lagarosiphon is spreading throughout the Haldon Arm and regular surveillance programmes are in place at high risk areas like the delta at the top of Benmore and around boat ramps. Macrophyte proliferation is another example of the emergence of environmental issues as a result of cumulative effects. While permitted changes to waterway configurations, such as the creation of hydro impoundments, has increased the area 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 Benmore and the lower lakes would cause a further escalation of the weed problem that would adversely affect Meridian.

62. In summary I understand why 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 the Proposed Plan to manage activities which may have an effect on water quality of hydro storage lakes.

Trophic lake index

63. As discussed above the TLI was developed as a way to rank lakes according to their trophic state. A target summer TLI has been set at 3.0 for Lake Benmore as the major receiving water body for the upper catchment i.e maintaining the present oligotrophic status. While this is appropriate as an outcome and is supported in Table 1b of the Proposed Plan, parts of Benmore are already close to this upper threshold and the management of nutrient loads to ensure that this goal is achieved most of the time needs to be more conservative. There are two main reasons for this.

64. Firstly the index is a continuum and is prone to natural variation in the three sub-indices in response to changes in other variables. Therefore managing up to a threshold value risks exceeding it for significant periods. 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.

65. Secondly there are lag times between when nutrients enter groundwater and they reach downstream water bodies. It is possible

that the full implications of intensification over the last 10-20 years are yet to show up. This is supported by observations of Kellands pond which drains into the Wairepo Arm. After 4 years of 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 Mr Callander stated that it could be 10-20 years before we see the full effects of present land-use changes. Thus a precautionary approach must be taken and any further increase (such as 10% allowance under the definition of 'change') needs very careful consideration.

66. 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 Benmore and the lower lakes as well as deteriorating general river and lake health.

67. In order to be effective there must be a buffer for management of nutrient loads. Although arbitrary, 2.75 has been accepted as a suitable TLI for management (2009 hearing). The Ahuriri Arm is already past this point (latest reading is 2.94) thus **any** 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).

DEFINITIONS AND BASELINE FOR OBJECTIVES, POLICIES AND RULES

68. 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.

69. Of particular concern is recognition of ecological effects of Meridian's operations which have already occurred. An example is fish passage where the dams prevent natural migration and connection between the waterways. These effects have been addressed and mitigated through trap and transfer programmes. Another example is erosion which may be still occurring as lake shores adjust to changes in lake levels over the last 3-4 decades, as in the case of Pukaki. In the latter case, a plan change has been granted permitting, in emergency situations, further lowering of the lake which will potentially alter erosional processes.

70. The Proposed Plan (Objective 3.10) provides for the protection of natural processes of rivers. However the present infrastructure has already considerably modified the natural processes with parts of the Tekapo and Ohau and all of the Pukaki River downstream of the source lakes diverted to canals and the river beds dewatered. To maintain natural continuity of river flow from source to sea without reaches

running dry (Table 1a) is also at odds with the existing situation (and consents granted) in the likes of the Pukaki, Tekapo and Ohau Rivers.

71. Similarly the existing natural processes of rivers need to be maintained as they are now rather than protecting natural historical processes that are already modified (Proposed Plan Objective 3.10).

72. Objective 3.6 requires the enhancement of wetlands where they have been depleted. Creation of wetlands is not always cost-effective and successful thus overall goals are important and consideration needs to be given to wider biodiversity projects as mitigation to realise real benefits.

73. The purpose of Table 1a and 1b in defining outcomes is generally supported with the provisos above around management and TLI. However it is not at all clear from the maps provided what the classifications for Lakes Benmore, Aviemore, Waitaki and the Wairepo Arm and Lake Ruataniwha are. A maximum TLI of 3 is appropriate for Benmore, Aviemore and Waitaki which covers both "small to medium size high country lakes" and "artificial lakes - on river" (these lakes should be classified as the latter). Lake Ruataniwha should be classified as "artificial lakes – on river" but the Wairepo Arm and Kellands Pond area are not entirely artificial thus could be classified as "artificial lakes – other" with a TLI no more than 4. If the Wairepo Arm is classified as "artificial lakes – others" with a TLI of 4 there would be an increased potential for the receiving waters of Lake Benmore to exceed the target TLI of 3.0. Thus in practical terms, because the Arm is close to eutrophic and allowing for a buffer this means the water body should not receive any increase in nutrient loadings.

74. The requirement for 100% compliance at all times ("Lakes ... will meet the freshwater outcomes...") in Strategic policy 4.1 would be very difficult to achieve in dynamic river and lake systems such as those in the UWC. Examples are:

    74.1. 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)

    74.2. 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 Mansell units at times.

    74.3. Didymo biomass accumulation in a dry, warm year, without floods could exceed the limits that are present under existing nutrient loadings and conditions.

75. I do not know how the outcomes in Table 1 were derived but in other cases I am aware of there is a temporal and/or spatial component eg limits may be met for 95% of the time (95^{th} percentile) and never exceed an extreme high limit or there is no more than x change in the variable above baseline or control levels. It would be more appropriate to take into account natural variability as well as levels of environmental variables that impact on ecological values. I would like to see some consideration given to what would be a realistic level, and greater clarity around period of compliance (eg 95% of the time on a daily basis for temperature) and how the standard is measured (eg is it an instantaneous measurement, daily, weekly or monthly mean) for each of these standards to ensure the life supporting capacity of the system.

76. It is difficult to see the justification for a definition of fine sediment as sediment with grain size <2mm. This is defined in the NRRP Table WQL5 as grain size <0.0625mm which is consistent with silt particles. It is silt and clay particles (sometimes referred to as mud/clay) which cause the most impact on aquatic biota. Silt is easily transported in water and is fine enough to be carried long distances by air in the form of dust, unlike fine sand grains which deposit more rapidly and are not transported as easily. Thus I consider <0.0625 mm is a more appropriate variable.

77. Activity Policy 4.52 does 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[1] <1 m, cf. Tekapo 5 m and Ohau 10 m, - Stout 1978). The past and existing environment include significant movement of water between different water bodies through the canal system and rivers and there have been changes to source inputs eg 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.

78. Similarly Policy 4.79 does not recognise the existing hydrological connectivity and effects on wetlands and their biodiversity which will have resulted from consented developments. As an example of how this could be done Project River Recovery includes off-site mitigation for the loss of these wetlands and braided river habitats.

79. The enabling of up to a 10% increase in the loss of nitrogen before farming intensification should be considered to be a "change in farming" (for the purposes of the Proposed Plan rules – see Definitions Section 2.10) is of concern. This has the potential to cumulatively result in significant further degradation in water quality within "at risk",

[1] 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.

"over-allocated", and "sensitive lake catchments". Some of these, such as the Ahuriri Arm of Lake Benmore are already close to the tipping point for nutrient loadings and change in trophic state which would exceed the outcomes required in Table 1b.

80. The provisions of the Proposed Plan are focussed on nitrogen and do not capture the loss of phosphorus, which is also of significant importance in managing water quality and avoiding further degradation in water quality within "at risk", "over-allocated", and "sensitive lake catchments". While increased nitrogen loadings will impact on algal and macrophyte growth, some species rely on increases in both nitrogen and phosphorus for increased growth. It is an increase in phosphorus that is likely to increase issues for didymo (through increased stalk production) and both phosphorus and nitrogen for phytoplankton, other periphyton taxa and nuisance weeds.

81. Policy 4.80 refers to offsetting of significant effects in the same wetland. In some cases it may be of little value to try and restore habitat in the same wetland and there may be significant benefits to biodiversity and threatened species from restoring, enhancing or creating habitat in a different location. This was the basis for developing Project River Recovery and some subsequent agreements in the UWC (eg not providing fish passes on the Fork Stream but instead contributing to spawning mitigation in Scotts Creek (Lake Alexandrina)).

82. In summary it will be essential for the best sustainable management outcome that the Proposed Plan provides for the existing environment, structures and mitigation that is in place, and the continued:

    82.1. maintenance and improvement in water quality in the catchment by managing farming activities (and aquaculture); and

    82.2. management of nutrient loadings to lakes, to manage the potential for periphyton and weed growth in lakes.

MERIDIAN RELIEF SOUGHT

83. Meridian has provided suggestions as to relief for a number of the issues raised above. Overall I agree with Meridian's recommended relief as it relates to water quality and aquatic values and as detailed in their submission. In particular I support the following relief:

    83.1. The removal of "an increase of 10%" for change of farming (Definition applying to Rules 5.42 to 5.45) is supported as any increase in these sensitive environments needs to be carefully assessed in the light of existing loads, lag times for effects and TLI thresholds.

83.2. Because of the reliance of plant growth on both nitrogen (N) and phosphorus (P) and in some cases P being the major limiting nutrient it is appropriate that both N and P be included in assessments using models of nutrient inputs and effects. Both N and P were modelled in the water quality modelling by NIWA (Norton et al. 2009).

83.3. In a number of cases Meridian have provided additional or changed wording to clarify that the baseline for change should be the existing environment and consented developments/ infrastructure rather than natural values and processes which may have already been or are being modified. From an aquatic ecology management perspective it is important that existing significant ecological values and processes are recognised and managed appropriately and where possible enhanced or restored, but they cannot always be fully protected in their natural state. Meridian's suggested changes are supported.

83.4. In many cases mitigation off-site or as an offset in a different form may have greater biodiversity value and should be considered.

83.5. As discussed above 100% compliance is not always realistic nor achievable even if the systems were not altered. I agree that there needs to be a frequency of compliance included for some indicators, such as meeting the standard 95% of the time to allow for extreme conditions. As long as an appropriate frequency is applied then I do not consider this would compromise other environmental objectives. In addition there needs to be consideration of the degree of significance (eg natural colour and frequency of opening (Table 1a) should not be "significantly altered") rather than "any alteration" being a breach. This would apply to adverse effects on natural character, Ngai Tahu values and fish migration.

83.6. Natural continuity must take into account existing alterations to natural flows through developments such as the canals and water diversion for hydro-electricity.

83.7. The maps need redrafting to make it very clear how lakes are classified. As discussed above, a maximum TLI of 3 is appropriate for Benmore, Aviemore and Waitaki and they should be "artificial lakes – rivers". The water quality in the Wairepo Arm is of concern and should not be allowed to reach a TLI of 4 thus "artificial lake – other" may be the most appropriate.

83.8. There needs to be some flexibility where installation or development may modify natural wetlands, lakes or lagoons. In some cases off-site mitigation or offsetting may be more appropriate where it can be demonstrated that it provides greater biodiversity value.

83.9. Shoreline erosion is a longterm process and in many cases adjustments to lake level management or changes in the past are still to reach equilibrium. It is important that ongoing changes are recognised and taken into account and allowance made for consented regimes, such as recent changes for Lake Pukaki operating regime.

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Mark Richard James

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Appendix 1. Dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) at 8 historic Environment Canterbury monitoring sites. Data are means of all samples collected over a 20 year period with range in brackets. Sampling frequency is variable between sites, over time. (from Sutherland et al. 2012)

River	Site Name	DIN (mg/m3)	DRP (mg/m3)
Spring Creek	SH8	120 (5-278)	2.0 (<1 - 6)
Spring Creek	Glenbrook Boundary	91 (6 – 238)	3.5 (<1 – 9)
Wairepo Creek	Arm Inlet	72 (5 – 451)	3.6 (1 – 23)
Irishman Creek	SH8 Windy Ridges	29 (5 – 239)	2.5 (<1 – 9)
Mary Burn	Mary Burn Fill	22 (5 – 56)	2.0 (<1 – 7)
Maryburn	SH8 Bridge	40 (<5 – 102)	3.0 (<1 – 13)
Maryburn Stream – Lower	Tekapo River bed	67 (17 – 196)	3.0 (2 – 6)
Forks Stream	SH8 Tekapo Military Camp	25 (2 – 92)	2.0 (<1 – 5)
Tekapo River	above Grays River confluence	16 (5 – 59)	< 1 .0 (<1 – 3)
Tekapo River	Steel Bridge	19.5 (<5 – 75)	<1 .0 (< 1 – 1)
Twizel River	SH8 Bridge	21 (<5 – 61)	2.0 (< 1 – 8)
Twizel River - Lower	Below Black Stilt Station	17 (5 – 64)	2.0 (<1 – 3)