in the matter of:	the Resource Management Act 1991
and	
in the matter of:	a number of applications to take and use water from the Upper Waitaki catchment

Brief of evidence of Peter Francis Callander

Dated: 16 September 2009

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BRIEF OF EVIDENCE OF PETER FRANCIS CALLANDER

INTRODUCTION

1 My full name is Peter Francis Callander.

2 I hold the qualifications of BSc (Geology) from the University of Auckland and MSc (Earth Sciences) from the University of Waterloo (Canada). I am a member of the New Zealand Hydrological Society, Water NZ (formerly the New Zealand Water and Waste Association) and the USA based National Ground Water Association.

3 Since 1991, I have been employed as a senior Hydrogeologist with Pattle Delamore Partners Limited, an environmental consulting firm specialising in ground and water resources. In 1997, I was appointed as a Director of that firm.

4 Previously I had been employed for seven years by the Canterbury Regional Council (ECan) and its predecessor the North Canterbury Catchment Board. During this time, I was involved with the Regional Council's groundwater resource investigations and field trials. Between 1989 and 1991, I was in charge of that Council's groundwater section.

5 I have been involved with the assessment of groundwater effects and aquifer management in alluvial gravel aquifers for most of my career. This has involved work for Regional Councils in their regulatory capacity and for consent applicants seeking to abstract and use water. With regard to irrigation developments, I have been involved in the assessment of irrigation schemes and their impact on groundwater for the Waimakariri Irrigation Scheme, Rangitata South Irrigation Scheme, Southern Valleys Irrigation Scheme and the Wairau Valley Water Enhancement Scheme, as well as providing assessments for irrigation of individual farm properties. I have also undertaken reviews of other assessments on groundwater for the Barrhill Chertsey Irrigation Scheme, Hunter Downs Irrigation Scheme and Central Plains Water Scheme.

6 I have been involved in Environment Court hearings and mediation for individual consent applications and Regional Plans involving groundwater issues related to irrigation activities, quarries, landfills and the management of groundwater abstractions. This has included the irrigation consents for Lynton Dairy Ltd, the Rangitata River Water Conservation Order and the Kate Valley landfill.

7 I have been engaged by Meridian Energy Ltd (Meridian) to assess the evaluation of groundwater effects carried out on behalf of Mackenzie Water Research Ltd (MWRL) for the irrigation of an additional 25,000 hectares of land within the Upper Waitaki Catchment.

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

9 In preparing this evidence I have reviewed:

9.1 The August 2009 Groundwater Report and the Summary Report in the sequence of reports entitled "Cumulative Water Quality Effects of Nutrients and Agricultural Intensification in the Upper Waitaki Catchment", dated August 2009, prepared for Russell McVeagh on behalf of MWRL;

9.2 The Waitaki Catchment Groundwater Information Report prepared for the Ministry for the Environment by Sinclair Knight Mertz in December 2004;

9.3 A report entitled "Water Quality Impacts from Irrigation Development Upper Waitaki" prepared for Meridian by Glasson Potts Fowler Ltd in December 2005;

9.4 The evidence of MWRL witnesses in so far as they discuss groundwater issues, which is primarily the joint brief by **Dr Robson** and **Dr Bright**; and

9.5 The ECan section 42A Officer Reports that deal with groundwater, prepared by **Mr Heller** and **Mr Hanson**

10 I also note that I attended the caucusing session held at ECan on 22 July 2009 that was attended by experts on behalf of MWRL, Meridian and ECan.

SCOPE OF EVIDENCE

11 In this evidence I outline:

11.1 The hydrogeologic characterisation of the Upper Waitaki Catchment;

11.2 The existing information on groundwater in the area;

11.3 MWRL's evaluation of the groundwater changes that will arise from increased irrigation;

11.4 The thresholds that have been used by MWRL to determine whether or not the groundwater changes are acceptable;

11.5 My comments on the evidence of the MWRL experts that discuss the groundwater issues; and

11.6 My comments on the Section 42A reports that discuss the groundwater issues.

12 My review of the quantitative assessment of groundwater issues has been based on the information presented by MWRL. In my evidence I present some graphs and tables of their data to explain my understanding of their assessment and to check the consistency and robustness of the conclusions they have reached regarding potential environmental effects related to groundwater.

HYDROGEOLOGIC CHARACTERISATION OF THE UPPER WAITAKI CATCHMENT

13 Figure 1 shows a geologic map for the Upper Waitaki Catchment area. Low permeability greywacke and schist basement rock (blue and green colours in Figure 1) form the elevated hills within the area and underlies the younger strata throughout the basin. The elevated highland areas form the boundaries of broad basins, that have been scoured out by glacial action and infilled by gravel dominated sediments derived from glacial and fluvial processes. Poorly sorted glacial till sediments tend to occur around Lakes Pukaki and Tekapo. These sediments are typically of lower permeability due to their formation by glacial processes. Beyond the glacial till, outwash gravels occur, which tend to be better sorted and more permeable, although still exhibiting quite variable grain sizes due to their proximity to the glacial source. Zones of sand, silt and clay are also present, formed from sedimentary deposition in various lakes that have been present in the area during its geologic history.

14 These unconsolidated sedimentary deposits are of variable thickness over the greywacke and schist basement rocks, but reportedly extend up to 500 m thick in places. The permeability of the strata will be highly variable. In some areas, fluvial processes will have washed the fine grained matrix away from the gravel strata leaving relatively permeable zones that can supply high yielding wells. However, the bulk of the strata is likely to be a poorly sorted mixture of gravel, sand, silt and clay which has a lower permeability and even lower permeability zones of laucustrine deposits.

15 Figure 2 shows the general direction of groundwater flow and indicates how groundwater contributes to the Haldon Arm and the Ahuriri Arm of Lake Benmore. The groundwater flow pattern defines broad groundwater catchments that are separated from each other by up-faulted blocks of lower permeability older strata.

16 The depth to water is quite variable throughout the basin, being very close to ground surface in areas where groundwater discharges to surface water ways and up to 30 m deep in other areas.

17 The MWRL assessment has subdivided the area into ten broad basins which are shown in Figure 3. Groundwater flows through the unconsolidated sediments within each of these basin areas and discharges into the lower reaches of the streams or directly into Lake Benmore. The MWRL Summary Report has focussed on the two arms of Lake Benmore. Therefore the contributing groundwater areas shown in Figure 3 can be split into the following groups:

Contributions to the Ahuriri Arm come from the following groundwater catchments:

- Ahuriri River Basin;
- Chain Hill Basin;
- Hen Burn Basin;
- Omarama Stream Basin;
- Quail Burn Basin; and
- Willow Burn Basin.

Contributions to the Haldon Arm come from the following groundwater catchments:

- Ohau River Basin and Wairepo Creek Basin
- Pukaki River Basin;
- Tekapo River Basin;
- Stony Creek is also mentioned in some of the MWRL groundwater calculations, although it is not identified on their map of groundwater catchments (Figure 3). It occurs at the southern margin the Tekapo River Basin and discharges directly to the Haldon Arm.

18 The evidence of **Mr Turner** has outlined Meridian's interests in changes in water quality in the Upper Waitaki Catchment and the potential implications for the operation of the Waitaki Power Scheme. In particular, **Mr Turner** has identified water quality in the Wairepo Arm, the Tekapo River and the lower reaches of the Twizel and Ohau Rivers as areas of concern from a sub-catchment perspective. Groundwater contributions to those waterways come

from the Wairepo Creek Basin, the Tekapo River Basin, the Pukaki River Basin and the Ohau River Basin, as shown in Figure 3.

19 Groundwater within these unconsolidated strata is derived from three main sources:

- Infiltration of rainwater and irrigation water through the soils of the basin floor that directly overlie the unconsolidated strata;
- Infiltration of rainfall generated from the higher ground surrounding the basin floor; and
- Seepages from the rivers and lakes that cross the basin floor.

20 It is the first of these three recharge components that will change as a result of increased irrigation development.

21 The MWRL assessment of the current proportion of recharge entering each basin has been plotted in Figure 4. These numbers are derived from the MWRL Groundwater report:

- Deep Highland groundwater recharge is listed in Table 5 of that report;
- Infiltration is the soil drainage quantity listed in Table 8 of that report; and
- Stream seepage is taken as the difference between the total groundwater flow in Figures 15 – 17 of the Groundwater Report and the preceding two bullet points.

22 Figure 4 shows the relative magnitude of groundwater flow that MWRL have estimated to occur in the different catchments and the relative estimated contribution from the different recharge sources. The infiltration through the basin floor soils, which will be most affected by land use changes, is estimated to be a significant contributor to all catchments, except for the Ahuriri groundwater catchment.

23 An increase in irrigation area coincides with an increase in the amount of water that drains through the soil into the underlying groundwater and an increase in the nutrients in the soil as a result of increased use of fertilisers and increased stock numbers. Some of these nutrients will leach through the soils to contribute extra nutrients in the groundwater resource, which also affects the groundwater that discharges into the surface waterways. Even the most efficient irrigation schemes will cause some increase in drainage and nutrients into the underlying groundwater.

24 Therefore the critical issues for the groundwater assessment are the concentrations of nutrients in the groundwater, their effect on groundwater users and the contribution that groundwater flow makes to the nutrient content in the surface waterways. It is also relevant to consider the time it might take for nutrient migration through the groundwater resource. This information is important if a cap on nutrient loads is being proposed as the ability to allocate nutrients loads amongst contributors requires an understanding of the existing nutrient loads coming into the system via surface or ground water flows.

EXISTING INFORMATION ON GROUNDWATER

25 The accuracy of any groundwater assessment is typically judged by its ability to explain, and be consistent with, existing groundwater data. In the case of the Upper Waitaki Catchment there is unfortunately an absence of groundwater data and long term monitoring records. This is primarily because the strata does not represent a widespread highly permeable productive groundwater resource due to the relatively poor sorting of the sedimentary particles and as such there have not been a large number of groundwater abstraction bores completed. Despite this, the soils in the area are typically free-draining due to the coarse grained nature of the particles.

26 Table 1 summarises the catchment areas, irrigated area and number of boreholes detailed in the MWRL groundwater assessment for each of the catchment areas.

Table 1. Summary of Existing Bores

Catchment	Area of Basin Soils (Table 6 of MWRL groundwater report) ha	Current Irrigation Area (Table 6 of MWRL groundwater report) ha	Number of Boreholes with Hydrogeologic Data	Number of Boreholes with Groundwater Quality Data
AHURIRI ARM				
Ahuriri	4,760	327 (6.86%)	5	1
Chain Hills	4,909	613 (12.48%)	14	?
Hen Burn	3,730	131 (3.5%)	2	0
Omarama	5,772	1006 (17.43%)	16	?
Quail Burn	6,957	0 (0%)	0	0
Willow Burn	3,916	1098 (28.05%)	2	1
HALDON ARM				
Ohau	7,809	0 (0%)	0	0
Wairepo	11,896	1,300 (10.93%)	0	0
Pukaki	44,091	431 (0.98%)	28	?
Tekapo	84,138	2,119 (2.52%)	19	13

27 This summary table reveals there are relatively few wells within the study area and Appendix DD of the MWRL Summary Report shows an irregular distribution pattern, which results in a poor characterisation of the existing groundwater system. This is acknowledged in the Groundwater Report, where at page 17 it states: *"… generally, borehole stratigraphy data is sparse in the catchment. No borehole data could be found for large areas in the Quail Burn, Hen Burn, Wairepo Creek or Willow Burn sub-catchments or northern parts of the Pukaki sub-catchment"*. Furthermore, there appears to be no significant records of pumping tests to accurately determine aquifer parameters or long term trends in groundwater levels and groundwater quality.

28 On ECan's database the most frequently sampled wells have only three samples for nutrients, and there are only three wells with that number of samples. Therefore, there is very little information to reliably characterise the current groundwater situation. Having said

that, the measurements that have been made indicate the current nutrient concentrations are low, as summarised in Table 2.

Table 2. Summary of Records in Upper Waitaki Basin from ECan Groundwater Quality Database

	Number of Wells	Number of Samples	Minimum (g/m^3)	Mean (g/m^3)	Maximum (g/m^3)	Comparative Surface Water Quality Guideline for Upland Rivers (g/m^3)
Nitrate-N	33	49	0.05	0.42	1.6	0.167
Ammonia-N	35	52	0.0025	0.028	0.3	0.010
Dissolved Reactive Phosphorus	24	33	0.002	0.014	0.18	0.009

29 This information indicates relatively low nitrogen values in the groundwater. This will be due to the small proportion of irrigated land that has impacted on groundwater to date and the dilution of soil drainage water that is achieved from the inflows of stream seepage and highland seepage.

30 The existing sample results (Appendix C of the MWRL Summary Report) also indicate that dissolved reactive phosphorous is able to migrate into the groundwater system and is not fully absorbed by soils, which is a mechanism for phosphorous retention that is often assumed to prevent phosphorous entering groundwater. Therefore, it appears that many soils in the area are of such a stony nature that phosphorous is leached into the groundwater along with nitrogen.

31 Table 2 indicates that the mean concentration of both nitrogen and phosphorous in the groundwater are higher than their respective guideline values for surface waterways. Therefore, any assessment of the area where groundwater emerges into surface waterways needs to consider the impact of groundwater derived nutrients on those surface waterways.

MWRL'S EVALUATION OF GROUNDWATER EFFECTS FROM INCREASED IRRIGATION

32 The MWRL assessment presents a comparison between two different areas of irrigation:

- Existing irrigation is reported in the Summary Report at 8,850 ha (reported as 4,237 ha of border dyke and 4,612 ha of spray); and

- Future irrigation involving an additional 26,255 ha, made up of 1,255 ha of currently consented land that is not yet irrigated and 25,000 ha of land that can be irrigated under an agreement between the Mackenzie Irrigation Company (MIC) and Meridian. This future irrigation area is actually reported as 26,755 ha in the joint statement of evidence by **Dr Robson** and **Dr Bright**.

33 Figures 5a and 5b shows the change in irrigation area that is proposed to occur within the different catchments (based on information in Tables 34 – 43 of the MWRL Groundwater Report). This shows (Figure 5a) how the largest increase in irrigated area will occur in the Pukaki (7,930 extra ha), Tekapo (5,180 extra ha) and Wairepo Creek catchments (4,652 extra ha). However, in terms of percentage change within each area (Figure 5b), the areas that will end up with the largest increase in the proportion of irrigated land area will be the Wairepo Creek (39%), Ahuriri (32%), Quail Burn (24%), Omarama (20%) and Pukaki (18%) areas. The Quail Burn basin shows the largest proportional increase in irrigation area, going from no irrigation at present to 24% of the land area irrigated (1,672 ha). Conversely, the Hen Burn area has no increase in irrigation.

34 MWRL have modelled the change in land use under two different classifications of soil development, related to the capacity of the soil to immobilise nitrogen. In this respect:

- Scenarios 1 and 3 consider the change in irrigated area under soil conditions that are developing, building organic matter and retaining nitrogen;

- Scenarios 2 and 4 consider the same change in irrigated area under more highly developed soil conditions where nitrogen immobilisation in the soil has reached a steady-state.

35 MWRL have assumed that the current situation is most closely related to Scenario 1, although depending on the soil uptake of nitrogen, the existing land use could create the effects described in Scenario 3. My understanding of the basis of their modelling approach is that if consents are granted to allow the full implementation of the MIC/Meridian agreement then Scenario 2 will develop and ultimately Scenario 4.

GROUNDWATER QUANTITY

36 The groundwater assessment has been carried out by developing a groundwater flow model for the area using the groundwater flow

package MODFLOW. This provides a numerical representation of flow throughout the area.

37 Input of water to the model comes from the three water sources listed in Paragraph 19 of this evidence.

Infiltration of Water Through Soils

38 Infiltration of rainfall and irrigation water through the basin soils has been generated from the IRRICALC model. A review of that modelling is described in the evidence of **Mr Potts**. This is the groundwater input component that changes between the existing and future scenarios as a result of increased irrigation.

39 From my own review of the drainage values presented in the GHD Groundwater Report, there are inconsistencies in the drainage quantities between the numbers in various tables (Table 8 compared with Tables 34-40), including discrepancies between scenarios which should be equivalent (i.e. Scenarios 1 and 3 should have the same drainage volumes, as should Scenarios 2 and 4). These discrepancies are particularly significant for the Quail Burn, Ohau River, Wairepo Creek and Tekapo River groundwater zones.

40 As a result, based on the information available to me, I am not confident that all of the estimates of drainage values and/or mass of nitrogen entering groundwater are accurately reported for those areas.

Highland Recharge

41 Highland runoff is calculated from empirical relationships that have been developed for the Canterbury Region. This runoff is apportioned between runoff into surface waterways and infiltration to groundwater based on calibration with infiltration and runoff generated from the streamflow at the base of the highland areas. The remainder of highland runoff and infiltration is assumed to enter the groundwater. That seems to be a reasonable approach for dealing with highland flows, although it is a fairly broad brush assessment.

42 Having said that, the numbers presented in the Groundwater Report are not consistent with the explanation provided in the text, as summarised in Table 3.

Table 3. Summary of Inconsistent Numbers from Table 5 of the MWRL Groundwater Report

Groundwater Sub-Catchment	A Catchment Area (km^2)	P Average Precipitation (m/year)	I Infiltration (mm^3/year)	R Deep Groundwater Recharge (mm^3/year)	I/(PxA) (%)	R/I (%)
Pukaki	161.7	1.1	53.5	17.1	30	32
Ahuriri	719.8	1.2	350.9	122.8	41	35
Omarama	135.7	0.6	25.2	13	31	52
Stony	340.9	1.5	52.1	21.8	10	42
Tekapo	305.4	0.8	68	23.3	28	34
Quail Burn	36	0.9	10	5.3	31	53
Hen Burn	44.6	0.7	13.7	5.5	44	42
Chain Hills	36.5	0.6	6.7	3.5	31	52
Willow Burn	25.8	0.6	4.4	1.8	28	41
Wairepo	68.87	0.83	33.58	20.15	59	60

On page 30 of the Groundwater Report, it is stated that Highland Recharge is calculated as follows:

Highland infiltration: $I_h = 0.3\ P_h A_h$

Where:

I_h is highland infiltration;

P_h is highland precipitation;

A_h is highland Area contributing to node flow.

The fraction of the highland infiltration lost to deep groundwater was estimated as:

$Rh = 0.2\ I_h$

43 On that basis, the ratio of I/(PxA) should be 30% and the ratio of R/I should be 20%. These ratios are calculated in the last two columns of Table 3. Whilst some of the catchments are close to the reported relationships, there are some big discrepancies. I have pointed out these discrepancies in a memo that was passed on to the MWRL consultants, but have received no response. The joint

evidence by **Dr Robson** and **Dr Bright** makes general reference to the use of these partitioning equations in paragraph 7.4 of their brief and describes them as *"… the most practical option to use when there is a limited amount of measured flow data, as is the case here"*. Therefore, it is not clear to me why the Highland groundwater contributions do not follow the reported relationships.

Stream Seepage

44 The interaction between stream flow and groundwater as the streams flow across the basins may also be poorly defined - in many instances simply due to a lack of detailed data. However, in broad terms the general pattern that is presented, at a conceptual level, does not seem unreasonable. Figure 6 shows the MWRL assessment sections of streams that lose flow to groundwater (in yellow) and the sections of streams that gain flow (in green). There is some uncertainty as to the exact pattern of this interaction due to a lack of detailed information, however in general terms, streams will gain water from groundwater in areas where the gravels become thinner and narrower due to rising basement rock. However, the quantification of the gains and losses are not well defined. Both the stream seepage losses to groundwater and the total groundwater flow estimate are unlikely to be well defined given the lack of available data and the apparent inconsistencies in soil infiltration estimates and highland recharge (Table 3). As a result it is difficult to determine the accuracy of the total groundwater flow and the relativity of the different recharge sources that are presented in the MWRL reports and summarised in Figure 4.

45 Figures 4 – 6 of the MWRL Groundwater Report present a groundwater flow calibration plot that compares measured water level values with the model output of estimated water level values. Whilst it shows a general pattern that looks reasonable the scale on the plot is very large. Therefore many of the modelled water levels have errors of the order of 5 – 10 m compared to the measured data set. Therefore, at a localised level it is not a very precise representation of the groundwater situation. Furthermore, as discussed earlier in paragraphs 25-27, the existing dataset is very sparse in many areas which prevents any calibration match at all. This situation adds to the uncertainty of the groundwater assessment.

46 It is also important to recognise that the groundwater flow model is a steady state model dealing with long term average inflows and outflows. It provides no information on seasonal or longer term variations or the groundwater flow pattern. In reality the drainage of nutrients down to the underlying groundwater will vary throughout the year. As a result there will be times when groundwater levels (and nutrient concentrations) are higher than

what is predicted by a steady state model, and other times of the year when the concentrations are lower.

47 Consequently, in my opinion the groundwater model should be viewed as providing a general indication of potential flow patterns within this area, however the quantification of these flows has a large degree of uncertainty associated with it, particularly with regard to the partitioning of groundwater flow between shallow and deep pathways and quantification of the interaction of groundwater and surface water as it crosses the basins. A large part of this uncertainty is due to the absence of enough bores, monitoring data and aquifer tests to reliably represent the groundwater system and provide good calibration of the model.

48 I consider the MWRL groundwater assessment should have presented more discussion on the potential uncertainties that exist within their calculations of groundwater flows. The detailed reporting of a single set of groundwater flow components may create an unrealistic impression that the groundwater system is well defined and accurately quantified. In my opinion, that is not the case and we only have a broad brush generalised concept of the groundwater flow system in this area. Therefore the conclusions that are drawn from the groundwater report cannot be confidently relied on.

GROUNDWATER QUALITY

49 The joint evidence of **Dr Robson** and **Dr Bright** describes how a spreadsheet model has been used on a sub-catchment by sub-catchment basis to route water and nutrients through a sequence of node points down to Lake Benmore. Surface water and groundwater are tracked separately, but exchanges between these two water bodies occur to match measured surface flows (paragraphs 7.11 and 7.12 of **Dr Robson** and **Dr Bright** brief). My understanding is that the annual mass of nutrients entering groundwater has been calculated using OVERSEER, which is reviewed in the evidence of **Dr Ryan**. That mass of nutrients is assumed to mix evenly throughout the groundwater flows determined from the MODFLOW model.

50 The MWRL assessment has calibrated the model calculations for Scenario 1 with the limited groundwater quality measurements of nitrate-nitrogen that are available. However, in terms of groundwater effects and migration of those nutrients into surface water it is uncertain that the full effects of current irrigation activities have taken effect. For example, Table 4 shows the groundwater flow for each groundwater catchment area (from Figures 15 – 17 of the MWRL Groundwater report) combined with the estimate of storage volume from Table 9 of the same report).

Table 4. Replacement of Groundwater Storage Volume

Catchment	Total Groundwater Flow (Mm^3pa) (from Figures 15 – 17 of the MWRL Groundwater Report)	Storage Volume (Mm^3) (from Table 9 of the MWRL Groundwater Report)	Number of Years for Groundwater Throughflow to replace storage volume
AHURIRI ARM			
Ahuriri	210	286	1.4
Chain Hills	16.5	147	9
Hen Burn	23.7	112	5
Omarama	80.5	115	1.4
Quail Burn	18.7	278	15
Willow Burn	3.2	78	24
HALDON ARM			
Ohau	10	94	9
Wairepo	54	238	4
Pukaki	254	2205	9
Tekapo	378	4207	11

51 The results are quite variable between the catchments but indicate that in some areas it could take in the order of 10 – 20 years to see the full migration of drainage water through the aquifer system, particularly when allowance must also be made for the drainage water to reach the groundwater. In reality there will be a wide range of travel times for drainage water to pass through the groundwater system and enter the surface waterways. In some riparian areas the transfer will happen relatively quickly, whereas for other parts of the catchment the transfer could take several years to reach the surface waterway.

52 As far as I am aware the MWRL assessment provides no consideration of different nitrogen concentrations within the groundwater. It is expected that shallow groundwater will tend to have higher nitrate concentrations than deep groundwater and areas of groundwater receiving river recharge have lower concentrations (due to dilution) than areas of groundwater where the infiltration from irrigated soils is the dominant source of recharge. These variations in nitrate concentrations in groundwater will occur within the modelled area. However, in this assessment a bulk mixing approach has been used whereby the mass of nitrogen entering the groundwater has been assumed to mix evenly with all the groundwater flow.

53 Therefore the assessment of groundwater concentrations represents a bulk average concentration and does not recognise the spatial differences that will occur throughout the area. This might be a reasonable approach to the groundwater assessment given the paucity of groundwater quality data. However, it is important to recognise that there will be some areas, particularly those areas where soil drainage water is a dominant component of the aquifer recharge, which will have higher nitrate concentrations than the average values presented in the MWRL assessment. There will also be other areas of deeper groundwater and riparian groundwater that have lower concentrations.

54 As with the groundwater flow model, the water quality assessment deals with long term average inputs. No assessment has been made of the seasonal variability of nutrient movement from the soil and time varying migration into surface waterways. As a result the assessments are not particularly useful for considering seasonal variability and potential impacts on surface streams within the basin during critical periods for periphyton growth.

Nitrogen

55 The MWRL Groundwater Report focuses on nitrogen as the only nutrient migrating through the groundwater system.

56 Figure 7 shows the changes in nitrogen mass draining to groundwater that MWRL predicts will result from the increase in irrigation and the decreasing nitrogen uptake on the soils. These changes are presented in Tables 34 – 43 of the Groundwater Report. As discussed previously, the current situation is inferred to be Scenario 1, which depending on the soil characteristics, could become Scenario 3. If the future change in land use occurs, Scenarios 2 or 4 will develop.

57 With the exception of the Hen Burn and Chain Hill areas the information indicates a significant increase in nitrogen migrating

through the groundwater system can be expected compared to the current situation, if no mitigation measures are put in place.

58 Figure 8 shows the areas of future irrigation. Based on the distribution of irrigation areas, the areas that are at greatest risk of seeing higher than predicted groundwater concentrations are:

- The lower reaches of the Tekapo and Pukaki River basins - due to the increase in nitrogen draining to groundwater (Figure 7) and the concentration of new irrigation areas in the lower reaches (Figure 8);

- The Wairepo Creek area - due to the increase in irrigated land (Figure 5b) and the increase in nitrogen draining to groundwater (Figure 7);

- The Ohau area - due to the predominance of soil drainage (Figure 4) and the increase in nitrogen draining to groundwater (Figure 7); and

- The smaller basins draining to the Ahuriri Arm which have a significant increase in nitrogen drainage (Figure 7) and a significant groundwater component derived from soil drainage (figure 4), in particular the Quail Burn area.

59 Whilst significant increases in irrigation area are also shown in the Ahuriri and Omarama areas (Figure 5b) the smaller component of soil drainage recharge shown in Figure 4 for those catchments will lessen the concentrations that will occur within the groundwater.

60 A potentially important aspect of the groundwater flow assessment relates to an assumed denitrification process that is inferred to occur where shallow groundwater passes through soils that have the following characteristics:

- High soil moisture content;

- Low oxygen content;

- High soil temperature; and

- High soil organic matter.

61 The MWRL assessment has identified various areas of gley soils along riparian margins that are likely to have these characteristics and have applied a denitrification factor to a proportion of the leached nitrogen mass that corresponds to the proportion of groundwater flow that the MODFLOW model indicates will pass through the areas containing these soils.

62 It is unclear from the assessments what proportion of the Nitrogen mass is removed via this process. However there is a high degree of uncertainty about the amount of nitrogen removal that actually occurs, because:

- The report on which the alternative factors are based implies that the actual numbers are not particularly accurate as it notes that the values are based on anecdotal evidence and theory and that the absolute accuracy of the numbers is less important than their ranking;
- Surface drains or sub-surface tile or mole drains in these areas will allow the groundwater to by-pass the soils on their migration into surface waterways;
- Soil temperatures in this area would often be too low for significant de-nitrification to occur; and
- Due to the low permeability of these soils, it is unlikely that a large proportion of groundwater flow will pass through them, although it is unclear from the groundwater report how much flow has been assumed to pass through the soils.

63 **Mr Potts** and **Dr Ryan** will provide a more detailed assessment of this denitrification issue in their evidence.

64 Figure 9 shows the mass of nitrogen reported to be generated from the soils that enter groundwater. Two different numbers are shown. One set is taken from Tables 10, 13, 15, 17, 19, 22, 24, 26, 29 and 32 of the MWRL Groundwater Report. The other set of numbers appears in Tables 34-43 of the same report. The reason for these different numbers is unclear, but may be related to different assumptions about the contributing catchment areas. As a further point of uncertainty a third different set of numbers appear in Table 7 of the Summary Report for Ahuriri and Omarama areas.

65 Figure 9 compares these numbers for the mass of N draining through the soil, with the mass that is inferred to enter groundwater and reach Lake Benmore under the current situation (Scenario 1), as shown in Appendix CC of the Summary Report. This provides an indication of the nitrogen removal that has been assumed as the groundwater migrates back to the surface water environment. The results show a range of variability in the estimates, which is not explained. It is expected that the comparison between the numbers from Tables 34-43 and the mass of nitrogen entering the surface water indicates that change in nitrogen that has been assumed due to the denitrifying soils (i.e. the difference between the yellow bars and the blue bars in Figure 9).

66 To further assess how MWRL have quantified the migration of nitrogen through the groundwater, I have taken the mass of nitrogen that is estimated to drain into the soils, as identified in Tables 34-43 of the Groundwater Report (which is plotted in Figure 7 of my evidence), and compared it with the mass of nitrogen that is shown in the mass balance diagrams in Appendix CC of the Summary Report. The change in mass that occurs is summarised in Table 5.

Table 5. Loss of Nitrogen from Soil Drainage Values Compared to Groundwater Seepage Into Surface Waterways

Groundwater Catchment	Proportional Change from Nitrogen Draining Into Groundwater Compared to Nitrogen Entering Surface Water from Scenarios 1-4
Ahuriri Arm	
Ahuriri	91%-97%
Chain Hill	94%
Hen Burn	81-83%
Omarama	67-84%
Quail Burn	91%-238%
Willow Burn	53%-56%
Halden Arm	
Ohau	62%-76%
Wairepo	95%-122%
Pukaki	34%-85%
Tekapo	88%-139%

67 It is not clear why the percentages vary between the scenarios, because the mass balance charts in Appendix CC of the Summary Report show a constant groundwater flow is assumed in each scenario. Furthermore, the variation in the change in nitrogen seems large between the catchments, including some scenarios for some catchments where the mass of nitrogen entering the surface waterway is greater than the mass of nitrogen draining through the soil. This situation occurs for Quail Burn (Scenarios 2 and 3), Wairepo Creek (Scenarios 1 and 4) and Tekapo (Scenario 2).

68 Some of these differences between the mass of nitrogen entering the groundwater relative to the mass of nitrogen entering surface waterways may be due to differences in the contributing catchment areas of the sub-catchments. Therefore, I have prepared Table 6 as a final check of the overall mass of nitrogen in soil drainage compared to the total mass shown from groundwater to be entering the surface waterways.

Table 6. Comparison Between Soil Drainage N and N Emerging in Surface Waterways			
	Mass of Nitrogen Draining through Soil into Groundwater (from Tables 34-43 of the Groundwater Report) **kg per annum**	**Mass of Nitrogen Seeping from Groundwater into Surface Water** **kg per annum**	**Percentage Change**
Ahuriri Arm			
Scenario 1	143,510	118,547	83%
Scenario 2	195,153	191,728	98%
Scenario 3	266,460	268,252	101%
Scenario 4	363,421	298,667	82%
Halden Arm			
Scenario 1	442,872	395,881	89%
Scenario 2	793,260	840,714	106%
Scenario 3	534,968	470,860	88%
Scenario 4	1,045,646	791,566	76%

69 I would have expected that the percentage change in nitrogen should be equivalent for Scenarios 1 and 3 and for Scenarios 2 and 4. That is not the case. For Scenario 2, it appears that most of the leached mass is inferred to reach the surface waterways, which seem to me to be a realistic assumption. However, the inferred removal of between 11% and 24% of the mass of nitrogen that has drained through the soils for Scenarios 1, 3 and 4 seems to be a potentially unrealistic and unconservative assessment.

70 The mass of nitrogen from groundwater that is calculated by MWRL to reach Lake Benmore is compared with the mass of nitrogen from the surface water in Figures 10a and 10b. This indicates that the groundwater pathway makes a significant contribution to the total nitrogen composition of the surface water assessments. The significance of this groundwater migration pathway adds to the relevance of concerns about the uncertainties in the MWRL groundwater assessment.

Phosphorous

71 In many assessments of nutrient migration from agricultural soils, it is assumed that nitrogen drains downwards into the underlying groundwater, but phosphorous is more tightly adsorbed onto soil particles and only migrates off-site via an overland flow path. However, groundwater quality sampling in the Upper Waitaki Catchment has shown that phosphorous is present in groundwater, as described in Table 2 and paragraph 30 of my evidence.

72 This situation is recognised in the evidence of **Dr Snow** for MWRL, where she notes that initially she modelled all losses of phosphorous as directly entering the surface systems. However based on the water quality monitoring data she has assumed that "*not all the P lost from the farm was estimated to be captured in surface water, but was split between ground and surface water as determined by local hydrogeology*" (paragraph 40 vii of Dr Snow's evidence).

73 However, in the MWRL Groundwater Report, there is no discussion of the drainage of phosphorous into the groundwater and no quantification of its migration back to the surface water environment. Similarly, in the MWRL Summary Report, whilst it is recognised that phosphorous is present in groundwater, the mass balance assessment of nutrient migration in Appendix CC of that report does not account for any phosphorous migration in groundwater.

74 As a result, it is not clear to me how the partitioning of phosphorous between groundwater and surface water has occurred, and how the phosphorous that is present in the groundwater has been treated in the MWRL nutrient accounting system.

75 To provide a ballpark indication of possible phosphorous inputs to Lake Benmore, via a groundwater flowpath, I have taken the MWRL estimate of groundwater flow in Figures 15-17 of the MWRL Groundwater Report and assigned the MWRL average DRP concentration of 0.009 mg/L to them. The resulting mass of phosphorous entering the lake from groundwater is then estimated and compared with the estimated surface flow inputs presented in Appendix CC of the Summary Report.

Table 7. Potential Groundwater Contribution of Phosphorous (Scenario 1)		
Catchment Source	Estimated Mass of Phosphorous from Surface Water (kg per annum)	Possible Mass of Phosphorous from Groundwater (kg per annum)
Haldon Arm - directly connected catchments	20902	6435 (31%)
Haldon Arm – Ohau C canal catchments	19615	575 (3%)
Ahuriri Arm	9815	3182 (32%)

This suggests that a significant proportion of the phosphorous load that is assumed to enter Lake Benmore may have been assessed via an incorrect migration pathway. Such a situation adds to the uncertainty of the model calibration to measured values.

76 It seems to be generally accepted that OVERSEER provides a reasonable indication of the mass of nutrients that are lost from agricultural soils. How these nutrients migrate through the groundwater system has quite a degree of uncertainty surrounding it. The MWRL assessment has tried to quantify that subsurface migration, but only for nitrogen. From my review of the numbers in the MWRL Groundwater Report, it appears that their quantification of the groundwater migration is not very precise, and for some of the scenarios much of the nutrient mass does not reach the surface waterways. Given the uncertainty of the groundwater assessment, this may be an unwise assumption.

77 In my view, it would be preferable to consider the distribution of the irrigation areas shown in Figure 8 and consider the potential change in nitrogen and phosphorous in groundwater that will arise from the new irrigation areas, as estimated by OVERSEER. That increase in mass could then be apportioned to the sections of nearby surface waterways that gain seepage from groundwater. Such an approach would provide a better assessment of the effects arising from nutrients in groundwater.

78 The MWRL groundwater assessment provides a useful conceptual understanding of the overall hydrology of the Upper Waitaki Catchment, but it is not sufficiently robust to provide a reliable verification of the distribution of nutrient concentrations in

groundwater throughout the catchment and the pattern of emergence in surface waterways, other than a broad brush average assessment of nutrients entering the lower reaches of the rivers and Lake Benmore. The main reasons for this uncertainty are:

- Lack of detailed groundwater observations to calibrate the calculations of groundwater flow;
- Variations in the estimates of soil drainage values for the different scenarios;
- Uncertain determination of highland runoff flows;
- Variations in the estimates of total groundwater throughflow for the different scenarios;
- No consideration of the spatial variability of nutrient concentrations in groundwater, taking into account different spatial patterns of soil drainage relative to other recharge sources and variations with depth;
- No consideration of seasonal variations in drainage concentrations migrating down and through the groundwater system; and
- No consideration of phosphorous migration in groundwater.

79 From the point of view of Meridian's areas of interest in the catchment, the increased irrigation areas in the lower reaches of the Tekapo and Pukaki River basins and the Ohau and Wairepo Creek are areas where there is potential for greater effects than those estimated by MWRL.

THRESHOLDS

80 The MWRL assessment has compared the assumed nitrate – nitrogen concentrations in groundwater to the Drinking Water Standards for New Zealand 2005 (revised 2008) (DWSNZ) Maximum Acceptable Value concentration of 11.3 mg/L and to a concentration of 1 mg/L which is the estimated groundwater concentration that could be expected to occur if the land was used for extensive grazing of unimproved pasture.

81 Both the MWRL Summary Report and Groundwater Report state that this latter threshold was chosen because *"under the Proposed Canterbury Natural Resources Regional Plan (Policy) WQL9 states that groundwater nitrate-N concentration should not increase above the range naturally occurring under extensive grazing of unimproved pastures"*.

82 However that is not an accurate description of what Policy WQL9 requires, because it fails to mention that the nitrate-N limit is not to be exceeded, "at the down gradient boundary of a property." (Policy WQL9(1)(b)(iii)(1)).

83 The MWRL assessment does not consider such a localised assessment but simply presents broad scale average concentrations for each of their groundwater catchment areas. Within those catchments there can be expected to be quite a variation in groundwater concentrations.

84 The MWRL assessment notes that most bores in the area currently measure nitrate-nitrogen concentrations of less than 1 g/m^3. This is consistent with my own review of the ECan sampling results that are summarised in the Table 2 (paragraph 28).

85 Therefore, at the current time nitrate-nitrogen concentrations are low and generally below the 1 mg/L threshold proposed by MWRL to comply with Policy WQL9. It is assumed that the low concentrations are due to the small amount of irrigation that is currently occurring, the short time it has been in operation such that its full effects have not occurred yet, and the significant dilution of the infiltrating drainage water from other sources (Figure 3). However, even with those factors there are some occasions where groundwater has already exceeded the 1 mg/L threshold.

86 It is to be expected that, with increasing irrigation, there will be an increase in instances where groundwater is greater than 1 mg/L at the down-gradient boundary of an irrigated property. This may not occur in areas recharged rapidly by river seepage water, but is likely to occur on properties where land surface drainage forms a significant component of the recharge to the underlying groundwater resource.

87 Given that existing monitoring data shows current groundwater concentrations of nitrate-N are typically around 1 g/m^3 there seems little risk of widespread concentrations in groundwater reaching the DWSNZ threshold of 11.3 g/m^3. Localised breaches are possible in shallow groundwater that is dominated by infiltration recharge but such instances would largely be related to local farm practices and should be manageable at that scale by the types of approach described in the MWRL tool box and/or be a relocation or deepening of affected water supply wells.

88 The groundwater threshold of 1 mg/L seems to be a reasonable guideline value for unimproved pasture in this environment, although it is debatable whether that is a correct threshold to use for Policy WQL9. An alternative interpretation is that the currently measured values (many of which are significantly less than 1 mg/L) are representative of unimproved pasture and Policy WQL9 does not

intend that any increase in those numbers in order to protect surface water quality. Whilst these are low concentrations from a groundwater perspective, it can be seen from Figures 10a and 10b that they make a big contribution to the mass of nutrients in the surface waterways.

89 Whether groundwater concentrations are above or below a 1 mg/L threshold is of no consequence in terms of groundwater usage. At these low concentrations the significant issue is the groundwater contribution of nutrients to surface waterways. It is for this reason that Policy WQL9 sets such a high standard for Inland Basin areas such as the upper Waitaki Catchment. The PNRRP states that:

"One of the consequences of land use intensification is decline in the water quality of small rivers and groundwater, as a result of higher stocking rates, fertiliser use and cultivation contributing to an increase in the contaminants in runoff to rivers or leaching to groundwater. Inland basins are generally situated high in the catchment, and drained by a large number of small streams feeding the larger rivers or lakes. A decline in water quality in these small rivers may result in a significant decline in water quality of the larger rivers or the lakes in these areas."(NRRP Variation 1 page 4-68)

90 Therefore, even though Policy WQL9 may be breached, the intention of the policy seems to be for management of effects on surface waterways. This breach has the potential to create the biggest adverse effects on small spring fed streams and waterways, although that localised issue has not been considered in the MWRL assessment. Instead their assessment has focussed on the lower reaches of larger water bodies and their conclusions about those effects should be the main criteria for which their study can be used to assess groundwater issues. Those effects on the surface water bodies are described in the evidence of **Dr Snelder**.

91 MWRL have proposed mitigation measures to try and avoid the increase in irrigation areas causing nitrate-N concentrations in groundwater to increase above the 1 mg/L threshold as occurs in the Quail Burn catchment. Although no such mitigation measures are proposed where their modelling shows the 1 mg/L concentration already is exceeded under existing land use conditions – as occurs in the Chain Hills, Willow Burn, Ohau River and Wairepo Creek catchments.

92 In my view, the 1 mg/L threshold in groundwater is somewhat arbitrary and of no great consequence for groundwater users. Therefore it does not form a particularly robust criteria for requiring mitigation measures. It would seem more appropriate that mitigation was focussed on areas where adverse surface water effects are expected. The evaluations of these should start from

local scale effects (which are not covered in the MWRL assessment) and then move up to larger catchment scale and basin wide effects (which are the focus of the MWRL assessment).

93 Therefore the conclusions that can be reached regarding threshold issues are:

- On some irrigated properties the threshold in Policy WQL9 (1) (b) (iii) (1) is unlikely to be met particularly away from riparian recharge areas;

- A breach of this policy does not represent an adverse effect for groundwater users and the risk of the increased irrigation breaching the nitrate-nitrogen Maximum Acceptable Value of 11.3 g/m^3 in water supply bores seems to be low;

- The breach of Policy WQL9 could potentially cause adverse effects in some small surface waterway, although that effect is not considered in the MWRL report and it provides no guidance on that issue. However, it is to be expected that this could be a significant migration pathway for nutrients in groundwater to enter surface water at a local scale. This would require more detailed mapping of streams receiving a significant contribution of groundwater derived from soil drainage and their position relative to areas of future irrigation; and

- Whether or not the breach of Policy WQL9 causes issues for the larger rivers and lakes is the focus of the MWRL study and the impacts on those waterways should be the main way in which the study should be used to judge the groundwater effects.

PROPOSED MONITORING PROGRAMME

94 If consents are granted, MWRL propose a groundwater monitoring programme to assess changes in groundwater quality. I consider the distribution of wells needs some refinement to better reflect the widespread patterns of groundwater quality and the impacts of irrigation activities. There also needs to be a clear definition of bore depths to ensure that the monitoring represents the following groundwater areas:

- the water table near areas of irrigation activities;

- the water table in areas where groundwater discharges to surface waterways; and

- the groundwater in areas where it is used for abstraction purposes.

95 The nutrient suite that is proposed by MWRL for sample analyses is realistic. Various monitoring frequencies are proposed by MWRL, depending on the results that are obtained and whether the bores are "on-farm" or "off-farm". However, these two groups of wells are not clearly identified, nor are the well depths. Given the lack of available data, it would seem to me that it is important that sampling should be undertaken at quarterly intervals for the duration of the consents. If at some stage in the future sufficient data is gathered to provide a better understanding of effects then a change in frequency could be addressed by an application to vary consent conditions.

96 However, prior to the commencement of any new irrigation activities it would be prudent to undertake a 12 month period of detailed monitoring of groundwater levels, groundwater quality, surface flows and surface water quality to provide a more robust background to the groundwater issues in this area. If this could be combined with a clearer quantification of the potential groundwater effects we would then be in a better position to assess these effects than is currently the case.

COMMENTS ON EVIDENCE FROM MWRL WITNESSES

97 The statements of evidence from the MWRL witnesses do not cover the groundwater assessment in any particular detail. None of the witnesses carried out the groundwater study, although **Dr Bright** is listed as having carried out a peer review.

98 The joint statement of evidence by **Dr Robson** and **Dr Bright** describes the MWRL water quality assessment as being *"comprehensive and robust"* (paragraph 3.1), the methods that have been used are *"fit for purpose and have been competently applied"* (paragraph 3.3) and that *"an additional 25,000 hectares (approximately) of agricultural land in the Upper Waitaki can be irrigated without significant adverse effect on the aquatic environment"* (paragraph 3.4). Whilst these opinions might be correct, my current understanding of the MWRL reports does not allow me to reach such a positive conclusion. As described in my evidence, there appear to be uncertainties and inconsistencies in the MWRL assessment of the movement of water and nutrients through the groundwater system. No clear explanation of these discrepancies was provided in response to a written query or at the caucusing meeting on the 22nd July 2009. It would be helpful if such discrepancies could be clearly explained to better understand the likely effects of the proposed increase in irrigation.

RESPONSE TO SECTION 42A REPORT

99 **Mr Heller** and **Mr Hanson** have prepared Section 42A Reports that discuss the MWRL groundwater assessment. They both make

frequent references to the lack of clarity and uncertainty in the quantitative evaluation of groundwater effects. I agree with those views.

100 Paragraph 24 of Mr Hanson's statement indicates that the reporting of long-term average nitrate-nitrogen discharges from groundwater into surface water is probably acceptable because by the time the groundwater reaches the surface water, the seasonal variations in nitrate leaching will have been smoothed out. I agree with that viewpoint for irrigated areas that are distant from areas where groundwater enters surface waterways. However, referring to Figure 8, there are some irrigation areas in close proximity to gaining streams and seasonal variability in groundwater effects will likely arise in those areas, and therefore should be taken into consideration.

101 Paragraph 50 of **Mr Hanson's** evidence raises concern about microbiological contaminants. I agree that is a relevant issue of concern, but is a localised farm management scale issue and should be manageable by a combination of good farm management practices and good well design.

102 Both the Section 42A reviewers of groundwater issues conclude that the MWRL cumulative effects assessment does not demonstrate that the additional irrigation will not cause "significant adverse water quality effects". I agree with that conclusion, although that is largely due to a lack of long-term monitoring data and a lack of clarity in MWRL's quantification of groundwater effects. This situation could be rectified over a 12 month period of detailed monitoring, as described in paragraph 96. During this period a clarification of the uncertainties related to groundwater quantification that have been identified in my evidence should be able to be rectified, including the migration of phosphorous in the groundwater system

CONCLUSIONS

103 The conclusions that I reach are:

103.1 At a conceptual level, the MWRL assessment of groundwater recharge, throughflow and discharge appears to be correct and matches the expected behaviour of groundwater in this area;

103.2 The quantification of the groundwater flow and its emergence into surface waterways is uncertain, and there is insufficient data to reliably calibrate the MWRL calculations;

103.3 Whilst the available monitoring data is sparse, the measurements that have been made indicate that groundwater concentrations of nitrate-nitrogen in the area are currently low, with average concentrations around 0.4 g/m^3 and high concentrations around 1.5g/m^3. These numbers can be compared with drinking water guideline values of 11.3 g/m^3 and surface water quality guideline values of 0.167 g/m^3;

103.4 Dissolved Reactive Phosphorous has been measured in the groundwater at concentrations averaging around 0.009 g/m^3 with a high concentration at 0.032 g/m^3. These numbers can be compared with surface water quality guidelines of 0.009 g/m^3;

103.5 Nitrate leaching into groundwater has been evaluated in the MWRL assessment. The average concentration within each groundwater catchment that contributes flow to Lake Benmore has been calculated by MWRL. However, within each catchment, there will be variable concentrations both spatially and in time. For this reason, it seems unlikely that the increase in irrigation will comply with Policy WQL9(1)(b)(iii)(1) of the Proposed Natural Resource Regional Plan (PNRRP);

103.6 The increases in irrigation development proposed by the applicants are unlikely to cause widespread breaches of the Maximum Acceptable Value of the Drinking Water Standards for New Zealand, 2005, which is set at 11.3 g/m^3. Any localised breaches should be manageable by improved farm management practices and/or deepening of water supply wells;

103.7 The key issue with nitrate migration in groundwater is its contribution to surface waterways. MWRL have assumed that some of the nitrogen that leaches into groundwater is removed by denitrification processes and does not reach the surface waterways. This is a non-conservative assumption and is not well justified. The distribution of where that nitrogen enriched groundwater emerges along the surface water flow paths is poorly quantified due to the lack of calibration data for the groundwater flow model and the broad brush averaging approach that has been undertaken for the assessment;

103.8 The numbers reported in the MWRL assessment indicate that the groundwater migration pathway makes a much larger contribution of nitrogen into surface waterways than the surface derived concentrations. Temporal and spatial variations in the groundwater pattern have not been considered in the MWRL groundwater assessment. Therefore, the uncertain quantification of its migration through the groundwater system creates a significant area of uncertainty;

103.9 Despite phosphorous having been measured in the groundwater, its migration through the groundwater into surface waterways has not been considered as part of the groundwater assessment. In the absence of any detailed assessment, it would be prudent to assume that phosphorous that drains into the groundwater will follow a similar pattern to nitrogen;

103.10 The effects of these groundwater derived nutrients on surface waterways will be greatest in areas where groundwater is predominantly recharged by infiltration through irrigated areas and emerges in small streams where the flow is dominated by groundwater seepage. This localised stream flow issue is not covered in the MWRL assessment. It will need to be addressed in the evidence regarding the individual consent applications;

103.11 On a broader catchment scale, it appears that the increased irrigation will have its greatest impact on:

- The lower reaches of the Tekapo and Pukaki River areas;
- The Ohau and Wairepo Creek areas;
- the Quail Burn catchment.

Of these areas, the Tekapo and Pukaki River basins and the Ohau and Wairepo Creek areas are of particular concern to Meridian's operations;

103.12 A groundwater monitoring programme will be required if consents are granted. This should include quarterly monitoring of groundwater in boreholes that characterise groundwater at the downgradient margin of the various irrigation areas, in areas where groundwater enters surface waterways and in areas where groundwater is abstracted for water supply purposes.

103.13 Given the uncertainties in the current groundwater assessment it would be prudent to carry out a detailed groundwater and surface water monitoring programme for at least 12 months prior to the commencement of new irrigation activities, and to clarify the quantification of groundwater effects that are predicted to occur from new irrigation activities.

Dated: 16 September 2009

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Peter Francis Callander