BEFORE THE CANTERBURY REGIONAL COUNCIL

In the matter of	The Resource Management Act 1991
And	
In the matter of	Resource consent applications lodged for the water take consents in relation to the Waitaki Basin under section 120 of the Resource Management Act 1991

STATEMENT OF EVIDENCE OF DOUGLAS NGONIDZASHE MZILA

Dated: November 6, 2009

Introduction

1. My name is Douglas Ngonidzashe Mzila.

2. I hold the qualifications of BSc and MSc in Civil and Environmental Engineering from the University of Witwatersrand, South Africa; MSc in Engineering Hydrology from Russian State Hydrometeorological University and PhD in Civil and Environmental Engineering from Nanyang Technological University, Singapore. These degrees included studies in surface and groundwater hydrology,, environmental engineering, and advanced studies in contaminant transport through surface and groundwater systems. As a PhD student and Research Fellow at Nanyang Technological University, Singapore, I pioneered and led a research unit on utilising reclaimed landmasses for storage and recovery of treated wastewater for reuse.

3. My career, in environmental engineering, groundwater flow and contaminant transport, hydrology, water resources and catchment management fields, spans over 15 years. I have published over 40 conference and journal papers in the fields of environmental engineering and ground water flow and contaminant transport.

4. I joined GHD Ltd as a Senior Environmental Engineer in 2007.

5. From 2005 to 2007, I worked for another consultant in New Zealand on a range of hydrologic, hydraulic, water resources, and environmental engineering projects. The work included providing technical direction and management for land disposal of wastewater at Taupo, including an assessment of current and projected changes in flow and contaminant transport to the receiving environment.

6. Recent projects with which I have been involved and have relevance to my involvement in this Water Quality Study (WQS) in the Upper Waitaki Catchment are:

   (a) Detailed surface and groundwater water balance exchange assessment along a reach of the Wairau River using Visual Modflow and a piezometer grid for water table measurements.

   (b) Contaminant generation and transport modelling at Belfast.

   (c) Arnold Valley surface and groundwater assessment of the impact of the changed flow regime from the proposed river diversion using Visual Modflow.

   (d) Taupo Land Disposal System for the View Road site.

   (e) Kinloch wastewater land disposal system.

Scope of Evidence

7. My statement of evidence addresses the following in the Mackenzie Basin:

   (a) Identifies and quantifies sources of groundwater recharge;

   (b) Estimates transport and mixing of nitrogen leaching from land surface recharge;

   (c) Quantifies the total nitrogen load in the catchment and discharges to the receiving lake environment;

   (d) Determines the volume of groundwater flow (flux) moving through the catchment to the receiving environment;

   (e) Determines the interchanges in flow and nutrients between surface and groundwater in order to derive concentrations in both groundwater and surface water environments;

   (f) Methods used in the WQS to estimate nutrient concentrations in surface water and ground water in the Mackenzie Basin under current and proposed land uses.

8. I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court Practice note and that I have complied with it in the preparation of my statement of evidence. I agree to comply with it when presenting this evidence before this Panel. I confirm that the evidence I present is within my area of expertise and I am not aware of any material facts that may alter or detract from the opinions I express.

9. In preparing this evidence, I have reviewed the following:

   (a) Joint statement of evidence of John Charles Bright and Melissa Claire Robson.

   (b) Hydrology of the Stony River-Lake Benmore Report prepared for Haldon Station by Richard de Joux, May 2009.

   (c) Hydrology of the Snow and Grays Rivers-Lake Benmore prepared for Grays Hills Station Ltd and AN Hope by Richard de Joux, May 2009.

   (d) Hydrology of East Branch of Ahuriri River prepared for Ohau Company Trust Ltd by Dave Boraman (Appendix D).

(e) Hydrology of Otamatapaio River prepared for Otamatapaio Station and Bogroy Station by Dave Boraman, May 2009 (Appendix F).

(f) Hydrology of the upper reaches of Omarama Stream prepared for Dunstan Peaks Limited by Richard de Joux, July 2009.

(g) The Waitaki Catchment Groundwater Information Report prepared for the Ministry for the Environment by Sinclair Knight Mertz in December 2004.

(h) Sinclair Knight Merz (SKM), 2004. Draft national cost benefit analysis of proposals to take water from the Waitaki River.

(i) River and stream flow data from NIWA's TIDEDA.

(j) River and stream flow data from the Environment of Canterbury (ECan) database.

(k) Groundwater well data from the ECan database.

(l) Surface and ground water quality data from the from the ECan database

10. I also attended caucusing sessions held at ECan on 14th October 2009 and at GHD offices in Christchurch on 28th October 2009. The meeting was attended by experts on behalf of ECan, Meridian and MWRL. There were no specific minutes of the caucusing. However, from my recollection of outcomes my understanding is that there was a broad consensus on the methodology of the groundwater modelling. but Mr Heller, Mr Callander and Mr Hanson requested an opportunity to review the data. Mr Heller in a personal communication further confirmed our agreement that the methodology is appropriate.

Background

11. Intensified agricultural practices based on irrigation can lead to a release of nutrients that may cause the degradation of environmental values. The pathways for released nutrients may include surface water, groundwater or wind dispersion. However the main pathways for nutrient transportation are through water in terms of both dissolved and suspended constituents. This evidence addresses transportation of nutrients from the generation to the receiving environments through water transport processes. The receiving environments in this case are both groundwater and surface water systems, and ultimately Lake Benmore.

Data Collection and Data Reliability

12. The assessment of groundwater resources, groundwater flow directions and relations with surface water systems requires information on hydrogeological characteristics of

the study area. Data on hydrogeological characteristics (aquifer transmissivity and hydraulic conductivity) are mainly derived through installation and aquifer tests of wells or piezometers. Bore/well logs are also studied to derive the hydrogeological parameters. Groundwater flow directions can be estimated through measurements of depth to groundwater table. For this study, this information was collected from currently installed wells and piezometers in sub-catchments.

13. The Upper Waitaki Basin was divided into 10 sub-catchments and the delineation is discussed in later sections of my evidence. Wells that have been used for groundwater assessment studies and the reliability of the data are summarised in the Table 1.

Table 1 Summary of wells with groundwater information

Catchment	**Well Density (km^2/well)**	**Area (km^2)**	**Number of boreholes with water level data**	**Number of boreholes with stratigraphy data**	**Number of boreholes with Groundwater Quality Data**
Ahuriri Arm					
Ahuriri	9.5	47.60	5	3	1
Chain Hills	3.5	49.09	13	8	6
Hen Burn	19	37.30	2	2	1
Omarama	3.6	57.72	13	9	6
Quail Burn	No wells	69.57	0	0	0
Willow Burn	19.6	39.16	2	1	1
Haldon Arm					
Ohau	No wells	78.09	0	0	0
Wairepo	119	118.96	1	1	1
Pukaki	16	440.91	18	13	8
Tekapo	44	841.38	15	15	13

14. The table indicates a relatively sparse distribution of wells with the greatest coverage being in the Chain Hills and Omarama sub-catchments with approximately 1 well per 3.5 km^2. The greatest coverage for wells with groundwater quality data is the Omarama subcatchment with 1 well in 8 km^2 (Table 1). Still this database does allow development of an appropriate level of understanding of the flow directions and groundwater levels within the basin, as will be explained in more detail later in my evidence.

15. In Table 2 is a summary of groundwater quality availability within the basin. This data is sufficient to provide a general understanding of groundwater quality in the basin. Wells with groundwater quality information are generally located in areas of intensive land use and would provide an indication of nutrient loads to groundwater within those areas.

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

Parameter	**No. of wells**	**Number of samples**	**Minimum (mg/l)**	**Mean (mg/l)**	**Maximum (mg/l)**	**Upland River Guideline (mg/l)**
Nitrate-N	33	49	0.05	0.42	1.6	0.167
Dissolved Reactive Phosphorus	24	33	0.002	0.014	0.18	0.009
Ammonia-N	35	52	0.0025	0.028	0.3	0.010

Modelling Methodology and Analysis

16. The overall modelling strategy included the following assessment of:

(a) Groundwater subcatchment delineation for the Upper Waitaki;

(b) The hydrogeologic characteristics of the Upper Waitaki sub catchments;

(c) Derivation of the groundwater flow directions of each sub catchment;

(d) Aquifer storage and aquifer yield;

(e) Modelling groundwater recharge components:

(i) Highland flow calculations;

(ii) Recharge drainage calculations for each subcatchment;

(iii) Flow gains and losses between groundwater and surface water systems.

(f) Estimation of mean and base flow in rivers and streams;

(g) Developing and using a numerical model to estimate flow budgets for each sub catchment. The model was also used to establish areas of gains and losses and base flow where there was inadequate data;

(h) Develop a spreadsheet toolkit to route flows from the highlands, through the sub catchments to the receiving environments of surface and ground water;

(i) Use of existing groundwater level and groundwater quality data for model calibrations; and

(j) Use of stream flow and water quality data to calculate nutrient loading from groundwater to surface water systems.

Hydrogeologic Characterisation

17. The geology and hydrogeology of the Upper Waitaki Catchment are discussed in the GHD Groundwater Report (2009). The main geologic and hydrogeologic features are:

(a) Elevated highland areas that form the boundaries for broad basins;

(b) The basins that have been scoured out by glacial and fluvial processes;

(c) Poorly sorted glacial moraines around Lake Tekapo and Pukaki;

(d) Better sorted unconsolidated sedimentary deposits (outwash gravels) with potential higher yields occur in the basin with increasing distance from the Lake boundaries;

(e) Depth of sedimentary sediments lying over the greywacke and schists basement rocks are of variable thickness, but reported to extend up to 500m thick in places;

(f) Groundwater flow direction generally follows surface water drainage systems and are as shown in the GHD Groundwater Report;

(g) Depth to groundwater is variable throughout the basin with up to 30m in some areas of the basin. The water table is close to the surface (approximately 5 m deep) where groundwater discharges to surface water systems.

Groundwater Catchment Delineation

18. Topographical and drainage features were used to delineate groundwater sub catchments that contribute discharges to the Ahuriri and Haldon Arm of Lake Benmore. The contributing subcatchments are as shown in Appendix A - Figure 1 and also listed in Table 1. The lakes and rivers were used as boundary conditions to groundwater flow taking into consideration that groundwater flows from higher water table elevations to lower elevations. Furthermore highland areas were considered to constrict and direct groundwater flow.

Groundwater Flow Direction

19. Groundwater flow directions were developed through a numerical model Visual MODFLOW with an understanding of drainage and water surface features of the catchment. These visuals are in Appendix C at page 38 and 39.

20. Groundwater flow directions were confirmed through groundwater level measurements and groundwater level model calibrations. Model simulated groundwater levels were calibrated against measured groundwater levels and the calibration results are shown in Appendix A - Figure 2 and Figure 3. Data from Simons Hill Pass Station has also been included in Appendix A, Figure 3A to show the calibrated result is closely matched to the measured data. A comparison between modelled and measured indicates a sufficient correlation to confirm our understanding of the groundwater flow directions.

Aquifer Storage Capacity and the Storage Coefficient for each sub-catchment

21. The aquifer storage capacity and storage coefficient are important parameters for the management of aquifers. These parameters are also applied to estimate the residence times of groundwater in aquifers. The aquifer storage capacity is defined as the maximum volume of water that can be stored in an aquifer. The aquifer storage coefficient is the volume of water released from the aquifer per unit decline in groundwater levels per unit area. For unconfined aquifers, the storage coefficient is approximate to the value of specific yield and ranges from 0.1 to about 0.3. The specific yield and storage capacity of each of the 10 sub catchments are summarised in Table 3.

Table 3 Aquifer Yield Storage

Catchment	**Surface Area (km^2)**	**Estimated Average Specific Yield (l/s/m)**	**Estimated Average Aquifer Thickness (m)**	**Aquifer Storage (Mm^3)**	**Aquifer Residence Time S (Years) =Aquifer storage/Groundwater discharge**
Ahuriri Arm					
Ahuriri	47.60	0.2	30	286	3
Chain Hills	49.09	0.2	15	147	42
Hen Burn	37.30	0.2	15	112	17
Omarama	57.72	0.2	10	115	2
Quail Burn	69.57	0.2	20	278	15
Willow Burn	39.16	0.2	10	78	8

Haldon Arm					
Ohau	78.09	0.2	10	94	8
Wairepo	118.96	0.2	10	238	5
Pukaki	440.91	0.2	25	2205	15
Tekapo	841.38	0.2	25	4207	15
Stony	88	0.2	50	880	12

22. The aquifer residence time would indicate the time it would take to replace all the groundwater in storage. The Omarama and Ahuriri sub catchments have the shortest residence times. In these sub-catchments Nitrate-N concentrations in groundwater discharge are expected to respond to changes in land use within a short period of time. The responses would be slower for the Chain Hills, Pukaki, Tekapo and Hen Burn sub-catchments.

Groundwater Recharge and Budget

23. Groundwater within the basins is derived from three main sources:

    (a) Highland flows;

    (b) Infiltration of rainwater and irrigation water through the soils of the basin floor that directly overlie the unconsolidated sediments; and

    (c) Seepage through drainage systems such as creeks, streams, rivers and lakes of the basin.

24. Highland recharge has been developed from empirical relationships that have been developed for the Canterbury Region (Kingston Morrison Ltd (KML),. (1999). Hawea Basin Groundwater Report). Total water flow from the highlands is derived from the highland precipitation minus losses to evapotranspiration. Flow pathways are direct surface runoff, shallow groundwater infiltration and deep groundwater infiltration. The relationship for these components is as follows:

    Highland Infiltration = Ih =0.3PhAh

    Where:

    Ih is highland infiltration;

    Ph highland precipitation;

    Ah is highland area contributing to node flow;

Rh = 0.2Ih (is the fraction of highland infiltration lost to deep groundwater).

Highland Flow Calculations

25. The relationships in paragraph 24 are used for calculating groundwater flow contributions to each of the 10 groundwater sub catchments.

26. Highland flows have been partitioned to runoff and deep groundwater seepage based on measured streamflow at the bottom of the highlands. Where stream flow data was inadequate, flows have been estimated using similarity analysis between highland catchments by way of specific discharge based on catchment yield.

27. Input parameters for highland flow calculations are:

    (a) Catchment areas for each drainage node (flow site at the downstream end of the highland) calculated using GIS;

    (b) Mean annual precipitation for each drainage node calculated from isohyets derived from NIWA data;

    (c) Potential evapotranspiration from NIWA data.

28. Individual node drainages contributing to each sub-catchment were aggregated and the results are summarised in Table 5.

Table 4 Components for calculating highland flows

		Omarama	Pukaki	Ahuriri	Quailburn	Hen Burn	Chain Hills	Willow Burn	Tekapo	Stoney	Wairepo
Row 1	Area (km^2)	135.67	161.73	719.83	35.96	44.6	36.51	25.83	305.38	340.86	68.87
Row 2	Precip (m)	0.62	1.10	1.48	0.73	0.68	0.61	0.56	0.74	0.51	0.70
Row 3	PE (m)	0.601	0.601	0.601	0.641	0.601	0.601	0.601	0.601	0.601	0.601
Row 4	Total Preci (Mm^3/year)	83.98	178.16	1061.96	26.22	30.18	22.27	14.59	226.77	173.65	48.48
Row 5	infiltration=0.3*preci*area (Mm^3/year)	25.19	53.45	318.59	7.87	9.05	6.68	4.38	68.03	52.1	14.54
Row 6	Streamflow (m3/s)	1.6	3.97	24.5	0.485	0.5767	0.277	0.365	3.97	2.704	0.704
Row 7	Streamflow (Mm3/year)	50.46	125.2	772.63	15.29	18.19	8.74	11.51	125.2	85.27	18.57
Row 8	Deep Aquifer Recharge =0.2*infiltration (Mm^3/year)	5.04	17.08	63.72	1.57	1.81	1.34	0.88	13.61	10.42	2.91
Row 9	Flux back to stream (Mm^3/year)	20.15	36.36	254.87	6.29	7.24	5.35	3.5	54.42	41.68	11.63
Row 10	Catchment Yield (l/s/km^2)	11.79	24.55	34.04	13.49	12.93	7.59	14.13	13.00	7.93	10.22
Row 11	Total flux=surface+groundwater (Mm^3/year)	55.5	142.28	836.35	16.86	20	10.08	12.39	138.81	95.69	21.48
Row 12	Evaporation losses (Mm^3/year)	28.48	35.87	225.61	9.35	10.18	12.2	2.21	87.97	77.96	27
Row 13	Evaporation losses %	33.9	20.1	21.2	35.7	33.7	54.8	15.1	38.8	44.9	55.7

Notes:

Row 4 = Row 1 x Row 2

Row 5 = Row 1 x 0.3 (30%)

Row 6 = Measured Streamflow (m^3/s)

Row 7= Measured Streamflow (m^3/year)

Row 8 = Row 5 x 0.2 (20%)

Row 9 =Row 5 x 0.8 (80%)

Row 10 = Row 6*1000/(Row1/1000000)

Row 11=Row 7 + Row 8

Row 12 =Row 4-Row 11

Row 13=100 x Row 12/Row 4

Infiltration of rainwater and irrigation water

29. Infiltration of rainfall and irrigation water through the basin soils has been generated from the IRRICALC Model as described in section 7.1.2 of the GHD Groundwater Report. Mr McIndoe's evidence discusses the formulation and results from the IRRICALC Model. Detailed results for current and projected infiltration drainage are presented in Appendix A of the GHD Groundwater Report and summarised in Table 5.

Table 5 A summary of Infiltration drainage under current and proposed land use

Catchment	Area (ha)	Current Drainage		Drainage under Proposed Irrigation		Change in drainage depth	Change in groundwater levels
		Volume Mm^3/year	Depth Mm/year	Volume Mm^3/year	Depth Mm/year		
Ahuriri	4853	85	175.1	99	204.0	28.9	14
Chain Hills	4906	9.2	187.5	9.3	189.6	2.1	1
Hen Burn	3730	7.9	211.8	8	214.5	2.7	1
Omarama	5772	14.3	247.7	15.3	265.1	17.4	9
Quail Burn	6957	15.8	227.1	17.2	247.2	20.1	10
Willow Burn	3916	5.1	130.2	5.4	137.9	7.7	4
Ohau	5641	12.4	219.8	13.2	234.0	14.2	7
Wairepo	11896	23.8	200.1	28.2	237.1	37	19
Pukaki	44091	87.6	198.7	94.5	214.3	15.6	8
Tekapo	88707	214	241.2	218	245.8	4.6	2

30. The greatest increase in drainage depth will be in the Wairepo and Ahuriri subcatchments at 37 and 29 mm/year, respectively. This is the difference between the drainage under proposed and under current conditions in Table 5. . The increase in drainage will not result in significant average increases in groundwater levels as this equates to groundwater level changes of 19 and 14 cm, respectively, based on a storage coefficient of 0.2. The typical storage coefficient for sands and loams is between 0.1 and 0.3. We have assumed an average of 0.2.

Seepage through drainage systems such as creeks, streams, rivers and lakes of the basin

31. The interaction between stream flow and groundwater as the streams traverse the basins is based on a quasi-dynamic model that incorporates some statistical analysis.

32. The stream flow is initiated at the foot of the highlands and is estimated as described in paragraph 26 and summarised for each of the subcatchment in Table 4.

33. Concurrently measured flow in different sections along the streams or creeks quantifies the amount of stream gain or loss.

Estimation of Mean and MALF

34. Mean flows and low flows for the nodes were been derived from NIWA database using TIDEDA. However, the NIWA database did not contain all current flow data. GHD updated flow data to include current flow data from ECan and also spot gauged data.

35. At locations or nodes with no adequate information, GHD applied single and multiple regression analysis to estimate mean and mean annual low flows (MALF). However, stream correlations are generally poor within the basin.

36. GHD applied a dynamic model to route the flows from the foot of the highlands through the subcatchments to Lake Benmore by considering gains and losses within the sub catchments. The routed flows were then compared to the calculated values. The derived mean and low flows were compared to catchment specific yield for the basin to verify consistency, as this is the most plausible technique when data is inadequate.

37. In areas with no data or inadequate information, stream gains and losses including mean and base flows where estimated using the model Visual MODFLOW, with stream functions and ZONE budget modules.

38. Stream gains and losses reaches and also mean flows at nodes within the catchments are summarised in Appendix A - Figure 4 and Figure 5.

39. The interaction between lakes and wetlands and groundwater is determined to a large extent by their position with respect to local and regional groundwater flow systems. A common conception is that lakes and wetlands that are present in

topographically high areas recharge groundwater, and that lakes and wetlands that are present in low areas receive discharge from groundwater.

Data for Model Calibrations at Nodes

40. Surface and groundwater quality (nutrient loads) within the Mackenzie Basin and at nodes are associated with land use. The on-farm nutrient generation is discussed in Dr Robson and Dr John Bright's joint evidence.

41. GHD has compiled surface water and groundwater quality data from the:

(a) ECan database;

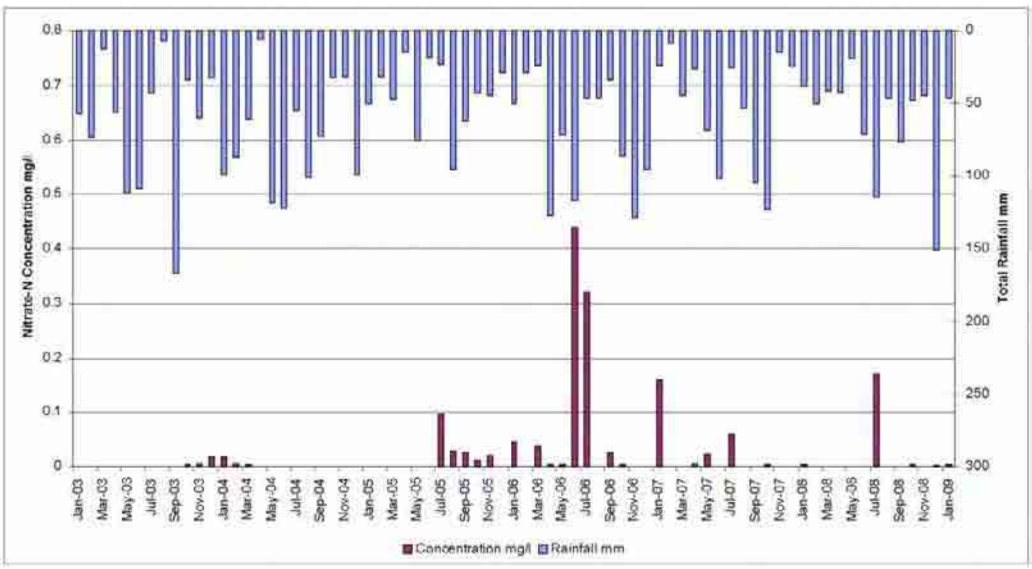
(b) Sampling at nodes; and from the

(c) Upper Waitaki Water Quality Trust database.

Relationship between flow and nutrient concentration

42. Nodes considered for calibrations are as shown in Figure 4 and Figure 5. An analysis of Nitrate-N concentrations at each node within the Mackenzie Basin is summarised in Appendix A - Figure 6, Figure 7 and Figure 8. We have used the Wairepo stream Nitrate-N concentrations and mean monthly rainfall to understand the relationship between stream flow and concentrations. Mean monthly rainfall was used as there were only two concurrently measured flows and concentrations at this node. The relationships are shown in Figure 1.

Figure 1 An example of the relationship between stream concentration and rainfall



43. The low Nitrate-N concentrations during low flow periods could be explained as follows. At times of low groundwater levels, surface flow may be sustained by surface flows in the upper catchment (e.g. from snow melt). This flow will contribute seepage to groundwater water through leakage of the streambed. As the water table rises due to rainfall recharge to the aquifer at large, the losing reach may become a gaining reach as the water table rises above the level of the streambed.

44. From stream concentration data and total monthly rainfall for the Mackenzie catchment, this occurs during the winter rains from June to August. This explains the influx of higher Nitrate-N loaded groundwater during these months resulting in higher Nitrate-N concentrations at stream nodes.

45. The degree of hydraulic connection between groundwater and surface water can also change of over different reaches within any one stream and from time to time over the same reach.

46. From Figure 1 there is no clear relationship between low rainfall periods and low stream concentrations. However, high concentrations generally occur during the month of July. This month is characterised by high winter rainfall values for the Mackenzie basin.

47. Mean monthly rainfall and available flow data were used to determine whether sampling for concentrations was during low, average or high flow conditions

48. The results indicate that the use of MALF would result in significant underestimation of nutrient transport and concentrations in surface waterways. The use of median or mode statistic would not be appropriate recognising the availability of concurrent measured flow and Nitrate-N concentrations. The relationship between flow and concentrations as described in paragraphs 37 to 40 justified the use of the mean annual flow to calculate concentration for annual nutrient load, and not some other flow statistic.

49. The justification I set out above was discussed and agreed at the caucusing meeting on 28 October 2009 between groundwater experts

Modeling nutrient transportation and exchanges between surface and groundwater systems

50. Nutrient transport in the basin has been assessed using two methods:

(a) The GHD spreadsheet Toolkit; and

(b) The MT3D Module in Visual MODFLOW. (Input data used for this model is shown in Appendix C at page 37). The MT3D Module in Visual MODFLOW model is discussed in the GHD Groundwater Report and is not included with this evidence.

GHD Toolkit

51. The GHD toolkit routes flow and Nitrate-N loads from the highland areas through basins and discharge to Lake Benmore. The toolkit takes into consideration natural surface waterways, canal flows and groundwater.

52. The GHD toolkit is presented in Appendix B and is described using an example of the Tekapo sub catchment

53. Inputs to the GHD Toolkit are:

(a) Highland generated flows;

(b) Highland generated Nitrate-N loads;

(c) Nitrate-N loads within reaches in the subcatchments;

(d) Irrigation and rainfall drainage volume as calculated through IRRICALC within reaches in the sub-catchment;

(e) Measured baseflows at nodes within the sub catchments;

(f) Measured surface water flows at nodes;

(g) Modelled or measured mean flows at nodes.

54. Toolkit Assumptions are:

(a) Stream Nitrate-N loads are lost to groundwater in zones where surface water is lost to groundwater.

(b) Surface water gains Nitrate-N loads from groundwater in areas of stream gains. The flow gains are assumed to be derived from the catchment recharge and regional flow.

(c) The concentration of recharge to a stream is assumed to equal drainage concentration.

(d) Groundwater discharges to surface water are subject to denitrification in riparian margins. The coefficient for denitrification is related to drainage conditions through the riparian margins.

55. The outputs of the toolkit are:

(a) Surface Water Nitrate-N loads through each node and aggregated to Lake Benmore;

(b) Groundwater Nitrate-N loads through each node and aggregated to Lake Benmore;

(c) Surface water Nitrate-N concentrations under baseflow conditions;

(d) Surface water Nitrate-N concentrations under any prescribed flow condition;

(e) Surface water Nitrate-N concentrations under mean flow conditions;

(f) Groundwater Nitrate-N concentrations in each subcatchment;

(g) Total groundwater nitrate transport to the lake;

(h) Total surface water nitrate transport to the lake;

(i) Total water surface water flows to the lake;

(j) Total groundwater flows to the lake;

(k) Loss of Nitrate-N loads due to denitrification at the relevant reach and also for the whole catchment.

56. Model Results from the Toolkit Spreadsheets are summarised as follows:

(a) GHD calculated Nitrate-N concentrations at baseflow conditions are greater than those derived from sampling;

(b) GHD calculated Nitrate-N concentrations at flows equivalent annual mean flow conditions are greater but closer to average Nitrate-N concentrations from measured data;

(c) Groundwater calculated Nitrate-N concentrations are greater than measured in all subcatchments.

57. GHD Toolkit results are conservative for both surface and groundwater Nitrate-N load calculations.

58. The results and spreadsheets were discussed and presented on the caucusing meeting of the 28th of October 2009. The methodology employed to develop the toolkits was accepted as being robust.

Response to Section 42a reports / Hearing Commissioners Questions/ Meridian Evidence

George Anthony Griffiths

59. Dr Griffiths presents information on surface water balances for the Upper Waitaki Basins draining to both the Haldon and Ahuriri Arms of Lake Benmore. He suggests a comparison of GHD flow calculations and those from Mr Freestone and Mr Henderson is required and presents a summary table (Table 4) in his evidence. GHD flows are generally in agreement with flows from the Table 4 of Dr Griffiths evidence. However, mean flows calculated in Table 4 are approximately 10% higher than those calculated by GHD. Mr Freestone's total flows to Lake Tekapo are 9.5 m^3/s compared to GHD's 8.5 m^3/s. The difference in flows is primarily due to the flow averaging periods. Further, work by Richard de Joux, and reported in his evidence, shows that the contribution of the Grays River is about 2.5 m^3/s compared to 3.0 m^3/s reported in Dr Griffiths' evidence. Mr de Joux's estimated flow rate is in agreement with the GHD estimated flow.

60. In paragraph 50 Dr Griffiths noted that GHD flows for the Stoney and Tekapo nodes are lower than those calculated by Mr Freestone and ECan. The flows have been re-routed through a dynamic model and the updated flows are 47.3 M m3/year and 277 M m3/year for the Stony and Tekapo node respectively. This is in comparison to 54 M m3/year and 280 M m3/year, respectively reported by Dr Griffiths. There is no significant difference in flow estimates.

(a) Paragraph 52 to 54 of Dr Griffiths' evidence he deals with the treatment of spills estimated by GHD. He presents data on spill flows and a reference to Annexure 2 of his evidence. Dr Griffiths calculates that spills account for approximately 12% of all flows i.e. 30 m^3/s or 1200 M m^3 per year. The 30 m^3/s is stated to discharge through Lakes Tekapo (10 m^3/s) and Pukaki (19.

m^3/s). The treatment of spills by GHD has no significant impact on the overall mass balance estimates because a weir down stream of Lake Tekapo diverts all the flows (10 m^3/s) into the Tekapo-Pukaki canal through gate 17 such that this spill does not contribute flows into the Tekapo River downstream of the weir.

(b) The overflow spills (19 m^3/s) into the Pukaki river from Dr Griffiths evidence are rare and last a maximum of 8 weeks per year when they occur. To protect the environment and be conservative, GHD has therefore not considered the rare spills.

61. Paragraph 55 of Dr Griffiths' evidence addresses flows into the Ahuriri Arm of Lake Benmore. The total discharge of 38.9 m^3/s is reported in Figure 11 of the GHD Groundwater Report. The GHD report provides the total flows into the Lake, with 28 m^3/s as surface flow, 8 m^3/s as groundwater flow and the rest comes from catchments contributing direct flow to the Lake such as Otamatapaio River (mean flow 1.116 m^3/s, Hydrology of Otamatapaio River by Dave Boraman).

62. Dr Griffiths discusses implications of the mass balance on nutrient concentration and load assessment. GHD procedures were discussed at the caucusing meetings on 16th and 28th October 2009 and it was agreed that the procedures were appropriate considering that there is not a strong relationship between flow and Nitrate- N concentration. Data and analysis of nutrient concentrations versus flows were circulated on 28th October 2009. However, there were several more data on measured concentrations but without concurrent flow data. An understanding of flow versus stream concentrations was derived through the use of monthly rainfall values as discussed in paragraph 36 to 42 of this evidence.

63. Furthermore, GHD calibrated estimates for periods with concurrent measured flow and sampled concentrations. GHD modelled values for base flows and mean flows are mostly higher than measured concentrations, leading to a conservative outcome.

Mr Peter Francis Callander

64. I agree with Mr Callander's appreciation of our methodology in assessing sources of groundwater recharge in the groundwater basins.

65. Paragraphs 25 to 30 of Mr Callander's evidence discusses what he considers as inadequacies in groundwater information to reliably characterise groundwater flow conditions in the Mackenzie basin.

The topographical and drainage features of the Mackenzie basin allows for the groundwater flow patterns to be well defined. The geomophological development and basin formation of the Mackenzie basin indicates the large extent of sediments of low and high permeability which have local anisotropy but function as a single homogeneous mass. Because of the lack of information it is difficult to define the subsurface hyrogeology precisely. However, investigations were based on fundamental principles treating first of all general characteristics and then particular ones. Inductive reasoning has been used from verified conditions in areas with significant data such as the Pukaki, Chain Hills, Omarama and Tekapo, but with the care needed by the different scales in such a vast area.

66. From the above and following the same ideas, it was established that the isophreatic maps would reflect in an approximate way the general groundwater flow directions. Such investigations have great value in characterising hydrogeological conditions when there little or no other information available to characterise the aquifer in sub catchments. The methods have been applied in sub catchments such as the Wairepo, Quail Burn, Hen Burn and Willow Burn

67. Paragraphs 41 to 43 of Mr Callander's evidence discusses what he considers discrepancies in highland flow calculations.

The partitioning of highland flows has been revisited and the discrepancy is less than 6%. An agreement was reached at the caucusing meeting of the 30 October 2009 that the GHD methodology and toolkit was robust and "sound" and partitioning of flows was correct and any differences were due to numeracy and not the methodology. Any inconsistency in numeracy should be addressed, however, such inconsistency is not expected to result in significant changes in GHD conclusions.

68. Paragraph 38 - 40 of his evidence Mr Callander discusses inconsistencies in the drainage quantities between the numbers in various tables, including discrepancies between scenarios which should be equivalent.

GHD acknowledged the inconsistencies and discrepancies and these were due to editorial errors and this was explained to Mr Callander during the caucusing.

69. In paragraphs 44 – 48 of his evidence Mr Callander discusses differences in groundwater levels of the order of 5-10 m between modelled and measured data.

GHD has used all reported groundwater level measurements that are available within the basin. Large differences in measured and modelled values could be related to the fact that some measurements were carried out during well installation. There were large variations between groundwater levels at well installation and after well development in some wells, notably in the Chain Hills area. However, it should be noted that GHD Modelled values are in strong agreement to measured groundwater levels.

70. In paragraphs 49 to 66 of his evidence Mr Callander's discusses the GHD calculations of flows and nitrate transportation. Paragraph 78 of his evidence lists reasons for his uncertainty in the groundwater assessment.

71. At the caucusing a step by step analysis and auditing of the GHD Toolkit spreadsheet was undertaken where I explained all the components of its development and application. An explanation on how the gains and losses were computed was also presented and agreed. Mr Callender also agreed, at the caucusing meeting of the 28th October 2009 that the GHD methodology and toolkit was robust and 'sound'. During the same meeting, the

72. In response to Mr Callander's comments on denitrification (paragraph 62) I note that the proportion of Nitrogen removed is related to the conditions at the riparian margins as recognised by in the evidence of Mr Callander. Results of denitrification percentage calculations are as shown in the spreadsheets in Appendix B. Results of the GHD calculations with and without consideration of denitrification show that denitrification accounts for approximately 4 to 6 percent of all Nitrate- N loads to the basin. Errors in estimating denitrification, on average are not expected to result in significant changes to the conclusion.

Mr Tom Heller's Report

73. Mr Tom Heller's report is an audit of the following:

(a) General climate and environment inputs;

(b) Surface water; and

(c) Groundwater.

My evidence responds to the paragraphs 112 to 120 of Mr Heller's report. These items are his overall conclusions of his assessment.

74. Paragraph 112 of Mr Heller's report states his dissatisfaction with individual subcatchment water balance components and paragraph 113 of Mr Heller's report reflects on his inability to fully audit the input, path, fate and attenuation of N within the GHD mass balance calculations.

This has since been discussed and agreed to at the caucusing meetings. Mr Heller concurred that he had understood how individual subcatchments have been dealt with in the GHD Groundwater report. The path, fate and attenuation of N was explained and understood. GHD further submitted their spreadsheet toolkit for auditing. I have yet to receive consolidated responses from the experts.

75. Paragraph 115 of Mr Heller's evidence addresses the alleged lack of transparency in the calculation of highland flows by GHD. Calculations of highland flows were presented at the caucusing and Mr Heller was in agreement that the procedure and results were robust.

76. Paragraph 116 of Mr Heller's evidence relates to the using of mean flow rather than MALF for assessing surface water quality.

Mr Heller (paragraphs 68 to 79) reconstructed the mass balance by using MALF to calculate concentrations at stream nodes. GHD completed a similar procedure and arrived at similar results to those of Mr Heller. However, measured data showed that nitrate concentrations were generally lower at MALF conditions. GHD presented the relationships between mean flows, MALF and nitrate concentrations at surface nodes. Furthermore, GHD submitted analysed and raw data to Ecan and Meridian for auditing. It was agreed that the use of mean flow was the most appropriate. Further personal communications with Mr Heller (Telephone conversations of 03/11/2009) confirmed that the methods were correct.

Conclusion

77. GHD assessment of groundwater recharge from highlands and basins and discharges to surface water matches measured flows and groundwater behaviour in the Upper Waitaki.

78. GHD has accomplished the following:

(a) GHD has adequately identified sub catchments that contribute flows and nutrients to the receiving lake environment;

(b) GHD has adequately identified and quantified sources of groundwater recharge for the Mackenzie Basin;

(c) GHD has adequately established transport and mixing of nitrogen leaching from land surfaces to groundwater;

(d) GHD has used robust methods to calculate mean annual flows and mean annual low flows for surface water systems in the Mackenzie Basin;

(e) GHD has used robust methods to quantify nitrate loads from each contributing sub catchment;

(f) GHD has adequately determined the interchanges in flow and nutrients between surface and groundwater and derived nitrate concentrations in both surface and groundwater systems.

(g) GHD has calibrated both surface and groundwater concentrations for the purpose of forecasting changes in these concentrations with changes in land use.

(h) GHD has used robust methods to calculated nitrate loads to the receiving lake environment under both current and proposed land use.

79. Consequently I believe that the WQS is robust and when the mitigation measures as indicated by the other WQS team member evidence are applied there will be appropriate measures in place to ensure environmental values are maintained.

Douglas Ngonidzashe Mzila