BEFORE THE CANTERBURY REGIONAL COUNCIL

In the matter of the Resource Management Act 1991

and

In the matter of Variation 6 to Chapter 4 Water Quality of the Proposed Natural Resources Regional Plan

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BRIEF OF EVIDENCE OF PETER FRANCIS CALLANDER

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Introduction

1. My name is Peter Francis Callander. 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, the New Zealand Water and Waste Association and the USA based National Ground Water Association.

2. 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.

3. Previously I had been employed for eight years by the Canterbury Regional Council 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.

4. I have been involved with the assessment of groundwater flow and aquifer management in alluvial gravel aquifers for a large part of my career – particularly in Canterbury and Marlborough. This has involved work for the Regional Councils in their regulatory capacity and for organisations carrying out land use activities that impact on the groundwater resource.

5. I have been engaged by a group of organisations who quarry the gravel strata within the Christchurch Aquifer recharge area and who are concerned that their ability to continue operations will be unnecessarily limited by the groundwater management approach that is being proposed in Variation 6 to the Proposed Natural Resources Regional Plan.

6. I acknowledge that I have read the Practice Note on Expert Witnesses prepared by Principal Environment Court Judge R.J. Bollard that took effect from 31 March 2005 and I agree to comply with it. I have prepared this evidence in accordance with that note.

Scope of Evidence

7. The evidence that I shall present has been structured into four parts.

Part 1: The hydrogeological setting of the Christchurch Aquifer System and the effects of land use activities on that system.

Part 2: Comments on the Canterbury Regional Council Officer's reports.

Part 3: Comments on the effects of quarrying on groundwater.

Part 4: Comments on the proposed wording of Variation 6 with respect to quarrying.

The figures that I refer to in my evidence are attached at the end of this evidence in Appendix A.

1.0 Hydrogeological Setting

1.1 It appears to me that the Variation 6 Officer's reports from the CRC portray the information on the Christchurch groundwater resource in a way that paints a somewhat emotive picture of a high quality, but highly vulnerable groundwater resource which is at great risk from any further development of land occurring within its recharge zone. Whilst such an approach supports the Objectives, Policies and Rules that they are promoting in Variation 6, in my opinion it is not a balanced or objective presentation of the available hydrogeological information. Therefore, Part 1 of my evidence presents data on the hydrogeological information of the area to provide the hearing panel with a good understanding of the pattern of groundwater occurrence and the current distribution of groundwater quality throughout the aquifers. A good understanding of these patterns is essential to ensure that appropriate and defensible Objectives, Policies and Rules are established through Variation 6.

1A. Geological Structure and Groundwater Flow Direction

1.2 Unconsolidated deposits of gravel, sand and silt extend to depths of around 500 m beneath the Christchurch area. Drilling for water supply wells has typically extended through the upper 200 m of these strata. Across this upper thickness of the strata, five separate aquifers are recognised. From shallow to deep these are known as the Riccarton, Linwood, Burwood and Wainoni gravels as well as deeper unnamed gravel strata. These gravel aquifers are extensive deposits that occur across most of the City area.

1.3 Each gravel aquifer is separated by lower permeability aquitards comprising finer grained deposits. In the east and centre of the City these aquitards are formed by low permeability marine and estuarine deposits that confine the groundwater in the aquifers under pressure, creating flowing artesian wells. In the west of the City the aquitards comprise poorly sorted alluvial deposits with a greater proportion of sand and silt than the more permeable gravel aquifers.

1.4 This sequence of aquifers and aquitards has been created by the changing glacial and interglacial climatic conditions over the last 500,000 years and the changing depositional environment of glacial and river conditions that formed the Canterbury Plains during that time.

1.5 Groundwater flows beneath the City in a general easterly direction towards the coast, as shown in Figure 1. The source of the water primarily comes from:

- seepage out of the Waimakariri River to the north-west of the City area;
- rainfall infiltrating through the soils in the western part of the City
- leakage from the Paparua stormwater race network that occurs across the rural land to the west of the city
- groundwater throughflow from more distant areas.

1.6 The sequence of aquifers and aquitards also gives rise to differing groundwater flow patterns with depth. Groundwater flow depicted in a vertical cross-section shows lateral flow through the strata in the west of the City, and upwards flow in the central and eastern part of the City, as shown in Figure 2.

1.7 Groundwater discharge via springs is the predominant source of flow to the main waterways of Christchurch – the Avon, Heathcote, Styx and Otukaikino waterways. Therefore there is a relatively rapid groundwater throughflow in the shallow gravels (Riccarton aquifer) to the spring fed streams and a slower, deeper lateral and upward flow through the deep aquifers of the western City and all the confined aquifers of the central and eastern City.

1.8 Much of the rainfall recharge that infiltrates through the land to the west of the City discharges into the spring-fed streams and therefore is flushed through the groundwater system rather than entering the deeper aquifers. The water in these deeper aquifers is predominantly derived from seepage out of the Waimakariri River.

1.9 Within the Christchurch area, the presence of extensive discrete aquifers provides many options for the construction of water supply wells that draw from aquifers that are protected (and not at risk) from any potential activities on the land surface that may impact on the shallow water table.

1.10 This protection arises from:

- The low permeability aquitards that overlie the gravel aquifers;
- The hydraulic gradients that occur in a predominantly lateral or upwards direction. This flow pattern will tend to keep contaminants from land surface activities within the near surface strata;
- The extensive nature of the gravel aquifer deposits provides ample opportunity for attenuation of potential contaminants before they reach any water supply wells.

1B. Existing Groundwater Quality Data

1.11 Patterns of groundwater quality in the Christchurch aquifer system are best indicated by the following parameters:

- Concentrations of Faecal Coliforms and E.coli; which are used in the Drinking Water Standards for New Zealand to indicate the potential presence of pathogenic viruses and bacteria.

- Concentrations of Nitrate-Nitrogen; which is one of the most widespread groundwater quality parameters in Canterbury aquifers resulting from land-use activities.

- Concentrations of Total Dissolved Solids; which are an indicator of all the chemicals dissolved in the groundwater.

1.12 I have included a series of plots for each of these parameters to indicate how these groundwater quality parameters vary with depth, along with a second plot to show the spatial pattern of occurrences within wells less than 60 m deep. It is these shallower wells that show the greatest variability of the water quality parameters throughout the City.

1.13 Figure 3 shows the detections of Faecal Coliforms and *E.coli* with depth and indicates that all the affected wells occur at depths less than 60 m. The longer travel times and flow paths that are required by infiltrating water to reach the deeper well screens allow the processes of filtration, dispersion and bacterial die-off to avoid any effects from pathogenic micro-organisms in the deeper aquifers.

1.14 Figure 4 shows the pattern of detections of *E.coli* and Faecal Coliforms across the City in wells less than 60 m deep. It indicates that most of these originate in rural areas (west of the urban area) and occur as localised effects rather than causing widespread groundwater contamination. The causes of this contamination are most commonly related to poor siting and/or construction of wells, due to nearby septic tank discharges or insecure wellheads that allow surface runoff to enter the well casing.

1.15 Figure 5 shows the pattern of Nitrate-Nitrogen concentrations with depth and once again shows the effects are restricted to shallow wells less than 60 m deep. The Maximum Acceptable Value for Nitrate-Nitrogen in the Drinking Water Standards for New Zealand 2000 is 11.3 mg/L.

1.16 Figure 6 shows the pattern of Nitrate-Nitrogen concentrations across the City in the wells less than 60 m deep. When reviewing these concentrations it is worth noting that concentrations of nitrate-nitrogen up to 3 mg/L are considered to be naturally occurring (ECan report R02/17), i.e. the black and light blue coloured dots in Figure 6.

1.17 The pattern in Figure 6 shows some elevated concentrations in the rural land to the west of the city and a tongue of elevated concentrations in an area of southern Christchurch, from Islington to Hillmorton. This pattern is primarily due to industrial activities (including the Islington freezing works and multiple gravel pits that have historically been used for waste disposal in southern Christchurch).

1.18 Finally, as a general indicator of all dissolved chemicals in Christchurch groundwater, Figure 7 presents Total Dissolved Solids (TDS) with depth. Once again, we see higher concentrations in shallower wells.

1.19 Figure 8 is a reproduction of Figure 3.13 in ECan report U05/12 (which is the Barber et al 2005 report referred to in Mr Hanson's Officer's report). It shows the relative pattern of dissolved chemicals in Christchurch aquifers, although it is important to put the magnitude of the measured values into perspective. The aesthetic guideline value for TDS in the Drinking Water Standards for New Zealand 2005 is 1000 g/m^3. Therefore the vast majority of Christchurch groundwater is of very good quality, even though there are relative differences across the City. The main exception is a localised area of saline water that has entered the shallowest aquifer at the mouth of the Heathcote Valley near the Avon-Heathcote estuary. This is a localised issue at the sea coast and is not related to land use activities.

1.20 In the ECan report U05/12, Figure 3.14 shows detections of organic chemicals in Christchurch groundwater. These have occurred in the southern area of Christchurch and at one location to the north, adjacent to the former Waimairi Landfill (which occurred in an unlined gravel pit). All these detections were recorded in wells less than 45 m deep. It is important to put those occurrences into perspective, so in Figure 9 of this evidence I have reproduced ECan's Figure 3.14 and shown the occurrences of organic chemicals as a percentage of their respective Maximum Acceptable Values in the Drinking Water Standards for New Zealand 2005. This shows that most of the detections are at very low concentrations that would not be classified as causing an adverse health risk by our Ministry of Health.

1.21 Figures 3-9 indicate a consistent spatial pattern of the groundwater quality of the Christchurch aquifers. Deep groundwater is good quality. Shallow groundwater is of generally good quality but shows the following three areas, plotted in Figure 10:

- a large northern zone of water with very low chemical concentrations due to the dominant effect of Waimakariri River recharge (Area A on Figure 10);

- a southern zone where rainfall recharge has a more dominant effect, causing slightly raised chemical concentrations (Area B on Figure 10);

- a small zone in southern Christchurch that shows greater effects from former gravel pit disposal of municipal and industrial wastes.

1.22 The main areas of elevated chemical concentrations in the near surface aquifer occur within southern Christchurch and a small area near the former Waimairi Landfill in the Harewood area. The explanation for this pattern is found in Figure 11 which shows the distribution of industrial zoned land and old landfill sites (which were mostly filled with refuse dumped in an uncontrolled manner in old gravel pits, such as the Owaka Road pit). The combination of gravel pits, uncontrolled waste disposal and industrial activities during the past 50 – 100 years, when little consideration was given to effects on

groundwater protection, has impacted on the groundwater quality in this area.

1.23 However, despite these very poor land management practices, the effects on groundwater quality are of limited extent and have not prevented the City from providing its highly valued good quality water supply.

1.24 Furthermore, it is interesting to note that a number of contaminants in the shallow groundwater in southern Christchurch have actually decreased in concentration. This is attributed to a reduction in industrial discharges to ground and improved land management practices compared to the activities of many years ago. This indicates that even when the shallow aquifers in western Christchurch have been affected by land use activities, they have an ability to recover from these effects.

1.25 It is well recognised that Christchurch City is provided with a very good water supply drawn from the aquifers that lie beneath the City. But it is also important to acknowledge that some areas of Christchurch experience adverse groundwater quality effects due to naturally occurring processes.

1.26 In particular, the pH of shallow aquifer groundwater in the western part of the City tends to be low due to the naturally acidic nature of water that infiltrates through the soil zone. In some water supply wells in western Christchurch a pH adjustment has previously been applied to this water prior to it entering the reticulation, to avoid corrosion in pipe work, water cylinders and tap fittings. However, this pH correction is not currently required because the drilling of new deeper wells provides sufficient dilution with higher pH water so that this naturally occurring water quality problem is avoided.

1.27 Also, in areas where groundwater passes through organic peat and estuarine deposits within the natural strata making up the sequence of aquifers and aquitards, the oxygen status of the water becomes reduced and creates chemical conditions such that some metals adsorbed onto the sedimentary particles that make up the aquifer

dissolve within the groundwater. This can cause elevated concentrations of iron, manganese and arsenic to be present in groundwater – derived entirely from natural groundwater flow. In situations where this has occurred, CCC has tended to re-screen the wells at different depths where better quality water is found or to rely on the dilution effect from other wells in the network to ensure a good quality of supply is maintained. This is an example of how the extensive nature of the aquifer system provides many opportunities to avoid issues arising from poor quality water – either as a result of natural conditions or from land-use activities.

Conclusion from Hydrogeological Setting Assessment

1.28 The conclusions that can be reached from this review of hydrogeologic data in Christchurch City are:

- There are good quality extensive aquifers throughout the City area – particularly at depths greater than 60 m, but also in most areas at shallower depths. This provides ample scope for the siting of wells supplying good quality water. Figure 12 shows the location of CCC pumping stations to indicate the extent of where the water is drawn from.

- Shallow groundwater quality has been affected by land use activities related to rural land use practices, industrial discharges and unlined landfills. These are potentially significant sources of groundwater contamination, yet most of their effects occur in quite localised areas, most contaminant concentrations are well within the maximum acceptable values of the Drinking Water Standards for New Zealand 2005 (revised 2008) and many of the effects are improving with time.

2.0 Comments on the Council Officer's Report

2.1 Whilst Part 1 of my evidence presents a more detailed set of maps than the Officer's reports, the information is not contrary to any of the information that the Officer's have presented. The purpose of my Part 1 information is simply to ensure that the hearing panel has a good understanding of the current groundwater quality patterns throughout the Christchurch aquifer system and how that relates to historical and current land use activities, which include some very bad historical management practices (e.g. rubbish dumps in unlined gravel pits), which would not be allowed to occur today.

2.2 I also want to make it clear that I share a common understanding with the Officers about much of the Christchurch City aquifer system and the importance of protecting the good quality water supply. In particular:

- I agree that the Christchurch groundwater system is the source of a high quality and highly valued water supply.

- I agree that it is important that we manage land use to avoid any degradation of that supply. To that end, I agree that it is appropriate to have a regional plan that has special Objectives, Policies and Rules that deal with groundwater quality for the Christchurch aquifer system.

- I agree with the Officer's definition of Zones 1, 2 and 3, and that in Zone 1 contaminants from land use activities can migrate down into the aquifer.

2.3 The main point of difference between myself and the Officer's report is that I am of the view that the Objectives, Policies and Rules must have a sound technical basis and be consistent with the information we have about contaminant movement within this groundwater system. However, what is currently proposed in Variation 6 appears to be based on an emotive presumption of potential contamination risk that is inconsistent with the technical information on the aquifer system.

2.4 In the following paragraphs (2.5-2.8), I will try and demonstrate the differences between the Officer's approach and what the existing information tells us about the response of the aquifer to land use activities. Each of the following main paragraphs (2.5-2.8) begins with a statement of the Officer's views in italics, followed by some observations based on the factual information that is available.

2.5 The Officer's view:

Part 9 of the Officer's report records how Christchurch residents rate their water supply highly (paragraph 11) and are of the view that their water supply must be maintained in its present high quality state (paragraph 12). The Officers have taken these views and then concluded that the entire Christchurch groundwater system must have its quality maintained or improved in order to meet the resident's expectations.

2.5.1 That appears to be a flawed logic. The water supply is the water that is drawn through a bore intake and delivered into the reticulation network. That is what is highly valued by Christchurch residents and must be protected. As shown by Figures 3-9 of my evidence and described in Part 8 of the Officer's report (Mr Hanson), there are some areas of poorer quality groundwater that occur within the Christchurch aquifer system, but they do not jeopardise the high quality water supply.

2.5.2 Therefore, it is important that we make a clear distinction between the water supply, which must remain available in its current high quality, and must be able to expand with the drilling of new wells, but we must also recognise that this can be achieved with some other areas of groundwater that are affected by land use activities, or naturally occurring contaminants (paragraphs 1.26 and 1.27 of my evidence) as is currently the case and is continuing to occur alongside the highly valued water supply.

2.5.3 To provide a further demonstration of this point, the drainage effects from land use activities have their biggest impact at the water table and on shallow groundwater. A properly constructed water supply well has its screened intake many metres below the water table and, due to the great thickness of the Christchurch aquifer system, this can be many tens of metres below the water table. This difference between groundwater quality and groundwater depth is clearly shown in Figures 3, 5 and 7 of my evidence.

2.5.4 It is also important to recognise and acknowledge that it is impossible for human activity to occur in a groundwater recharge area without having some effect on groundwater quality. Even some of the permitted activities in Variation 6 allow effects on groundwater quality to occur, such as Rule WQL5 (stormwater discharges) and Rule WQL8 (on-site wastewater discharges).

2.5.5. Therefore, the Objectives, Policies and Rules must be realistic and must recognise that effects on groundwater quality can occur and we can still have a very high quality groundwater supply.

2.5.6 It is important that these comments are not misconstrued to suggest that we should promote or allow widespread contamination of groundwater to occur, as long as it is not at a water supply well. That is not the case at all, and I strongly support the implementation of policies and rules that achieve good management to minimise the risk of contaminants entering groundwater. However, the protection of the water supply can be achieved by good management practices. Variation 6 goes much further than this and seeks to prohibit intensification of land use in Zone 1 and to avoid contamination arising from many other land use activities. The Officers justification for this is that the entire groundwater source must be protected. However, existing groundwater data shows that this is not a requirement to protect the water supply.

2.5.7 The need for the special management measures of Variation 6 arises solely due to the Christchurch water supply, because this is the special attribute of Christchurch groundwater that makes it different from all other groundwater in Canterbury. Therefore, Variation 6 must focus solely on issues related to the water supply.

2.6 *The Officers emphasise a view that the aquifer system is highly vulnerable to contamination in Zone 1, and therefore no further intensification of land use can occur and existing areas of intensification must be closely managed.*

2.6.1 This state of high vulnerability is very emotive, but inconsistent with existing groundwater quality data. It is true that contaminants in Zone 1 can drain down into the aquifer. But the aquifer has significant attenuating characteristics that prevent the contaminants having no more than a minor effect on the groundwater quality. In particular:

- whilst drainage downwards from land use activities into the aquifer typically occurs intermittently during rainfall events, there is a continuous throughflow of good quality groundwater passing through the aquifer that emanates from seepage out of the Waimakariri River. Part 8, paragraph 44 of the Officer's report notes that this is very good quality water. It dilutes the slugs of land use recharge contaminants to minimise the resulting concentrations in the groundwater. This is particularly demonstrated by the very good quality even in very shallow (i.e. most vulnerable) groundwater in north-western Christchurch, as shown in Figures 4, 6, 8, 9 and 10 of my evidence. As noted on page 4 of the PowerPoint slides of Part 7 of the Officer's report, this good quality Waimakariri recharge source makes up more than 60% of the recharge to the Christchurch groundwater system;

- the spring-fed streams that emerge at the western edge of Zone 3 and Zone 2 remove a large proportion (around

50%) of the groundwater from the system. They are fed from shallow groundwater which is the groundwater that is most affected by contaminants derived from land use activities. Therefore, these contaminants do not accumulate in the groundwater but rather they are flushed through and out of the system;

- the alluvial gravel aquifers that have formed across the Canterbury Plains have very fast and dispersive flow characteristics compared to most other groundwater systems. This causes a rapid reduction in contaminant concentrations.

The development of the Variation 6 approach has drawn heavily from the experience of land management and aquifer protection from Perth in Western Australia (in the Barber et al report referred to in paragraph 24 of Part 10 of the Officers report). I agree that the Variation 6 approach is very appropriate for Perth, because it is a slower moving sand aquifer recharged almost entirely by rainfall recharge, so that land based contaminants move slowly into the groundwater and accumulate in the aquifer. But Perth does not have the key hydrogeological differences that are mentioned in the preceding bullet points. Because of these differences, it is entirely appropriate that the Christchurch aquifers can utilise a different approach to groundwater quality management.

2.6.2 In addition to the unique characteristics of the Christchurch aquifer system, groundwater in general has a range of significant natural attenuating processes that eliminate contaminants namely:

- **Dilution** – with other groundwater and recharge water

- **Dispersion** – through the spatially variable groundwater velocities that occur within the highly heterogeneous strata in the Christchurch aquifers

- **Filtration** – through zones of sand and silt

- **Adsorption** – onto the solid particles that form the aquifers and aquitards

- **Decay** – micro-biological contaminants all die off over a period of time

- **Biological degradation** – naturally occurring organisms within the subsurface environment degrade a range of contaminants

- **Chemical transformation** – some contaminants transform into innocuous by-products within the subsurface environment.

These attenuating processes apply to both point sources and to contaminants associated with the general infiltration of rainfall recharge across wider areas of land use. These rainfall induced recharge events occur as discrete pulses of finite duration with intervening periods where no land based recharge enters the aquifer. Attenuation processes act to reduce chemical concentrations from land based recharge in the periods between recharge events.

2.6.3 Rather than simply rely on these descriptions of contaminant attenuation mechanisms, we have actual direct observation of groundwater quality effects arising from land use activities. This includes some significant contamination sources that have been situated in the aquifer recharge zone, most notably:

- city and industrial refuse disposal into unlined gravel pits;

- waste products from the Islington Freezing Works buried in unlined gravel trenches;

- poor quality management of industrial wastes and spillages.

Despite these significant contamination sources (none of which would be allowed to occur today), the effects on Christchurch groundwater quality are localised and relatively minor, and have not prevented the City from enjoying its very high quality supply.

2.6.4 Such occurrences are not consistent with a highly vulnerable groundwater source as claimed by the Council Officer's. The activities mentioned in paragraph 2.6.3 represent some of the most significant groundwater contaminant sources that could ever occur. If the aquifer is highly vulnerable, there should be widespread and long lasting contamination at concentrations that would jeopardise the water supply, but the factual situation is that this has not occurred, and with our improved awareness of the groundwater recharge system and improved land management systems, the picture of significant and more widespread contamination that we are supposedly at risk from simply does not seem credible.

2.6.5 Further information on the realistic scale of risk comes from existing land use intensification activities. As the Officer's report notes (Part 7, paragraph 19), land use intensification has already occurred and Variation 6 creates separate zones to ring fence this intensification. These are:

- Zone 1A – urban spread (residential, commercial and industrial);
- Zone 1B – mineral extraction (i.e. gravel quarries);
- Zone 1C – airport – including bulk fuel storage, transfer and freight handing;
- Zone 1D – designated land for state highways, prisons and defence force activities.

The Officer's report (Part 7, paragraph 9) refers to these zones as “already highly and intensively developed”, and

occurring within the “highly vulnerable” groundwater area. The commentary on page 14 of the PowerPoint slides (Part 8 of the Officer's report) notes that these are existing “intensive land uses which pose a significant risk to the groundwater”.

2.6.6 Of the various water quality plots I have presented, Figure 8, showing Total Dissolved Solids, gives the widest measure of contaminants affecting groundwater. The intensified land use that is of relevance to this brief of evidence is the mineral extraction area, i.e. Zone 1B. Therefore, in Figure 13 I have re-created the Total Dissolved Solids plot and marked on the Variation 6 definition of the existing areas of intensification, i.e. Zone 1B. It is worth noting that quarrying has been occurring in those areas for several decades. It is also worth noting that the eastern parts of the 1B Zone occur in the area that Mr Hanson (Part 8, paragraph 50) defines as the biggest threat to the Christchurch aquifer system because “most contaminants of concern do not generally travel more than a kilometre in groundwater” and” it is unlikely that land use activities more than a few kilometres west of the confined aquifer system (that is west of the boundary between Zones 1 and 2 proposed in Variation 6) will affect the current water supply wells serving Christchurch”.

2.6.7 Despite several decades of this intensive quarrying activity, Figures 4, 6, 8 and 9 show very good quality groundwater in the areas directly downgradient of these intensified land uses. This pattern of generally good quality groundwater associated with the areas of intensified land use does not support the Officer’s claim (Part 3, paragraph 28) that “intensification of land use will result in degradation of shallow unconfined groundwater”.

2.7 *The Officer's report makes reference that the Christchurch water supply in the north-west has received a “D” grading from the Ministry of Health (MoH) due to its vulnerability to contamination.*

2.7.1 It is unfortunate that this has been mentioned without a proper explanation of the grading system for public water supplies. There are two reasons why shallow water supply wells in the north-west of Christchurch receive a D grading:

- firstly, the water is assessed to take less than one year to move from the ground surface to the well screens and MoH have deemed that this relatively young water should require a higher standard of treatment than older water;

- secondly, the standard of treatment that MoH require to achieve a higher grading is chlorination, which is a practice that is not implemented by the water supply manager of the Christchurch City Council.

2.7.2 Therefore, it is important to recognise that this is a grading classification system rather than any statement about actual contamination. Furthermore, even if all the Officers measures that are proposed in Variation 6 were adopted, it would not change the water supply grading for these wells, i.e. the groundwater will still be less than one year old and it still will not be chlorinated.

2.7.3 It is also worth noting that some of the CCC wells in the north-west area are deeper and abstract older groundwater that therefore achieve a B grade rating from the MoH (an "A" grade rating would require chlorination), so the "D" grading simply reflects the groundwater characteristics of relatively rapid shallow groundwater movement in the Christchurch system and a preference to avoid chlorination of the supply.

2.8 *The Officer's claim that with increasing intensification of land use the "assimilation capacity" of the aquifer system is being used up (Part 10, paragraph 24) and eventually, perhaps not too far away, there will be a widespread breakthrough of contamination.*

2.8.1 However, if that was the case, then there should be signs of declining groundwater quality, but that is not the case.

Furthermore, Part 8, paragraphs 17 and 40 of the Officer's report notes that areas that have been affected by contamination have subsequently shown reductions in the concentration of the contaminants. Therefore, the Officer's claim in Part 3, paragraph 21, “once groundwater becomes contaminated, remediation is unlikely to be practically or financially achievable” does not seem to tie in with those observations of improving groundwater quality that are being achieved simply through improved land management practices.

2.8.2 The available groundwater quality data seems to indicate that we may have lost some of the assimilative capacity of the aquifer in some parts of the aquifer system due to poor historical land use practices, but with a modern awareness of groundwater issues and improved land management practices we are regaining some of the lost capacity. Therefore the current trend is one of improving assimilative capacity and a strong indication that good land management controls are effective for addressing this groundwater quality issue.

2.9 In Part 8 of the Officer's report, Mr Hanson gives a good coverage of all the contamination incidents that have occurred in Christchurch (paragraphs 17-24). It is important to recognise that their impact is limited to localised effects within relatively small areas of Aquifer 1 (as noted in Part 8, paragraphs 45, 50 and 51). Therefore, despite decades of historically poor management practices, the effect on groundwater has been limited and relatively minor. There are still large areas of the Christchurch groundwater system able to provide a very good water supply from existing wells, and with a large scope for siting future good quality wells.

2.10 Having said that, any of the contamination incidents referred to by Mr Hanson are undesirable and a review of his evidence provides an indication of the types of activities that should be the focus of the Variation 6 planning controls. These are:

- unlined gravel pits used for municipal and industrial waste disposal (Part 8, paragraphs 17, 18, 24);

- poor industrial practices where waste products are disposed via on- site soakage systems (Part 8, paragraphs 17, 21, 22, 23);

- spillages of industrial chemicals into stormwater systems that discharge to ground soakage systems (Part 8, paragraph 19);

- industrial wastes buried in unlined gravel pits (Part 8, paragraph 20).

2.11 Mr Hanson also mentions an incident where part of the water supply became tainted with hydrocarbons (Part 8, paragraph 27). However, it is important to clarify that was not an aquifer contamination issue, but rather an unsecured wellhead that allowed spilled hydrocarbons to seep into the well casing.

2.12 Recognising the causes of the contamination events described in Part 8 of the Officer's report, it seems to be an unjustified jump in logic to take these extreme examples of historical bad practice and use that as a basis to prevent well managed land development practices.

2.13 In my view, the practices listed in paragraph 2.10 are historical bad practices that would not be allowed today by planning rules, best practice industry guidelines, consent requirements and HSNO regulations (Hazardous Substances and New Organisms). So it is important that Variation 6 is consistent and supportive of these good site management practices.

Overview of Council Officer's Approach

2.14 I have prepared a table to summarise my understanding of the Officer's reasoning for their approach to Variation 6 compared to what I consider to be a more objective analysis of the available groundwater data. In very general terms, the Officer's view is that we have a highly valued aquifer and in those areas where contaminants can reach the groundwater, we must place a significant limitation on any activities that might contribute to a risk of contaminants entering the groundwater system.

2.15 However, the Officer's place no emphasis on a description of the processes by which contaminants migrate into and through the groundwater system and the potential distribution of contaminants and abstraction wells within the groundwater system. If these processes are explained and understood (as presented in Part 1 of my evidence), it would support a conclusion that good management of a variety of land use practices is an appropriate planning approach and the significant restrictions proposed in Variation 6 are not well justified.

2.16 Therefore, the conclusion reached in paragraph 33 of Part 2 of the Officer's report does not appear to be supported by the available technical data where they suggest that prohibited activity status is warranted due to the scientific uncertainty about the effects which activities may have on the environment. That paragraph suggests we have knowledge of various activities that cause significant adverse groundwater effects and uncertainty about where a safe limit of intensification might be. However, the reality is that we have seen some relatively minor and limited effects from very bad historical site practices. Those effects are receding with improved land management. That perspective provides confidence that further well developed management of land can continue without threatening the quality of the City water supply.

Summary of the Different Approaches	
What the Officer's Say	**What the existing information on Christchurch groundwater tells us**
Christchurch residents enjoy a high quality water supply and Variation 6 should have Objectives, Policies and Rules that protect that water supply.	Christchurch residents enjoy a high quality water supply and Variation 6 should have Objectives, Policies and Rules that protect that water supply.
Therefore we must maintain or improve groundwater quality throughout the entire Christchurch groundwater system.	The current groundwater quality is variable at different locations and at different depths. The excellent water supply can be maintained despite some poorer quality areas that arise due to either land use activities or due to natural processes.
Zone 1 defines an area where the aquifer is highly vulnerable to contamination.	Zone 1 defines an area where contaminants leached from land use activities can enter the groundwater.
These contaminants continually build up and degrade the aquifer quality.	There are many attenuating mechanisms that limit the magnitude and extent of the effect of contaminants from Zone 1.
Existing areas of highly intensified land use need to be limited to Zones 1A, 1B, 1C and 1D and need to be carefully controlled.	Existing areas of highly intensified land use in Zones 1A, 1B, 1C and 1D have not caused widespread or long-lasting adverse effects on the Christchurch water supply despite some poor management practices occurring in the past.
There must be no intensification of land use in Zone 1.	Intensification of land use combined with good management practices can occur whilst preserving the good quality characteristics of the Christchurch groundwater system and the water supply.

3.0 Sources of Groundwater Contamination Associated With Quarry Activities

3.1 The gravel extraction activities that occur in the area around Christchurch involve excavation of pits which reduce the thickness of strata overlying the groundwater table. Groundwater levels fluctuate over a range of several metres on a seasonal and longer term basis, being high following late winter and spring periods of heavy rainfall and lower during dry summer periods, coinciding with abstraction of groundwater for irrigation. Due to these fluctuations, there can be some instances where groundwater can rise up into the gravel pits and remain there for several weeks before receding again to leave a dry pit.

3.2 The strata that overlies the water table provides some protection for the overlying groundwater by filtering, adsorbing and attenuating contaminants that are leached from the land surface. Therefore, I agree with the Council Officers that reducing the thickness of strata over the water table and having periods of time where groundwater enters the pit increases the risk of contamination. But whether or not such activities are acceptable from a water management point of view requires a consideration of the significance of the risk.

3.3 Quarrying involves the operation of digging or scraping machinery and a loader or conveyor system to excavate gravels and transport them to equipment where they are screened and sorted into various products to be used in the construction industry.

3.4 That activity is relatively inert and poses a very low risk to groundwater. The sources of potential groundwater contamination that arise from the quarrying activity are:

- a risk of leakage of hydraulic oil from excavation machinery operating in the quarry area (any such leaks involve very small, almost insignificant volumes of hydraulic oil);

- a risk of fuel spillage associated with leakage from a machinery fuel tank. This is a very low risk and involves limited volumes of fuel.

Quarrying can also involve related activities that could pose a risk to groundwater, including:

- maintenance and re-fuelling of machinery;
- bulk storage of hazardous substances such as fuel and hydraulic oil.

However, even these activities do not pose a significant risk to Christchurch groundwater and are required to be carried out to high industry standards involving containment and monitoring. The risks from spillages can be mitigated by:

- good site management practices;
- regular vehicle maintenance;
- availability of spill kits;
- quarry staff trained in spill prevention and clean-up procedures.

These and other measures are described in greater detail in the evidence of Mr Murray Francis.

3.5 Therefore, the actual activity of quarrying does not pose any significant risk to groundwater and it is worth emphasising that Mr Hanson's thorough commentary of groundwater contamination incidents in Part 8 of the Officer's report does not include any specific reference to issues that have arisen from quarrying, and this is despite the Zone 1B activities having been in existence for several decades.

3.6 The more important groundwater contamination risk related to quarrying is the placement of any backfill into the quarry pit and the ongoing land use once quarrying has been completed. In that regard,

Mr Hanson has correctly pointed out some unacceptable historical practices in Christchurch involving the use of worked out gravel pits for municipal refuse (e.g. the Waimairi pit) and industrial waste disposal (e.g. Islington Freezing Works and many of the pits in the south-west Christchurch area).

3.7 Many of the pits in the Zone 1B area are currently consented for disposal of cleanfill which is used to backfill the excavated pits. Whilst some chemicals can leach out of these deposits, they are not likely to pose a risk to the operation of any water supply wells. Wastes that are currently backfilled into the pits must also comply with the Christchurch City Cleanfill Licensing Bylaw 2008, which is attached at the end of my evidence.

3.8 My understanding is that many years ago the materials that were received to backfill the pits were only loosely controlled. In recent years, the tracking and inspection processes of these wastes have been tightened significantly to ensure that any wastes deposited meet the definition in paragraph 3.7.

3.9 Many of the quarries undertake monitoring of groundwater quality at their downgradient boundary, and this does show some localised effects on groundwater quality – often with regard to the presence of calcium, chloride and bicarbonate, which will leach from concrete and other allowable cleanfill. However, the concentrations are relatively low, do not pose a risk to water supply wells, and are localised to the quarry area. This pattern of effect is entirely consistent with the observations in Mr Hanson's report (Part 8 of the Officer's report), where in paragraph 18 he describes the extreme example of the Waimairi landfill, with the most extensive contaminant effects limited to "several hundred metres" and in paragraph 50 where he correctly observes that "most contaminants of concern do not generally travel more than a kilometre in groundwater". In my experience of monitoring landfill effects in Canterbury gravels, detectable concentrations are unlikely at more than 100-500 m from the wastes.

3.10 Based on this information, it is concluded that quarrying activities over much of the Zone 1 recharge area will not threaten the Christchurch

water supply. However, it is relevant that restrictions should be placed on backfill materials (as per the attached CCC Bylaw), and planning guideline criteria should be provided for the longer term land use after the completion of quarrying, taking into account the reduced cover material over the groundwater – although the details of such future land use are best defined on a case by case basis via resource consents.

Environment Court Decision on Road Metals Quarry Extension (C163/2006)

3.11 With regard to the issue of quarries, it is particularly relevant to consider the decision of the Environment Court on a consent application to extend their gravel pit outside of the Yaldhurst quarry zone area as it existed at that time and into what was then defined by CRC as the highly vulnerable Zone 1.

3.12 CRC opposed the extension because of its potential contribution to groundwater quality problems in the Christchurch aquifer system. The court recognised that the quarry zone occurred in the recharge zone of the Christchurch aquifers (paragraph 11 of the decision). However, they concluded that with the imposition of appropriate conditions "the prospects of any contamination of groundwater during the excavation process are remote in the extreme" (paragraph 33 of the decision).

3.13 The court correctly identified that the issues of potential concern relate to the filing of any quarry pits and the post-extraction land use. But for all these issues, they concluded in paragraph 42 of the decision that "with the imposition of appropriate consent conditions, all adverse effects of the activity could be reduced to a level where they are insignificant and difficult to detect beyond the existing and permitted uses within the area".

3.14 This view is reinforced in paragraph 98 of the decision the court points out the apparent inconsistency of an attempt to restrict quarry activities and keep them out of Zone 1, given the absence of any groundwater quality effects compared to other effects that are allowed

to occur from permitted activities that allow nitrates and microbiological contaminants to enter the aquifer.

3.15 It is fair to say that Road Metals framed their consent application in a very conservative manner, including:

- limiting their excavation to a depth that is above the highest groundwater level;
- no backfilling with wastes;
- covering the floor of the completed pit with silt, topsoil and limiting the future use to low intensity grazing with stock.

However, the key point of this decision on the Road Metals consent application is that it demonstrates that an expansion of quarry areas can occur into Zone 1 with appropriate controls via consent conditions that create an acceptably low level of risk with regard to groundwater quality issues.

4.0 Proposed Changes to Variation 6

4.1 Evidence on the proposed changes that are required to Variation 6 are presented in the evidence of Ms Kim Seaton. The comments in this section of my evidence are of a general nature based on my technical understanding of the groundwater system and the contamination risks that occur.

4.2 As a general comment, much of the currently proposed Variation 6 could be acceptable if an over-riding definition was provided to explain that all references to groundwater refer to groundwater that is drawn into the Christchurch City Council water supply as opposed to groundwater at any location.

4.3 Even with that over-riding definition, there is still a change needed from the emphasis on preventing or avoiding the risk of any effects on groundwater quality, which is present in the Officer's version of the text, and could be used to prevent some activities occurring that in

reality could take place with appropriate management measures and create minimal risk of adverse groundwater effects.

4.4 Specific comments on some of the inappropriate wording used in the Officer's proposed version of Variation 6 in relation to quarrying (Part 6 of the Officer's report) includes the following:

- references to "inert waste" such as Policy WQL8(1)(a) (page 10), Policy WQL13(11)(f) (page 40) and repeated in other clauses of Policies WQL14-19. It would be better to refer to "cleanfill as described in the Christchurch City Cleanfill Licensing Bylaw 2008" so as to allow consistent regulatory control of this activity between the territorial and regional authorities;

- Policy WQL13-WQL19 all use similar phrases which could be used to significantly restrict activities such as:

  - "the risk of contamination of groundwater" as opposed to the likelihood of contamination actually occurring. For example, as discussed in paragraph 3.2, the excavation of a gravel pit increases the risk of contamination, but the activity can be managed to limit the likelihood of any potential contamination occurring (as I have discussed in Part 3 of this evidence);

  - references to "groundwater" in general, as opposed to the Christchurch City groundwater supply;

  - references to "avoiding" and "preventing" activities as opposed to using best practicable management practices to minimise the increase in risk;

  - Policy WQL13(6)(a) requires no aggregation of large quantities of hazardous substances on a site, which on the face of it means no more than one storage tank on any site. That is a potentially very restrictive and unreasonable requirement. Furthermore, the use of new larger storage tanks is often a lower risk scenario than maintaining larger numbers of smaller older tanks, which have more frequent filling requirements. The management and installation of

such tanks to store these substances is well controlled and regulated through HSNO controls and industry codes of practice (e.g. the Department of Labour/OSH, Code of Practice for the Design, Installation and Operation of Underground Petroleum Storage Systems). Therefore clause (a) should be deleted and clause (b) should become part of the main wording of clause 6.

- also on page 40 (Part 6 of the Officer's report), Policy WQL13(11) deals with quarrying and includes the following points for which changes should be considered:

  - The intention of clause 11 is to provide guidance on how mineral excavation activities can occur, yet the requirement in clause (a) to maintain a thickness of strata between the bottom of the pit and the highest groundwater level, "to avoid any increased risk of contaminants directly or indirectly entering groundwater" appears on the face of it to be a requirement to prevent any quarrying occurring. As noted earlier in paragraph 3.2 of my evidence, quarrying does increase the risk of contamination, so a policy to provide guidance on quarrying should not deny that reality. It should promote good management to ensure that the risk is minimal as is the case with the currently operating quarries.

  - Clause (a) is very loosely defined and requires measures that would only be appropriate for more significant contaminant sources that have not occurred in the currently operating quarries. For example, impermeable liners and containment bunds are associated with waste disposal facilities, which could not be allowed to occur under clause 11(e). Therefore, on the basis of this point and the preceding bullet point clause (a) should be deleted;

  - Similarly, clause (b) is inconsistent with the activity of quarrying. Machinery is powered by hydrocarbons and if machinery is in a pit it must increase the risk of hydrocarbons entering land as compared to no machinery at all, regardless of how minuscule the risk is. The only way to avoid increasing

risk is to not use machinery. It is therefore not possible to quarry in a manner that is consistent with this clause. Given that the intention of clause 11 is to provide guidance on quarry developments, part (b) needs to be reworded in a manner that is consistent with the quarrying activity.

- As noted earlier, the reference to cleanfill in clause (e) might be better referenced to the Christchurch City Cleanfill Licensing Bylaw 2008. With this definition in clause (e) then any reference to the type of fill material in clause (f) becomes redundant and should be deleted to avoid unnecessary confusion.

- Clause (g) should replace the phrase "avoid any increased risk" would be better replaced with the words, "must be managed to minimise the risk"

Similar wording is repeated in clauses within Policy WQL14-19;

- Rule WQLYY on page 97 (Part 6 of the Officer's report) increases consenting requirements for storage of hazardous substances, which is perhaps unnecessary as these are already well regulated by the City Plan, HSNO regulations and the Industry Code of Practice. In particular, the following comments should be considered:

  - the discrepancy criteria for stock reconciliation should be "25 litres or 0.5 percent, whichever is larger", as this is the industry standard and my understanding is that detections of less than an accuracy of 0.5% are unachievable. The Code of Practice for the Design, Installation and Operation of Underground Petroleum Storage Systems, Supplement No. 1, Management of Existing Underground Petroleum Storage Systems (1995) requires that if the trend from stock reconciliation "indicates that losses are consistently in excess of 0.5 percent you must investigate further". Therefore, the current Variation 6 requirement of a 25 litre tolerance for tanks greater than 5,000 L is unachievable;

  - the references to aggregate quantities within a site is perhaps unhelpful and would make many fuel storage tanks a

non-complying activity. That is inconsistent with the enabling intention of Zone 1B and is unhelpful to the operation of well managed activities in other areas;

- it would seem more helpful for this rule to classify the use of land to store or use a specified hazardous substance as a Controlled Activity, provided that it complies with Schedule WQL5. If it does not meet that standard it could be Discretionary.

4.5 From my review of Part 6 of the Officer's report, which is their updated wording of Variation 6, it appears that the same Rules apply to Zones 1, 1A, 1B, 1C and 1D. My understanding of the intention of creating Zones 1A, 1B, 1C and 1D was to enable existing authorised land uses to occur. However, if all the same rules apply, it is difficult to see how those land uses are enabled. Rule WQLYY is an example of where a more relaxed requirement (Controlled Activity) could apply in Zones 1B, 1C and 1D.

4.6 Furthermore, given the lack of adverse effects from quarries to date and the Environment Court decision C163/2006, Variation 6 should be more accommodating of the possibility of allowing some quarry activity in the other Christchurch groundwater zone areas beyond Zone 1B. In this regard the general tone of the "Explanation and principal reasons" following the policies still emphasises the high vulnerability of the aquifer and the dire consequences that will result unless development is avoided or prevented, which based on my review of the existing information appears to be an unsubstantiated viewpoint.

4.7 With regard to quarrying, as a general overview comment, it would be appropriate to consider policies and rules that might include the following measures:

- from a groundwater perspective, the enabling of well managed quarries should not be restricted only to Zone 1B. Based on the Environment Court decision described in paragraphs 3.11-3.15 of my evidence, it is acceptable for quarrying to occur in the area defined as Zone 1. However, I agree with the comments in

paragraph 50 of Mr Hanson's evidence that most contaminants are unlikely to travel more than 1 km. It is important to recognise that the NRRP already provides protection for such a situation by defining special management areas called Community Drinking Water Supply Protection Zones, which extend 1 km upgradient of community drinking water supply wells that are less than 30 m deep and 500 m upgradient of wells that are 30-70 m deep, which represents the high risk zone for such wells;

- despite the preceding point, it is still appropriate to have a policy related to the existing quarry zone for consistency with the Territorial Authority, and to have policies that refer to how quarrying should be carried out within the Christchurch Aquifer area;

- quarry activities should be required to prepare a management plan that describes how the quarrying and gravel processing activities will be carried out in a manner that is controlled and monitored in such a way as to minimise the risk of contaminants adversely affecting groundwater quality. The management plan would contain the type of measures that are described in the evidence of Mr Murray Francis;

- it would be appropriate for any backfilling of gravel pits to be limited to cleanfill, as defined in the CCC 2008 bylaw, or any other material that does not cause a detectable change in the quality of water supply bores downgradient of the site boundary;

- the long-term land use of quarry pits could appropriately be considered as part of the consenting process for the quarry.

- monitoring of groundwater quality on the upstream and downstream boundaries of the quarry should be undertaken to check on any changes in groundwater quality that occur.

5.0 Conclusion

5.1 The Christchurch aquifer system is highly valued as a water supply source for Christchurch City. It is appropriate for the Natural Resources Regional Plan to have a special Objective and associated Policies and Rules to protect the quality of that water supply.

5.2 The Objectives, Policies and Rules must be reasonably based on the realistic effects on groundwater quality that arise from land use and discharge activities.

5.3 The Officer's report provides a generalised view of the potential risk arising from contaminant sources in the aquifer recharge area and concludes that existing land use must be significantly restricted and any intensification of land use must be prohibited.

5.4 Such a view is not consistent with the evidence from several decades of quarrying activities in the Zone 1B areas that have not caused any adverse effects on the water supply.

5.5 An objective assessment of existing groundwater quality and land use effects indicates that further development can occur, provided that it is well managed, without jeopardising the quality of the Christchurch water supply.

5.6 This includes the development of further quarry areas, which can include measures to minimise contamination risks by:

- management of the quarrying activity;
- controlling any backfilling that occurs;
- controlling the long-term use of the pit area.