in the matter of: the Resource Management Act 1991

and

in the matter of: an application by the Central Plains Water Trust to take water from the Rakaia and Waimakariri Rivers

and applications by the Central Plains Water Trust to use water from the Waimakariri and Rakaia Rivers and for all associated consents required for the construction and operation of the Central Plains Water Enhancement Scheme

in the matter of: a Notice of Requirement by Central Plains Water Limited to the Selwyn District Council for the designation of land for works associated with the construction and operation of the Central Plains Water Enhancement Scheme

Brief of evidence of James Arthur Renwick

Dated: 1 August 2008

Chapman Tripp *Barristers & Solicitors*

119 Armagh St Tel +64 3 353 4130
PO Box 2510 Fax +64 3 365 4587
Christchurch NZ DX WP21035

Reference: JM Appleyard (jo.appleyard@chapmantripp.com)
BG Williams (ben.williams@chapmantripp.com)

BRIEF OF EVIDENCE OF JAMES ARTHUR RENWICK

Introduction

1 My full name is James Arthur Renwick.

2 I am employed as the Science Leader for Climate Variability and Change research at NIWA (National Institute of Water and Atmospheric research). I have a BSc (Honours) in mathematics from Canterbury University, MSc in statistics from Victoria University of Wellington, and PhD in Atmospheric Sciences from the University of Washington, Seattle, USA.

3 I am a member of the Meteorological Society of New Zealand, the New Zealand Association of Scientists, the Royal Society of New Zealand, the American Meteorological Society, and the American Geophysical Union. I have around 30 years' experience in weather and climate research, both at the Meteorological Service of New Zealand and at NIWA. I have 48 relevant publications in the refereed scientific literature, and have written a similar number of related user-specific reports.

4 My present role involves scientific research, advice to government agencies and industry groups on climate variability and change, liaison within national and international scientific communities, development and management of major research programmes, and development of science strategy within NIWA. I was a lead author for Chapter 3 of Working Group I of the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report, and the subsequent IPCC Technical Paper on Climate Change and Water.

5 I was the 2005 Recipient of the Edward Kidson Medal of the Meteorological Society of New Zealand, and was a co-recipient of the 2007 Nobel Peace Prize.

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

Scope of evidence

7 In this evidence I outline:

7.1 A description of fog, including what is it, how it forms and dissipates, different kinds of fog, and forecasting fog occurrence;

7.2 a discussion of the location and climate of the CIAL and the influences on the weather and climate of the CIAL in terms of orography and large-scale atmospheric conditions;

7.3 the occurrence of fog at CIAL;

7.4 a discussion of how the proposed CPW scheme might affect fog occurrence at CIAL, including:

(a) the intended area for the CPW scheme, in relation to the CIAL and the possibility of an increase in the amount of water and irrigation in the area;

(b) an increased frequency in high water levels in Lake Ellesmere and other lowland water bodies in Canterbury, and increased soil moisture and surface wetness;

(c) interactions between local meteorological and land surface conditions and larger-scale wind flows across the Canterbury Plains, and from the south.

7.5 A summary overview of the likely effects of the Central Plains Water (*CPW*) scheme on fog and atmospheric conditions associated with the operation of Christchurch International Airport Limited (*CIAL*) based on the above.

Fog and fog occurrence

8 Fog is essentially cloud formed at ground level. Meteorologically, a fog is defined as a cloud which envelops the observer at the ground and reduces visibility to one kilometre or less. Fog conditions which reduce visibility to greater than one kilometre are usually termed "mist" or "thin fog".

9 Fogs form when air near the ground reaches saturation point and the water vapour in the air condenses into cloud droplets. Water vapour condenses onto condensation nuclei present in the air, tiny particles of dust, soil, organic matter, salt etc. For condensation to occur, the air must either be cooled to saturation point, or the moisture content of

the air must be raised to the saturation point, or some combination of the two effects. There are two main processes that lead to fog formation.

10 The first process is radiation fog. On clear nights, emission of infrared radiation from the ground cools the ground surface in relation to the air above it. In the absence of downward turbulent heat flux (i.e. in light-wind conditions), a shallow cold layer ("temperature inversion") forms near the ground. The relative humidity of the air in the inversion layer will rise, provided the rate of temperature decrease exceeds the rate of moisture loss through dew deposition. If saturation (100% relative humidity) is reached, condensation occurs and a fog forms. As cooling continues, the fog deepens as the temperature inversion rises, since once a fog has formed, the level of maximum cooling moves to the top of the fog layer.

11 The second process is advection fog. Advection fog is formed when relatively warm moist air moves (is advected) over a colder (and possibly moist) surface, thereby cooling the air to saturation. Typically, such fogs are formed when moist maritime air moves over a cold landmass, or lake or ocean surface.

12 Turbulent mixing near ground level may lead to the formation of a low cloud layer, rather than a fog, since the mixing will act to dry the very lowest layers of the air. Air that is relatively dry to begin with may deposit dew as it cools, but may not support the formation of fog. Hence, the formation of fog depends sensitively upon the initial moisture content of the air, the moisture content of the underlying surface, ambient wind and turbulence conditions, and cloud cover.

13 Once a fog has formed, it may itself be advected, in relatively light wind conditions. This typically occurs when moist air passes over a cold surface. Fog forms, and as the air continues to flow, the fog moves with the ambient flow. A striking example is the fogs that sometimes affect Wellington Airport, where moist subtropical air moves over the cold waters of Cook Strait in a light south-easterly air flow. Fog forms over Cook Strait and is advected northwards through the harbour entrance and over the airport area.

14 Prediction of fog occurrence remains a difficult forecasting problem. As described in paragraph 5.4, correct prediction of fog requires accurate specification and prediction of micro-scale turbulence, atmospheric moisture content, cloud cover and so on. The advent in recent years of very high-resolution weather prediction models has improved the success rate of fog predictions, but forecast skill remains low.

Climate of Christchurch and CIAL

15 Elements of the following are based upon previous studies of the climate of Christchurch (Renwick 1989, 1997), climatological information (e.g. N.Z. Meteorological Service 1983), and information from the general scientific literature (Bergot et al 2007, Maunder 1971, Sturman and Tapper 1996, Wratt et al 1996):

15.1 The South Island lies in the middle latitudes of the Southern Hemisphere (41° to 47°S), and CIAL is situated at 43.5°S on the eastern coast, approximately 100km east of the Southern Alps. The climate is affected all year round by the band of Southern Hemisphere mid-latitude westerly winds. Much of the weather is influenced by the passage of fronts and depressions in the westerlies, which cross New Zealand longitudes every 4-5 days at all times of year.

15.2 Year to year variability in New Zealand climate is influenced by the El Niño-Southern Oscillation (ENSO) phenomenon, and by the Interdecadal Pacific Oscillation (IPO). During an El Niño, New Zealand generally experiences enhanced southerly flow in winter and stronger than normal westerly winds in spring and summer. The La Niña phase generally results in weaker westerly winds, and an enhanced frequency of north-easterlies over much of the country. The positive phase of the IPO favours El Niño events (e.g. during 1977-2000) while the negative phase favours La Niña events (e.g. during 1945-1976, and since 2000).

15.3 The Southern Alps are aligned almost at right angles to the prevailing westerly wind flow and provide a significant barrier to that flow. Much of the regional detail in New Zealand climate comes from interactions between the large-scale atmospheric circulation and the rugged topography. The most notable effect is the east-west gradient in rainfall, ranging from several metres per year in Westland and the Alps, but only 600-700 mm on the Canterbury coast. The other key effect for CIAL is on the wind climate, leading to the predominance of near-surface north-easterly winds with occasional episodes of warm and often gusty north-westerly conditions.

15.4 Calm conditions occur at CIAL 15% of the time on average, being most common in the early morning in winter (calm 28% of the time). Overnight, in relatively light-wind situations, the surface wind at CIAL is often a light north-westerly, which is a drainage flow of cool and relatively dense air flowing down the

Canterbury Plains towards the coast. Such drainage flows can occur at any time of year, but are most common in winter.

Fog at CIAL

16 The following is based largely upon the study carried out by Renwick (1989):

16.1 Based on hourly observations from CIAL, fog (visibility 1km or less) occurs 1.4% of the time, while mist (fog, but with visibility greater than 1km) occurs on another 3.2% of occasions, with a total occurrence rate of 4.6%. For New Zealand aerodromes, this is a relatively high occurrence rate. Fogs typically occur in the hours just before sunrise, and a typical fog event lasts for 2-3 hours.

16.2 Fog events are most common in late autumn-winter (May-August), and are least common in summer (November-January). On average, fog is observed at CIAL on six days per month from May to August, but on only two days per month from November to January.

16.3 Fog occurs at CIAL most commonly (around half of all cases) as radiation fog, on clear calm nights. Sea fog (advection fog) can affect CIAL in persistent moist north-easterly wind flows (around 30% of cases). CIAL can also be affected by advection fog where the fog forms over Lake Ellesmere and is advected over the airport in light southerly or south-westerly wind flows (around 15% of cases).

16.4 Fogs tend to form just before dawn, as this is when radiational cooling of the land surface is at a maximum. Fogs tend to dissipate shortly after sunrise, as solar heating results in turbulent mixing and warming of the lowest layers of the air.

16.5 Fog events at CIAL lasting more than 6 hours are rare. Long-lasting events often begin as radiation fogs formed in situ, but prolonged by advection of fog from elsewhere (most often Lake Ellesmere or from off the Canterbury coast).

CPW and fog occurrence at CIAL

17 The following is written in consideration of the planned extent of CPW, and upon information provided in respect of the likely outline area for the scheme:

17.1 Irrigation on a scale planned by CPW on land immediately to the west of the airport would raise average soil moisture levels in the regions irrigated, and would raise ground water levels over a broad area extending to the western outskirts of Christchurch City (including CIAL). This would lead to increases in near-surface relative humidity over the irrigated regions, and would therefore lead to increased risk of radiation fog formation on cool clear nights.

17.2 As noted above in paragraph 15.4, light westerly or north-westerly wind conditions are common across the Canterbury plains at night, especially in winter. Should fog form over irrigated land adjacent and to the west of the airport, it is my opinion that there is a significant risk of a westerly drainage flow carrying fog over the runways at CIAL.

17.3 As a consequence of an increase in the incidence of more regular high lake levels in Lake Ellesmere, more water in lowland streams or other water bodies, and the possibility of extant pits becoming at least partly fill with water, it is my opinion that this would increase the risk of CIAL being affected by advection fogs, notably in light south-westerly air flows, where the source of the fog is Lake Ellesmere or the land adjacent to the lake.

17.4 Moreover, should soil moisture and ground water levels increase significantly in the immediate vicinity of CIAL runways, there would in my opinion be an increased risk of radiation fog forming *in situ* at CIAL. This would also extend to any surface water conveyance or storage structures in the vicinity of CIAL.

17.5 Should the CPW go ahead and should fog occurrence at the airport increase, it may be necessary to either:

(a) require remedial action such as a ban on irrigation within a certain radius of the airport in certain meteorological conditions to allow aircraft operations to continue uninterrupted; or

(b) to consider the upgrade of CIAL's existing instrument landing system to a level that would allow it to operate in fog conditions.

Conclusions

18 Fog occurs at CIAL most commonly through radiation cooling, but also by advection of fog from areas adjacent to the airport.

19 Irrigation of land adjacent to, and to the west of CIAL would increase soil moisture and surface wetness, and would raise ground water levels over a wide area to the west and south-west of the airport, and possibly in the vicinity of the airport itself.

20 These factors would increase the risk of fog formation in the vicinity of CIAL, leading to an increased risk of fog being advected over CIAL in light westerly or south-westerly air flow conditions. Should surface wetness increase at CIAL itself, the risk of radiation fog forming *in situ* at CIAL would also increase.

Dated: 1 August 2008

____

James Arthur Renwick

References Bergot, T., E. Terradellas, J. Cuxart, A. Mira, O. Liechti, M. Mueller, and N. W. Nielsen, 2007: Intercomparison of Single-Column Numerical Models for the Prediction of Radiation Fog. *Journal of Applied Meteorology and Climatology*, 46**,** 504-521. Maunder, W. J., 1971: The climate of New Zealand - physical and dynamic features. *World Survey of Climatology*, J. Gentilli, Ed., Elsevier, 213-227. New Zealand Meteorological Service, 1983: *Summaries of Climatological Observations to 1980*. N.Z. Meteorological Service Misc. Pub. 177, 172pp. Renwick, J.A., 1989: *Short-range prediction of fog occurrence at Christchurch aerodrome*. Unpublished MSc thesis, Statistics and Operations Research Department, Victoria University, Wellington, 93 pp. Renwick, J. A., 1997: *A climatology of northwest winds at Christchurch airport*. Report prepared for Christchurch International Airport Ltd., NIWA Report WLG97/56, 25 pp. Sturman, A. P., and N. J. Tapper, 1996: *The Weather and Climate of Australia and New Zealand.* Oxford University Press, 476 pp. Wratt, D.S. et al., 1996: The New Zealand Southern Alps Experiment. *Bulletin of the American Meteorological Society*, 77, 683-692.