

TABLED AT HEARING
Date 21/4/2010

IN THE MATTER

of the Resource Management
Act 1991

AND

IN THE MATTER

Resource consent applications
lodged for the water take
consents in relation to the
Waitaki Basin of the Resource
Management Act 1991

STATEMENT OF EVIDENCE OF DAVID ANTHONY HORN

1. INTRODUCTION

1.1 My full name is David Anthony Horn.

1.2 I am a Chartered Professional Engineer with over 20 years of professional experience in environmental engineering research and practice. I have a Bachelor of Engineering with first class honours (1985) and PhD in Environmental Fluid Mechanics (2000) from the University of Western Australia.

1.3 For the period 1998-2002 I was Manager of Contract Research at the Centre for Water Research at the University of Western Australia. The Centre for Water Research (CWR) is a multi-disciplinary scientific research and teaching organisation located at The University of Western Australia. CWR carries out applied research for clients on a commercial basis and develops and distributes a range of hydrodynamic and ecological computer models. I was responsible for the overall operation the group, including the development of the numerical models ELCOM and CAEDYM, which are the models used by NIWA to assist with the assessment of nutrient loadings in Lake Benmore (Norton et al., 2009). While at CWR I was involved in the application of these models to investigate water quality and develop management strategies in many lakes and reservoirs in Australia and other countries.

- 1.4 Since 2004 I have held positions with the consulting firm GHD Pty Ltd (GHD) in Perth, where I am currently Business Group Manager, Environment. At GHD I provide specialist technical advice on the investigation and management of environmental water quality.
- 1.5 I attach a full CV at **Appendix A**.
- 1.6 I confirm that the evidence has been prepared in accordance with, and that I agree to comply with, the Code of Conduct for expert witnesses (Consolidated Practice Note 2006).
- 1.7 I have not visited Benmore Lake and am not familiar with the lake or its catchment. My evidence is based on a review of the reports provided to me.

Scope of Evidence

- 1.8 I was requested to review evidence presented in relation to the following specific issues:
- the mixing between the Ahuriri Arm and the Northern Arm of Lake Benmore;
 - localised effects at the river mouth of the Halden Arm; and
 - the residence times for the lake.
- 1.9 In preparing this evidence I have reviewed:
- Norton, N., Spigel, B., Sutherland, D., Trolle, D and Plew, D. (2009). Lake Benmore Water Quality: a modelling method to assist with assessments of nutrient loadings. Report prepared for Environment Canterbury, August 2009.
 - GHD (2009). Cumulative Water Quality Effects of Nutrients from Agricultural Intensification in the Upper Waitaki Basin – Rivers and Lake Report, August 2009. Report prepared for Mackenzie Water Research Ltd (MWRL), August 2009.
 - The evidence of Donna Sutherland, 16 September 2009;
 - The evidence of Dr Marc Schallenberg, 21 September 2009;

- The evidence of Dr Nimal Priyantha Dodampe Gamage, 6 November 2009;
- The addendum evidence of Donna Sutherland, 30 November 2009; and
- The evidence of Dr Robert Spigel, 11 December 2009.

2. RESPONSE TO ISSUES

Mixing of Northern and Ahuriri Arms

- 2.1 In her evidence and addendum evidence, **Donna Sutherland** raises concern that *“at present the lower nutrient waters of the Haldon Arm provided a level of protection to the Ahuriri Arm. As nutrients increase in the Haldon Arm, under land-use intensification, the level of protection that the Haldon Armwater exchange offers the Ahuriri Arm will be diminished.”* (para 25, Addendum evidence dated 30th November).
- 2.2 In his Section 41C Report, **Dr Bob Spigel** noted that the ELCOM simulations showed the exchange between the two arms of the lake. He noted that the relative temperature of the waters of the Ahuriri and Haldon arms caused:
- the cold underflow of the Ahuriri River water in winter all the way to the dam;
 - the overflow of the Ohau C water into the Ahuriri Arm in winter;
 - the interflow of Ohau C water into the Ahuriri Arm in summer;
 - the much weaker penetration of the Ahuriri River water into the Haldon Arm.
- 2.3 In her evidence **Donna Sutherland** referred also to a simulation by the hydrodynamic model ELCOM (Figure 2 in her evidence dated 16th September 2009) to demonstrate the extensive water exchange that occurs between the Ahuriri and Haldon Arms of Lake Benmore.

- 2.4 I have reviewed the ELCOM animations presented to the Commission by **Dr Bob Spigel** and the figure included in the evidence of **Donna Sutherland** (Figure 2 in her evidence dated 16th September 2009 and included below as Figure 1 for easy reference). The upper panel of that figure clearly shows the Ohau C water arriving at the confluence of the two arms as an intrusion at a depth of 10-15 m below the surface. The intrusion moves up the Ahuriri Arm until it intersects the bottom boundary in the vicinity of the Neck. There is evidence of some vertical mixing of the Ohau C water with the surface waters in Ahuriri Arm. The lower panel confirms this picture, showing the dilution of the Ahuriri tracer by the Ohau C water.

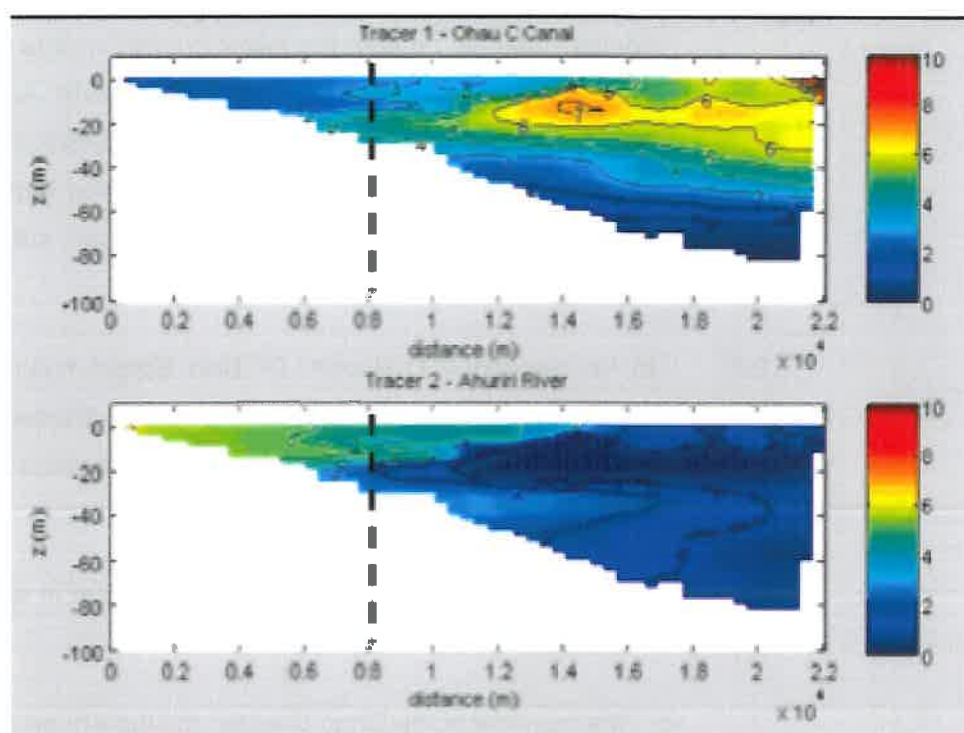


Figure 1 A transect through the Ahuriri Arm from the Ahuriri River delta (left hand side) to Benmore Dam showing water exchange between the two arms (Figure 2 in the evidence of **Donna Sutherland** dated 16th September).

- 2.5 It is my opinion that the ELCOM simulations confirm that the Ohau C water intrudes into and dilutes the water of the Ahuriri Arm.
- 2.6 Since the source of the Ohau C Canal water is upstream of the majority of the proposed irrigation areas, its nutrient concentration is not expected to significantly increase under any of the development scenarios (Norton et al., 2009). Thus the exchange of the Ohau C water with the Ahuriri Arm will continue to dilute the water of the Ahuriri

Arm, mitigating the potential impact of future increased nutrient concentrations in the inflows to the Ahuriri Arm.

Mixing of Northern Arm (1km area below Ohau C Canal)

- 2.7 The evidence of **Donna Sutherland** raises concerns that the water from the Ohau C Canal does not appear to mix with the inflows of the Tekapo-Pukaki and Ohau Rivers in the 1 km² region near the river mouths. Donna Sutherland expressed concerns that, since the nutrient concentrations in the Tekapo-Pukaki Rivers are expected to increase under most development scenarios, this poor mixing could lead to algal blooms in this region. Two photographs were presented to support this concern: Plate 2 in the evidence of **Donna Sutherland** dated 16th September and Plate 1 in the dated 30th November (Plate 1 from the Addendum is included below for easy reference as Figure 2).



*Figure 2 Aerial photograph showing the distinct inflows from the the Ohau C Canal, lower Ohau River and Tekapo-Pukaki River (Plate 1 from the Addendum to evidence of **Donna Sutherland** dated 30th November 2009)*

- 2.8 The photographs clearly show the distinct waters of the Ohau C Canal, the lower Ohau River and the Tekapo-Pukaki Rivers. The images show the momentum of the canal and rivers carrying their respective inflows into the lake, pushing the lake water ahead of it. As the inflow slows, spreading out, it starts to feel the influence of the buoyancy difference caused by the temperature difference between the inflow and the lake water. During the summer, the temperature of the Ohau C canal water and the other rivers is expected to be several degrees cooler than the surface layer of Lake Benmore. This causes the inflow to sink below the surface water of the lake as a subsurface intrusion. The ELCOM simulation presented by **Donna Sutherland** clearly shows the Ohau C water intrusion as far as the confluence of the Haldon Arm with the Ahuriri Arm.
- 2.9 Using some standard equations (Fischer et al., 1979¹) and some assumptions regarding the inflow characteristics of the Ohau C Canal and the Tekapo-Pukaki River, I have estimated the distance into the lake that these inflows would be expected to travel before plunging below the surface. Assuming a temperature difference of 1°C between the inflow and the surface of the lake the Ohau C Canal inflow would travel approximately 2 km before plunging while the Tekapo-Pukaki River inflow would only travel approximately 500 m. For greater temperature differences the plunge lines would be closer to the shore.
- 2.10 In my opinion, these calculations, the figures from the ELCOM simulation and the photographs presented by **Donna Sutherland** all indicate the inflows do not initially mix in the 1 km² region where they enter the Haldon Arm but intrude into the lake where they are subsequently mixed.
- 2.11 Although agreeing that waters from the Ohau C Canal and Tekapo-Pukaki Rivers do not mix in the 1 km² region near the river mouths, in my opinion this does not mean that this region is not well flushed nor

¹ The following equation, used to estimate the location of the plunge point of the Ohau C Canal and Pukaki River is based on Eq. 6.114 in Fischer et al. (1979), but corrected to make

the units consistent:
$$h_0 = \left\{ \frac{2Q^2 \rho_0}{Fr^2 \Delta \rho_0 g \tan^2 \alpha} \right\}^{1/5}$$

that the region near the mouth of the Tekapo-Pukaki River is at risk from phytoplankton blooms.

- 2.12 The flushing timescales for the shallow region near the river mouths are very short. **Donna Sutherland** is concerned about the area of about 1 km² with an average depth of <2.5 m. Assuming the inflow from the Tekapo-Pukaki River is equivalent to the mean annual inflow (1.3 M m³/day based on an annual inflow of 470.6 M m³ (see Figure 9, GHD 2009)), the flushing timescale for that area is approximately 1.9 days. This is considerably shorter than the timescales associated with phytoplankton blooms.

Calculation of residence times for Lake Benmore

- 2.13 I have reviewed the Lake Benmore residence times presented to by **Dr Nimal Gamage** (para. 50) and agree with his calculations. The basis of the residence time calculation is presented in Table 1 below.

Table 1 Residence times

| | Volume (FSL-5 m) | Inflow (Mm ³ /day) | Residence time (days) |
|---------------|---------------------|----------------------------------|--------------------------|
| Haldon Arm | 162 | 3.36 | 48 |
| Ahuriri Arm | 994 | 26.9 | 37 |
| Lower Benmore | 360 | 30.2 | 12 |
| Whole lake | 1862 | 30.2 | 50 |

- 2.14 **Dr Nimal Gamage** bases his residence time calculations on a lake volume at 5 m below full supply level (FSL). The use of a water level 5 m below FSL is intended to represent the average operating level (and therefore average operating volume) of the lake. If the residence time calculation is based on a lake volume at FSL, the residence times increase by approximately 20%. For example increasing the overall residence time for Lake Benmore from 50 days to 62 days. However, this would represent a conservative estimate of the overall residence time of the lake when it is operating at lower water levels.

- 2.15 It is unclear whether the residence times calculated by NIWA (Norton et al., 2009, Section 6, page 52) are based on FSL.

3. CONCLUSIONS

- 3.1 From my examination of plots from the ELCOM simulation presented by **Donna Sutherland**, it is my opinion that the exchange between the Ahuriri and Haldon arms of Lake Benmore is driven by the intrusion of Ohau C Canal waters into the Ahuriri Arm. Since the water quality of the Ohau C Canal is relatively unaffected under any of the proposed development scenarios, the water from the Ohau C will continue to dilute the Ahuriri Arm, mitigating potential impacts from increasing nutrient concentration.
- 3.2 Based on my examination of the figures from the ELCOM simulation and the photographs presented by **Donna Sutherland**, together with my calculations of the location of plunge points for the Ohau C Canal and Tekapo-Pukaki River inflows, I agree that the waters from these inflows do not initially mix in the 1 km² region near the river mouths. In my opinion the inflows intrude into the lake where they are subsequently mixed. However, in my opinion the relatively high inflow rates of the Tekapo-Pukaki River will result in a flushing timescale of less than 2 days, much shorter than the timescale associated with the formation of phytoplankton blooms.
- 3.3 I have reviewed the calculations of residence time presented by **Dr Nimal Gamage** and agree with his estimates.

4. REFERENCES

- Fischer, H. B., List, E. J., Imberger, J., Brookes, N. H. (1979). *Mixing in Inland and Coastal Water*, Academic Press, San Diego.
- GHD (2009). *Cumulative Water Quality Effects of Nutrients from Agricultural Intensification on the Upper Waitaki Catchment – Rivers and Lakes Reoprt*. GHD Report 51/25986 prepared for Mackenzie Water Research Ltd, August 2009.

Norton, N., Spigel, B, Sutherland, D., Trolle, D. and Plew, D. (2009). *Lake Benmore Water Quality: a modelling method to assist with assessments of nutrient loadings*, NIWA Report CHC2009-091 prepared for Environment Canterbury.

Date: 21st April 2010

David Horn



Dr David Horn

Profession: Environmental Engineer
Qualifications: Bachelor of Engineering (Hons)
PhD (Environmental Fluid Dynamics)
Position in GHD: Business Group Manager - Environment



David Horn is a Chartered Professional Engineer with a PhD in Environmental Engineering. He has 19 years of professional experience in environmental and civil engineering and environmental engineering research. He has particular technical knowledge and experience related to the water and wastewater industry, the management of water quality in lakes, rivers and reservoirs, hydrodynamics and catchment management. David has previously held academic and research positions at the Centre for Water Research at the University of Western Australia.

Key Skills and Experience

- ▶ Water quality investigations and management in reservoirs, lakes and wetlands
- ▶ Salinity and catchment management
- ▶ Hydrodynamic and water quality modelling
- ▶ Urban water management
- ▶ Construction and Remediation project Management

Relevant Experience

Water quality investigations and management

- ▶ Leschenault and Busselton Drainage Masterplans. Preparation of drainage masterplans for improving water quality in the Leschenault and Busselton rural drainage districts. This project included the design of a demonstration site to evaluate water quality improvement techniques.
- ▶ Russell Road Buffer Lake. Preliminary Design of a constructed wetland to remove nutrients from urban stormwater.
- ▶ Bioretention Curtain Trial. Design and implementation of a trial bioretention trench to intercept and treat nutrient enriched groundwater before it discharges to a deep open drain.
- ▶ Hedges Gold Mine Downstream Discharge Treatment. Design of wetlands and passive treatment train to improve water quality of underdrainage discharge from the rehabilitated tailings dam.
- ▶ Rottnest Island Water Quality Monitoring. Monitoring groundwater and lake water quality in areas around the landfill site and wastewater treatment plant to ascertain the extent of groundwater contamination, the movement of groundwater, and the potential risk to Lake Herschel.
- ▶ Collie Power Station Saline Water Management. Assess the hydraulic capacity of the existing saline wastewater discharge system at Collie Power Station and determine the impact on power station blowdown of a range of potential water sources with varying water quality.
- ▶ A review of National Water Policy Options, Australia. An independent study for Future Directions International Pty Ltd and resulting in publication of major report and articles.
- ▶ Kelian Equatorial Mining - Final Water System Predictions, Indonesia. An investigation of solute transport and mixing in final mining voids.



- ▶ Strategies for the Improvement of Water Quality in San Roque Reservoir, Argentina. The strategies developed included design of a destratification system aimed at reducing the frequency and duration of potentially toxic blue-green algal blooms and long-term catchment management strategies.
- ▶ Lake Maracaibo Remediation Study, Venezuela. Field and modelling investigation of the environmental condition of the Lake and recommendations on appropriate remediation measures.
- ▶ Field data and modelling study of water quality in Mundaring Weir, Australia. Collection and interpretation of field data and use of 1D modelling of alternative operating strategies for the reservoir and for the design of a new offtake structure.
- ▶ Quantification of the Nutrient and Metal Budget in North Pine Dam, Australia. Investigation of processes that determine nutrient and metal concentrations in the dam and an assessment of relative contributions of sources of nutrients and metals.
- ▶ Limnological study of Lake Burragarang Cryptosporidium incidents, Australia. Investigation of the mixing and transport processes in Lake Burragarang during the period of the Cryptosporium/Giardia alert in spring 1998
- ▶ Optimisation of salt production in the Shark Bay solar salt field, Australia. The development of a numerical model to describe the physical and biological processes of the Useless Loop solar salt fields.

Salinity and catchment management

- ▶ Collie River Salinity Recovery Plan. Develop feasibility level designs, cost estimates and implementation plans for management options for the Collie Recovery Catchment. Short-term options involve diversion of saline flows from the Collie River into adjacent mining voids and then discharge to the Indian Ocean.
- ▶ Seagroatt Reserve - Engineering Management Options. The project involved developing conceptual designs for a range of engineering options for mitigating the impacts of salinity and on Seagroatt Nature Reserve, an assessment of the engineering feasibility, economic cost-benefit and environmental impact of each option and recommendations for implementation of the preferred option.

Hydrodynamic and water quality modelling

- ▶ Capel River Saline Intrusion. Prediction of the tidal and seasonal movement of the salt wedge up the Capel River if the existing Stirling Estate Weir is removed.
- ▶ Modelling study of ALCOA Wagerup ponds, Australia. An investigation of mixing of the ROWS pond at the Wagerup alumina refinery and potential links with odour.
- ▶ Brisbane River pathogen modelling, Australia. Developing a pathogen module for coupling to an existing hydrodynamic and water quality model of the Brisbane River, to be used for managing risks from wastewater treatment plant discharges.
- ▶ Two-dimensional modelling of Point Duoro, Australia. Hydrodynamic modelling of the mouth of the Collie River to investigate the potential impacts of a proposed development on the samphire flats at Point Duoro.



- ▶ One-dimensional modelling of Lake Samsonvale, Australia. Use of one-dimensional water quality model DYRESM-CAEDYM to optimise the operation of a bubble-plume destratifier used to control blue-green algae and metal concentrations.
- ▶ Hydrodynamic Modelling of Mundaring Weir, 2000, Australia. Preliminary assessment of the mixing in Mundaring Weir and the feasibility of a destratification system to increase dilution of the poor quality pump-back water.
- ▶ Nam Theun 2 Reservoir Water Quality Modelling Update, Laos. Modelling (ELCOM and DYRESM) of a number of operational scenarios and provision of advice on options to address some predicted water quality problems.
- ▶ Hydrodynamic and ecological model of Barbamarco Lagoon, Italy. An intensive field and 3D modelling study (ELCOM-CAEDYM) to develop strategies to increase the clam and mussel productivity of the lagoons of the Po River delta.
- ▶ Integrated Ecological Model of the Swan River Estuary, Australia. Catchment modelling (LASCAM) of very large agricultural and urban catchment and coupled 3D hydrodynamic-ecological modelling (ELCOM-CAEDYM) of the Swan-Canning Estuary to assess impact of catchment management options.
- ▶ Limnological Modelling Systems for Warragamba Dam. This project developed real-time monitoring and modelling systems for Sydney Catchment Authority.
- ▶ Feasibility study for modelling alumina residue ponds, Australia. An investigation of the feasibility of developing a numerical model of the hydrodynamic and biogeochemical processes in ALCOA Pinjarra residue lakes
- ▶ Hydrodynamic distributions of pathogen in lakes and reservoirs, Australia. This AWWARF funded research project developed techniques to help water utilities monitor and predict the distribution of pathogens in drinking water reservoirs.
- ▶ Lake Kinneret Water Quality Management System, Israel. The development and implementation of a scientifically based decision support system for the management of water quality in Lake Kinneret.

Urban water management

- ▶ Strategic Urban Drainage Planning. Development of an arterial drainage scheme for the Forrestdale Main Drain and the Peel Main Drain. These are substantial catchments in low-lying areas with rapid urbanisation.
- ▶ Design Standard for Non-potable Water Supply. Developing draft water quality and design guidelines for the provision of non-potable water in Western Australia for the Water Corporation.
- ▶ Integrated Water Management for Rural Towns. Development of preliminary designs and implementation plans for integrated water management in rural towns in the Avon River Basin. These plans are aimed at protecting community assets from the adverse impacts of salinity and rising groundwater.
- ▶ Developing BMPs for integrated urban water management in Perth. Chair of the technical reference group engaged by the Water Corporation to develop and test BMPs for urban water management.
- ▶ Kennedy Bay Integrated Water Management. Feasibility study for the incorporation of integrated urban water management into a new residential development.



- ▶ Pinjarra Light Industrial Area. Development of a drainage and nutrient management plan for a proposed light industrial area. The proposed development is in an area of shallow groundwater in the environmentally sensitive Peel-Harvey Estuary catchment and nutrient export from the site is a critical constraint.
- ▶ Alkimos Integrated Water Management study. This study examined the feasibility of adopting an integrated urban water management strategy for the provision of water and wastewater services to future urban areas to the north of Perth. included an investigation of the existing groundwater levels and groundwater quality and the groundwater dependent ecosystems. The potential environmental impact of a range of development, re-use and infiltration scenarios was then evaluated.
- ▶ Maddington-Kenwick Strategic Industrial Area. An engineering feasibility study of the development, including the development of drainage, groundwater and nutrient management strategy and an assessment of existing and future service infrastructure requirements.
- ▶ Pinjarra Rail Yard Drainage and Culvert. Catchment assessment and hydraulic analysis to size a new rail crossing over Tate Gully and detailed design of surface and subsoil drainage for the Pinjarra rail yard.

Construction and Remediation Project Management

- ▶ HMAS Stirling contamination event. An investigation of soil contamination due to a diesel spill near Building B17 at HMAS Stirling. The investigation included an assessment of nature and scale of the contamination, recommendations for remediation and ongoing monitoring and advice regarding compliance with Department of Environment reporting requirements.
- ▶ Eastbourne Gasworks Remediation. Project Manager (Site Agent) for a significant Design and Construct project for remediation of heavily contaminated former gasworks site. Required construction of perimeter slurry-membrane curtain wall to depths of 9m; removal of coal tar storage tanks; excavation and disposal of contaminated soil; import of clean fill and placement impermeable capping membrane.
- ▶ A31 Runfold Diversion: Project Manager (Site Agent) for a major road construction contract for Surrey County Council and consisting of 6km of dual 2-lane carriageway, 7 bridges and 467,000m³ gravel quarry. The site also included a NAMAS accredited soils and concrete testing laboratory.
- ▶ A3 Milford Bypass: Project Manager (Site Agent) for a major road construction contract for Surrey County Council and consisting of 3.5km of dual 2-lane carriageway, 3km of side roads, demolition and replacement of 3-span river bridge and construction of 3 other bridges.
- ▶ Ryde Seafront Development: Project Manager (Site Agent) for marine construction project for Ryde Borough Council and consisting of 2ha of land reclamation, breakwater and seawall construction for new small boat harbour, 4000m² hovercraft slipway and piled substructure for several buildings.

Nissan Development, Waterloo: Project Manager (Site Agent) for a Design & Construct project for a commercial and retail development for Nissan UK.

Qualifications and Affiliations

- ▶ Bachelor of Engineering (Hons) – University of Western Australia, 1985
- ▶ PhD (Environmental Fluid Dynamics) - University of Western Australia, 2000



- ▶ Chartered Professional Engineer
- ▶ National Professional Engineers Register (NPER) – Civil
- ▶ Member Institution of Engineers, Australia
- ▶ Member Australian Water Association

