Ex 40.

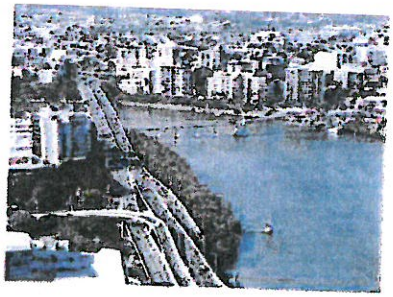
Air Noise Environment
Environmental Monitoring and Assessment

Hazelwood Mine Fire Inquiry -

Supplementary Statement of Ms Claire Richardson

30 May 2014





This document has been prepared and issued by Air Noise Environment Pty Ltd in accordance with our Quality Assurance procedures. Should you have any queries regarding the contents of this document, please contact your nearest Air Noise Environment office:

Brisbane Office

A: Unit 3, 4 Tombo Street,

Capalaba, QLD 4157

T: +61 7 3245 7808

E: qld@ane.com.au

Sydney Office

A: Level 6, 69 Reservoir Street

Surry Hills, NSW 2010

T: +61 2 9680 8599

E: nsw@ane.com.au

Townsville Office

A: Level 1, 25 Sturt Street,

Townsville, QLD 4810

T: +61 7 3245 7808

E: qld@ane.com.au

DOCUMENT CONTROL SHEET

Document Details

Project Reference:	3805
Document Title:	Hazelwood Mine Fire Inquiry
Author:	Claire Richardson BSc(Hons), MAAS
Document Reference:	/Network/Projects/3805/Reporting/3805 Supplementary Expert Report 30 May 2014.odt

Declaration

I, Claire Marie Richardson, confirm that

(i) I have received and read a copy of the Supreme Court (General Civil Procedure) Rules 2005 - Form 44A and agree to be bound by the Expert Witness Code of Conduct.

(ii) I understand that an expert witness is not an advocate for a party.

(iii) I have not been given or accepted to adopt or reject any particular opinion in preparing this report.

Furthermore, I, Claire Marie Richardson confirm that:

(i) The factual matters stated in the report are, as far as I know, true and correct;

(ii) I have made all enquiries that I consider desirable and appropriate with respect to the matters considered in this report;

(iii) I genuinely hold the opinions stated in this report; and

(iv) This report contains references to all matters that I consider relevant with respect to the matters considered in this report. Furthermore, there are no matters of significance which I believe to be relevant to matters considered in this report, that have been withheld from the Hazelwood Mine Fire Board of Inquiry.

Signature:

Claire Richardson

Date: 30 May 2014

Table of Contents

1 Matters Considered

1.1 Request from Hazelwood Mine Inquiry

1. The Hazelwood Mine Fire Inquiry, on 14 May 2014, requested a written report that addressed a series of specific questions raised by the Commission of Inquiry. On the 21st May 2014 the Commission of Inquiry requested a supplementary written report to address the following additional matters:

    - Item 1: The current Workplace Health and Safety exposure limits for substances emitted to atmosphere from the Hazelwood Fire.
    - Item 2: The appropriateness of the number and location of air monitors installed by the VIC EPA to determine the impacts of air emissions from the Hazelwood Fire.
    - Item 3: Is the current number of ambient air monitoring stations in the Latrobe Valley appropriate.
    - Item 4: Whether the thresholds adopted in the air quality alert protocol developed for the Hazelwood Mine Brown Coal Smoke are appropriate based on the current air quality research and standards, and how these compare to the threshold levels that have been adopted by other regulatory agencies in Australia and Overseas.

2. This statement presents my response and opinions with respect to Items 1 – 4 as requested by the Board of Inquiry.

1.2 Qualifications and Experience

3. My relevant qualifications and experience are as follows:

    - Bachelor of Science (Hons) from London University.
    - Post Graduate Diploma in Air Pollution Control (awarded by UK Royal Society of Health).
    - Post Graduate Diploma in Acoustics and Noise Control (awarded by UK Institute of Acoustics).
    - Member of the Clean Air Society of Australia and New Zealand since 1996, prior to that a Member of the UK Royal Society of Health and the UK Clean Air Society from 1989.
    - I have practised in the fields of Air Pollution and Acoustics since 1988. During this time I have completed an extensive range of air quality monitoring studies and assessments for a broad range of industries and operations in Australia and Europe. Since 1999 I have directed three research studies investigating particulate emissions from Australian open cut coal mines (PM_{10} and/or $PM_{2.5}$), and have also completed research into the risk of impacts associated with coal rail transport and the benefits of mitigation measures.

- I am currently the Principal Consultant of Air Noise Environment Pty Ltd, a Company I founded in 1998. Prior to that, I was employed as an Environmental Scientist by ERM (Australia and UK) and Travers Morgan (UK).
- Air Noise Environment holds NATA accreditation under ISO 17025 for the monitoring of a broad range of ambient air quality and air emissions, and is responsible for the operation of 5 continuous ambient air quality monitoring stations for the Airport Link Northern Busway Tunnel in Brisbane. I am approved under our NATA accredited Quality Assurance system for the review and issue of Ambient Air and Emission testing reports.

4. A copy of my curriculum vitae is presented in Appendix A.
5. My particular expertise in the air quality field relates to air quality monitoring and assessment against air quality criteria. Where this Statement makes reference to the potential health impacts of exposure to air quality and to health based air quality criteria, the commentary is based on review of published studies where epidemiological data has been reviewed, and conclusions drawn, by national and international health experts or teams of health experts.

2 Items 1 – Workplace Standards

- Item 1: The current Workplace Health and Safety exposure limits for substances emitted to atmosphere from the Hazelwood Fire.

2.1 Workplace Health and Safety Exposure Limits

6. Workplace air quality standards are defined in Australia by the National Occupational Health and Safety Council and Safe Work Australia[1,2,3].

7. Workplace exposure criteria are defined for a broad range of compounds that may be encountered in workplaces. The Safe Work Australia air quality exposure standards cover approximately 700 different compounds that may be encountered in the working environment. Hence, the scope of these standards is much broader than ambient air quality exposure guidelines and criteria.

8. Table 1 presents the current short term exposure level (15 minute STEL) and time weighted average exposure levels (8 hour TWA) for the key compounds that may have been emitted to atmosphere as a result of the Hazelwood Mine fire, and selected metals, VOC and PAH's. The equivalent ambient air quality goal, and air quality goal considered by the Victorian Environment Protection Authority (VIC EPA)[4] are also presented in Table 1.

9. Comparison of the occupational exposure thresholds indicates that the occupational exposure criteria are significantly higher than the criteria considered by the EPA and VIC Health during the Hazelwood Fire.

1 National Exposure Standards. NOHSC:1003 (1995). Exposure Standards for Atmospheric Contaminants in the Occupational Environment

2 Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants. Safe Work Australia 2012.

3 Workplace Exposure Standards for Airborne Contaminants. 22 December 2011. Safe Work Australia.

4 As detailed in Table 3 of the Statement of Paul Torre, May 2014 in the Matter of the Hazelwood Mine Fire Inquiry

Table 1: Occupational Exposure Criteria

Substance	8 hour Time Weighted Average (TWA)	15 minute Short Term Exposure Limit (STEL)	NEPM Air Toxics[5] /ADSTR[6]/TQEC[7]	NEPM AAQ[8]/SEPP AAQ[9]
Particulates	10 mg/m^3 for dusts not otherwise classified 0.1 mg/m^3 - crystalline silica as quartz	-	-	24 hours PM_{10}: 50 $\mu g/m^3$ 24 hours $PM_{2.5}$: 25 $\mu g/m^3$
Carbon Monoxide	30 ppm	Peak exposure thresholds: 15 minute average: 200 ppm 30 minutes average: 100 ppm 60 minutes average: 60 ppm		8 hour average: 9 ppm
Nitrogen Dioxide	3 ppm	5 ppm	-	0.12 ppm
Sulphur Dioxide	2 ppm	5 ppm	-	1 hour average: 0.2 ppm 24 hour average: 0.08 ppm Annual average: 0.02 ppm

5 National Environmental Protection (Air Toxics) Measure. 2004 as varied 2011.

6 United States Agency for Toxic Substances and Disease Registry.

7 US Texas Commission on Environmental Quality

8 National Environmental Protection (Ambient Air Quality) Measure 1998 as varied in 2003.

9 State Environmental Protection Policy (Ambient Air Quality), Victorian Government Gazette, 9 February 1999

Substance	8 hour Time Weighted Average (TWA)	15 minute Short Term Exposure Limit (STEL)	NEPM Air Toxics /ADSTR/TQEC μg/m³	NEPM AAQ/SEPP AAQ
Metals: Magnesium	10 mg/m³ (as magnesium oxide)	-	95 ppb 24 hour average	
Metals: Manganese	1 mg/m³ (as manganese dust or manganese fume)	-	3.8 ppb 24 hour average	
Metals: Mercury	0.003 ppm (elemental vapour)	-	0.5 ppb 24 hour average	
Metals: Zinc	10 mg/m³ (as zinc oxide dust) 5 mg/m³ (as zinc oxide fume)	-	38 ppb 24 hour average	
PAH: as Benzo-a-pyrene	-	-	0.03 μg/m³ annual average	
PAH: Napthalene	10 ppm	15 ppm	4.3 ppb 24 hour average	
VOC: Ethyl benzene	100 ppm	125 ppm	230 ppb 24 hour average	
VOC: Formaldehyde	1 ppm	2 ppm	40 ppb 24 hour average	
VOC: Benzene	1 ppm	-	9 ppb 24 hour average 3 ppb annual average	
VOC: 1,3 Butadiene	10 ppm	-	145 ppb 24 hours	
VOC: Propene	-	-	232 ppb 24 hour average	

Substance	8 hour Time Weighted Average (TWA)	15 minute Short Term Exposure Limit (STEL)	NEPM Air Toxics /ADSTR/TQEC	NEPM AAQ/SEPP AAQ
VOC: Chloromethane (methly chloride)	50 ppm	100 ppm	155 ppb 24 hour average	-
VOC: Acetone	500 ppm	1,000 ppm	497 ppb 24 hour average	-
VOC: Ethanol (ethyl alcohol)	1,000 ppm	-	10,084 ppb 24 hour average	-
VOC: Carbon disulfide	10 ppm	-	106 ppb 24 hour average	-
VOC: 2-Butanone (MEK)	150 ppm	300 ppm	339 ppb 24 hour average	-
VOC: Hexane	20 ppm	-	284 ppb 24 hour average	-
VOIC: Heptane	400 ppm	500 ppm	2,684 ppb 24 hour average	-
VOC:Toluene	50 ppm	150 ppm	1,000 ppb 24 hour average 100 ppb annual average	-

3 Items 2 and 3 – Monitoring Station Locations

- Item 2: The appropriateness of the number and location of air monitors installed by the VIC EPA to determine the impacts of air emissions from the Hazelwood Fire.
- Item 3: Is the current number of ambient air monitoring stations in the Latrobe Valley appropriate.

3.1 Item 2 – Monitoring Stations Installed for Monitoring of Hazelwood Fire

10. In my experience, it would be unusual for a continuous air quality performance monitoring station, a 'reference station', operated by a State regulatory agency to be located in a suitable position for monitoring of emissions from specific air pollution incidents such as the Hazelwood Mine fire. Therefore, the usual approach adopted for a major incident would be that initial assessment of the pollution risk is completed by a specialist team within emergency services. This assessment may include subjective indicators for visible pollutants (e.g. particulates and some gaseous emissions) and, more commonly, monitoring using portable hand held instruments. Often these instruments are intended for measurement of the higher concentrations expected during an emergency incident. The range and resolution of these instruments may not be suitable for measuring at or slightly above normal ambient air quality concentrations.

11. Where an incident is expected to cause significant air emissions that extend for periods beyond a day, the appropriateness of providing additional air monitoring stations would be considered. The proximity of residents would be a significant consideration in determining whether air quality monitoring of the incident should be implemented, along with other factors such as the forecast meteorological conditions. Where it was considered necessary to implement additional air monitoring, the initial response would be installation of temporary portable monitoring stations as soon as possible. These monitors would not be full 'reference' monitors that comply with all requirements of the Australian Standards, but the instruments would be expected to provide greater certainty in terms of data accuracy than the initial emergency response monitoring. A key feature of these monitors would be ease and speed of installation, and the ability to have immediate access to monitoring data to inform the emergency and public health response.

12. Subsequently, if considered appropriate, full 'reference' stations of the type installed at Morwell East and South would be considered for extended incidents.

13. In summary, the stages of the monitoring response could be defined as follows:

    - Stage 1: initial emergency response: subjective response and monitoring using hand held emergency type instrumentation intended to screen for extremes in pollution

exposure.

- Stage 2: rapid deployment of relatively low cost portable monitors that offer a known degree of accuracy, are able to be installed quickly and easily, and can be installed at a number of locations to provide reasonable spatial coverage.
- Stage 3: implementation of a high quality monitoring station to provide accurate data that is compliant with the relevant Australian Standards.

14. In the case of the Hazelwood Mine fire, I understand from the Statements of Dr Rosemary Lester (Vic Health), John Merritt and Dr Paul Torre (VIC EPA) that this general approach was adopted for the Hazelwood Mine fire. In particular the VIC EPA were requested to monitor air quality impacts to inform the public health response to the incident on 11 February 2014, Day 2 of the fire. From 13 February 2014 (Day 4), the EPA and the Country Fire Authority (CFA) conducted CO monitoring in Morwell, on the boundary of the mine and within the community, using hand held monitors.

15. A summary of the air quality monitoring instrumentation that was subsequently installed by the VIC EPA is as follows:

    - a real time 'Dustrak' monitor to provide continuous estimates of particulate concentrations in Morwell, commencing on 13 February:
        - 13/2 - 20/1 - Morwell East.
        - 21/2 - 3/3 Kernot Hall.
        - 5/3 - 15/3 St Lukes Church.
    - Re-commissioning of a high quality automated monitoring station at Morwell East, with continuous $PM_{2.5}$ data available from 13 February 2014 and carbon monoxide (CO) data from 19 February 2014.
    - Installation of a high quality automated monitoring station at Morwell South, with continuous $PM_{2.5}$ data available from 20 February and CO data available from 19 February 204.
    - Completion of additional monitoring of using a 'travel blanket' from 22 February 2014.

16. An EPA media release on Thursday 20th February identifies that four CO monitors were being operated in Morwell South areas, in addition to the hand held monitoring of CO by EPA staff and the CFA. I have not been provided with CO date from these four monitors, or from the hand held instruments operated by the EPA and CFA staff, hence cannot provide comment on the suitability or otherwise of this information.

17. Throughout this period, the automated air quality performance monitoring station at Traralgon was operational. This station is one of a network of ambient air quality monitoring stations operated by the VIC EPA in accordance with the requirements of the NEPM AAQ.

18. In terms of timing, initial monitoring commenced on 13 February within 4 days of the fire starting. This monitoring involved the emergency services personnel and the EPA using

portable devices. On the same day, the Morwell East continuous monitoring station was recommissioned hence providing a continuous source of data to inform public health decisions. It is fortuitous that the monitoring station at Morwell East had not been fully decommissioned, and this allowed rapid commencement of monitoring that could provide high quality data. If this station had not been available, the provision of a single continuous monitoring station of this standard at Morwell South would have been considered appropriate, providing the data was supplemented by additional monitoring using lower cost portable instruments in the broader community to assess spatial variation in the measured concentrations.

19. It is understood that there were some delays in the commencement of monitoring at Morwell East and South associated with the availability and serviceability of the instrumentation. The air quality monitors that were installed are sensitive, high quality instruments, and it is to be expected that the commissioning of these stations would take a period of days, possibly a week or more.

20. A peer review of the monitoring programme has been completed by Associate Professor Howard Bridgeman[10], and a submission from the Clean Air Society of Australian and New Zealand[11] (CASANZ) also comments on the timing of the monitoring that was completed by the VIC EPA. Associate Professor Bridgman comments that the major monitoring needs were met quite well, and suggests that additional monitoring for PM_{10} and nitrogen oxides at Morwell South would have been beneficial. I have been provided with EPA monitoring data from Morwell South for PM_{10} (for the period 28 February to 26 March 2014) and nitrogen oxides (from 6 March 2014 – 31 March 2014). This monitoring may have commenced after the review completed by Associate Professor Bridgman.

21. One of the conclusions of the submission from CASANZ is that it would be beneficial to have low cost, highly mobile, indicative air monitors on standby. In the case of the Hazelwood Fire, this would allow monitoring to have commenced earlier in the incident, particularly the period when the highest air pollution concentrations are likely to have affected the community. It is noted that whilst I am a member of CASANZ, the submission to the Board of Inquiry was prepared by members of the Victorian Branch, and I was neither aware of this submission being made nor involved in preparation of the document.

22. In my opinion, the EPA monitoring that was completed from 20 February 2014 onwards at Morwell South was high quality, detailed, and provides an extensive database of results that was available to inform the public health response from 20 February 2014, and will also inform subsequent studies into the air quality impacts of the fire. The monitoring that commenced at Morwell East on 13 February also provides a valuable dataset relating to the potential impacts on the broader community in Morwell. However, the location of this

10 Review of the EPA Victoria response to the Morwell Coal Fire - Air Quality Assessment and Monitoring Programs, Associate Professor Howard Bridgman, undated.

11 Submission to the Board of Inquiry into the Hazelwood Coal Mine, Clean Air Society of Australia and New Zealand (CASANZ) 16 May 2014

monitoring station is not representative of the acute impacts likely to have affected the Morwell South community during the period up until 20 February 2014. Because of this, whilst the monitoring data from this station could be used to infer the possible impacts on Morwell South, directing more of the monitoring effort toward positions in closer proximity to the incident and the parts of the community most likely to be affected by the emissions would, in my opinion, have been appropriate during the period 9th February to 20th February.

23. I agree with the comments made in the CASANZ submission that monitoring during the initial period of the incident could have been improved by the use of lower quality, portable instruments. Whilst providing high quality air monitoring data is of significant importance in informing compliance with criteria as defined in the NEPM AAQ, in an emergency response situation it is the timing of the data availability that, in my opinion, over-rides the necessity for provision of data that is fully compliant with Australian standards. In such situations, informed decisions can be made on the basis of data that may have a greater statistical error attached to it than reference instruments, providing that a reasonable understanding of the error is available.

24. Both the CFA and the EPA completed initial monitoring from Day 4 of the incident using lower cost monitoring devices. Review of the PM_{10} monitoring data from Traralgon indicates that the peak air quality impacts are likely to have affected Morwell just after midday on 9th February 2014, with significant air quality impacts likely to have continued for the remainder of the day. A slightly higher peak occurred around midday on 10th February. Had portable monitoring instruments been in use at the time, data relating to the impacts on the Morwell South community may have been available to inform the public health response.

25. It is possible that additional short term monitoring was completed by Hazelwood Mine, the CFA and/or VIC EPA, prior to 13th February 2104 and the data has not been provided to the Board of Inquiry for review. However, on the basis of the monitoring data that has been made available to me for review, and the information provided in the statements from the EPA and Vic Health, I conclude that air quality monitoring using portable analytical instruments was not being completed during the initial period when the greatest risk of public health impacts occurred.

26. In my experience of monitoring in response to typical operational emissions and incidents for a range of industries, commencement of monitoring within 24 hours of an event is generally practicable using low cost, portable instruments.

27. In the United States the Californian Air Response Planning Alliance (CARPA), chartered in 2008, provides an example as to how agencies can work together to respond to emergency events with appropriate air monitoring in a timely manner. The impetus for the formation of the alliance was as follows:

'Following the 2003 wildfire disaster in Southern California, issues surrounding the massive air quality impacts underscored a critical need to improve the coordination and capabilities of federal, state, local, and tribal agencies to collect, interpret, and provide air quality information to the public, media, and elected officials in a timely and effective manner.

Although particulate matter (PM) monitoring data was being collected by air districts during the 2003 fires and reported online in near real time, air toxics data collection by various agencies was spotty and not well coordinated. Agencies were not able to provide a coordinated and clear public health message on what was in the smoke and the potential short- and long-term public health effects.'

28. At a CARPA workshop in May 2014, approaches to providing air quality monitoring data of an appropriate quality for incidents expected to last one day or more were considered. Maintaining a working group or forum of this type may be beneficial in Australia.

3.2 Item 3 - Number of Monitoring Stations in the Latrobe Valley

29. The Commonwealth National Environment Protection (Ambient Air Quality) Measure[12] defines requirements for the number and siting of air quality performance monitoring stations in Australia. To comply with these requirements, the VIC EPA operates 13 performance monitoring stations in Metropolitan Areas of Victoria, and a single continuous air quality performance monitoring station located in the Latrobe Valley, at Traralgon. This station commenced operations in 1981 and is the only performance monitoring station located in a non-metropolitan area. Monitoring of the following air quality parameters is completed continuously at Traralgon:

- ozone;
- nitrogen dioxide;
- PM_{10};
- SO_2.

30. The NEPM AAQ provides a population based formula for determining the required number of performance monitoring stations. On the basis of the population in the Latrobe Valley, a single performance monitoring stations is required to comply with the requirements of the NEPM AAQ.

not necessarily

31. NEPM AAQ performance monitoring stations are intended to obtain a representative measure of the upper boundary air quality likely to be experienced by the general population in the region or sub- region.

32. State environment agencies can elect to install additional continuous monitoring stations to assess specific sources of pollution or for other reasons, however these are not considered as performance monitoring stations for the purposes of the NEPM AAQ. For the Latrobe Valley, the VIC EPA completed air quality monitoring in Morwell over the period February 2012 to May 2013. Based on the results of the monitoring at Morwell, it was concluded that air quality complied with the NEPM AAQ except for particulate concentrations associated with bush fire events. The Morwell East monitoring station is not located in close proximity to specific

12 National Environmental Protection (Ambient Air Quality) Measure. 1998 as varied in 2003.

sources of pollution in the local area, and is likely to be representative of the combined impacts of the sources of emissions in the surrounding area.

33. There are significant costs associated with installation and operation of fully automated, continuous 'reference' air quality monitoring stations to comply with the NEPM AAQ. Capital costs are typically in excess of $ 100,000 per installation, and operational costs are likely to be in excess of $ 50,000 per station per year. Therefore, the deployment of stations of this type involves a significant financial commitment.

34. In locations where there is a significant density of industrial sources, such as the Hunter Valley in NSW and potential for impacts on nearby communities, additional 'peak' stations are provided and operated by or on behalf of the EPA.

35. In addition to monitoring completed by State regulatory agencies such as the VIC EPA, it is a common requirement for industries posing a risk to local or regional air quality to be required to complete air quality monitoring and reporting. This is usually specified in the operating or environmental licences issued by the relevant State authority. Data obtained through industry monitoring exercises is generally required to be lodged with the administering authority in annual returns or licence renewals. It is noted that some scheduled operators, such as the City Link Tunnel and East Link Tunnel, complete continuous monitoring to Australian Standards and unvalidated data is provided continuously to a publically accessible web portal.

36. The requirements for industry monitoring are specific to the risks posed by the activities at the site, and monitoring of the full suite of compounds included in the NEPM AAQ is not generally required. Industry data also provides an important source of information regarding the risk of air quality impacts from specific activities. The imposition of sampling requirements in environmental licences assists regulatory agencies to reduce the cost of monitoring for specific pollution sources, and allows allocation of State resources to assessing the broader pollution exposure of the general population as required by the NEPM AAQ.

37. I have reviewed a copy of the Hazelwood Power Environmental Protection Licence. This licence covers the scheduled activities associated with both the power station and the mining activities (A01, A05, C01, K01). Maximum discharge limits for emissions to air from the power station are defined. Stack emissions monitoring of the power station would be required to demonstrate compliance with these limits. The licence does not impose requirements relating to air quality monitoring for the mine, or for environmental (ambient) air that could be affected by emissions from the Hazelwood power station and mine.

38. My experience in QLD and NSW indicates that where a mining operation is in close proximity to residences, there would be a requirement for the mine operator to complete monitoring of particulates. For a number of mines in the Hunter Valley and QLD, continuous particulate monitoring using high quality monitoring instrumentation operated in full compliance with the relevant Australian Standard methodologies is a licence requirement. I am aware that in Victoria, for some sources of emissions to air from scheduled premises, continuous air quality monitoring is a requirement of the operating licence.

39. Had continuous particulate monitoring at positions representing the nearest residences been a condition of the operating licence of the Hazelwood Mine, monitoring data would have been available to inform the initial public health response to the emergency situation.

4 Items 4 – Alerts

- Item 4: Whether the thresholds adopted in the air quality alert protocol developed for the Hazelwood Mine Brown Coal Smoke are appropriate based on the current air quality research and standards, and how these compare to the threshold levels that have been adopted by other regulatory agencies in Australia and Overseas.

4.1 Adopted Thresholds

40. I understand that the Bushfire Alert Categories[13] developed by the EPA in conjunction with the Department of Health were made reference to during the initial periods of the Hazelwood Mine fire.

41. Subsequently, two incident specific response protocols were drafted by the Department of Health and the Environment Protection Authority:

    - Latrobe Valley Coal Fires Carbon Monoxide Response Protocol, Department of Health, Version 1, 27 February 2014.
    - Hazelwood Open Cut Brown Coal Fires – $PM_{2.5}$ Health Protection Protocol, 6 March 2014 – Final Draft for CHO (DH) & EPA Endorsement.

42. These incident specific protocols are provided in Appendices to the Statement of John Merritt, CEO of the EPA at the time of the Hazelwood Mine fire.

43. The stated objective of the draft $PM_{2.5}$ Health Protection Protocol is to prevent sensitive groups in the community being exposed to fine particles in air as $PM_{2.5}$ above 250 $\mu g/m^3$ for more than 3 consecutive days. At the end of two days where the 24 hour (rolling average) $PM_{2.5}$ concentration has been at or above 250 $\mu g/m^3$, and the smoke intensity is predicted to remain or increase, the protocol indicates that the Chief Health Officer will strongly recommend that sensitive groups temporarily relocate until there is sustained improvement in air quality.

44. The air quality categories for each of these protocols are presented in Tables 1a – 1c. For the $PM_{2.5}$ Health Protection Protocol and the Bushfire protocol, cautionary health advice/actions are provided in the final column of Tables 1b and 1c. It is important to appreciate that the draft $PM_{2.5}$ health protection protocol uses these alert categories to inform a response procedure between the DH and the EPA. Once the 24 hour average of $PM_{2.5}$ reaches 250 $\mu g/m^3$, the EPA notifies the DH on-call Officer with further updates provided at 36 and 48 hours.

13 http://www.epa.vic.gov.au/your-environment/air/bushfires-and-air-quality

Table 1a: Health Protection Air Levels - Carbon Monoxide (CO)

Health Protection Air Levels for CO (ppm)	Averaging period for monitoring against the health protection level for CO
Acute Exposure Level Guide Level for CO:	Averaged over:
420 ppm	10 minutes
150 ppm	30 minutes
83 ppm	1 hour
33 ppm	4 hour
27 ppm	8 hours

Table 1b: Smoke Advisory Levels for $PM_{2.5}$ (24 hour rolling average) & cautionary advice for increasing smoke impacts

Smoke advisory level	Air Quality Categories	$PM_{2.5}$ 24 hour µg/m³	Potential Health Effects	Cautionary health advice/actions
Not applicable	Good	< 25	Meets the relevant air quality standard	None
Low	Unhealthy sensitive	26 - 55	People with lung or heart conditions, elderly, children	**Sensitive groups:** people with heart or lung conditions, children and older adults should reduce prolonged or heavy physical activity. No specific message for everyone else other than sensitive groups.
High- General	Unhealthy - all	56 - 95	**Increased** likelihood of effects for people with lung or heart conditions, the elderly, and children. General Population respiratory systems	**Sensitive groups:** People with heart or lung conditions, children and older adults should avoid prolonged or heavy physical activity. Everyone else should **reduce** prolonged or heavy physical activity.
High - General	Very unhealthy - all	96 - 156		**Sensitive groups:** People with heart or lung conditions, children and older adults should avoid all physical activity outdoors. Everyone else should **avoid** prolonged or heavy physical activity.

Table 1b: Smoke Advisory Levels for $PM_{2.5}$ (24 hour rolling average) & cautionary advice for increasing smoke impacts

Smoke advisory level	Air Quality Categories	$PM_{2.5}$ 24 hour µg/m³	Potential Health Effects	Cautionary health advice/actions
High - Hazardous	Hazardous	157 - 250	Significant likelihood of effects for people with lung or heart conditions, the elderly, and children. Increased likelihood of respiratory symptoms in the general population.	**Sensitive groups:** People with heart or lung conditions, children 5 years and younger, pregnant women[a] and people over 65 years should temporarily relocate to a friend or relative living outside the smoke-affected area. If this is not possible, remain indoors and keep activity levels as low as possible. Consider closing some or all **schools** until air quality improves to below 156 µg/m³ Everyone should **avoid all** physical activity outdoors. Healthy people with symptoms should seek medical advice and take a break away from the smoky situations. **Reschedule outdoor events** eg concerts and competitive sports schools until air quality improves to below µg/m³
High – Extreme	Extreme	> 250 µg/m³	Serious likelihood of effects for people with lung or heart conditions, the elderly, pregnant women, and children.	Cautionary health advice/actions the same as for High-hazardous above except for sensitive groups. **Sensitive groups:** If the 24 hour rolling average $PM_{2.5}$

Table 1b: Smoke Advisory Levels for $PM_{2.5}$ (24 hour rolling average) & cautionary advice for increasing smoke impacts

Smoke advisory level	Air Quality Categories	$PM_{2.5}$ 24 hour µg/m³	Potential Health Effects	Cautionary health advice/actions
			Increased likelihood of respiratory symptoms in the general population.	values remain in this category for two days and are predicted to continue at this level or increase: People with heart or lung conditions, children 5 years and younger, pregnant women and people over 65 are **strongly recommended** to temporarily relocate until there is sustained improvement in air quality.

[a] Pregnant women have been added to this category for the extended time of the Latrobe Valley brown coal mine fire incident as an additional level of protection. This group is not a vulnerable group for the Smoke Protocol (ie, bushfires).

Table 1c: Bushfire Alert Categories based on PM_{10} monitoring and visibility

Visibility	Bushfire smoke alert level	Categories	24 hr PM_{10} µg/m³	1 hr PM_{10} µg/m³	Cautionary advice and actions
More than 20 km		Good	Less than 50	Less than 80	None
Less than 20 km but more than 10 km	Low	Unhealthy - Sensitive	51 - 65	81 - 175	People with heart or lung conditions, children and older adults should reduce prolonged or heavy physical activity.
Less than 10 km but more than 5 km	High	Unhealthy – all	65 - 155	176 - 300	People with heart or lung conditions, children and older adults should avoid prolonged or heavy physical activity. Everyone else should reduce prolonged or heavy physical activity.
Less than 5 km but more than 1 km		Very unhealthy	156 - 310	301 - 500	People with heart or lung conditions, children and older adults should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy physical activity.
Less than 1 km		Hazardous	Greater than 310	Greater than 500	Everyone should should avoid all physical activity outdoors; people with heart or lung conditions, children and older adults should remain indoors and keep activity levels low.

45. Review of the available monitoring data for $PM_{2.5}$ confirms that the rolling 24 hour average exceeded> 250 µg/m^3 for the Morwell South monitoring data set on the following occasions:
    - 21 February from 14.15 hrs - 23 February at approximately 16.15 hrs;
    - 26 February for a period of 3 hours;
    - 27 February for a period of 11 hours.
46. Figure 1 presents a graph of the 24 hour rolling average $PM_{2.5}$ concentrations for the Morwell South monitoring station and a comparison to the 250 µg/m^3 extreme threshold.

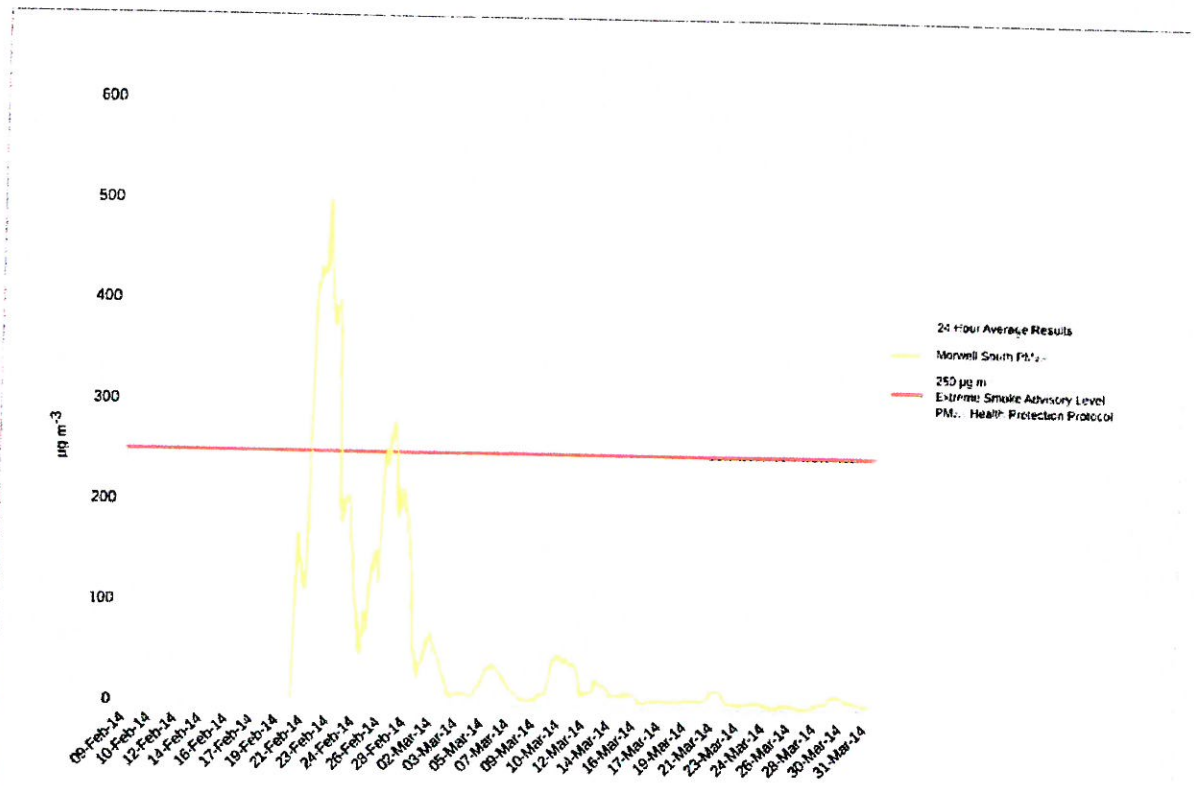


Figure 1 – $PM_{2.5}$ 24 hour rolling averages Morwell ~~East~~ South.

47. For periods with $PM_{2.5}$ concentrations in excess of 250 µg/m^3, the Hazelwood Open Cut Brown Coal Fires – $PM_{2.5}$ Health Protection Protocol advice is as follows:

'Sensitive groups: If the 24 hour rolling average $PM_{2.5}$ values remain in this category for two days and are predicted to continue at this level or increase:

People with heart or lung conditions, children 5 years and younger, pregnant women and people over 65 are strongly recommended to temporarily relocate until there is sustained improvement in air quality.'

48. For those periods where monitoring data is available for Morwell South, the objective of the Hazelwood Open Cut Brown Coal Fires – $PM_{2.5}$ Health Protection Protocol to prevent community exposure to 24 hour rolling average $PM_{2.5}$ concentrations in excess of 250 µg/m^3 for periods of 3 days or more was achieved.

4.2 Suitability of the Alert Protocols and Adopted Levels

49. In terms of the appropriateness of the response protocols, I have considered the peer reviews commissioned by the EPA and have consulted examples of air quality index and response protocols adopted in other jurisdictions.

50. I understand from the Statement of Dr Rosemary Lester that the Bushfire Protocol was relied upon during the first week of the Hazelwood Mine fire in terms of determining the appropriate air quality response. Subsequently, it was determined that due to the duration and characteristics of the fire, new decision making tools were required.

51. In my opinion this strategy was reasonable given the circumstances. Bushfires are a regular event in Australia, and it is appropriate to develop and maintain air quality response protocols to facilitate public health responses when bushfires occur. The duration of bushfire smoke impacts are generally a few days or a week, although in some cases longer exposure has occurred. One example where these exposures have been documented and the resultant acute health impacts considered is the bushfire impacts that occurred in Albury, NSW from early January to mid March 2003[14]. In the case of the Hazelwood Mine fire, particulate impacts were the primary concern. Whilst the characteristics of the particulate matter emitted from the Hazelwood Mine fire may differ in some respects from a bushfire, currently environmental health standards and goals generally do not provide differing standards according to the source type. It is the particulate mass concentration and particle size that are the primary consideration in defining the public health risk.

52. Extended emergencies relating to industrial type emissions and fires are less common. As each of these types of incident has unique characteristics (e.g. air pollution type, concentration, exposure risk and variability of emissions over time) it is neither practical nor appropriate to develop incident specific protocols in advance.

14 Bushfire Smoke Pollution, Albury, 2003. The acute health impact Greater Southern Area Health Service. NSW Health

53. In terms of the appropriateness of the levels adopted in the alert protocols, it is important to recognise that these documents were prepared rapidly in response to a specific incident. Development of protocols, such as the Bushfire Smoke protocol, would normally involve a team of specialists, include consultation with various agencies and be completed over a period of some months. The Hazelwood Mine fire protocols were developed rapidly and, within the time constraints associated with an emergency of this type, expert review of the draft protocols was sought to provide a level of assurance regarding the appropriateness of the adopted thresholds.

54. I have considered the Peer reviews completed of the draft CO protocol by Professor Ross Anderson[15] and by Dr Fay Johnstone & Dr Guy Marks[16], and the $PM_{2.5}$ protocol by Toxikos[17]. I understand from the statement of Dr Rosemary Lester that the Bushfire Smoke Protocol is formally reviewed by Department of Health and the Environment Protection Authority (EPA) each year, and is endorsed by the Chief Health Officer and the Director, Environmental Regulation, EPA.

55. The reviews of the CO protocol completed by Professor Ross Anderson, and by Dr Fay Johnstone & Dr Guy Marks, identify that the adopted thresholds may not be sufficient to protect public health. Both peer reviews suggest that a lower threshold may be appropriate for short term, acute exposure to CO.

56. In terms of acute exposure criteria adopted in Australia, the occupational exposure standards defined for CO by Safe Work Australia[18] and the NOHSC[19] are as follows:

    - Exposure duration 15 minutes: 200 ppm
    - Exposure duration 30 minutes: 100 ppm
    - Exposure duration 60 minutes: 60 ppm
    - Exposure duration 8 hours: 30 ppm

57. The Australian occupational exposure thresholds are slightly higher than the Latrobe Valley Coal Fire protocol threshold for 8 hour exposure, and lower than the CO health protection thresholds adopted in the protocol for the 1 hour and 30 minute exposures.

58. In the context of the more stringent acute exposure thresholds adopted by Safe Work

15 Review of the EPA Victoria response to the Morwell Coal Fire - Process for Public Health Protection, Professor Ross Anderson, undated.

16 Review of the EPA Victoria response to the Morwell Coal Fire. Process for Public Health Protection, Dr Fay Johnstone and Dr Guy Marks undated.

17 Expert Review $PM_{2.5}$ Protocol for Morwell Fires, Toxicos 5 March 2014

18 Guidance in the Interpretation of Workplace Exposure Standards for Airborne Contaminants, Safe Work Australia, April 2005.

19 National Exposure Standards, NOHSC:1003 (1995), Exposure Standards for Atmospheric Contaminants in the Occupational Environment

Australia and the peer reviews, it is considered appropriate to complete a more detailed review of appropriate CO health protection thresholds for short term acute exposures (1 hour exposure or less) to inform the response to any future incidents.

59. The potential significance of applying lower acute exposure criteria can be considered by review of the available CO monitoring data for Morwell South and Morwell East during the Hazelwood Fire. This confirms that the maximum measured one hour average concentration was 17 ppm. This is within the 1 hour threshold of 60 ppm defined by Safe Work Australia by a factor of 3, and indicates that if lower CO thresholds were adopted for sub-1 hour exposures, compliance may have occurred. The monitoring instrumentation utilised at the Morwell South and East monitoring stations is capable of providing CO data at a resolution of less than 1 hour hence data for comparison to the acute short term exposure thresholds is likely to be available thus allowing a direct comparison with sub 1-hour exposure criteria.

60. The Toxikos peer review of the draft $PM_{2.5}$ Health Protocol concludes that the document provides a practical approach to minimising the risks to public health. A detailed review of the appropriate air quality thresholds was not completed by Toxikos, and similarly is not possible for this Statement given the timing restrictions of the Commission of Inquiry. Some preliminary comments, based on preliminary review of air quality indices adopted in other jurisdictions, follow. It is considered appropriate for a detailed review of the appropriate acute trigger thresholds for $PM_{2.5}$ to be completed by a panel of experts to inform public health responses to future events.

61. In January 2013 the United States amended the $PM_{2.5}$ concentrations that are referred to as trigger points for public health alerts[20]. These are summarised in Table 2.

62. Comparison of the alert thresholds adopted in the United States for $PM_{2.5}$ with those adopted in the draft Latrobe Valley Brown Smoke $PM_{2.5}$ protocol confirm that similar trigger levels are adopted for the high hazardous and extremely hazardous categories. This suggests that the categories of key relevance for informing the public health response in extreme circumstances are soundly based. There are some differences in the lower categories.

63. A more detailed review of the appropriate thresholds by a team of public health experts is considered appropriate prior to finalising this response protocol.

20 United States Federal Register, Environmental Protection Agency, Vol 78, No 10, Tuesdat January 15, 2013 Rules and Regulations - National Ambient Air Quality Standards for Particulate Matter

Table 2: United States Environmental Protection Agency Air Quality Index $PM_{2.5}$ Thresholds

AQI Category	AQI Values[a]	Corresponding health advice based on overall AQI (ie, considering a range of pollutant exposures)[b]	$PM_{2.5}$ µg/m³ 24-hour average
Good	0 - 50	Air quality is satisfactory and poses little or no health risk.	0.0 - 12.0
Moderate	51 - 100	Air quality is acceptable; however, pollution in this range may pose a moderate health concern for a very small number of individuals. People who are unusually sensitive to ozone or particle pollution may experience respiratory symptoms.	12.1 - 35.4
Unhealthy for Sensitive Groups	101 - 150	Members of sensitive groups may experience health effects, but the general public is unlikely to be affected.	35.5 - 55.4
Unhealthy	151 - 200	Everyone may begin to experience health effects when AQI values are between 151 and 200. Members of sensitive groups may experience more serious health effects.	55.5 - 150.4
Very Unhealthy	201 - 300	AQI values between 201 and 300 trigger a health alert, meaning everyone may experience more serious health effects.	150.5 - 250.4
Hazardous	301 - 400	AQI values over 300 trigger health warnings of emergency conditions. The entire population is even more likely to be affected by serious health effects.	250.5 - 350.4
Hazardous	401 - 500	AQI values over 300 trigger health warnings of emergency conditions. The entire population is even more likely to be affected by serious health effects.	350.5 - 500

[a] Based on carbon monoxide, sulphur dioxide, ozone and particulate concentrations.

[b] United States EPA - Air Quality Index, A Guide to Air Quality and Your Health. February 2014.

Appendix A – Curriculum Vitae of Claire Richardson

Air Noise Environment Pty Ltd

Curriculum Vitae
Claire Richardson

Title	Managing Director and Principal Consultant
Academic Background	Bachelor of Science (Hons), University of London, 1987 Post Graduate Diploma in Air Pollution Control, 1989 Post Graduate Diploma in Acoustics and Noise Control, 1990 Certificate of Competence in Workplace Noise Assessment, 1994 Company Directors Diploma, 2010
Professional Affiliations	Member of the Clean Air Society of Australia and New Zealand Member of the Australian Acoustical Society
General Description of Experience	An Environmental Scientist with key expertise in the fields of air quality and acoustics, Claire has been involved in technical assessments, auditing, environmental monitoring, environmental modelling and policy studies throughout her career both in Australia and overseas. Claire is regularly called upon to provide Expert Advice and Expert Evidence with respect to Planning and Environment Court related matters, and has completed a number of research projects on behalf of industry and government.
Gas and Particulates Research, Measurement and Prediction	▪ Research project to determine emission rates of $PM_{2.5}$ particulates from emission sources at open cut coal mines. ▪ Investigation of the risk of impacts associated with particulate emissions during coal transport by rail, including analysis of the potential health impacts and the benefits of control solutions such as veneering. ▪ Fine particulate research project on behalf of the Australian Coal Industry (ACARP) assessing emissions and fate of particulates from open cut coal mining. ▪ NPI particulate emission factor validation research projects for open cut mines to refine and improve emission datasets for open cut mining activities. The studies included assessment of watering as a control mechanism. ▪ Particulate investigation study at Mt Coo-tha Quarry over a 12 month period. This project including auditing emission sources at the quarry, completing particulate measurements in the quarry and surrounding community for 12 months, and investigating and recommending control solutions. ▪ Occupational exposure sampling at Darwin International Airport. ▪ Suspended and deposited particulate monitoring and investigation, including chemical analysis of composition of particulates at a metal recycling facility, identification of control solutions, auditing compliance, community liaison. ▪ Ambient particulate sampling during the construction of Beenleigh Road, Beenleigh, over a twelve month period. ▪ Continuous monitoring of nitrogen oxides and carbon monoxide within warehouse structure during fitout of a major retailing distribution centre in Brisbane for a 9 month period.

© Air Noise Environment Pty Ltd
3/4 Tombo Street • Capalaba • QLD 4157
Phone: 07 3245 7808 • Fax 07 3245 7809 • Email claire.richardson@ane.com.au

- Measurement and assessment of ambient particulate deposition rates for Newcrest mining.
- Suspended particulate and aerosol sampling and analysis for mass, PAHs and dioxin content for a proposed incinerator site.
- Analysis and assessment of particulate emissions from a proposed quarry for a P&E Appeal in North Queensland.
- Suspended and deposited particulate measurement for an existing concrete batching plant operation to determine appropriate control strategies for a proposed new plant on the Sunshine Coast.
- Measurement and prediction of dust emissions from a range of extractive and construction sources both in Australia and overseas, including projects for British Coal, Blue Circle, ARC, MIM, BHP, Newcrest Mining and others.
- Nitrogen oxide monitoring at a proposed residential development site adjacent to the Gateway Motorway for a 2 month period to determine existing exposure levels.
- Occupational monitoring for a range of compounds using real time and static sampling methodologies.

Air Quality Modelling:

- Air Quality assessment for proposed power generation plant for CSG operations, on behalf of QGC.
- Project Director for air quality assessment for CSG operations near Dalby.
- Airport Link and Northern Busway Project, Brisbane. Air quality modelling and assessment of the potential impacts of the final project design on behalf of the PBAJV/TJH. Supply and installation of particulate sampling network for the construction phase including completion of staff training.
- Clem 7, Brisbane: EIS phase, peer review of the air quality modelling, liaison role with the community consultation and air quality steering group.
- Waterview Connection, Auckland. Project director and technical review for the air quality modelling completed for a range of project options for this project.
- Eastlink Motorway, Melbourne. Project Director and in-house technical review of the mathematical modelling of the final detailed design for the tunnel and surface roads for this major project.
- Victoria Park Tunnel, Auckland – Peer review of the air quality assessment completed by Holmes Air Sciences.
- Cross City Tunnel, Sydney (Downer Engineering). Mathematical modelling of emissions from the stack, community consultation and input to the selection of compliance monitoring stations.
- Quay Street Underpass, Auckland. Air dispersion modelling of emissions from the portals of this extended underpass in Auckland City.
- M5 Motorway Tunnel, Sydney (Hyder Consulting). Modelling and assessment of the potential for air quality impacts as a result of atmospheric emissions from the tunnel portals and stack.
- Mathematical modelling of urban renewal areas in inner suburbs of Brisbane. These complex projects include auditing and emission inventories of remnant

© Air Noise Environment Pty Ltd
3/4 Tombo Street • Capalaba • QLD 4157
Phone: 07 3245 7808 • Fax 07 3245 7809 • Email claire.richardson@ane.com.au

industry in areas earmarked for residential development, followed by detailed computational modelling using Ausplume and Calpuff.

- Industrial point source emission modelling including power stations, hazardous waste incinerators, manufacturing industry through to fugitive sources such as mines and ponds.
- Road traffic air quality modelling using Caline4 and CAL3QHC for a range of projects.

Expert Witness:

- P&E Appeal 3354/10 & 3764/2010 – particulate emissions from proposed expansion of an open cut sand and gravel extraction operation and associated processing facility.
- Land Court matter – particulate emissions from expansion of a proposed open cut coal mine (2014)
- P&E Appeal 3370/2012 – Odour and noise impacts from a proposed abattoir expansion.
- P&E Appeal 19/2012 – Odour and noise impacts associated with a proposed poultry breeder rearer farm.
- P&E Appeal 700/2012 – Odour impacts from a proposed major poultry farming development located in the Southern Downs Regional Council area.
- P&E Appeal 5172/2011 & 5174/2011 – The impact of existing industrial emissions on a proposed major housing development.
- P&E Appeal 5192/2011 – Air quality and noise emissions from a proposed poultry litter fired power station in Redland City.
- P&E Appeal 3587/2010 & 411/2011 – Noise and dust impacts from an existing scrap metal yard operation seeking a material change of use to formalise existing operations.
- P&E Appeal 510/2010 – Air and noise impacts from existing sandstone rock quarry on proposed subdivision, Warwick.
- P&E Appeal 129/2009 – Air quality impacts from existing industrial estate on proposed new high rise retirement development on the Gold Coast.
- P&E Appeal 12/2009 – Reverse amenity impacts from an existing abattoir with respect to a proposed small lot residential subdivision.
- P&E Appeal 2186/2009: Expert advice regarding noise impacts from a proposed vehicle workshop at an existing car salesyard, on behalf of Brisbane City Council.
- P&E Appeal 3664/2007: Expert advice with respect to odours, noise and dust relating to a proposed cattle saleyard at Roma (on behalf of co-respondents, instructed by King & Co).
- P & E Appeal BD940/2007 – Poultry Farm at Tramway Road, Tabooba – Odour and noise issues, on behalf of Gary Pemberton (Co-respondent), instructed by Clayton Utz.
- P & E Appeal 2526/2005 – Proposed childcare centre at Delathin Road – Air quality and noise issues on behalf of Brisbane City Council.

© Air Noise Environment Pty Ltd
3/4 Tombo Street • Capalaba • QLD 4157
Phone: 07 3245 7808 • Fax 07 3245 7809 • Email claire.richardson@ane.com.au

- P & E Appeal 2801/2004 – Proposed childcare centre at Maundrell Terrace – Air quality and noise issues on behalf of Brisbane City Council.
- P & E Appeal 2260/2004 – Proposed childcare centre at Lucy St. Albion – Air quality and noise issues on behalf of Brisbane City Council.
- NSW P & E Court matter 10729/2004 Proposed cherry fumigation operation at Griffith – Air quality issues, Court Appointed Expert.
- P & E Appeal 4703/2005 – Proposed Poultry Farm at Coominya, Odour, noise and dust issues, on behalf of Esk Shire Council.
- Proposed residential development at Holland Park, P & E Appeal, Odour issues (on behalf of Australian Property Developments).
- Proposed concrete batching plant at Cooloola, P & E Appeal, dust issues (on behalf of Readymix Holdings, Appellant).
- Proposed concrete batching plant at Kawana, P & E Appeal noise and dust issues (on behalf of Readymix Holdings).

Papers and Publications:

- *Development of $PM_{2.5}$ Emission Factors for the Open Cut Coal Industry*, Claire Richardson, Clean Air Society of Australia and New Zealand, National Clean Air Conference, September 2013.
- *The Historical and Current Challenge of Environmental Nuisance*, Claire Richardson, Environmental Institute of Australia and New Zealand, National Conference, October 2012.
- *The Clem7 Motorway Tunnel: Mechanical and Electrical Plant Acoustic Design and Performance*, Claire Richardson and Beau Weyers, Proceedings of Acoustics 2011, November 2011.
- *Environmental Monitoring – Science or Black Art?* Claire Richardson, Queensland Environment Law Society Annual Conference 2011.
- *Environmentally Friendly Surface Coatings – Friend or Foe?* Claire Richardson and Craig Beyers, Clean Air Conference 2007.
- *Noise and Air Quality Policy – Issues and Risks for the Industry, Claire Richardson, presented at the Cement, Concrete and Aggregate Australia Conference 2005*
- *Particulate Emission Estimation Techniques – Field Validation for Area Sources*, Claire Richardson, Craig Beyers and Ramses Zietek, Clean Air Conference 2002
- *The Brisbane River Management Plan*, Claire Richardson, Proceedings of Acoustics 1998.
- *A Comprehensive Noise Management Strategy for the an Urbanised River Catchment*, A L Brown & C M Richardson, Journal of Environmental Planning and Management, 41(3), 299-312, 1998.
- *Pop Concert Noise Control – A UK Perspective*, Claire Richardson, Proceedings of Acoustics 1995.
- *Bio-Technology for Odour Control*, Claire Richardson, Institute of Water and Waste Management (UK), 1991.

© Air Noise Environment Pty Ltd

3/4 Tombo Street • Capalaba • QLD 4157
Phone: 07 3245 7808 • Fax 07 3245 7809 • Email claire.richardson@ane.com.au