From: Wayne Somerville
To: info@frackinginquiry.wa.gov.au
Subject: Submission to WA Fracking Inquiry
Date: Thursday, 1 March 2018 7:49:50 AM
Attachments: CSG Air Pollution in the Darling Downs (2015).pdf
Dr W Somerville (2014) Is CSG Safe - A Failed Debate.pdf
Dr W Somerville''s Response to Dr A Finkel''s Comments.pdf
Submission on Assessment of CSG Fugitive Methane (2012).pdf

Dear Inquiry Members,

I would like to submit the attached documents for consideration by the Inquiry.

Please contact me if you require further information.

Thanking you.

Regards,

Wayne Somerville

Dr Wayne Somerville
Clinical Psychologist
[redacted]

Is CSG Safe?

A failed public debate in the interests of community health

QGC's Kenya CSG Plant and Gasfield – Tara, Queensland

By Dr Wayne Somerville B.A.(Hons.), M.Clin.Psych., D.Psy. Clinical Psychologist

For further information, please contact:

Dr Wayne Somerville [redacted]

Download copies from www.creeksbend.com

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This paper, "Is CSG Safe? - A Failed Public Debate in the Interests of Community Health", supplements my earlier "Self-help Risk Management Tools: A Report on the Health Impacts of CSG and Shale Gas Mining".[1] Copies of both papers are available for free download from the "CSG" page at www.creeksbend.com.

[1] Dr Wayne Somerville (2013) Self-help Risk Management Tools: A Report on the Health Impacts of CSG and Shale Gas Mining, download from the "CSG" page at www.creeksbend.com. http://www.creeksbend.com/CSG%20Health%20Risk%20Management%20Tools%20-%20Dr%20W%20Somerville.pdf

Is CSG Safe?
A failed public debate in the interests of community health

Dr Wayne Somerville B.A.(Hons.), M.Clin.Psych., D.Psy. Clinical Psychologist

Introduction

Heavily industrialised gas fields are being established in populated areas across Australia with little public discussion of potential health risks. When development could negatively affect the health of generations to come, the community is entitled to an open debate based on scientific evidence and rational argument. My recent dialogue with Metgasco CEO Mr Peter Henderson initiated a much-needed public discussion about the potential health impacts of gas field industrialisation in the Northern Rivers.

On 14 November 2013 Metgasco's CEO Mr Peter Henderson and Community Relations Manager Mr Stuart George attended a 90 minute meeting with Kyogle Mayor Danielle Mulholland, Kyogle Shire Council General Manager Mr Arthur Piggott, and myself as a community representative and policy adviser. Mr Henderson called the meeting to promote Metgasco's plans to develop gas fields in the Northern Rivers. Mr Henderson said that if the yet-to-be drilled Bentley gas well is successful, Metgasco will establish a gas field there and build a pipeline along Kyogle's Lions Road to transport gas to the export market. After the 14 November 2013 meeting, Mr Henderson e-mailed me and offered to follow up on "health concerns" that I raised at the meeting.

In subsequent correspondence, I asked Mr Henderson to provide the scientific evidence for his claims that: a) CSG operations have been proved to be safe; b) the CSG mined in the Northern Rivers is pure methane and contains no impurities, or any substance other than some water that requires processing; and c) there is no benzene in coal seams in the Northern Rivers. I also asked Mr Henderson if he could reconcile the situation in Queensland gas fields, where significant quantities of hazardous substances are discharged into the environment, with his claim that any future processing of CSG in the Northern Rivers would produce no significant waste or pollution.

Mr Henderson responded to the above requests in a letter dated 29 November 2013. A copy of this letter is attached to this paper as Appendix A.

Mr Henderson's responding to my request for evidence to support the claims about the safety of the CSG industry that he made at the meeting with Kyogle's Mayor was a welcome first step in an important debate that contrasts two very divergent viewpoints.

In my "Self-help Risk Management Tools: A Report on the Health Impacts of CSG and Shale Gas Mining"[2], I concluded that there is a high probability of potentially catastrophic health impacts from operating gas fields in populated areas. My review of the scientific literature indicated that air, water and soil pollution from unconventional gas mining creates a complex mix of persistent, bio-accumulative, toxic, carcinogenic, mutagenic, teratogenic, and endocrine disrupting substances, some which can seriously injure human health even in minute quantities.

[2] Dr Wayne Somerville (2013) Self-help Risk Management Tools: A Report on the Health Impacts of CSG and Shale Gas Mining, download from the "CSG" page at www.creeksbend.com

In marked contrast, Mr Henderson argued that the CSG industry has been proven to be in all ways safe, and operating gas fields in the Northern Rivers could not expose people to dangerous substances capable of causing illness.

I have considered the arguments and reports cited in Mr Henderson's 29 November 2013 letter and, in my opinion, there was no relevant scientific evidence there to support Mr Henderson's claims regarding the "proven" safety the CSG industry and the composition of local coal seam gas and CSG waste water. Further, Mr Henderson did not explain why CSG processing in the Northern Rivers would not result in pollution similar to that produced by Queensland CSG gas fields and processing plants.

In his 29 November 2013 letter, Mr Henderson did not provide any primary data for the Northern Rivers, but instead cited Australian Gas Light's (AGL) Camden Environmental Health Impact Assessment (EHIA)[3] as a source of relevant information regarding the chemical composition of coal seam gas.

In my opinion, there was nothing in Mr Henderson's 29 November 2013 letter, or the studies and reports he cited, to contradict the conclusion of my risk assessment report[4] that there is a high level risk of potentially catastrophic health impacts associated with operating gas fields in populated areas.

Mr Henderson received a pre-publication copy of this paper and was invited to provide a response to be attached to this document. Mr Henderson was also asked if he would be willing to participate in further public discussion about the potential health impacts of operating gas fields in populated areas. Mr Henderson's response, dated 24 January 2014, is attached to this paper as Appendix B.

The following discussion presents and comments on Mr Henderson's claims regarding the safety of the CSG industry and the nature of coal seams, CSG, and CSG wastewater in the Northern Rivers.

On the Gas Industry

Mr Henderson began his 29 November 2013 letter with the following statements about the energy needs of the community:

> "NSW and Northern Rivers residents need energy for heating, lighting and cooking in their homes and to power domestic appliances. We all need transport fuels and in the work place our jobs depend on reliable energy supplies to power equipment and to provide heating and cooling. Our lives depend on reliable energy supplies."

Most people would agree that our community needs reliable supplies of energy, but it does not follow that operating gas fields in populated areas is necessary, desirable, or safe.

The issue is not "gas versus no gas". The vitally important question is whether it is safe to operate heavily industrialised gas fields where people live.

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[3] AGL's Environmental Health Impact Assessment – Camden Northern Expansion Project, 30 October 2013.
[4] Dr Wayne Somerville (2013) Self-help Risk Management Tools: A Report on the Health Impacts of CSG and Shale Gas Mining, download from the "CSG" page at www.creeksbend.com

Is CSG Clean and Green?

In his 29 November 2013 letter, Mr Henderson wrote that:

> "Exports of natural gas from Australia are helping less developed countries to reduce the extent of air pollution and associated illness."

The gas mining industry argues that natural gas is a clean fuel because when burnt it creates less carbon dioxide than coal. But this benefit for consumers is offset by the creation of potentially dangerous air, water and soil pollution where the gas is mined and processed.

On the Composition of Northern Rivers CSG

In his 29 November 2013 letter, Mr Henderson wrote:

> "Our coal seam gas is almost pure methane. The natural gas we produce from our coal seams is about 98% methane, with very small amounts of ethane (another colourless, odourless and non-toxic hydrocarbon gas), carbon dioxide and nitrogen. Gas chromatograph data for our coal seam gas shows virtually no hydrocarbons heavier than ethane. By inspection, there is absolutely no reason for concern in terms of metals, volatile organics or BTEX chemicals. For your information, the gas we found in our Kingfisher exploration well (a conventional gas field) has a similar composition to our CSG. It has a little more ethane and propane than our CSG but gas chromatograph data shows hydrocarbons no heavier than pentane and, again by inspection, provides no reason for concern. Our coal seam gas meets specifications for sales gas, it does not need to be treated to be sold into the gas market. It might need to have small quantities of water removed to be distributed in a large pipeline system."
>
> "Should you wish to explore the wealth of data that is available on websites you will find that gas produced from other Australian coal seams is also primarily methane, with very low concentrations of any hydrocarbons heavier than ethane. For example, we draw your attention to AGL's Environmental Health Impact Assessment – Camden Northern Expansion Project, 30 October, 2013, provides further information to support high methane levels and correspondingly low levels of heavier hydrocarbons in its gas. Again, by inspection, there is no reason for concern about volatile organic compounds, BTEX or metals. This information can be found on the AGL website."

In his letter, Mr Henderson stated that local CSG consists of methane, ethane, carbon dioxide, nitrogen and "virtually no hydrocarbons heavier than ethane". I note that a definition of "virtually" is "in essence or effect but not in fact".

It is not clear whether Mr Henderson's statement, "By inspection, there is absolutely no reason for concern in terms of metals, volatile organics or BTEX chemicals" indicates that none of these potentially dangerous substances is present in local coal seam gas, or that he is personally unconcerned when he looks at chemical assay reports.

As Mr Henderson suggested, I read AGL's EHIA[5], but could find nothing there to support his claim that AGL's, and by implication Metgasco's, CSG was "almost pure methane" with no other substance worthy of "concern".

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[5] AGL's Environmental Health Impact Assessment – Camden Northern Expansion Project, 30 October 2013

The following table from AGL's EHIA presents data from testing of coal seam gas at their Camden operation.

Table 4.5 Screening Level Review of Fugitive Emissions from Proposed Wells – Northen Expansion.[6]

Table 4.5 Screening Level Review of Fugitive Emissions from Proposed Wells – Northern Expansion

Component of CSG (all compounds detected)	Composition from Analysis (%)**	Predicted Worst-case Downwind Air Concentration		Screening Level Guideline
		At well head (within 5 m)	50 m from well	
Total gas release as CO_2 equivalents	100% - 0.026 g/s emission	22000 µg/m^3	1678 µg/m^3	NA
Methane	90%	19800 µg/m^3 or 0.003%	1510 µg/m^3 or 0.0002%	>0.5% in buildings[v] 5% explosive risk
Nitrogen	up to 5%	1100 µg/m^3 or 0.00006%	83.9 µg/m^3 or 0.000005%	NA - Negligible contribution to ambient levels
Oxygen	1.5%	330 µg/m^3 or 0.00003%	25 µg/m^3 or 0.000002%	Negligible contribution to ambient levels
Carbon dioxide	3.2%	704 µg/m^3 or 0.00004%	54 µg/m^3 or 0.000003%	0.5% in buildings[v]
Argon	<1%	<220 µg/m^3 or 0.00001%	<17 µg/m^3 or 0.000001%	NA - Negligible contribution to ambient levels
Ethane	<0.2%	<44 µg/m^3	<3.3 µg/m^3	NA – TLV = 1 230 000 µg/m^3 (ACGIH), HSDB does not report effects in the few studies available at higher levels of exposure. No public health guideline
Propane	<0.01%	<2.2 µg/m^3	<0.17 µg/m^3	NA – TLV = 1 800 000 µg/m^3 (ACGIH), HSDB lists no effects in other studies up to this level of exposure. No public health guideline available
Acetone	180 µg/m^3 0.000008%	0.0018 µg/m^3	0.00013 µg/m^3	30000 µg/m^3 based on chronic public health guideline from ATSDR
Ethanol	550 µg/m^3 0.00003%	0.0066 µg/m^3	0.00050 µg/m^3	100000 µg/m^3 based on chronic public health guideline from OEHHA
Hexane	250 µg/m^3 0.000007%	0.0015 µg/m^3	0.00012 µg/m^3	700 µg/m^3 based on chronic public health guideline from USEPA*
Cyclohexane	260 µg/m^3 0.000008%	0.0018 µg/m^3	0.00013 µg/m^3	6000 µg/m^3 based on chronic public health guideline from USEPA*
TPH C5-C6 aliphatics	3420 µg/m^3 0.0001%	0.022 µg/m^3	0.0017 µg/m^3	18400 µg/m^3 based on chronic public health guideline from TPHCWG
TPH >C8-C10 aliphatics	40600 µg/m^3 0.0008%	0.18 µg/m^3	0.013 µg/m^3	1000 µg/m^3 based on chronic public health guideline from TPHCWG
TPH >C10-C12 aliphatics	4770 µg/m^3 0.00007%	0.015 µg/m^3	0.0012 µg/m^3	

Environmental Health Impact Assessment – Camden Northern Expansion Project
Ref: AGL/13/CNHIA001-F
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Note. "TPH" means Total Petroleum Hydrocarbons.

[6] AGL's Environmental Health Impact Assessment – Camden Northern Expansion Project, 30 October 2013, Page 39

The Report of Analysis of a sample of CSG on the following Page 8 of this paper is from Appendix A of the AGL EHIA.

I note that the "LOR", or "Limit of Reporting", figures used in the following AGL EHIA Report of Analysis represent arbitrary cut-off points for reporting the presence and quantity of the indicated substance. According to the Wisconsin Analytical Detection Limit Guidance and Laboratory Guide for Determining Method Detection Limits[7],

> "Reporting Limit is an arbitrary number below which data is not reported. The reporting limit may or may not be statistically determined, or may be an estimate that is based upon the experience and judgement of the analyst. Analytical results below the reporting limit are expressed as 'less than' the reporting limit. **Reporting limits are not acceptable substitutes for detection limits unless specifically approved by the Department for a particular test**". (Page 2, bold type in original).

The AGL EHIA "Report of Analysis" of Camden coal seam gas reported the presence, above the "limit of reporting", of ethanol, dichloromethane, hexane, cyclohexane, heptane, styrene, benzene, toluene and ethylbenzene.

Significant differences are apparent when Mr Henderson's claims about the composition of Northern Rivers CSG are compared to data in Table 4.5 and the "Report of Analysis" in the AGL EHIS. For example, Mr Henderson claimed that local CSG "is about 98% methane", while AGL reported that their CSG is 90% methane. More importantly, AGL reported the presence in their CSG of many substances other than methane, including BTEX chemicals and other Volatile Organic Compounds (VOCs).

In his 29 November 2013 letter, Mr Henderson did not provide any direct data to support his claim that benzene does not exist in coal seams.

I note that the Queensland Government's Department of Environment and Heritage Protection website advises that "BTEX compounds are found naturally in crude oil, coal and gas deposits and therefore they can be naturally present at low concentrations in groundwater near these deposits."

In regards to the presence of benzene and other BTEX chemicals in coal seams, the AGL EHIS noted that:

> "There are have been (sic) a few detections of low concentrations of benzene, toluene, ethylbenzene and xylene (BTEX) in production water. BTEX is not used for any aspect of the process (drilling, hydraulic fracturing or maintenance), however a review of the nature of the target coal seam by CSIRO (Volk et al. 2011) has identified the likely presence of low levels of BTEX in the target coal seam aquifer. The small number of low level detections reported from some existing wells is consistent with the presence of BTEX in the target coal seam aquifer."[8]

[7] Wisconsin Department of Natural Resources, Laboratory Certification Program (1996) Analytical Detection Limit Guidance & Laboratory Guide for Determining Method Detection Limits, April 1996, PUBL-TS-056-96.
[8] AGL's Environmental Health Impact Assessment – Camden Northern Expansion Project, 30 Oct 2013, Pg 60.

Report of Analysis of CSG from Appendix A of AGL's EHIA, 30 October 2013[9]

Australian Government

National Measurement Institute

NATA

REPORT OF ANALYSIS

Report No. VOC13_267

Client :	AGL PO BOX 67 MENANGLE NSW 2568	**Job No.** :	AGLU01/130917
		Quote No. :	
		Order No. :	
		Date Sampled :	12-Sep-2013
		Date Received :	17-Sep-2013
		Sampled by :	CLIENT
Attention :	AARON CLIFTON		
Project Name :			
Your Client Services Manager :	DANNY SLEE	**Phone** :	(02) 9449 0111

Laboratory Reg. No. :	NV13/00802	**Method:**	VOC_01
Client Sample Ref. :	RPGP120913	**Date Analysed** :	18-Sep-2013
Matrix :	Air Canisters	**Canister No.** :	F1905
Description :	12.9.13 5:35 12.9.13 5:55	**Receipt Vac/Press ("Hg):**	-5
		Dilution :	20

Compound	LOR ppbv	Level ppbv	LOR ug/m3	Level ug/m3	CAS Number
Propene	2	<2	3	<3	115-07-1
Dichlorodifluoromethane	2	<2	10	<10	75-71-8
Chloromethane	5	<5	10	<10	74-87-3
1,2-Dichlorotetrafluoroethane	2	<2	10	<10	76-14-2
Vinyl chloride	2	<2	5	<5	75-01-4
1,3-Butadiene	2	<2	4	<4	106-99-0
Bromomethane	8	<8	30	<30	74-83-9
Chloroethane	2	<2	5	<5	75-00-3
Acrolein	2	<2	5	<5	107-02-8
Acetone	5	<5	10	<10	67-64-1
Ethanol	5	290	9	550	64-17-5
2-Propanol	2	<2	5	<5	67-63-0
Trichlorofluoromethane	2	<2	10	<10	75-69-4
1,1-Dichloroethene	2	<2	8	<8	75-35-4
Dichloromethane	5	<8	20	<30	75-09-2
1,1,2-Trichloro-1,2,2 trifluoroethane	2	<2	20	<20	76-13-1
Carbon disulfide	2	<2	6	<6	75-15-0
trans-1,2-Dichloroethene	2	<2	8	<8	156-60-5
1,1-Dichloroethane	2	<2	8	<8	75-34-3
Methyl-tert-butylether (MTBE)	2	<2	7	<7	1634-04-4
Vinyl acetate	2	<2	7	<7	108-05-4
2-Butanone (MEK)	2	<2	6	<6	78-93-3
cis-1,2-Dichloroethene	2	<2	8	<8	156-59-2
Hexane	2	71	7	250	110-54-3
Chloroform	2	<2	10	<10	67-66-3
Ethyl Acetate	2	<2	10	<10	141-78-6
Tetrahydrofuran	2	<2	6	<6	109-99-9
1,2-Dichloroethane	2	<2	8	<8	107-06-2
1,1,1-Trichloroethane	2	<2	10	<10	71-55-6
Benzene	5	<20	20	<50	71-43-2

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[redacted]

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[9] AGL's Environmental Health Impact Assessment – Camden Northern Expansion Project, 30/10/2013, App A.

Report No. VOC13_267

Carbon tetrachloride	2	<2	10	<10	56-23-5
Cyclohexane	2	74	7	250	110-82-7
1,2-Dichloropropane	2	<2	9	<9	78-87-5
Bromodichloromethane	2	<2	10	<10	75-27-4
Trichloroethene	2	<2	10	<10	79-01-6
1,4-Dioxane	2	<2	7	<7	123-91-1
Heptane	2	<10	8	<60	142-82-5
Methyl methacrylate	2	<2	8	<8	80-62-6
cis-1,3-Dichloropropene	2	<2	9	<9	10061-01-5
4-Methyl-2-pentanone (MIBK)	2	<2	8	<8	108-10-1
trans-1,3-Dichloropropene	2	<2	9	<9	10061-02-6
1,1,2-Trichloroethane	2	<2	10	<10	79-00-5
Toluene	2	<4	8	<20	108-88-3
2-Hexanone (MBK)	2	<2	8	<8	591-78-6
Dibromochloromethane	2	<2	20	<20	124-48-1
1,2-Dibromoethane	2	<2	20	<20	106-93-4
Tetrachloroethylene	2	<2	10	<10	127-18-4
Chlorobenzene	2	<2	9	<9	108-90-7
Ethylbenzene	2	<6	9	<30	100-41-4
Bromoform	2	<2	20	<20	75-25-2
m & p-Xylenes	5	<5	20	<20	108-38-3 / 106-42-3
Styrene	2	<6	9	<20	100-42-5
1,1,2,2-Tetrachloroethane	2	<2	10	<10	79-34-5
o-Xylene	2	<2	9	<9	95-47-6
4-Ethyltoluene	2	<2	10	<10	622-96-8
1,3,5-Trimethylbenzene	2	<2	10	<10	108-67-8
1,2,4-Trimethylbenzene	2	<2	10	<10	95-63-6
Benzyl Chloride	2	<2	10	<10	100-44-7
1,3-Dichlorobenzene	2	<2	10	<10	541-73-1
1,4-Dichlorobenzene	2	<2	10	<10	106-46-7
1,2-Dichlorobenzene	2	<2	10	<10	95-50-1
1,2,4-Trichlorobenzene	2	<2	10	<10	120-82-1
Hexachlorobutadiene	2	<2	20	<20	87-68-3
Naphthalene	2	<2	10	<10	91-20-3
Internal Standard: BCM (%Rec.)	1	108			74-97-5
Internal Standard: 1,4-DFB (%Rec.)	1	102			540-36-3
Internal Standard: MCB-d5 (%Rec.)	1	105			3114-55-4

Robert Crough
Chemist

Accreditation No. 198

20-Sep-13

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The issue of the presence or absence of benzene as a CSG pollutant in the Northern Rivers is further highlighted by a comparison of Mr Henderson's description of Metgasco's waste water with data provided by AGL from their Camden operation.

On the Composition of Metgasco's CSG Waste Water

In his 29 November 2013 letter, Mr Henderson claimed that Metgasco's CSG waste water is suitable, without treatment, for stock watering, and with removal of some salt, for irrigation and human consumption.

Specifically, Mr Henderson wrote that:

> "A thorough analysis of our CSG produced water shows that it meets Australian Drinking Water Guidelines, apart from its salt levels, which are about 1/10 of the level in sea water. Bioassay (acute toxicity) testing has provided further and broader confirmation that the CSG water is not toxic. We have a range of studies to demonstrate that our water, after some salt removal, is suitable for irrigation. It is suitable for stock watering, even without salt removal."

Mr Henderson provided no primary data to support his claims about Metgasco's CSG waste water, but offered his personal opinion regarding the significance of the analyses in the "range of studies" he has access to. In the absence of any local data, I examined the AGL EHIA that Mr Henderson referred to for information about the composition of CSG waste water from AGL's Camden operation.

The following table Table 7.2 from the AGL EHIA presents an analysis of chemicals in AGL's Camden CSG waste water. In Table 7.2, substances highlighted in grey were present in CSG waste water at levels exceeding Australian drinking water guidelines.

The pollutants in AGL's CSG waste water that exceeded Australian drinking water guidelines included arsenic, strontium, barium, nickel, lead, bromine, iodine, fluoride, methane, naphthalene, benzo(b)fluoranthene, benzo(a)pyrene, benzene, and Total Petroleum Hydrocarbons (TPHs) in the range C10 to C36. The maximum readings for arsenic, barium, benzene and the TPHs exceeded drinking water standards by 10 or more times, and naphthalene exceeded the drinking water standard threefold.

I note that AGL reported a reading of 10 micrograms per litre in the maximum recording of benzene in their waste water - a level ten times greater than the 1 µg/L drinking water standard.

The substantial variations between minimum and maximum readings evident in AGL's CSG waste water assays indicate that multiple analyses are needed to accurately assess the chemical composition of CSG and CSG waste water.

Unfortunately, only minimum and maximum levels of chemicals are reported in Table 7.2 of AGL's EHIS, and there is no information regarding the number and distribution of readings that were within the minimum to maximum range.

It is not known what analyses or standards Mr Henderson is using to support his claims that CSG wastewater in the Northern Rivers is safe and free of dangerous pollutants even without processing.

Table 7.2 from AGL's Environmental Health Impact Assessment – Camden Northern Expansion Project, 30 October 2013.[10]

Table 7.2 Preliminary Review of Chemicals Detected in Produced Water (existing operations)

Analyte grouping/Analyte	Units	Range of Concentrations in Produced Water		Drinking Water Guideline			Comments
		Minimum	Maximum	Health Based	Aesthetic	Reference	
Total Dissolved Solids (Calc.)	mg/L	5320	23500	--	600	NHMRC 2011	Salinity of produced water not suitable for drinking water
Sulfate as SO_4^{2-} Turbidimetric	mg/L	1	202	500	250	WHO 2011	
Chloride	mg/L	93	1310	--	250	NHMRC 2011	Common in groundwater and certain catchments (from natural mineral salts)
Metals and Inorganics							
Aluminium	mg/L	<0.01	0.07	16	0.2	USEPA 2012a, NHMRC 2011	NHMRC guideline relevant to aesthetics only
Arsenic	mg/L	<0.001	0.113	0.01	--	NHMRC 2011	
Boron	mg/L	<0.05	0.26	4	--	NHMRC 2011	
Strontium	mg/L	0.151	10.2	9.3	--	USEPA 2012a	
Barium	mg/L	0.448	35.5	2	--	NHMRC 2011	
Beryllium	mg/L	<0.001	<0.001	0.06	--	NHMRC 2011	
Cadmium	mg/L	<0.0001	0.0003	0.002	--	NHMRC 2011	
Cobalt	mg/L	<0.001	0.001	0.0047	--	USEPA 2012a	
Uranium	mg/L	<0.001	0.002	0.017	--	NHMRC 2011	
Chromium	mg/L	<0.005	0.012	0.05	--	NHMRC 2011	Guideline based on chromium VI
Copper	mg/L	<0.001	0.025	2	1	NHMRC 2011	
Manganese	mg/L	<0.001	0.133	0.5	0.1	NHMRC 2011	
Molybdenum	mg/L	<0.001	0.138	0.05	--	NHMRC 2011	
Nickel	mg/L	<0.001	0.024	0.02	--	NHMRC 2011	
Lead	mg/L	<0.001	0.026	0.01	--	NHMRC 2011	
Selenium	mg/L	<0.01	0.01	0.01	--	NHMRC 2011	
Vanadium	mg/L	<0.01	<0.01	0.078	--	USEPA 2012a	
Zinc	mg/L	<0.005	0.074	4.7	3	USEPA 2012a, NHMRC 2011	NHMRC guideline relevant to aesthetics only
Iron	mg/L	<0.05	15.4	11	0.3	USEPA 2012, NHMRC 2011	NHMRC guideline relevant to aesthetics only
Bromine	mg/L	<0.1	5.7	2	--	WHO 2011	Lower value calculated for a young child for bromide
Iodine	mg/L	<0.1	0.8	0.16	0.15	USEPA 2012, NHMRC 2011	NHMRC guideline relevant to aesthetics only
Mercury	mg/L	<0.0001	<0.0001	0.001	--	NHMRC 2011	
Silica	mg/L	<0.1	40.7	--	80	NHMRC 2011	
Fluoride	mg/L	<0.1	3.9	1.5		NHMRC 2011	
Ammonia as N	mg/L	<0.01	11.3	30	0.5	USEPA 2012b and NHMRC 2011	Health based value is a lifetime health advisory derived by the USEPA (2012), NHMRC only presents a guideline based on aesthetics
Nitrite as N	mg/L	<0.01	0.42	3	--	NHMRC 2011	
Nitrate as N	mg/L	<0.01	0.19	50	--	NHMRC 2011	
C1 - C4 Hydrocarbon Gases							
Methane	µg/L	290	10500	10000	--	US	US Investigation level for methane in water (flammability/explosive risks, action level at 28000 µg/L). No guidelines are available for the rest of the C1-C4 gases and the hazards are equivalent to those identified for methane, hence this group has been assessed together (sum total) and compared with the methane investigation level
Ethene	µg/L	<10	<10				
Ethane	µg/L	16	16				
Propene	µg/L	<10	<10				
Propane	µg/L	<10	<10				
Butene	µg/L	<10	<10				
Butane	µg/L	<10	<10				

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Ref: AGL/13/CNHIA001-F

[10] AGL's Environmental Health Impact Assessment – Camden Northern Expansion Project, 30 October 2013, Table 7.2, Page 59-60.

Analyte grouping/Analyte	Units	Range of Concentrations in Produced Water		Drinking Water Guideline			Comments
		Minimum	Maximum	Health Based	Aesthetic	Reference	
Phenolic Compounds							
Phenol	µg/L	1.5	1.5	4500	--	USEPA 2012a	
2-Methylphenol	µg/L	1.5	1.5	720	--	USEPA 2012a	
3- & 4-Methylphenol	µg/L	<2.0	<2.0	1100	--	USEPA 2012a	
2-Nitrophenol	µg/L	<1.0	<1.0	60	--	USEPA 2012b	
2.4-Dimethylphenol	µg/L	<1.0	<1.0	270	--	USEPA 2012a	
2.4-Dichlorophenol	µg/L	<1.0	<1.0	35	--	USEPA 2012a	
2.6-Dichlorophenol	µg/L	<1.0	<1.0	35	--		Guideline for 1,4-dichlorophenol adopted
4-Chloro-3-Methylphenol	µg/L	<1.0	<1.0	35	--		Guideline for 2,4-dichlorophenol adopted
2.4.6-Trichlorophenol	µg/L	<1.0	<1.0	9	--	USEPA 2012a	
2.4.5-Trichlorophenol	µg/L	<1.0	<1.0	890	--	USEPA 2012a	
Pentachlorophenol	µg/L	<2.0	<2.0	10	--	NHMRC 2011	
Polynuclear Aromatic Hydrocarbons							
Naphthalene	µg/L	<1.0	19.2	6.1	--	USEPA 2012a	
Acenaphthylene	µg/L	<1.0	<1.0	400	--		Guideline for acenaphthene adopted
Acenaphthene	µg/L	<1.0	<1.0	400	--	USEPA 2012a	
Fluorene	µg/L	<1.0	12.9	220	--	USEPA 2012a	
Phenanthrene	µg/L	<1.0	18.5	630	--		Guideline for fluoranthene adopted
Anthracene	µg/L	<1.0	<1.0	1300	--	USEPA 2012a	
Fluoranthene	µg/L	<1.0	<1.0	630	--	USEPA 2012a	
Pyrene	µg/L	<1.0	2.4	87	--	USEPA 2012a	
Benz(a)anthracene	µg/L	<1.0	<1.0	0.1	--	TEF	See Note 1
Chrysene	µg/L	<1.0	1	1	--	TEF	See Note 1
Benzo(b)fluoranthene	µg/L	<1.0	1.8	0.1	--	TEF	See Note 1
Benzo(k)fluoranthene	µg/L	<1.0	<1.0	0.1	--	TEF	See Note 1
Benzo(a)pyrene	µg/L	<0.5	1.1	0.01	--	NHMRC 2011	
Indeno(1.2.3.cd)pyrene	µg/L	<1.0	<1.0	0.1	--	TEF	See Note 1
Dibenz(a.h)anthracene	µg/L	<1.0	<1.0	0.01	--	TEF	See Note 1
Benzo(g.h.i)perylene	µg/L	<1.0	1.7	1	--	TEF	See Note 1
BTEX							
Benzene	µg/L	<1	10	1	--	NHMRC 2011	
Toluene	µg/L	<5	16	80	25	NHMRC 2011	
Ethylbenzene	µg/L	<2	5	300	3	NHMRC 2011	
Total Xylenes	µg/L	<4	46	600	20	NHMRC 2011	
Total Petroleum Hydrocarbons							
C6 - C9 Fraction	µg/L	20	80	90 to 15000	--	WHO 2011	
C10 - C14 Fraction	µg/L	60	21700	90 to 300	--	WHO 2011	
C15 - C28 Fraction	µg/L	180	38800	90	--	WHO 2011	
C29 - C36 Fraction	µg/L	130	17200	90	--	WHO 2011	

Note 1: TEF = toxicity equivalent factor adopted to derive the guideline based on the guideline adopted for benzo(a)pyrene. The TEF relates to carcinogenic PAHs and relates the toxicity of individual carcinogenic PAHs to the most well studied PAH, benzo(a)pyrene, using a factor (ranging from 1 to 0.01) as per (CCME 2010).

On CSG Pollution in Queensland and Northern Rivers Gas Fields

At the 14 November 2013 meeting, and in my subsequent correspondence, I asked Mr Henderson if he could reconcile the known discharges of pollution in Queensland gas fields with his claim that processing in Northern Rivers CSG gas fields would result in no significant waste products or pollution.

In response to Mr Henderson's request for further information regarding my reference to pollutants in Queensland gas fields, my 20 November 2013 e-mail to Mr Henderson included the following information from Lloyd-Smith and Senjen (2011)[11] and data provided by CSG companies to the Australian National Pollutant Inventory.

[11] Lloyd-Smith, M. and Senjen, R. (2011) Hydraulic Fracturing in Coal Seam Gas Mining: The Risks to Our Health, Communities, Environment and Climate. http://ntn.org.au/wp/wp-content/uploads/2012/04/NTN-CSG-Report-Sep-2011.pdf

In my 20 November 2013 email to Mr Henderson, I replied:

> "Referring to Queensland CSG operations, Lloyd-Smith and Senjen (2011) wrote: 'Permits are provided for the release of wastewater produced in association with the fracking process. In one authorisation for one CSG company (i.e., Schedule C, Australian Pacific LNG Pty Ltd Environmental Authority No. PEN100067807) the release of treated water into the Condamine River was authorised for a period of 18 months at a maximum volume of 20 megalitres (ML) per day.'"
>
> "Over 80 chemical compounds as well as radionuclides were listed in the permit and included a range of persistent, bioaccumulative toxic substances such as nonylphenols, Bisphenol A (BPA), chlorobenzenes, bromides, lead, cadmium, chromium, mercury, BTEX."
>
> "There was no requirement for an assessment of the cumulative load or the potential to contaminate sediment, plants, aquatic species and /or animals prior to release. While release limits were included for the listed compounds, the majority of these were not based on the ANZECC water guidelines as many of the chemicals were not listed in the ANZECC guidelines or were marked as having insufficient data to set a water quality guideline."
>
> "Table 3 provides volumes and quantities of a selection of compounds permitted for release into the Condamine River over an 18 month period."

Table 3. Waste Water Permit (Total as Release rate X 20ML X 547.5days/18mths)

Chemical compound	Release rate/day	Total
BPA	200g/ML	2,298KG (2.298 tonnes)
Bromide	7,000g/ML	76,650KG (76.65 tonnes)
Total Chlorobenzenes	1,840g/ML	20,148KG (20.148 tonnes)
Monochloramine	3,000g/ML	32,850KG (32.85 tonnes)
Nitrate	50,000g/ML	5,475,000KG (5,475 tonnes)
Uranium	20g/ML	219KG
Toluene	800g/ML	8,760KG (8.76 tonnes)
Xylene	600g/ML	6,570KG (6.57 tonnes)
Ethylbenzine	300g/ML	3,285KG (3.285 tonnes)
Benzene	1g/ML	10.95KG
Cyanide	80g/ML	876KG
Lead	10g/ML	109.5KG

My 20 November 2013 e-mail to Mr Henderson also included the following information from the Australian National Pollutant Inventory.

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http://ntn.org.au/wp/wp-content/uploads/2012/04/NTN-CSG-Report-Sep-2011.pdf

2011/2012 National Pollutant Inventory reports of Total Air Pollution for:
A) ARROW ENERGY (DAANDINE) PL, Daandine Gas Field - Dalby, QLD;
B) QGC P/L, Kenya Processing Plant and Compressor Stations – Tara, QLD; and
C) QGC P/L, Windibri Processing Plant & Compressor Stations-Condamine, Qld.

Substance	**A) Arrow Dalby Air Total (kg)**	**B) QGC Tara Air Total (kg)**	**C) QGC Condamine Air Total (kg)**
Arsenic & compounds	0.27		
Beryllium & compounds	0.013		
Cadmium & compounds	0.016		
Carbon monoxide	140,000	520,000	500,000
Chromium (III) compounds	3.1		
Copper & compounds	1.3		
Fluoride compounds	8.9	17,000	
Formaldehyde (methyl aldehyde)	13,000	47,000	42,000
Lead & compounds	1.6		
Mercury & compounds	0.0027		
Nickel & compounds	2.2		
Oxides of Nitrogen	210,000	840,000	850,000
Particulate Matter 10.0 um	13,000	2,700	8,300
Particulate Matter 2.5 um	73	2,700	8,200
Polycyclic aromatic hydrocarbons	0.044		
Sulfur dioxide	190	690	640
Total Volatile Organic Compounds	30,000	110,000	99,000
On-site long term waste storage		17,000	

Note: Air Total = Air Point + Air Fugitive

In his 29 November 2013 letter, Mr Henderson did not directly address the apparent disparity between the documented discharge into the environment of pollutants in Queensland gas fields and his claim that CSG processing in the Northern Rivers would involve no significant pollution. Instead, Mr Henderson wrote:

> "Your comment '*When we export coal we do so with its impurities. But with gas the impurities are taken out here and they are dumped on the environment and the local community'* is simply incorrect and unnecessarily alarmist. The air emissions you quote for Queensland CSG operations are mainly from engine exhausts, no different in nature from any other engine exhausts, including cars, tractors and farm equipment. The emissions are not 'impurities' removed from the gas." (Italics in original)

It is not clear why Mr Henderson described as "simply incorrect" my comment that impurities are removed from coal seam gas in Australia and dumped on local environments and communities. Presumably, CSG wastes in the form of drilling chemicals and muds, flared and vented gases, fugitive emissions, evaporations from waste water ponds, produced water from coal seams, contaminants removed by reverse osmosis filtration, impurities filtered from the gas, and pollutants created during processing, are not exported overseas, and are therefore discharged into local environments.

On their website, QGC describes their compressor and processing stations as removing "impurities" from CSG prior to transport via pipeline. As these impurities are not exported overseas, they presumably contribute to the pollutants discharged into the air as documented in QGC's reports to the National Pollutant Inventory (see above).

It is not clear what Mr Henderson means by his comment that the documented air pollution from Queensland CSG gas fields and compressor/processing stations is "mainly from engine exhausts, no different in nature from any other engine exhausts, including cars, tractors and farm equipment". In regards to the health impacts of CSG operations, it seems irrelevant whether the pollutant or dangerous substance that people are exposed to originated in the coal seam, was added by the miners, or entered the environment as a result of the burning of fossil fuels during processing of the gas.

On the Safety of the CSG Industry

In regards to the "proven" safety of the CSG industry, in his 29 November 2013 letter Mr Henderson wrote:

> "Contrary to points you have previously raised, the safety of CSG and the broader oil and gas industry has been examined and demonstrated."
>
> "….our industry has a proven and safe track record over a number of decades."
>
> "CSG has operated in Australia for nearly 20 years without health problems. AGL's CSG project at Camden, on the outskirts of Sydney, has been operating safely for nearly 13 years with 144 wells drilled in the Macarthur Region."
>
> "CSG in Australia has operated in Australia for nearly 20 years, without any health concerns. There are now about 4000 wells drilled, without health concerns.
>
> "The industry is heavily regulated and there are numerous studies to demonstrate health and safety."
>
> "The CSG and petroleum industry is heavily regulated and must pass stringent health, safety and environmental checks before developments can proceed. There are numerous studies available to show that CSG operations represent a low health risk to the community."

In his 29 November 2013 letter, Mr Henderson cited the Australian Institute of Petroleum's (AIP) Health Watch program, the Queensland Government's report on health problems in Tara, AGL's Camden Northern Expansion Project Environmental Health Impact Assessment, and the recent Public Health England report, as providing scientific support for his claim that the CSG industry has been proved to be safe.

In my opinion, Mr Henderson's arguments, and the studies he cited, do not provide scientific evidence to support his claim that the CSG industry has been proved to be safe. Rather, there is much in the studies and reports cited by Mr Henderson to support my assessment that there is a high level risk of potentially catastrophic health impacts associated with operating industrialised gas fields in populated areas.

A discussion of what constitutes scientific "proof", and the questions that various kinds of studies can address, will be followed by a brief review of what the AIP Health Watch program, the Queensland Government's CSG Health Report, AGL's Camden Northern Expansion Project EHIP, and the Public Health England Report tell us about the safety of the CSG industry.

Scientific "Proof" and Research Design

Findings from randomised, controlled experimental trials are the closest that scientists can come to "proof" that some "intervention" (e.g., a medical treatment, living near a CSG gas field etc) has or does not have an effect. The basic requirement is that data obtained from "experimental" subjects, both before and after they are exposed to the "intervention", is compared with pre- and post-test data obtained from "control" subjects who are similar to the experimental subjects, except that they do not experience the intervention.

For instance, to prove the efficacy and/or safety of a new medication, health data obtained before and after "experimental subjects" take the medication are compared with corresponding results obtained from "control subjects" who take a convincing "placebo" or "sugar pill" fake medication. If and only if these conditions are satisfied, can it be concluded that a medication is effective and/or safe.

If the experimental trial only obtains pre-test and post-test data from subjects who take the new medication, with no control group, then it can not be concluded that any observed changes are due to the effects of the medication. A comparison with control group subjects is necessary to rule out the influence of such extraneous factors as natural change over time, random events, and the expectations of subjects.

The "burden of proof" is on the pharmaceutical company that wants to sell a new, potentially hazardous medication to the public, and well-designed, controlled outcome studies are essential to scientifically demonstrate the safety and efficacy of their product.

By contrast, the CSG industry has not collected the very pre-drilling "baseline" health data that is essential if they are to demonstrate that their operations are safe. It is not up to the community to prove that CSG mining is harmful "beyond a reasonable doubt". The onus is on corporations that seek to profit from operating gas fields in populated areas to prove that their operations are safe.

The essential experiment that is needed to demonstrate the safety of the CSG industry would compare health data, taken before and after gas drilling commences, from a community exposed to CSG pollutants, with health data obtained from a similar community that is not exposed to CSG operations. No other experimental design is capable of approaching scientific "proof" that operating CSG gas fields in populated areas is safe.

The reports and studies cited by Mr Henderson in his 29 November 2013 letter provide useful scientific information, some of which is relevant to the CSG industry, but none of these documents include data obtained pre- and post-drilling, or from an appropriate control group. Consequently, none can provide scientific "proof" that the CSG industry is safe.

Nonetheless, the materials cited by Mr Henderson do provide scientific data that is relevant for the assessment of CSG-related health risks.

Following are brief reviews of what the AIP Health Watch program, the Queensland Government's CSG Health Report, AGL's Camden Northern Expansion Project EHIP, and the Public Health England Report, do and do not tell us about the safety of the CSG industry.

The Australian Institute of Petroleum (AIP) Health Watch Program

The AIP Health Watch program is a prospective cohort study of all-cause mortality and cancer incidence, and a case-control study of leukaemia and benzene exposure, for 20,000 past and current employees in the petroleum industry. The recently released, 14th Health Watch Report[12], provided an updated comparison of illness and cause of death statistics for petroleum industry employees compared with age-adjusted data for the Australian population. The study does not investigate acute health effects from working in the petroleum industry.

In his 29 November 2013 letter, Mr Henderson suggested that the AIP Health Watch program provided scientific evidence to support his claim that the CSG industry has been proven to be safe. Mr Henderson wrote:

> "The people most exposed to petroleum are healthy. The people probably most exposed to hydrocarbon gases and liquids, including substances such as BTEX which are naturally found in crude oil, are those who work in oil refineries and conventional natural gas processing plants. The AIP Health Watch program, which has been in operation since 1980 and is run by Monash University, shows that workers in the petroleum and natural gas production industry have better health than the general Australian community and are less likely to die of the diseases commonly causing death - including cancer, heart and respiratory conditions."

On a number, but not all, of the cancer and death statistics reported in the AIP Health Watch study, participating petroleum industry employees enjoyed better health outcomes than age-matched people in the general population. Nonetheless, this research does not indicate that working in the petroleum industry is either good or bad for your health - nor does it have any direct relevance to the question of whether the CSG industry is safe for workers and the public.

The AIP Health Watch study's "prospective cohort" design does not compare employees' pre-employment to post-employment changes in health with matched people in a control group. Consequently, the study can tell us some useful things about the health risks associated with working in the petroleum industry, but it cannot "prove" that working in the petroleum industry is safe or unsafe.

The 14th AIP Health Watch report is based on data obtained from petroleum industry employees who joined the study before the year 2000 and who had worked in the industry for five or more years. Consequently, there are likely to be few, if any, CSG industry employees contributing data to the study. Nonetheless, the research does provide some insights into the potential health risks of the CSG industry.

Throughout its history, the AIP Health Watch study has reported generally better health and mortality statistics for petroleum industry workers compared to age-adjusted figures for the Australian population. The Health Watch researchers attribute this result to the effects of a "selection bias" known as "The Healthy Worker Effect".

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[12] The Australian Institute of Petroleum Health Surveillance Program (2013) Fourteenth Report, Monash University, November 2013.

As the Health Watch researchers explained:

> "One cause of the 'healthy worker effect' is the relative social and economic advantage of employed people, especially for people with relatively secure employment. Unemployed people as a whole tend to have lower socioeconomic status. This commonly correlates with lower income, fewer years of education, lower health status and higher age-adjusted mortality rates than employed people. Hence when the mortality of occupational cohorts is compared with that of the general population, the mortality rate is higher in the latter because it includes many socially disadvantaged people. Another factor is that people with life-threatening conditions, such as cancer, tend not to seek or obtain employment after diagnosis: this further lowers the mortality rate in the workforce compared with the general population, especially in the years immediately following recruitment of members of the cohort into Health Watch."[13]

The sample of subjects in the AIP study was further biased towards healthier people because:

- Data was only included after the employee worked for five years in the industry, thereby excluding people who left due to illness before they completed five years employment;
- The Health Watch participants had a low average lifetime tobacco use compared with the general population; and
- Prospective petroleum industry employees underwent health checks before they were employed.

Participants in the AIP study are likely to enjoy better cancer and mortality outcomes than the corresponding age group in the Australian population because they were selected from the beginning to be healthier than the average.

But does working in the petroleum industry have a beneficial, deleterious, or neutral effect on health?

According to the 14th AIP Health Watch report, when compared to the general population, for petroleum industry employees:

- "The chance of contracting cancer is similar for men and women … as for all Australians", but mortality from cancer is significantly reduced for male employees;
- "(For men) Two cancers, mesothelioma and melanoma, have been and are still occurring at statistically significantly higher rates than in the general population. Prostate cancer is also in statistically significant excess";
- "Prostate cancer incidence in the cohort is now statistically significantly higher than in the general population, however prostate cancer mortality remains similar to that of the general population";
- "There were 14 cases of melanoma in women. The incidence is slightly higher than in the general female population, but the increase is not statistically significant";
- "There were ten cases of lung cancer among women. This rate was slightly higher than the general female population….";
- "….This updated analysis now shows an almost identical risk of bladder cancer compared to the general population";

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[13] The Australian Institute of Petroleum Health Surveillance Program (2007) 13th Report, Monash University, November 2013, Page 35.

- "There was a statistically significant lowering of lung cancer, liver cancer and cancers of the lip, oral cavity and pharynx and COPD which is probably a result of less tobacco consumption by members of the cohort than by the reference population";
- "Bladder and kidney cancers in the cohort remain similar to the general population, as does multiple myeloma";
- "Cancer mortality is also lower for men in all occupational groups investigated compared to the general population and is statistically so except for Terminal Operators and Maintenance workers";
- "Leukaemia, kidney and bladder cancers were also elevated in the driver group compared with office only workers but only statistically significantly so for bladder cancer"; and
- "The findings of this study (the case controlled study) provide strong evidence for an association between previous benzene exposure in the Australian petroleum industry and an increased risk of leukaemia."[14]

Given that the selection of participants in the AIP study was biased towards people who are healthier than average, findings that, relative to the general population, petroleum industry employees have: a similar chance of contracting cancer; a statistically significant increased incidence for men of mesothelioma, melanoma, and prostate cancer; and similar rates of bladder and kidney cancers, are causes for concern and warrant further investigation.

Due to its design, the AIP study cannot determine whether working for a minimum of five years in the petroleum industry is good or bad for an employee's health. It could well be that employees would have been healthier if they had not worked in the industry.

As the authors of the 14th AIP report noted:

> "There is an argument for using a reference population composed of workers with similar demographic characteristics including the likelihood of obtaining and retaining employment rather than the general population".

That is to say, the study needs a genuine control group, matched on relevant characteristics, to enable more informative analyses of the obtained results.

The AIP study provides some information about the health of petroleum industry employees, but tells us nothing about the health impacts of petroleum and gas industries on the general population. I note that, in this regard, in the USA, Lefall et al. (2010)[15] compared nationwide cancer mortality statistics with the incidence of cancer in three New York counties that had a distinctively rural character and a history of intensive gas and oil industry activity. Based on nation-wide statistics from 1950 to 1994 for 55 different types of cancer, women in these three counties were consistently in the top bracket for deaths caused by cancer of breast, cervix, colon, endocrine glands, larynx, ovary, rectum, uterus and vagina. Men from the same region were consistently in the highest statistical bracket for deaths caused by bladder, prostate, rectum, stomach, and thyroid cancers.[16]

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[14] Monash University and Deakin University (2001) Lympho-haematopoietic Cancer and Exposure to Benzene, in the Australian Petroleum Industry Technical Report and Appendices, June 2001.
[15] Leffall, L., Kripke, M. and Reuben, S. (2010). "Reducing Environmental Cancer Risk: What We Can Do Now"; *2008-2009 Annual Report of the President's Cancer Panel,* Part 2, Chapter 1, pp. 29 – 40, April 2010.
[16] National Cancer Institute (2011). Cancer Mortality Maps & Graphs, NIH, DHHS. http://www3.cancer.gov/atlasplus/type.html (January 2011).

AGL's Camden Northern Expansion Environmental Health Impact Assessment

In his 29 November 2013 letter Mr Henderson cited the AGL Camden EHIS[17] as evidence that the CSG industry has been proven to be safe. Specifically, Mr Henderson wrote that:

> "AGL's CSG project at Camden, on the outskirts of Sydney, has been operating safely for nearly 13 years with 144 wells drilled in the Macarthur Region."
>
> "We recommend that you take the time to read the huge amount of material that is available to the public in relation to the Queensland CSG projects and to AGL's recent Camden Northern Expansion Project Environmental Health Impact Assessment. AGL's study, which covers the full spread of potential health risks, concludes that its proposed Camden Northern Expansion would have posed low and acceptable risks to community health and to air, groundwater and surface water."

After studying AGL's EHIA, I could find no evidence there to support Mr Henderson's claim that AGL's CSG project at Camden "has been operating safely for nearly 13 years" or that the CSG industry has been proven to be safe.

I could find no health data in the AGL EHIA which compared the health status of local residents prior to, and following the setting up of AGL's gas fields in Camden, even though such data would be essential to establish the safety of the Camden CSG operation. I could not find any reference to any health data collected during 13 years of operations.

The AGL EHIA is "… a screening level health risk assessment that assesses the likelihood and severity of risks to human health."[18] That is to say, the AGL EHIA is not a real-world study of health impacts, and is not concerned with health data obtained from potentially affected people. The AGL EHIA is an assessment of risks in a possible future, and is based on certain assumptions, computer modelling and health guidelines, rather than real-life data.

As the authors of the AGL EHIA explained:

> "The EHIA presented in this report is a desk-top assessment. The term desk-top is used to describe that the EHIA has not involved the collection of any additional data over and above that which has been provided from Project specific EA technical studies, or studies undertaken for existing operations within the CGP or community consultation."[19]
>
> "The EHIA assessment presented in this report is largely qualitative, with some aspects addressed in a quantitative manner, and has been conducted for the purpose of summarising all the environmental health impacts that may be associated with the proposed Project, evaluating those impacts (on a qualitative or quantitative basis where relevant) and where an impact has been identified, determining if it can be mitigated through existing or other management measures."[20]

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[17] Environmental Health Impact Assessment – Camden Northern Expansion Project, Prepared for AGL Energy Limited, 30 October 2013.
[18] Environmental Health Impact Assessment – Camden Northern Expansion Project, 30 October 2013, Page 1.
[19] Environmental Health Impact Assessment – Camden Northern Expansion Project, 30 October 2013, Page 3.
[20] Ibid.

The AGL EHIA does not include any controlled outcome study or data that could support the claim that CSG mining has been proven to be safe. The AGL EHIA can only support a claim that, on the basis of certain assumptions, in the opinion of the authors, there is a certain level of potential risk to human health.

Like other CSG risk assessments, the AGL EHIS assumes that gasfield industrialisation takes place in an ideal world, free of accidents, misadventure and negligence - where all works are carried out "in accordance with best practice, as well as the current policies and codes of practice".[21]

The limitations of such "desk-top" assessments as the AGL EHIA become apparent in the real world where, even with stringent regulation and best practice engineering, wells leak and 200 metres of bore pipe can be blown high into the air, CSG wastewater is dumped into rivers, and even AGL's risk assessment procedures can break down.

In March 2013 the NSW Environment Protection Authority (EPA) fined AGL for not maintaining its emissions monitoring equipment.[22] In the August 2013 "Undertaking to the Environment Protection Authority"[23], the EPA expressed "concern" that in 2007 AGL's emissions monitoring equipment began to break down, and by 2009 all their monitoring equipment had stopped operating.

AGL provided false information to the EPA in Annual Returns from 2006 to 2011, and its publicly available 2007 to 2011 Annual Environmental Performance Reports included the "false and misleading" statement that, "Full results of the continuous emissions monitoring for the reporting period are kept on file". "AGL advised that the non-reporting was due to oversight combined with a lack of understanding by AGL staff regarding the significance of the equipment breakdown".[24]

A serious limitation of CSG health impact risk assessments like the AGL EHIA and the Public Health England Report is their lack of health data obtained from people actually exposed to CSG operations, and their reliance on "guidelines" to determine the potential health risk posed by individual pollutants.

For many CSG pollutants, guidelines for safe levels of exposure do not exist, are inadequately researched, or only provide toxicity ratings which do not address all potential health impacts. For the compounds listed in AGL's EHIS Table 4.5 and "Report of Analysis" for air emissions (see Pages 6, 8&9 above) and Table 7.2 for waste water (see Pages 11&12 above), where available, "screening level guidelines" were derived from a variety of sources.

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[21] Environmental Health Impact Assessment – Camden Northern Expansion Project, Prepared for AGL Energy Limited 30 October 2013, Page 1.
[22] AGL Press Release (2013). AGL installs new continuous emissions monitoring equipment to satisfy EPA licence conditions, 13 March 2013. http://www.agl.com.au/about-agl/media-centre/article-list/2013/mar/agl-installs-new-continuous-emissions-monitoring-equipment-to-satisfy-epa-licence-conditions
[23] Gifford, M. (2013). Chief Environmental Regulator, NSW EPA, Protection of the Environment Operations Act 1997 (NSW) Undertaking to the Environment Protection Authority given for the purposes of Section 253A, AGL Upstream Investments Pty Limited, signed 8 August 2013. http://www.epa.nsw.gov.au/epamedia/EPAMedia13071501.htmhttp://www.epa.nsw.gov.au/resources/prpoeo/undertakingEPA0011.pdf
[24] Ibid.

As the authors of the AGL EHIS explained in Appendix 3 of their report:

> "It is noted that a number of chemicals have very limited data available and hence the studies available have been further evaluated for the purpose of determining the potential for adverse health effects to be of significance."[25]

> "It is noted that there are a number of chemicals where no suitable human health guidelines are available or relevant, hence the evaluation of these chemicals has been undertaken on a qualitative basis only."[26]

If "health guidelines" are to be used as criteria for ignoring the possible effect of a detected pollutant, then the validity, reliability and interpretation of guideline cut-off levels become vitally important.

In CSG health impact assessments such as the AGL EHIS, the ultimate conclusion that there is likely to be a minimal health impact from exposure to a large number of CSG pollutants newly introduced into an environment, is based on a procedure that only considers possible impacts of individual substances one at a time.

As the authors of the AGL EHIS explained the process:

> "Once an estimate of exposure has been developed it was compared to appropriate National or International health protective guidelines to determine if the Project poses a risk with regard to each of the hazards. If the exposure from the Project is less than the guideline then there is no unacceptable risk. If the exposure from the Project may be larger than the guideline there is potential for unacceptable risk which can be addressed by refining the worst case assumptions or by recommending control/ management measures be included in the Project."[27]

That is to say, in the AGL EHIA it is assumed that if any one of the many substances is present at a level below the adopted guideline cut-off point, then the health impact of that substance can be ignored. This process is based on the dubious assumption that there is no cumulative, interactive, or magnifying effects when people are exposed to a complex mix of dangerous substances that are poorly understood, and some of which can damage health even in minute doses.

The simultaneous exposure to numerous dangerous substances could present a greater risk to health than exposure to individual substances by themselves. While it might be safe to consume a particular substance at a dose of say 1/10th of a recommended health guideline, the level of risk increases in an unknown manner when a number of substances are consumed even if each of them constitutes only a 1/10th dose of a recommended guidelines dose.

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[25] Environmental Health Impact Assessment – Camden Northern Expansion Project, Prepared for AGL Energy Limited 30 October 2013, Appendix C Human Health and Ecological Risk Assessment – Hydraulic Fracturing Activities, Page 22.
[26] Environmental Health Impact Assessment – Camden Northern Expansion Project, Prepared for AGL Energy Limited 30 October 2013, Appendix C Human Health and Ecological Risk Assessment – Hydraulic Fracturing Activities, Page 23.
[27] Environmental Health Impact Assessment – Camden Northern Expansion Project, Prepared for AGL Energy Limited 30 October 2013, Page 6.

The appropriateness and usefulness of this procedure is seriously undermined by the limited data and lack of guidelines for many chemicals, and the poor understanding of accumulative and synergistic effects that many of these chemicals and their metabolites can have on human physiological systems.

As US toxicologist Dr David Brown (2013)[28] explained, gas field toxicology is complicated because:

- We have incomplete identification of the chemicals present
- Chemicals can interact with other chemicals in complex unknown ways
- The presence of one agent can greatly increase the toxicity of another agent
- Agents have multiple physiological actions on various target organs
- Health effects of exposure to many chemicals is unknown
- How certain chemicals alter the biological processing of other chemicals is unknown
- Substances that inhibit metabolism or excretion magnify the effects of other chemicals
- Some agents can change the physiologic distribution of other chemicals
- Some agents can cause chemicals that would not normally do so to enter the brain
- Medications can affect the impact of toxic substances

The Public Health England Report on Health Impacts of Shale Gas Mining[29]

As recommended by Mr Henderson in his 29 November 2013 letter, I read the Public Health England (PHE) Report on the potential health impacts of shale gas mining in the UK, but could find nothing there to support Mr Henderson's claim that the CSG industry has been proven to be safe.

Like AGL's Camden EHIA, the PHE report is a "desktop" exercise in risk assessment, based on a particular set of assumptions, health guidelines applied to individual substances in a complex mix of pollutants, and a belief that regulation can ensure the safety of people who live amongst gas fields. The risk assessment design of the PHE report precludes it from providing scientific evidence to support the claim that the CSG industry has been proven to be safe.

I note that the authors of the PHE report concluded that, "Where potential risks have been identified in the literature, the reported problems are typically a result of operational failure and the poor regulatory environment", and UK regulations will "minimise the potential for pollution risk to human health."[30]

Significantly, the authors of the PHE report recommended that: a) "to facilitate the assessment of the impact of shale gas extraction on the environment and public health" the UK shale gas industry carry out the kind of baseline monitoring that is lacking in Australian CSG operations; and that b) "emission inventories", which already exist in Australia, be established to provide important information needed for proper assessment of health risks.

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[28] Brown, D. (2013). Fundamental new Chemical Toxicology with Exposure Related to Shale Gas Development, Physicians Scientists & Engineers for Healthy Energy, http://www.psehealthyenergy.org/COURSES; http://www.youtube.com/watch?v=AhkswtBom4s
[29] Public Health England (2013) Review of the potential public health impacts of exposures to chemical and radioactive pollutants as a result of shale gas extraction, October 2013.
[30] Public Health England (2013) Review of the potential public health impacts of exposures to chemical and radioactive pollutants as a result of shale gas extraction, October 2013, Page iv.

The Queensland Government CSG Health Report[31]

In his 29 November 2013 letter, Mr Henderson cited the March 2013 Queensland Department of Health CSG Report as evidence that the CSG industry has been proved to be safe. As Mr Henderson wrote:

> "In March, 2013, the Queensland Government published a report which assessed health complaints from the Tara area and concluded that the available evidence does not support the concern among some residents that excessive exposure to emissions from CSG activities is the cause of the symptoms reported."

I note that the Queensland Department of Health report also concluded that the information it relied on from the Darling Downs Public Health Unit (DDPHU) investigation "did provide some evidence that might associate some of the residents' symptoms to exposures to airborne contaminants arising from CSG activities."

Like my recent report on the health impacts of CSG and shale gas mining[32], the Queensland Department of Health Report is an exercise in risk assessment based on the evaluation of available evidence that people have been exposed to CSG pollutants in doses sufficient to cause illness. Due to their design and the lack of any pre-drilling to post-drilling health data, neither investigation is capable of providing scientific "proof" that the CSG industry is or is not safe. Both reports can only generate probabilistic statements, based on specified evidence and assumptions, which assess the likely degree of risk to health.

The methodological, technical and analytical inadequacies of the Queensland CSG Health study have been discussed by Dr Geralyn McCarron[33] and Dr Mariann Lloyd-Smith[34], and the reader is directed to these papers for detailed analyses of this report.

My report on the health impacts of CSG and shale gas mining[35] and the Queensland Department of Health Report reached different conclusions regarding the probability of deleterious health impacts. Whereas the Queensland Department of Health report concluded that a "clear link" was not evident between the health complaints of some Tara residents and exposure to CSG pollutants, I concluded that there was a high probability of potentially catastrophic impacts from operating gas fields in populated areas.

In my opinion, the differing conclusions reached in my and the Queensland Department of Health assessments were due primarily to the different medical and environmental data that was available to, and used for, each report.

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[31] Queensland Department of Health (2013) Report on "Coal seam gas in the Tara region: Summary risk assessment of health complaints and environmental monitoring data", March 2013.

[32] Somerville, W. (2013) Self-help Risk Management Tools: A Report on the Health Impacts of CSG and Shale Gas Mining, download from the "CSG" page at www.creeksbend.com

[33] McCarron, G. (2013) Symptomology of a Gas Field: An Independent Health Survey in the Tara Rural Residential Estates and Environs. https://sites.google.com/site/frackingireland/symptomatology-of-a-gas-field

[34] Lloyd-Smith, Mariann (2013) No clean bill of health for CSG: A Critique of the Queensland Department of Health's Report on the Health Impacts of CSG Activities on the Tara Community, National Toxics Network.

[35] Somerville, W. (2013) Self-help Risk Management Tools: A Report on the Health Impacts of CSG and Shale Gas Mining, download from the "CSG" page at www.creeksbend.com

The Queensland Health Department risk assessment was based on:

- The Darling Downs Public Health Unit (DDPHU) investigation of 56 people who attended GPs and hospitals in the Tara region or who registered CSG related health complaints with a government phone service;
- A report by Dr Keith Adam based on "direct participation" with 15 people in person and two by telephone who attended clinics at Tara Hospital on 11–12 October 2012;
- Environmental Resources Management Australia Pty Ltd's (ERM) 13 air samples collected at nine residential sites in the Tara Estates from 11 to 19 July 2012; and
- Environmental monitoring from July-December 2012 at the Wieambilla Estates by Environmental Monitoring and Assessment Sciences.

My report on the health impacts of CSG and shale gas mining was based on information including:

- A review of the scientific literature on substances used, and liberated during, mining of gas from coal and shale seams;
- A review of the scientific literature on the contamination of air, water and soil systems by gasfield pollutants;
- A review of the scientific literature concerning the health impacts of exposure to CSG and shale gas pollutants;
- Dr Geralyn McCarron's (2013)[36,37] study on the health status of 113 people from 35 households in the Tara residential estates and the Kogan/Montrose region;
- CSG company reports to the 2013 Australian National Pollutants Inventory; and
- A 2013 medical test finding of a high level of hippuric acid, a metabolite produced following exposure to toluene, in the blood of a boy who lived in the Tara estates.[38]

As Dr Geralyn McCarron (2013) pointed out, the Queensland CSG health study did not consider the case of a boy whose blood tests indicated the presence of hippuric acid:

> "Toluene metabolites found at high levels in a child in a non-occupational context is worrying, taking into account the short half-life i.e. toluene is quickly metabolised. This should have prompted investigation by the health department as a matter of urgency. Toluene is a known neurotoxin, an irritant and a suspected reproductive toxin that can be absorbed via inhalation. It is known to be associated with coal seam gas and has been found repeatedly in air samples in the residential estates. No action was taken by the health department."[39]

The Queensland CSG Health study relied on face-to-face interactions with 71 people, while my study referred to Dr Geralyn McCarron's (2013) survey of 113 people in the Tara area.

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36 McCarron, G. (2013). Symptomology of a Gas Field: An Independent Health Survey in the Tara Rural Residential Estates and Environs, Page 29.

37 McCarron, G. (2013). Submission to the NSW Chief Scientist and Engineer's review of coal seam gas activities in NSW with a focus on the impacts of these activities on human health and the environment. http://www.chiefscientist.nsw.gov.au/coal-seam-gas-review/?a=30015

38 McCarthy, J. (2013). Testing Times ahead for residents of Tara as boy found with hippuric acid in system, Sunday Mail QLD, 6 January 2013.

39 McCarron, G. (2013). Symptomology of a Gas Field: An Independent Health Survey in the Tara Rural Residential Estates and Environs. https://sites.google.com/site/frackingireland/symptomatology-of-a-gas-field

Another difference between my report on the health impacts of gas mining and the Queensland CSG Health Study was the data used to evaluate the likelihood that people who live near gas fields are being exposed to pollutants in sufficient doses to cause illness.

The Queensland CSG Health investigation relied on a limited number of potentially biased air samples. In the Queensland health study residents were instructed to take canister air samples when they smelled odours. This procedure was likely to bias results towards more samples being taken during the daytime, rather than at night when people were more likely to be indoors and pollutant levels are generally higher. The Queensland health study assumed that sampling when odours were present would guarantee that samples were taken when problematic pollution was at a maximum concentration, even though there are no grounds for assuming that the presence of the most dangerous pollutants is associated with odours.

By contrast, my assessment of potential health impacts from exposure to gas field pollutants also took account of recently available data from the Australian National Pollutant Inventory (ANPI) as well as from environmental sampling of air and water.

It was notable that data presented in the Queensland Health Study and the AGL Camden EHIS demonstrate a wide range of results when environmental testing involves multiple air or water samples obtained from the one site. For example, in the Queensland Health study benzene readings from one site varied from $<4.3\ \mu g/m^3$ in the daytime to $25\ \mu g/m_3$ at night. The wide variation in results indicates that adequate assessment of CSG pollution requires continuous sampling over extended periods of time to take into account fluctuations due to such factors as time of day, weather conditions, and season.

As the authors of the Queensland Health study commented:

> "However, the air monitoring program had important limitations. The total monitoring period was nine days, the methodology resulted in limits of reporting for some analytes that were substantially higher than reference air quality criteria and the monitoring was not designed to identify short-term peaks or troughs in air concentrations. It is considered a more strategic air quality monitoring program could be implemented to provide more useful information on the impacts of the CSG industry, if any, on ambient air quality in the region."

The problems inherent in the use of "guidelines" to evaluate the potential health impacts of exposure to a complex mix of pollutants by considering each pollutant one at a time have been discussed above in relation to the AGL Camden EHIS.

The combined health effects of simultaneous exposure to many pollutants, even if each is present in concentrations below a chosen "standard", is entirely unknown. This issue is especially important for interpreting the Queensland CSG Health report because testing of air samples over brief periods of time in a residential estate in Tara detected a diverse range of compounds including the VOCs hexane, propene, chloromethane, dichlorodifluromethane, methylene chloride, ethanol, acetone, methyl ethyl ketone, acrolein, vinyl acetate, pentane, heptane, tetradecane, hexadecane, heptadecane, cyclohexane, 2-methylbutane, 3-methylpentane, 3-methylhexane, methylcyclohexane, tetrachloroethylene, 2-ethyl-1-hexanol, ethylacetate, benzene, toluene, xylene, ethylbenzene, 1,2,4-trimethylbenzene, phenol, benzothiazole, naphthalene, and alpha-pinene.[40]

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[40] National Toxics Network (2013). No clean bill of health for CSG: A Critique of the Queensland Department of Health's Report on the Health Impacts of CSG Activities on the Tara Community, April 2013. www.ntn.org.au

While environmental sampling can evaluate the presence of CSG pollutants at a particular place and time, the Australian National Pollutant Inventory (ANPI) contributes to the assessment of the risk of human contamination by providing data that quantifies the overall volume of pollutants that gas mining companies release each year into the atmosphere and local environments.

For instance, from the National Pollutant Inventory data we know that during 2011/2012:

- Arrow Energy's Daandine Gas Field released into the air substances including 140,000 kg of Carbon monoxide, 13,000 kg of Formaldehyde, 210,000 kg of Oxides of Nitrogen, 13,073 kilograms of Particulate Matter, and 30,000 kg of Volatile Organic Compounds (VOCs); and

- QGC's Kenya CSG processing plant and compressor station in Tara released into the air 520,000 kg of carbon monoxide, 47,000 kg of formaldehyde, 840,000 kg of oxides of nitrogen, 5400 kg of Particulate Matter, 17,000 kg of fluoride compounds, 110,000 kg of VOCs, while 17,000 kg of waste was in long-term on-site storage.

The National Pollutant Inventory data makes it possible to estimate the scale of the total load of air pollutants that are discharged into local environments by specific CSG operations such as gas fields and compressor and processing plants. The CSG industry is being massively expanded in Queensland - QGC estimate that they will have 24 CSG compressor/processing plants operating by the end of 2014 - and National Pollutant Inventory data enables informed estimates of the environmental pollution that will be produced when these gas fields are fully developed.

As well as discharges into the air, the total environmental burden of pollutants from CSG operations includes air, water, and soil contamination from drilling chemicals and muds, flared and vented gases, fugitive emissions, evaporations from waste water ponds, produced water from coal seams, and substances removed by filtration.

Once the total environmental burden of pollutants is known, the scientific task is to determine the ability of local soil, water, and air systems to dissipate, process, and render inert the known quantities of persistent, bio-accumulative, teratogenic, mutagenic, carcinogenic, endocrine-disrupting, and toxic substances that will be regularly discharged into the local environment, often within earshot of where people live. Such empirical analyses could then inform debate about whether operating industrialised gas fields in populated areas constitutes a minimal or, as I argue, a high level risk of potentially catastrophic health impacts.

In his letter of 29 November 2013 Mr Henderson cited a comment about employee health from the Queensland Government report as support for his claim that CSG has been proved to be safe. Mr Henderson wrote:

> "To quote from the Darling Downs Public Health Unit report, one of the reasons for dismissing a link between CSG and reported health problems is '*the lack of evidence of employees working within the CSG industry having similar symptoms. If community members were experiencing symptoms due to CSG activities, it would be highly likely for workers in the industry to be reporting similar and probably more severe effects due to their likely much higher exposure'"*. (Italics in original)

In this "worker good health" argument, the validity of the conclusion depends on the truth of the supporting premises. This argument takes the form:

- Premise 1 - Workers have a much greater exposure to CSG pollutants than the public,
- Premise 2 - There is no evidence that CSG workers experience symptoms,
- Conclusion - Therefore, there is no link between exposure to CSG pollutants and symptoms reported by the public.

The first premise - that CSG workers have a much greater exposure to pollutants than residents who live amongst gas fields - might appear reasonable, but is not necessarily true. The Queensland CSG Health study does not cite any scientific research that compares the exposure to pollutants of local residents, and especially of children, who live amongst the gas fields 24 hours a day, seven days a week, with the exposure of workers selected to be of good health, who work shifts, often on a fly-in/fly-out basis, and who have access to worker health and safety training and protective equipment.

The second premise - that there is no evidence that CSG workers experience symptoms - begs the question as to whether this lack of evidence indicates that workers truly are not experiencing health problems, or that their health problems are not being reported, or are being reported to their family doctors rather than to their employers' medical personnel.

As Dr Penny Hutchinson, author of the Darling Downs Public Health Unit Investigation in the Queensland Health Report, commented:

> "Similarly there have been no reported presentations by employees of the mining companies with symptom patterns similar to those described by the residents. There are multiple potential reasons for this including:
> - the employees are not experiencing symptoms,
> - employees are presenting to health-care providers outside the local area (many mining employees work fly in/fly out or drive in/drive out rosters so they leave the local area and return to their usual place of residents between working shifts),
> - employee concerns that if they report similar symptoms to those in the community it may jeopardise their employment."[41]

I note that there is anecdotal evidence that CSG industry workers have experienced health problems similar to those reported by Tara residents. In her 2013 report, Dr Geralyn McCarron observed that:

> "Of the 113 people surveyed, 4 worked in the CSG industry. Two of these were involved in infrastructure construction and although both had ongoing skin irritation, neither believed their health was impacted. One person, after 4 months employment in a CSG facility, began to develop severe symptoms in their hands and feet. After biopsy they were eventually diagnosed with neuropathy (nerve damage) and can no longer work. The fourth worker also has a symptomatic neuropathy which has been, without tests, diagnosed as carpal tunnel. They also suffer from severe fatigue, headaches and nausea."[42]

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[41] Hutchinson, P. (2013) The Darling Downs Public Health Unit Investigation into the health complaints relating to Coal Seam Gas Activity from residents residing within the Wieambilla Estates, Tara, Queensland, July to November 2012, FINAL REPORT, January 2013.

Dr Geralyn McCarron further reported that:

> "Following the publication of the Queensland Government's health report and Lawrence Springborg's assertion that CSG workers have had no health problems, a person previously employed on CSG drilling rigs in a different area of Queensland was so disgusted that they contacted the Gasfields Support Group to relate their story. That data is not included in the numbers for this study. This worker's ill health included nosebleeds, spasms of the hands and extreme difficulty breathing, making it impossible to continue work. Their comment was: *"They wiped their hands of me."*[43] (Italics in original)

Mr Henderson's 29 November 2013 letter included an unfortunate reference to the Queensland CSG Health study to support his claim that the CSG industry has been proved to be safe. Mr Henderson wrote that:

> "The Queensland Government report highlighted concerns with Tara drinking water because it was contaminated by faecal matter, not hydrocarbons."

Mr Henderson's statement is problematic because the association of "faecal matter" with "drinking water" is likely to create a degree of disgust in the reader, and this emotion contributes to the potency of the implications that the statement carries about the hygiene of the Tara residents and the causes of their medical problems. Further, Mr Henderson's statement benefits from the authority of the Queensland Government but, in my opinion, does not properly represent the findings of the Queensland CSG Health study.

In regards to sampling of water, the Queensland Health CSG Report noted:

> "Samples were collected from potable drinking water sources (all nine lots) and ponds and surface water sites (five lots)… According to the ERM report, all properties reported use of roof-harvested water for drinking and most household purposes. Two properties reported use of on-site ponds or surface water created by a dam for washing and bathing."[44]
>
> "Two rainwater tanks were reported to contain E.coli, but all tanks had some type of microbial contamination as demonstrated by the other testing. The presence of microbes is expected in both roof-harvested water and untreated surface water. Further microbial analysis would be needed to identify potential health hazards."[45]

As noted in the Queensland Health CSG report, the presence of microbes in roof harvested water used for drinking is nothing unusual for rural areas. In my opinion, the finding of E.coli in two rainwater tanks does not justify Mr Henderson's claim that the Queensland Government report "highlighted concerns with Tara drinking water because it was contaminated by faecal matter, not hydrocarbons".

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[42] McCarron, G. (2013). Symptomology of a Gas Field: An Independent Health Survey in the Tara Rural Residential Estates and Environs, Page 27.
[43] McCarron, G. (2013). Symptomology of a Gas Field: An Independent Health Survey in the Tara Rural Residential Estates and Environs, Page 28.
[44] Queensland Department of Health (2013) Report on "Coal seam gas in the Tara region: Summary risk assessment of health complaints and environmental monitoring data", March 2013, Page 10.
[45] Queensland Department of Health (2013) Report on "Coal seam gas in the Tara region: Summary risk assessment of health complaints and environmental monitoring data", March 2013, Page 11.

Discussion, Implications and Recommendations

After attending Mr Peter Henderson's presentation at the 14 November 2013 meeting with Kyogle's Mayor, I understand why some local government councillors and business people, who have the community's best interests at heart, could support Mr Henderson's plans for the gas field industrialisation of the Northern Rivers.

Mr Henderson's account of what the CSG industry offers the Northern Rivers is very attractive – a proven safe, "clean and green" development with no downside, and economic benefits with no costs. And the Northern Rivers is special because our coal seams do not contain benzene, and the gas and CSG waste water are safe to use straight out of the ground.

For gas industry executives and employees, and others looking to profit from gas mining, Mr Henderson's claims that the CSG industry is in all ways safe and beneficial have potent commercial implications. The costs involved in meeting legal obligations to manage risk are greatly reduced - if there is no risk there is nothing to manage. When there is no danger, government regulations to protect health and the environment become unnecessary.

If members of local councils and regulatory authorities believe that local CSG wastewater is safe for use with minimal processing, then "a problem becomes a product". The issue of how to safely dispose of CSG wastewater disappears because the water can be sold as fit for human and agricultural use.

Mr Henderson's claims about the safety of the CSG industry and the nature of coal seam gas and waste water in the Northern Rivers were presented as facts about the real world, and are therefore testable by empirical evidence and rational argument.

In my opinion, Mr Henderson has not provided any direct or credible evidence that:

- CSG compressor and processing plants in the Northern Rivers would not create the pollution seen in Queensland gas fields;
- The CSG industry is proven safe;
- Northern Rivers CSG does not contain any impurities;
- There is no benzene in coal seams; and
- Metgasco's CSG waste water is fit, without treatment, for use with stock, and with the removal of some salt, suitable for irrigation and human consumption.

In his letter, Mr Henderson stated that, "Communities deserve sensible and open debate about the best ways to achieve our energy needs and balance any potentially competing interests".

To progress this "sensible and open debate", in my opinion, it would be useful if Mr Henderson made public chemical assays, with detail similar to the assays provided by AGL in their Camden EHIS, to support his claims about the nature and safety of CSG operations in the Northern Rivers.

In his letter Mr Henderson wrote, "Your exaggerated and incorrect comments do nothing to encourage such debate. They do no more than create unjustified fear."

Everyone prefers good news to bad, but when difficult issues have to be confronted, it is sometimes better to be anxious now than sick and sorry later.

Anxiety is a natural protective emotion that operates to warn us of the presence of danger. Anxiety that works well motivates people to take action to reduce the risk of harm. For the first time, heavily industrialised gas fields are being established where people live, work, and raise children, and the implications for community health are profound. The community confronts a potential health crisis reminiscent of that created by the asbestos industry.

In the 1930s it was known that asbestos caused cancer, but the industry thrived with government support until it was banned in 2003. Profits reaped over decades were never discounted to reflect the true costs in suffering, illness and death borne by the community. Today, asbestos is widely distributed throughout the environment and will continue to be a health hazard into the future.

Gas field industrialisation of the Northern Rivers has the potential to produce dangerous pollution that will impact on health for generations to come. In the interests of protecting community health, there is an urgent need for an expanded public debate on the safety of the industry.

On the basis of the scientific evidence detailed in my report on the health impacts of CSG and shale gas mining[46], I concluded that there is a high probability of potentially catastrophic health impact from operating gas fields in populated areas. In my opinion, there is nothing in Mr Henderson's letter that contradicts my conclusion, and there is much in the references he cites to support my assessment.

Democracy and the giving of informed consent depend on citizens and their political representatives having access to accurate evidence-based information. Citizens are entitled to express their opinions and beliefs but, in my opinion, claims about the safety of the CSG industry that purport to be factual need to be supported by scientific evidence.

Mr Henderson received a pre-publication copy of this paper and was invited to provide a response which would be attached to the document when it was made public. Mr Henderson was also asked if he would be willing to participate in further public discussion about the potential health impacts of operating gas fields in populated areas.

In a letter dated 24 January 2014, Mr Henderson responded to my analysis of the arguments and scientific evidence that he presented in his 29 November 2013 letter. Mr Henderson declined the invitation to further debate CSG health impacts. Mr Henderson's 24 January 2014 letter is attached to this paper as Appendix B.

[46] Dr Wayne Somerville (2013) Self-help Risk Management Tools: A Report on the Health Impacts of CSG and Shale Gas Mining, download from the "CSG" page at www.creeksbend.com

Mr Henderson's Parting Statements

In my opinion, in his 24 January 2014 letter Mr Henderson did not provide any relevant scientific evidence or reasoned argument to support his claims that: the CSG industry is proven to be safe; local CSG and CSG waste water contain no dangerous substances and are fit for human, animal and agricultural use with minimal to no processing; and that the CSG industry in the Northern Rivers would involve none of the documented pollution produced by CSG operations in Queensland.

Rather, Mr Henderson provided debatable statements of personal opinion. For instance, Mr Henderson wrote:

> "As a final comment, we note that your paper refers to the "healthy worker effect" and the association between unemployment and lower health status and higher mortality rates. If you are genuinely interested in the health of the Northern Rivers people, shouldn't you be promoting an industry that provides secure employment and income security for landholders? Surely, job security, supplementary income for farmers and a reliable energy supply go a long way to reducing stress, more than offsetting any discomfort associated with change."

My concerns go well beyond being "interested in the health of the Northern Rivers people". I have lived in the Northern Rivers most of my life - raising a family and working as a farmer and as a health professional. I know that this region "abounds in nature's gifts of beauty rich and rare" and, for good reasons, I strongly believe that, if protected, our natural resources of sweet water, clean air, and healthy communities will ensure the prosperity of this region for generations to come.

I do not believe that the coal seam gas industry can provide "secure employment and income security for landholders". Short-term construction jobs and limited payments to farmers will not offset the loss of land values and the long-term economic damage done to agricultural, tourism, residential, and other industries that otherwise have a bright future in this area.

The stress from being forced to live and raise families amongst gas fields is not mere "discomfort associated with change". "Change" is not desirable in itself - it can be good or bad, depending on what is lost and what is gained. For most citizens, the change brought about by gasfield industrialisation would result in profound personal, social, and economic losses. Imposing the CSG industry on rural communities is a radical experiment in social and environmental engineering that violates the conservative principle of protecting that which already exists and is truly precious.

In his 24 January 2014 letter, Mr Henderson stated:

> "More importantly, you continue to maintain an alarmist position when you conclude that 'there is high probability of potentially catastrophic health impacts for operating gas fields in populated areas'. This position has no credibility whatsoever."
>
> "By inspection, any reasonable person can look at the data and conclude that there is no substance to your position. Apart from the succinct response we made to your first paper, please note that:

> "The oil and gas industry has operated on a large scale all around the world for more than 100 years – it is not new or unusual.
> In the USA there are currently more than 1,000,000 producing oil and gas wells. These wells produce the full range of hydrocarbons (oil and gas), not just methane. (Our CSG wells produce essentially just methane. Methane is not toxic. It occurs naturally and is also produced from compost bins and cows. People are exposed to it as part of their everyday lives.)
> These USA oil and gas wells have been drilled in rural areas and in areas much more highly populated than the exploration licences we have in the Northern Rivers region."

Regarding Mr Henderson's statements, I note that:

- Mr Henderson's "response" in his 29 November 2013 letter may have been "succinct" (i.e., expressed in few words) but, in my opinion, it failed to provide any credible scientific evidence to support his claims about the "proven safety" of the CSG industry, or the pure quality of CSG and CSG waste water in the Northern Rivers;

- The oil and gas industry may have operated "all around the world for more than 100 years", and there may be more than 1 million producing oil and gas wells in the US, but the development of unconventional gas fields involving thousands of wells across extensive areas of populated, previously rural countryside, is a recent phenomenon;

- Breathing methane in low doses may not be toxic, even though the health effects are unknown, but the dangerous substances liberated, used, and produced by the CSG industry constitute a real and serious threat to human health;

- Denying the existence of scientific evidence which indicates a high level risk of potentially catastrophic health impacts from operating gas fields in populated areas, does not mean that the industry is safe - ignoring the science does not make the danger go away.

In his 24 January 2014 letter, Mr Henderson stated:

> "Where is the catastrophic health impact associated with all these USA wells? The answer is that there is no catastrophic health impact. A similar review of the 4000 CSG wells drilled in Queensland over the past 20 years also shows that there is no health concern."

The answer to Mr Henderson's question, "Where is the catastrophic health impact", is to be found in the rapidly growing body of research that documents the health impacts of living near gas fields. The full extent and severity of the health impact will become evident in the health status of children conceived and born in gas fields, who develop while being exposed to gasfield pollutants, and who mature to have families of their own.

For example, a recently published study by Kassotis, Tillitt, Davis, Hormann, and Nagel (2013)[47] found a strong association between unconventional gas mining and the presence of endocrine-disrupting chemicals (EDCs) in water systems used for human consumption.

[47] Kassotis, C.D., Tillitt, D.E., Davis, J.W., Hormann, A.M., and Nagel, S.C. (2013) Estrogen and Androgen Receptor Activities of Hydraulic Fracturing Chemicals and Surface and Ground Water in a Drilling-Dense Region, *Endocrinology*, endo.endojournals.org, doi: 10.1210/en.2013-1697.

Kassotis et al (2013) found that water samples taken from drilling sites within a 10,000 well gas field in Garfield County, Colorado, as well as the Colorado River which takes run-off from the gas field, showed moderate to high levels of endocrine-disrupting chemical (EDC) activity, while samples from sites in Colorado and Missouri with little drilling showed little EDC activity.

About 100 chemicals used in gas mining are known or suspected to be endocrine-disrupting. The researchers reported, for the first time, estrogenic, anti-estrogenic, and anti-androgenic activity in a subset of 12 chemicals used in natural gas operations (i.e., ethylene glycol monobutyl ether, 2-ethylhexanol, ethylene glycol, diethanolamine, diethylene glycol methyl ether, sodium tetraborate decahydrate, 1,2-bromo-2-nitropropane-1,3-diol, n,n-dimethyl formamide, cumene, styrene, bronopol and naphthalene). One of the twelve chemicals exhibited estrogenic activity, eleven had anti-estrogenic activity, and ten had anti-androgenic activity.

Research indicates that exposure to EDCs increases the risk of reproductive, metabolic, neurological, and other diseases, especially in children, by interfering with the body's response to the reproductive hormones estrogen and testosterone. Research has linked EDC exposure to infertility (decreased sperm quality and quantity), impaired gonadal development (including undescended testis), reproductive tract deformities (including hypospadias - a congenital defect in which the urinary meatus is on the underside of the penis), cancer, and birth defects (including decreased anogenital distance).

Kassotis et al (2013)[48] noted that a particular concern with exposure to EDCs is the potential for additive effects of mixtures of chemicals that act through a common biological pathway, even when each chemical in the mixture is present at levels below an observed effect threshold.[49] Laboratory experiments have shown a wide range of effects at environmentally relevant, low concentrations that were not predicted by traditional risk assessments from high-dose testing. EDCs may be of particular concern during critical windows of child development when exposure can alter normal development.

In his 24 January 2014 letter, Mr Henderson brought to an end our discussion on CSG health impacts in the following manner:

> "NSW has a plethora of approval processes and regulations that Metgasco and other gas exploration and production companies must comply with if we are to explore and develop gas."
>
> "The processes and regulations allow and promote community participation and awareness and are designed to ensure that health, safety and environmental risks are managed acceptably. We will continue to work within this approval and regulatory environment. We are also committed to transparency and community consultation and will continue to discuss safety, health and environment issues accordingly. We are not, however, willing to participate in the poorly managed public discussions that have occurred in the Northern Rivers over recent years. Instead, we ask you to respect the

[48] Kassotis, C.D., Tillitt, D.E., Davis, J.W., Hormann, A.M., and Nagel, S.C. (2013) Estrogen and Androgen Receptor Activities of Hydraulic Fracturing Chemicals and Surface and Ground Water in a Drilling-Dense Region, *Endocrinology*, endo.endojournals.org, doi: 10.1210/en.2013-1697.
[49] Silva E, Rajapakse N, Kortenkamp A. Something from "nothing"– eight weak estrogenic chemicals combined at concentrations below NOECs produce significant mixture effects. *Environmental Science,Technology*. 2002;36(8):1751–1756.

> approval and regulatory processes that exist and to participate in the associated review processes. If you are not happy with them you should approach the relevant NSW government ministers and justify changes to the processes and regulations."

That is to say, Mr Henderson and Metgasco are "committed to transparency and community consultation and will continue to discuss safety, health and environment issues", but only within the Government's "approval and regulatory environment", and not via participation in "poorly managed public discussions" in the Northern Rivers.

And so this CSG health debate ended before it got very far.

Mr Henderson indicated that he will not engage in further public discussion of the scientific "evidence" that he says he has to support the claims about the safety of the CSG industry he made to Kyogle's Mayor. Instead, Mr Henderson recommended that I "participate in the associated review processes" and take any grievances that I might have to the relevant Minister.

As detailed above, in my opinion, Mr Henderson has provided no credible scientific evidence to support his claims that the CSG industry has been "proven" to be safe, or that local CSG and CSG waste water contain no benzene or any other dangerous substances, and are fit for human, animal and agricultural use with minimal processing. I do not know why Mr Henderson claimed that CSG compressor stations and processing plants in the Northern Rivers would not produce the documented pollution created by CSG processing in Queensland. I do not understand why Mr Henderson believes that Northern Rivers' gas, wastewater, and CSG processing are uniquely "clean" with no potential to pollute.

Mr Henderson has not retracted any of his specific claims about the safety of the CSG industry in the Northern Rivers. It seems reasonable to expect that he could repeat these claims in the future while promoting his business.

As I understand Mr Henderson's position, his compliance with a "plethora of approval processes and regulations" satisfies his obligations to provide evidence for his claims about the safety of local CSG operations.

Consequently, the Northern Rivers community will have to rely on the NSW Government to provide the scientific evidence that justifies the claims about safety that Mr Henderson presented as fact while promoting his CSG business to Kyogle's Mayor.

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Appendix A

METGASCO

29 November 2013

Dr Wayne Somerville
Clinical Psychologist
[redacted]

Cc: Councillor Danielle Mulholland, Mayor - [redacted]

Dear Dr Somerville,

NSW and Northern Rivers residents need energy for heating, lighting and cooking in their homes and to power domestic appliances. We all need transport fuels and in the work place our jobs depend on reliable energy supplies to power equipment and to provide heating and cooling. Our lives depend on reliable energy supplies.

Natural gas from coal seams currently meets a third of eastern Australia's gas supply needs and our industry has a proven and safe track record over a number of decades.
Exports of natural gas from Australia are helping less developed countries to reduce the extent of air pollution and associated illness.

Communities deserve sensible and open debate about the best ways to achieve our energy needs and balance any potentially competing interests. Your exaggerated and incorrect comments do nothing to encourage such debate. They do no more than create unjustified fear.

Contrary to points you have previously raised, the safety of CSG and the broader oil and gas industry has been examined and demonstrated.

- **Methane is not toxic** As any science student knows, methane, the major component of coal seam gas, is a colourless, odourless gas and is not toxic. It is used for heating every day in hundreds of thousands of homes and in thousands of industries, without adverse health impacts. Methane is also produced naturally from many sources including compost heaps and cattle. Methane gas seeps naturally from the ground. People have been exposed to coal and hence coal seam gas for centuries. It has been liberated in considerable quantities from coal mines. This is not new.

- **Our coal seam gas is almost pure methane** The natural gas we produce from our coal seams is about 98% methane, with very small amounts of ethane (another colourless, odourless and non-toxic hydrocarbon gas), carbon dioxide and nitrogen. Gas chromatograph data for our coal seam gas shows virtually no hydrocarbons heavier than ethane. By inspection, there is absolutely no reason for concern in terms of metals, volatile organics or BTEX chemicals. For your information, the gas we found in our Kingfisher exploration well (a conventional gas field) has a similar composition to our CSG. It has a little more ethane and propane than our CSG but gas chromatograph data shows hydrocarbons no heavier than pentane and, again by inspection, provides no reason for concern.

Metgasco Limited [redacted]

Our coal seam gas meets specifications for sales gas, it does not need to be treated to be sold into the gas market. It might need to have small quantities of water removed to be distributed in a large pipeline system.

Our gas quality data is consistent with measurements of CSG water quality. A thorough analysis of our CSG produced water shows that it meets Australian Drinking Water Guidelines, apart from its salt levels, which are about 1/10 of the level in sea water. Bioassay (acute toxicity) testing has provided further and broader confirmation that the CSG water is not toxic. We have a range of studies to demonstrate that our water, after some salt removal, is suitable for irrigation. It is suitable for stock watering, even without salt removal.

Should you wish to explore the wealth of data that is available on websites you will find that gas produced from other Australian coal seams is also primarily methane, with very low concentrations of any hydrocarbons heavier than ethane. For example, we draw your attention to AGL's Environmental Health Impact Assessment – Camden Northern Expansion Project, 30 October, 2013, provides further information to support high methane levels and correspondingly low levels of heavier hydrocarbons in its gas. Again, by inspection, there is no reason for concern about volatile organic compounds, BTEX or metals. This information can be found on the AGL website.

Your comment "*When we export coal we do so with its impurities. But with gas the impurities are taken out here and they are dumped on the environment and the local community"* is simply incorrect and unnecessarily alarmist. The air emissions you quote for Queensland CSG operations are mainly from engine exhausts, no different in nature from any other engine exhausts, including cars, tractors and farm equipment. The emissions are not "impurities" removed from the gas.

- **The people most exposed to petroleum are healthy**

  The people probably most exposed to hydrocarbon gases and liquids, including substances such as BTEX which are naturally found in crude oil, are those who work in oil refineries and conventional natural gas processing plants. The AIP Health Watch program, which has been in operation since 1980 and is run by Monash University, shows that workers in the petroleum and natural gas production industry have better health than the general Australian community and are less likely to die of the diseases commonly causing death - including cancer, heart and respiratory conditions. You can find more about this at:

  http://www.aip.com.au/health/ohs.htm

  The following Queensland Government website provides details about BTEX exposure sources and levels.

  http://www.ehp.qld.gov.au/management/non-mining/btex-chemicals.html

- **CSG has operated in Australia for nearly 20 years without health problems** AGL's CSG project at Camden, on the outskirts of Sydney, has been operating safely for nearly 13 years with 144 wells drilled in the Macarthur Region.

  CSG in Australia has operated in Australia for nearly 20 years, without any health concerns. There are now about 4000 wells drilled, without health concerns.

  In March, 2013, the Queensland Government published a report which assessed health complaints from the Tara area and concluded that the available evidence does not support the concern among some residents that excessive exposure to emissions from CSG activities is the

cause of the symptoms reported. To quote from the Darling Downs Public Health Unit report, one of the reasons for dismissing a link between CSG and reported health problems is

> "*the lack of evidence of employees working within the CSG industry having similar symptoms. If community members were experiencing symptoms due to CSG activities, it would be highly likely for workers in the industry to be reporting similar and probably more severe effects due to their likely much higher exposure.*"

The Queensland Government report highlighted concerns with Tara drinking water because it was contaminated by faecal matter, not hydrocarbons.

- **The industry is heavily regulated and there are numerous studies to demonstrate health and safety**

  The CSG and petroleum industry is heavily regulated and must pass stringent health, safety and environmental checks before developments can proceed.

  There are numerous studies available to show that CSG operations represent a low health risk to the community. We recommend that you take the time to read the huge amount of material that is available to the public in relation to the Queensland CSG projects and to AGL's recent Camden Northern Expansion Project Environmental Health Impact Assessment. AGL's study, which covers the full spread of potential health risks, concludes that its proposed Camden Northern Expansion would have posed low and acceptable risks to community health and to air, groundwater and surface water. You should also be aware of the recent Public Health England report which found that shale gas extraction emissions are a low to risk to public health.

Dr Somerville, the comments you have made in the media and in your report "CSG and Your Health" demonstrate that you have little understanding of the CSG industry and the technical and safety issues involved. Your comments about catastrophic health impacts do nothing for your credibility.

The community deserves intelligent, informed debate, not alarmist comments.

Yours sincerely

Peter J Henderson
Managing Director and CEO

Metgasco Limited [redacted]

Appendix B

METGASCO

24 January 2014

Dr Wayne Somerville
Clinical Psychologist
[redacted]

Dear Dr Somerville,

Thank you for the opportunity to read your latest paper (Is CSG safe, A Public Debate in the Interests of Community Health) and comment.

We are disappointed that you continue to exhibit a poor understanding of the petroleum industry and the approval and regulatory processes that we must comply with. More importantly, you continue to maintain an alarmist position when you conclude that “there is high probability of potentially catastrophic health impacts for operating gas fields in populated areas”. This position has no credibility whatsoever.

By inspection, any reasonable person can look at the data and conclude that there is no substance to your position. Apart from the succinct response we made to your first paper, please note that:

- The oil and gas industry has operated on a large scale all around the world for more than 100 years – it is not new or unusual.
- In the USA there are currently more than 1,000,000 producing oil and gas wells. These wells produce the full range of hydrocarbons (oil and gas), not just methane. {Our CSG wells produce essentially just methane. Methane is not toxic. It occurs naturally and is also produced from compost bins and cows. People are exposed to it as part of their everyday lives.}
- These USA oil and gas wells have been drilled in rural areas and in areas much more highly populated than the exploration licences we have in the Northern Rivers region.

Where is the catastrophic health impact associated with all these USA wells? The answer is that there is no catastrophic health impact.

A similar review of the 4000 CSG wells drilled in Queensland over the past 20 years also shows that there is no health concern.

NSW has a plethora of approval processes and regulations that Metgasco and other gas exploration and production companies must comply with if we are to explore and develop gas.

Metgasco Limited [redacted]

Page 2.

The processes and regulations allow and promote community participation and awareness and are designed to ensure that health, safety and environmental risks are managed acceptably. We will continue to work within this approval and regulatory environment. We are also committed to transparency and community consultation and will continue to discuss safety, health and environment issues accordingly. We are not, however, willing to participate in the poorly managed public discussions that have occurred in the Northern Rivers over recent years. Instead, we ask you to respect the approval and regulatory processes that exist and to participate in the associated review processes. If you are not happy with them you should approach the relevant NSW government ministers and justify changes to the processes and regulations.

As a final comment, we note that your paper refers to the “healthy worker effect” and the association between unemployment and lower health status and higher mortality rates. If you are genuinely interested in the health of the Northern Rivers people, shouldn’t you be promoting an industry that provides secure employment and income security for landholders? Surely, job security, supplementary income for farmers and a reliable energy supply go a long way to reducing stress, more than offsetting any discomfort associated with change.

Yours sincerely

Peter J Henderson
Managing Director and CEO

Metgasco Limited [redacted]

Dr Wayne Somerville
[redacted]

3 January 2018

Dr Alan Finkel
Office of the [redacted]

Dear Dr Finkel,

I was enjoying your ABC Big Ideas podcast (Tuesday 19 September 2017) in which you encouraged scientists to read more science-fiction until you shocked me with your use of false claims to denigrate citizens who are concerned about the impacts of unconventional gas mining.

You said:

> 'In terms of other examples of wiki net area where science is perhaps not being taken on board and recognised, concerns about unconventional gas extraction, whether its concerns of seismic activity or the unexpected release of methane that's called fugitive emissions or contamination of aquifers, are rampant through many communities but there's actually no data to support those concerns. There is no easy way to address those concerns because they've got the status of urban lore, but that's a clear case where the evidence and beliefs are out of sync.'

You are wrong that there is no data to support concerns about seismic activity, fugitive emissions, and aquifer contamination associated with unconventional gas fields. You are incorrect that there is 'no easy way to address those concerns'. And you are mistaken to suggest that concerned citizens are unscientific, prone to 'wiki net' thinking, and under the influence of 'urban lore'.

A recasting of your statement to reflect appropriate risk management and a truly evidence-based approach could have read:

> 'In terms of other examples of wiki net area where science is not being taken on board, the unconventional gas industry maintains that its operations are safe, even though they have no data to support such claims. Community concerns about the impacts of the industry are based on limited, but nonetheless solid, scientific evidence. These concerns could readily be addressed if regulatory authorities and the industry carried out evidence-based procedures for evaluating the safety of products and processes that expose communities or the environment to risk. There's no easy way to address the industry's avoidance of science-based risk management because they are focussed on making profit.'

Risk management is usually understood to be a process of thinking systematically about all possible risks before they occur, and setting up procedures to prevent problems or mitigate

impacts. Cost/benefit analysis is the reasoned consideration of all the potential costs and benefits of a proposed development. 'Duty holders' are legally obliged to exercise due diligence and to consider all risks, not just those for which regulations exist, but even hazards that are unknown at the time. A lack of knowledge of an impact does not indicate that there is no risk worth considering.

I think that managing the risks of operating unconventional gas fields in populated areas should be about protecting people and the environment from harm. Cost/benefit analyses need to consider costs as well as benefits. I believe that politicians and company executives have a duty of care to protect citizens and be receptive to, and actively seek out, information about possible risks.

In contrast, your statement reflects a very different form of risk management that is promulgated by the unconventional gas industry. In this approach there is no systematic thinking about possible risks because unconventional gas fields are assumed to be safe despite the lack of any evidence that they are. Benefits for gas field industrialisation are claimed, with no analysis of costs. The risk being managed is not that gas mining might harm people and the environment. Rather, the aim is to protect company profits and government revenue. The danger the industry fears is that they might lose their social license to operate. They extend their duty of care only to themselves and their shareholders. And they misapply the 'burden of proof'.

Your statement implies that, like a defendant in a criminal trial, the unconventional gas industry is entitled to the 'assumption of innocence'. Your comments suggest that gas fields can be assumed to be safe unless the community, acting like a prosecutor in a criminal trial, produces data to prove an adverse effect 'beyond a reasonable doubt'. That's not a proper application of the burden of proof in regulatory contexts where a company or a person seeks to profit from doing something that exposes the public to potential risk. For instance, when a pharmaceutical company wants to sell a new medication, it's not assumed that the product is safe. Rather, in accord with evidence-based science, they have to demonstrate the safety and efficacy of their product by comparing health data taken before and after people use the new drug.

There can be no doubt that industrialising previously rural landscapes with vast unconventional gas fields has significant impacts on human, water, air, and soil systems. For this industry, an evidence-based demonstration of safety would once have been a straight-forward process. Companies and regulatory authorities had only to collect baseline health and environmental data before drilling began, and compare this to data obtained after the gas fields were operating. And even if they failed to collect baseline measures, they could have obtained data from subsequent years to use for comparison and to correlate with the growth of the gas field. But they never did this. Consequently, they have no evidence that their operations are safe.

I will briefly address your claim that there is no data to support concerns about adverse impacts of the unconventional gas industry.

I'll leave it to you to research the association between the unconventional gas mining and seismic activity - the issue is mostly of interest to citizens in the USA and New Zealand - but the following references will get you started:

- Kuchment, A. (2016). Drilling for Earthquakes. *Scientific American,* July, pages 42 - 49.

- Weingarten, M., et. al. (2015). High-Rate injection is associated with the increase in US mid-continent seismicity. *Science*, V 348, June, pages 1336-1340.

The research on aquifer contamination is well-known and readily accessible, so it was very surprising that you are unaware of some widely-publicised incidents that have occurred in Australia.

Do you not know about the NSW Environmental Protection Agency's (EPA) finding that a faulty Santos holding pond in the Pilliga area contaminated an aquifer? In this incident, coal seam gas (CSG) waste water leaked through a torn plastic pond liner to contaminate an aquifer kilometres away with high levels of lead, aluminium, arsenic, barium, boron and nickel, and uranium levels 20 times higher than safe drinking limits.

Are you also unaware of the January 2015 report that monoethanolamine borate, a fracking chemical, was found in water samples near Australian Gas Light's (AGL) pilot CSG gas field at Gloucester? AGL decided to abandon CSG mining after this finding became public and the NSW EPA stopped their trial of using filtered CSG wastewater on agricultural land due to the build up of heavy metals in the soil.

Vast amounts of CSG waste water are stored in ponds and thousands of wells are drilled near and through underground water systems while there is scant monitoring of water quality going on. The above incidents indicate that aquifer contamination is a significant risk to our country and its citizens.

In this age of accelerating climate destabilisation, the potentially catastrophic effects of fugitive emissions from unconventional gas fields are of even greater concern. The scientific evidence warrants the most serious attention, and should not be dismissed out of hand, especially by Australia's Chief Scientist.

I'll give you some background.

Unlike conventional gas, in unconventional gas mining, injected and naturally-present water from gas bearing strata is brought to the surface. As intended, this frees up previously bound gases so they can be pumped up the well. This has consequences. Fracturing and removing the water from gas-bearing seams creates an unknowable network of new and previously existing cracks and faults that can act as conduits for the liberated gas to vent into the atmosphere. As gas comes up fissures and cracks, water goes down. The most obvious effect of this geologic turmoil is lowered water tables and depleted farm bores; the gas mining company Santos predicted that by 2028 the level of groundwater in the Bowen Basin gas fields would drop by up to 65 metres.

Gas companies and regulatory authorities do not systematically measure methane and other fugitive emissions above gas fields: they only estimate emissions with formulae that calculate likely leakage from valves and seals and such. To my knowledge, there has been no collection of baseline data that samples the atmosphere above gas fields.

The following peer-reviewed papers by Australian scientists are essential reading on fugitive emissions from unconventional gas fields:

- Maher, D., Santos, I., & Tait, D. 2014. Mapping methane and carbon dioxide concentrations and d13C values in the atmosphere of two Australian coal seam gas fields. *Water, Air, & Soil Pollution*, *225,* 2216. (See attached abstract and references.)

- Tait, D., Santos, I, Maher, D., Cyronak, T., and Davis, R. 2013. Enrichment of Radon and Carbon Dioxide in the Open Atmosphere of an Australian Coal Seam Gas Field, *Environmental Science and Technology*, 47, 3099−3104. (See attached paper.)

In 2012 Dr Isaac Santos and Dr Damien Maher recorded atmospheric methane concentrations as they drove the 500 kilometres from Lismore's Southern Cross University to the Tara gas fields in Queensland's Darling Downs. Their instruments showed concentrations close to the current global average of 1.8 parts per million until they approached Tara, where methane and radon readings increased threefold. They reported that Australia set a new world record with methane levels of 6.89 parts per million, exceeding the previous highest reading from a Siberian gas field. The methane to CO_2 isotope ratio indicated that these emissions were coal seam gases; as were the bubbles that have turned sections of the Condamine River into a spa.

These scientists discovered that a blanket of methane of unknown thickness extends for kilometres around Tara. Why is there a landscape-scale venting of coal seam gases into Tara's air? According to the researchers, 'In natural conditions, methane is contained within the coal seam by water pressure…(in CSG mining) we get lowering of the water table, horizontal drilling, fracturing, infrastructure leakage, but our evidence suggests that we also have leaks through the soil as well, and these leaks through the soil are not counted in any fugitive estimates'.

Methane is colourless and odourless; you can see it venting in the Condamine River because it bubbles through water. In 2016 NSW Greens MP Jeremy Buckingham clicked a stove lighter over the side of a boat and set the Condamine River on fire. The Condamine River has been bubbling methane since 2012, and according to CSIRO's Professor Damian Barrett the rate of gas flow had increased over the 12 months prior to Mr Buckingham's boat trip.

The following peer reviewed paper from US researchers is also essential reading on fugitive emissions:

- Turner, A., Jacob, D., Benmergui, J., Wofsy, S., Maasakkers, J., Butz, A., Hasekamp, O., & Biraud, S. 2016. A large increase in U.S. methane emissions over the past decade inferred from satellite data and surface observations. *Geophys. Res. Lett.*, *43*, 2218–2224.

In 2016 these US scientists reported that the 'global burden of atmospheric methane has been increasing over the past decade'. When they examined measurements of methane in the air above the United States, they discovered that from 2002 to 2014 - the period corresponding to America's shale oil and gas boom - methane emissions had increased by more than 30%. The scientists concluded that this increase in methane emissions accounted for '30 to 60 percent of the global growth of atmospheric methane in the past decade'.

The paucity of scientific findings regarding the impacts of unconventional gas mining does not indicate that there is no significant risk worth considering. Rather, the lack of data reflects

a systematic failure of regulatory authorities and gas mining companies to properly manage risks and undertake evidence-based research.

I urge you to contact Dr Isaac Santos and his colleagues at Southern Cross University to discuss how their research program has been effected by political and industry pressure. The attacks on independent scientists who work in this area have been demeaning and personal. When in 2012 Dr Isaac Santos and Dr Damien Maher made public their findings of landscape-scale methane emissions in Queensland gas fields, then Federal MP Martin Ferguson, who later took up an executive position with the Australian Petroleum Production and Exploration Association, accused them of ‘a cynical attempt to grab headlines’ and ‘trying to score political points without proper consideration of the best interests of the broader community’.

The following article from *The Conversation* (see attached document) penned by Prof. Isaac Santos, Dr Maher, and Mr Tait highlight the disturbing state of scientific research on an issue that has potentially profound global implications.

- Santos, I., Maher, D, & Tait, D. 2014. Science and coal seam gas – a case of the tortoise and the hare? *The Conversation.* 8 December. https://theconversation.com/science-and-coal-seam-gas-a-case-of-the-tortoise-and-the-hare-35100 1/3

I want to do what I can to counter the damaging effects of both your claim as Australia’s Chief Scientist that there is no data to support concerns about the adverse impacts of unconventional gas mining, and your portrayal of decent, concerned citizens as irrational and unscientific.

To this end, and to facilitate a much-needed public discussion of these matters, I will be sending this email/letter to: Australia’s state-based Chief Scientists; politicians; Paul Barclay, the host of ABC’s Big Ideas program; organisations; and groups of concerned citizens, amongst others. If you reply to my comments within a month from the date on this letter/e-mail, I will attach your response.

I respectfully ask that you educate yourself about these issues. Please do what you can to protect and promote evidence-based research and the efforts of scientists who are acting in the best interests of our nation and its people.

Please do not hesitate to contact me if you wish to discuss this letter.

Thanking you for your time and consideration.

Yours faithfully,

Wayne Somerville

Dr Wayne Somerville
Clinical Psychologist

Addendum

10 February 2018

I sent Dr Finkel e-mail and hard copy versions of my letter and the accompanying references. His office acknowledged receipt of the e-mail and wrote that their policy was to respond to all e-mails within a month. At the time of writing, neither Dr Finkel nor his office has replied. If he does, I will forward his comments to you separately.

Since I wrote to Dr Finkel, I have learned of new studies that further heighten concerns about the unconventional gas industry's fugitive methane emissions.

In the USA, Purdue University Researchers used an aircraft-based mass balance technique to measure methane concentrations above three natural gas-fired power plants and three oil refineries. They found that average methane emission rates for the gas-fired power plants were 21-120 times larger than facility-based estimates that are reported to the EPA. For oil refineries, methane emissions were 11-90 times larger than estimates.

- Reference: Lavoie, T., Shepson, P., Gore, C., Stirm, B., Kaeser, R., Wulle, B., Lyon, D. and Rudek, J. 2017. Assessing the Methane Emissions from Natural Gas-Fired Power Plants and Oil Refineries. *Environ. Sci. Technol, 51*, 3373−3381.

In the other study, a team led by scientists at NASA's Jet Propulsion Laboratory provided an explanation for the ~8 p.p.b. (parts per billion) per year increase in atmospheric methane since 2006. Their analysis of satellite measurements of atmospheric methane from the 2001-2007 and the 2008-2014 time periods showed that the majority of the worldwide increase in methane was due to emissions from the oil and gas industries.

- Reference: Worden, J., Bloom, A., Pandey, S., Jiang, Z., Worden, H., Walker, T., Houweling, S., Röckmann, T. 2017. Reduced biomass burning emissions reconcile conflicting estimates of the post-2006 atmospheric methane budget. *Nature Communications, 8*: 2227.

And since I wrote to Dr Finkel, new research has added further evidence of the deleterious impacts of unconventional gas mining on the environment and human health and well-being. But that's for another time.

***

Dr Wayne Somerville
[redacted]

4 September 2012

National Inventory Systems and International Reporting Branch
Land Division
Department of Climate Change and Energy Efficiency
Canberra ACT 2601
nationalgreenhouseaccounts@climatechange.gov.au

Dear Departmental Officers,

RE: Submission on Estimation of Fugitive Methane from Coal Seam Gas Operations.

I am writing in response to the request for comment on the future measurement of methane released into the atmosphere as a result of coal seam gas (CSG) mining operations.

As noted by the Australian Government's Department of Climate Change and Energy Efficiency (2012)[1], emissions from CSG operations:

> "Depend on a range of factors, including the geological properties of the gas basin, the techniques used in gas extraction and processing, emissions during pipeline transportation, further processing and transportation emissions if CSG is converted to LNG for sale to overseas customers, and the efficiency of end use."
>
> "Emissions occur at several stages during the production, supply and use of CSG. Fugitive emissions of methane are a significant source during the production phase. This includes methane released from exploration drilling, production testing and well completion, and gas production activities including processing, venting and flaring."
>
> "Other sources include fugitive emissions during transportation and supply, emissions from fossil fuel use during the development and operation of CSG facilities, and emissions from end-use combustion of CSG."

This submission is specifically concerned with methane emissions associated with the technology employed in CSG vertical well construction, and migratory emissions due to the fracturing of rock strata caused by horizontal drilling and the depressurization of coal seams.

CSG Mining Technology and Fugitive Methane Emissions

CSG is touted as a safe, cleaner than coal transitional fuel. The legitimacy of the CSG industry depends on the extent to which their drilling technology allows fugitive methane to rise to the surface, and whether this pollution can be effectively controlled and mitigated.

The United States is committed to massive landscape scale CSG and shale gas mining operations despite limited experience with relatively new drilling technologies and increasing scientific concern about the true nature and extent of fugitive methane emissions.[2,3,4,5]

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[1] Consultation Draft Measurement Determination, National Greenhouse and Energy Reporting Measurement Amendment 2012, Departmental Commentary (30 April 2012).

The Australian CSG industry began only about 15 years ago when new drilling techniques developed by US company Halliburton made it possible to unlock coal bed gases. Up until the development of this technology, the sought after methane had been buried under hundreds of metres of sandstone, safely sequestered from the atmosphere. Australia's coal beds were laid down 90 million years ago in a great dying-off which ended a period of extreme global warming.

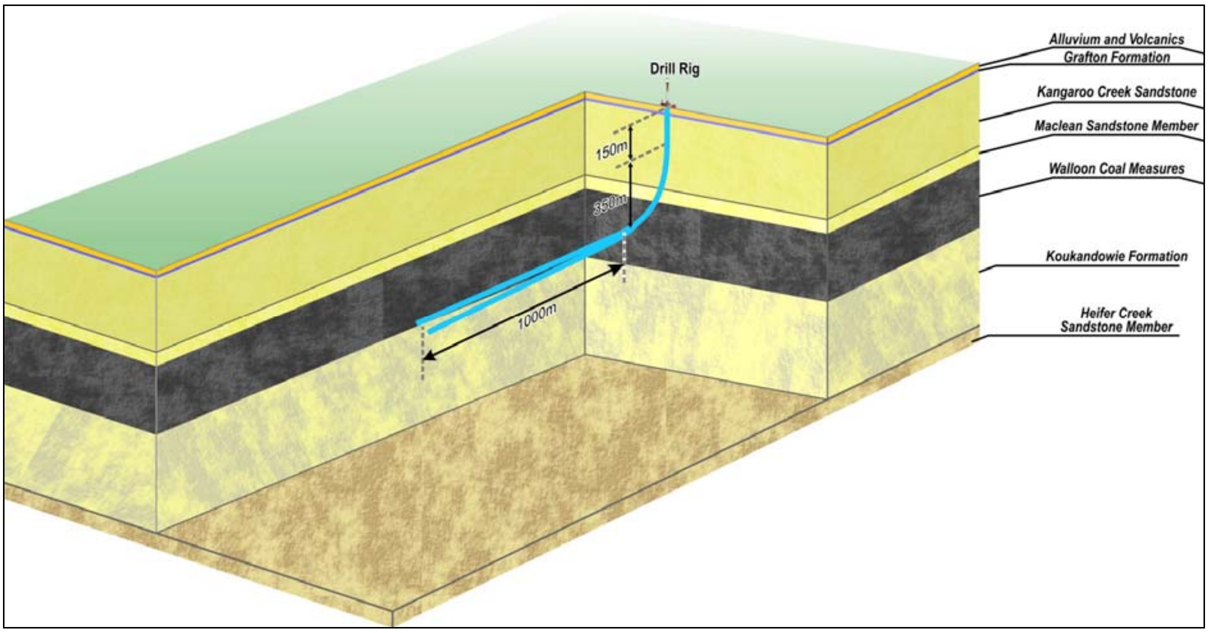

Figure 1: CSG Company Metgasco's Graphic of CSG drilling.[6]

CSG miners drill down 600 to 1,000 metres or more through aquifers and rock to the coal measure. They then drill horizontal shafts, for up to 4 kilometres, through the coal seam. Methane is liberated when water from the coal seam aquifer is pumped to the surface. A mix of water, sand and chemicals is sometimes pumped into the fractured coal to liberate the coal seam gases.

Conventional natural gas is extracted from large reservoirs via a small number of wellheads. Fugitive methane emissions from CSG mining come from thousands of interconnected wells, distributed across landscapes, with each well being connected to a system of shafts drilled horizontally through the coal seam.

A CSG well is essentially a metal pipe inserted into a very deep borehole. 1,000 m is greater than the height, measured from the water to the top of the arch, of seven Sydney Harbour Bridges stacked one on top of the other.

[2] Hardisty, P., Clark, T. and Hynes, R. (2012). Life Cycle Greenhouse Gas Emissions from Electricity Generation: A Comparative Analysis of Australian Energy Sources. *Energies* 2012, *5*(4), 872-897; doi:10.3390/en5040872. http://www.mdpi.com/1996-1073/5/4/872

[3] Pétron, G., et al. (2012), Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study, *J. Geophys. Res.*, 117, D04304, doi:10.1029/2011JD016360.

[4] Howarth, R., et. al. (2012). Methane Emissions from Natural Gas Systems: Background Paper Prepared for the National Climate Assessment, Reference number 2011-0003, February 25, 2012.

[5] Howarth, R., Santoro, R., and Ingraffea, A. (2011). Methane and the greenhouse gas footprint of natural gas from shale formations. *Climatic Change Letters*, doi:10.1007/s10584-011-0061-5

[6] Metgasco - Large Uncontracted Gas Reserves – Excellent Market, March 2012, International Road Show: Hong Kong, New York, London.

To prevent methane escaping into the atmosphere via the borehole, and to protect aquifers from bleeding into each other, for the entire length of the well the space between pipe and rock has to be sealed for all eternity. As CSG company Metgasco described the process in their submission to the NSW Parliamentary Coal Seam Gas Inquiry[7], this is achieved by pumping concrete into the gap between pipe and rock. This gap is two inches thick at the top, and three-quarters of an inch thick for the deepest 800 metres or so of the vertical borehole. The concrete sleeve ends where the horizontal drilling begins.

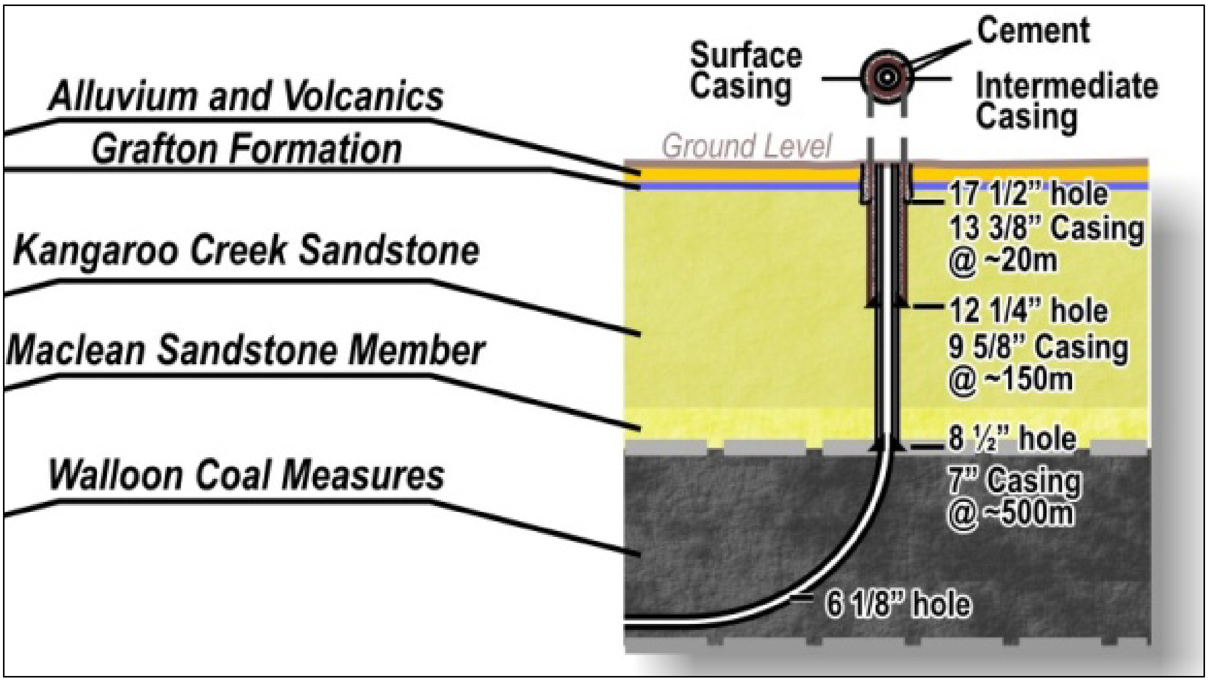

Figure 2: CSG Company Metgasco's Graphic of CSG Well Casing and Concrete Barrier.[8]

I know of no imaging or other kind of technology which would enable an accurate scientific assessment of the continuity and integrity of concrete barriers in deep underground CSG well casings.

Nonetheless, the notion that concrete can be routinely poured in thousands of wells to effectively seal ¾ inch gaps between pipe and rock, hundreds of metres underground, defies commonsense and contradicts practical experience. I am aware of no evidence that would suggest that the concreting techniques used in CSG well construction represent a technological wonder rather than a dangerous fantasy. And of course, with time, concrete inevitably breaks down, steel corrodes, and CSG wells will blow out.[9]

But not even concrete can prevent greenhouse methane rising through overlaying sandstone strata that have been fractured as a result of vertical and horizontal drilling processes.

Methane escaping though fissures that open up in the ground or via pre-existing boreholes and mines are a potentially massive source of migratory emissions that have yet to be properly assessed.

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[7] Shields, R. (2011). Metgasco's Submission to the NSW Parliamentary inquiry into Coal Seam Gas (CSG), Submission 287.

[8] Metgasco - Large Uncontracted Gas Reserves – Excellent Market, March 2012, International Road Show: Hong Kong, New York, London.

[9] Dr Tina Hunter (2012). Bond University, interview in *Echonetdaily*, http://echonetdaily.echo.net.au/csg-where-the-frack-to-next/

The CSG miner Santos noted that "the drawdown of ground water heads within coal seam gas aquifers is a necessary process and an unavoidable impact associated with the depressurisation of the coal seam."[10]

Further, Santos stated that;

> "There can be significant losses in pressure both within the aquifer, and/or in the overlying and underlying aquifers. Industry predicts groundwater drawdown for the Arcadia Valley and Fairview CSG fields within the Bowen Basin, Queensland of up to 15 metres by 2013 and 65 metres by 2028. For the four bore wells situated in and around the fields, it was estimated they would experience 7 to 25 metres drawdown in the groundwater level by 2028."[11]

If a depressurised coal seam many hundreds of metres down inevitably causes a drop in aquifer water levels close to the surface, it follows that CSG mining has to cause deep fracturing of sandstone rock layers. These fractures provide a potential conduit for methane from deep coal seams to vent into the atmosphere.

CSG Methane Emissions: Implications for Assessment and Policy

Many CSG wells in the Queensland gas fields have been reported to be leaking methane[12], but three recent cases of migratory methane emissions warrant particular consideration. These examples of methane releases in CSG gasfields demonstrate the potential significance of this source of atmospheric pollution, and also highlight important issues bearing on the future scientific assessment of fugitive emissions.

The reader is directed to the video, "Dr W Somerville - CSG Fugitive Emissions Submission" which can be downloaded at the following links:

FLV Format (Smaller You Tube file, but requires a .flv reader)

https://dl.dropbox.com/u/99105418/Dr%20W%20Somerville%20-%20CSG%20Fugitive%20Emissions%20Submission.flv

MP4 Format (Larger file, higher resolution)

https://dl.dropbox.com/u/99105418/Dr%20W%20Somerville%20-%20CSG%20Fugitive%20Emissions%20Submission.mpg

These videos show significant migratory methane emissions around CSG wells on a Queensland farming property and in the Condamine River. Such examples illustrate characteristics of migratory CSG emissions which have implications for thinking about the scientific assessment of methane pollution.

The video of leaking CSG wells was edited from the ABC 4 Corners program, "The Gas Rush"[13] and the 60 Minutes program, "Undermined"[14]. The scenes of the Condamine River were edited from video filmed by Dayne Pratsky on 28 May 2012.[15]

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[10] Groundwater (Deep Aquifer Modelling) for Santos GLNG Project – EIS, 31/3/2009.
[11] Groundwater (Deep Aquifer Modelling) for Santos GLNG Project – EIS, 31/3/2009.
[12] National Toxics Network (2011). Coal Seam Gas Briefing Update.
[13] Four Corners program on CSG, "The Gas Rush" aired 21/02/2011. www.abc.net.au/4corners/content/2011/s3141787.htm
[14] 60 Minutes program, "Undermined", aired 14 May 2010. www.youtube.com/watch?v=eZwWGlhqkbE
[15] www.youtube.com/watch?v=Di8cCrlyW6k29

In his interview for the ABC Four Corners program[16], Scott Lloyd, a Queensland farmer with a CSG gas field on his property, reported that QGC wells on his property had been leaking since 2006. Mr Lloyd said that attempts to plug the leaks with concrete had been unsuccessful, and the gas that was originally coming from the well head was now “coming straight out of the ground all around the site”. Further, the methane escaping from bores on the Lloyd’s and other farms in the area can now be set alight.

Dayne Pratsky’s video of a stretch of the Condamine River surging like a spa bath with venting methane should trouble anyone who is concerned about the dangers posed by uncontrolled CSG methane emissions into the atmosphere.

Incredibly, shortly after this video was released the Queensland Minister for Mining announced that the CSG miners had assured him that this was a natural phenomenon. Of course, no one has ever before witnessed Australian rivers seething with methane. There is no rational or scientific basis for the Minister’s implied belief that vast quantities of methane have been freely venting, presumably for millions of years, into the atmosphere from coal seams hundreds of metres below the Condamine River.

On 18 August 2012, a mining exploration hole in the Daandine coal seam gas field, west of Dalby, was found to be alight with leaking methane.[17] An Arrow Energy spokesman claimed that the methane did not come from their three CSG wells, which were located between 750m and 1km away, and Arrow attributed the leak to a 30-year-old coal mining exploration hole. Presumably, the Arrow Energy spokesman believed that this old hole had been freely venting large quantities of methane for 30 years, but had not been detected or ignited until recently.

The above three examples of methane leaking on Queensland gasfields illustrate the need for CSG methane emissions to be measured across landscapes, and not just at the well head.

Methane is a colourless, odourless gas. Leaking around the wells on the Lloyd's property and in the Condamine River can only be seen because the gas is bubbling through water. The Daandine CSG field methane leak was only detected because it ignited. It makes no sense to assume that the leaking methane is somehow narrowly confined to the Condamine River, to puddles on Scott Lloyd's farm, or to where it has been ignited. It is reasonable to assume that the methane is also venting across the countryside around the Condamine and the CSG wells on the Lloyd's property.

Aquifer systems can extend underground for many kilometres. Finding methane in bores at ignitable concentrations indicates that aquifers can potentially transport methane across great distances before it is discharged into the atmosphere.

In my opinion, the emphasis on measuring CSG fugitive emissions “at the CSG wellhead”, as recommended in The Australia Institute’s recent report[18], runs the risk of obscuring the potentially massive contribution of fugitive emissions that are likely to be occurring across the landscape, sometimes kilometres away from the well head. The above examples suggest that CSG methane emissions need to be scientifically assessed across landscapes and entire gasfields.

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[16] Four Corners program on CSG, “The Gas Rush” aired 21/02/2011. www.abc.net.au/4corners/content/2011/s3141787.htm

[17] http://www.couriermail.com.au/news/coal-gas-stream-blaze-still-alight-west-of-dalby/... 20/08/2012

[18] Grudnoff, M. (2012). “Measuring Fugitive Emissions: Is coal seam gas a viable bridging fuel? The Australia Institute, Policy Brief No. 41, August 2012 ISSN 1836-9014.

Self-assessment and self-reporting by the CSG mining companies will not work. The demonstrated first response of mining companies is to promptly deny that methane emissions have anything to do with their operations; even when such denials lead them to make patently ridiculous claims about the “naturalness” of methane agitated rivers.

In my opinion, when assessing migratory methane emissions from CSG operations it would be reasonable to assume that methane can potentially vent into the atmosphere via fractures in rock strata created by both vertical and horizontal CSG drilling.

A reasonable working hypothesis would be that methane venting will tend to be densest around lines corresponding to the direction of horizontal drillings, but no one yet knows how far fracturing is likely to radiate away from the vertical and horizontal drill shafts.

Future scientific research and assessment of migratory methane emissions in CSG gasfields due to fracturing of rock strata and transporting of the gas via aquifers would be greatly enhanced if miners provided government agencies with maps of the direction and length of horizontal shafts that radiate out from each wellhead. This data could inform future understanding of how far from the well head venting of such migratory emissions can take place.

It is not known how long migratory emissions due to venting via fractured rock strata and aquifers will continue into the future. Consequently, an accurate assessment of atmospheric pollution due to CSG operations would require long-term monitoring.

As recent events demonstrate, current CSG mining activity may activate emissions in older abandoned and capped wells and water bores. Mining companies need to be required to assume responsibility for methane emissions from an agreed area extending outwards from their operations for an agreed period of time into the future.

In my opinion, the appropriate assessment of fugitive methane emissions from CSG operations can only be achieved by the “Method 4: Direct monitoring of emissions systems, either on a continuous or periodic basis”, as described in the Consultation Draft Measurement Determination, National Greenhouse and Energy Reporting Measurement Amendment 2012, Departmental Commentary (30 April 2012).[19]

I note that Petron (2012)[20] described the use of a motor vehicle fitted with methane detecting instruments to locate a specific gasfield responsible for a high level of methane pollution identified in an atmosphere testing tower. Petron also referred to ongoing research collaboration with other scientists who were using aircraft to measure methane in the atmosphere over gasfields. Petron (2012) recommended that air pollution be measured over entire gas fields in addition to monitoring at well sites and compressor stations.

A Google search for “methane monitoring equipment” indicated that various handheld, stationery, vehicle mounted, and aircraft mounted instruments are available for assessing methane pollution on a landscape scale.

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[19] Consultation Draft Measurement Determination, National Greenhouse and Energy Reporting Measurement Amendment 2012, Departmental Commentary (30 April 2012).
[20] Pétron, G., et al. (2012), Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study, *J. Geophys. Res.*, 117, D04304, doi:10.1029/2011JD016360.

Unfortunately, the CSG industry in Australia, and particularly in south-east Queensland, has gone ahead without any assessment of methane emissions prior to widespread drilling operations. Consequently, for gasfields that have already been developed, the total amount of methane emissions due to CSG drilling can not be assessed by a comparison of pre-drilling to post-drilling emission data.

An alternative approach would be for landscape scale assessment of methane emissions to be made for a "control/comparison" area that is matched to the gasfield to be assessed on such variables as geology, previous mining activity, agricultural operations, and other relevant factors.

Even though CSG operations have impacted widely across some regions, the same coal seam underlies large areas, so identifying an appropriate control/comparison area should be practical.

Atmospheric assessment of methane in the control/comparison area, with an appropriate adjustment for natural variability established by research, would provide a baseline for likely natural emissions above which any methane present could be attributed to current mining operations.

I note that even in south-east Queensland the CSG industry is far from maturity, and massive further development is planned. Consequently, the accurate future assessment of methane emissions will require repeated assessments over time to accurately gauge the pollution due to specific mining operations.

Summary and Recommendations

- Due to its very nature, the recently developed drilling technology employed by the CSG industry is likely to produce significant fugitive and migratory methane emissions across landscapes.

- It is reasonable to assume that methane can potentially vent into the atmosphere via: a) fractures in rock strata created by both vertical and horizontal CSG drilling; b) contaminated aquifers, and c) faulty concrete well casings.

- Self-assessment and self-reporting by the CSG mining companies will not be viable.

- CSG methane emissions need to be measured across landscapes and entire gasfields, and not just at the well head.

- To facilitate research and assessment of migratory methane emissions, miners need to provide government agencies with maps of the direction and length of horizontal shafts that radiate out from wellheads.

- Given the possible long term persistence of migratory emissions due to venting via fractured rock strata and aquifers, an accurate assessment of atmospheric pollution will require long-term monitoring.

- Given the potential for CSG mining activity to activate emissions in older abandoned and capped wells and water bores, mining companies need to be required to assume responsibility for methane emissions from an agreed area extending outwards from their operations for an agreed period of time into the future.

- Methane venting might tend to be densest along lines corresponding to the direction of the horizontal drilling, but the likely extent and range of venting is currently unknown.

- The appropriate assessment of fugitive methane emissions from CSG operations can only be achieved by the “Method 4: Direct monitoring of emissions systems, either on a continuous or periodic basis”.[21]

- In proposed gas fields, pre-drilling assessment of emissions across the landscape would enable comparison with post-drilling emission data.

- In already developed gasfields, the total amount of methane emissions due to CSG drilling can be assessed by a comparison to a matched control/comparison area.

Yours faithfully,

Dr Wayne Somerville

[21] Consultation Draft Measurement Determination, National Greenhouse and Energy Reporting Measurement Amendment 2012, Departmental Commentary, (30 April 2012).

How Could CSG Air Pollution in the Darling Downs Be an "Acceptable" Risk to Health?

The Elephant That Can't Get Into the Room

Portion of a Darling Downs Gasfield

This report analyses recently released 2013/14 National Pollutant Inventory (NPI) data for air pollution from CSG processing in the Darling Downs, and discusses implications for community health and government policy

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How Could CSG Air Pollution in the Darling Downs Be an "Acceptable" Risk to Health? The Elephant That Can't Get Into the Room

> "Whether these (identified CSG-related) risks are acceptable or not depends on the level or (sic) risk Government, in consultation with the wider community, deems acceptable" (Prof O'Kane, NSW Chief Scientist and Engineer[1]).

Emeritus Professor Chris Fell described the problem of how to dispose of CSG water treatment concentrates as "the elephant in the room" (Page 45)[2]. It seems that air pollution created by the industrial processing of CSG is the elephant that can't get into the room.

Recently released National Pollutant Inventory (NPI) data[3] for the year 2013-2014 indicate a very significant, rapidly growing, but generally ignored threat to human health from air pollution created by the industrial processing of Coal Seam Gas (CSG) in Queensland's Darling Downs.

Prof O'Kane[4] extols an appropriate risk management attitude in which problems are approached with "eyes wide open, a full appreciation of the risks, complete transparency, rigorous compliance, and a commitment to addressing any problems promptly" (Page iv). But Prof O'Kane does not discuss the significance of air pollution created by CSG processing.

In her Independent Review of CSG Activities in NSW, Prof O'Kane appears to not have satisfied the Term of Reference to "identify and assess any gaps in the identification and management of risk arising from coal seam gas exploration, assessment and production, particularly as they relate to human health, the environment and water catchments"[5].

Prof O'Kane did not recognise that the substantial quantities of dangerous air pollution created during CSG processing represent a significant risk to health. Prof O'Kane identified CSG-related air pollution as potentially arising from drilling, seam depressurisation, spills and leaks, and incomplete combustion of methane from flaring, and concluded, "Of the risks identified, spills and leaks appear to be the only ones that have occurred to date" (Page 33).[6]

Despite its relevance for assessing CSG health impacts, Prof O'Kane did not reference or use the NPI's industry-provided estimates of yearly air pollution emissions from leaks and storage tanks, particulate matter generated by various sources, vented waste gas, gas dehydration and processing, and fuel combustion.

It seems possible that Prof O'Kane not considering the health impacts of CSG-related air pollution was a consequence of the exclusion policy in Section 1.2.2 of her report[7] which states that "risks common to other industrial activity, such as other natural gas and mining industries" were "considered beyond the scope in this report".

Prof O'Kane's decision to not consider NPI air pollution data has profound implications for the NSW Government's "Gas Plan", which is based on the recommendations from her report[8], and consequently impacts on the assessment and management of CSG-related risks to human health.

Effective policy is impossible when regulators are not even aware of a well documented threat to community health because the scientific report they rely on makes no mention of the problem.

This report concludes that 2013-2014 NPI data[9] for air emissions from CSG processing in the Darling Downs should not be ignored as a risk to health. CSG air pollution deserves serious consideration.

In the Darling Downs, known for its rich agricultural industries, 5.5% of Queensland's population, living in the same river catchment system, are being exposed to unknown, variable doses of a complex mix of newly introduced dangerous pollutants.

NPI data reveals rapidly increasing emissions of dangerous CSG related air pollutants in the Darling Downs. For example, in the year 2013-14, (see Table 2 in Appendix B) about 1,383 tonnes of Volatile Organic Compounds (VOCs), 13 tonnes of Acetaldehyde, 2.2 tonnes of BTEX, 241 tonnes of Formaldehyde, 8,788 tonnes of Carbon Monoxide, 12,189 tonnes of Oxides of Nitrogen, and 2,325 tonnes of particulates were emitted in the air above the Darling Downs, where the gas industry is set to expand a number of times over.

During 2013/14, on an average day, 3.79 tonnes of VOCs, more than 57.4 tonnes of Carbon Monoxide and Oxides of Nitrogen, and more than 6.37 tonnes of particulates were released into Darling Downs air.

Can science tell us if the CSG air pollution in the Darling Downs is an "acceptable" risk to health?

The negligent failure of industry and government to obtain baseline health measurements in the Darling Downs, and elsewhere, has denied the Australian people the opportunity to compare health statistics obtained prior to, and after, the establishment of CSG gas fields. But the lack of baseline data also makes it impossible to prove that the gas industry is safe.

It is arguable that Prof O'Kane's grounds for dismissing US epidemiological research as irrelevant to the Australian experience are not valid, and we know from the NPI data the type and quantities of dangerous air pollutants being released during the production of CSG in Australia.

Health Impact Assessments are computer-based, "screening" exercises that rely on a set of dubious assumptions and do not obtain data from the real world.

Could the environmental mechanisms and technical methods recommended by Prof O'Kane manage the health risks from CSG air pollution in the Darling Downs?

"Dilution is the solution" assumes that dangerous air pollutants are diffused in the atmosphere to harmless concentrations. As Prof O'Kane explained, the scientific study of the dilution of pollutants in the atmosphere is complex and should be performed before the granting of licences. This science does not exist, and it is unlikely that government and industry will put it in place anytime soon.

Prof O'Kane suggested that health risks could be managed by "the maturity of the industry", and improvements in professional standards, scientific research, technological development, and regulation. It is not apparent how these processes could result in a significant mitigation of the dangerous air pollution that is a necessary feature of this industry.

Effective policy is unlikely with policymakers blind to the air pollution health threat because the scientific report on which they rely does not recognise the problem.

What are the implications if governments and communities deem that health impacts resulting from CSG air-pollution are acceptable or unacceptable?

Gasfield Industrialisation of Queensland's Darling Downs

Figure 1. Regions of Queensland[10]

The Darling Downs is situated in the drainage basins of the Condamine and Maranoa Rivers, and is generally taken to be between 130-250 km west of Brisbane; bounded in the north by the Bunya Mountains, in the east by the Great Dividing Range, in the south by the Granite Belt and Herries Range, and on the west by the Condamine River.[11,12]

Figure 2. Towns of the Darling Downs

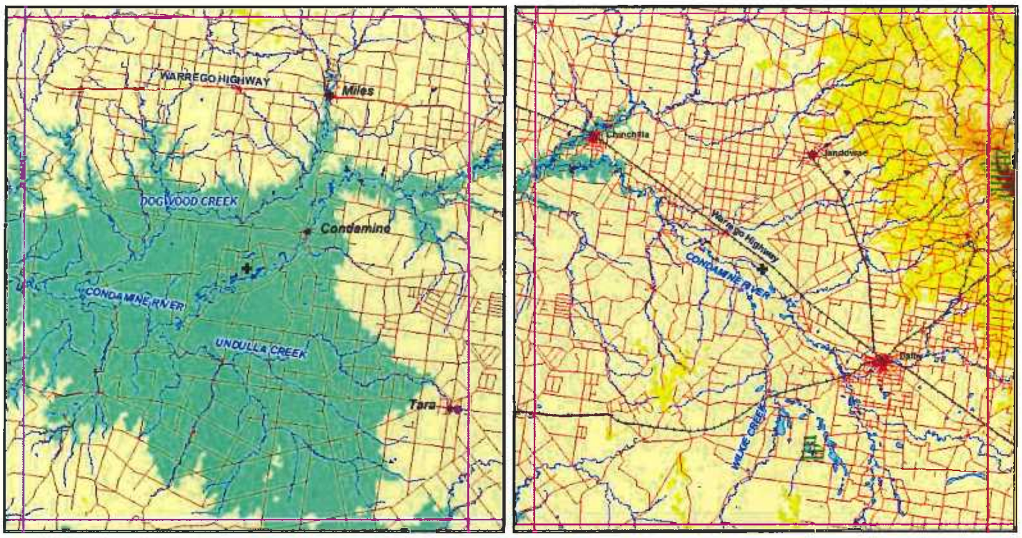

Figure 2. Royal Geographic Society Maps – "Condamine"[13] and "Western Downs"[14]

In June 2012, the Darling Downs population was 251,893 people, or 5.5 per cent of Queensland's total population, of which about 20 percent are children 14 years or younger.[15]

The rapid development of the unconventional gas industry across the Queensland's Darling Downs is an experiment in social and environmental engineering of unprecedented scale and potential risk to an Australian community's health.

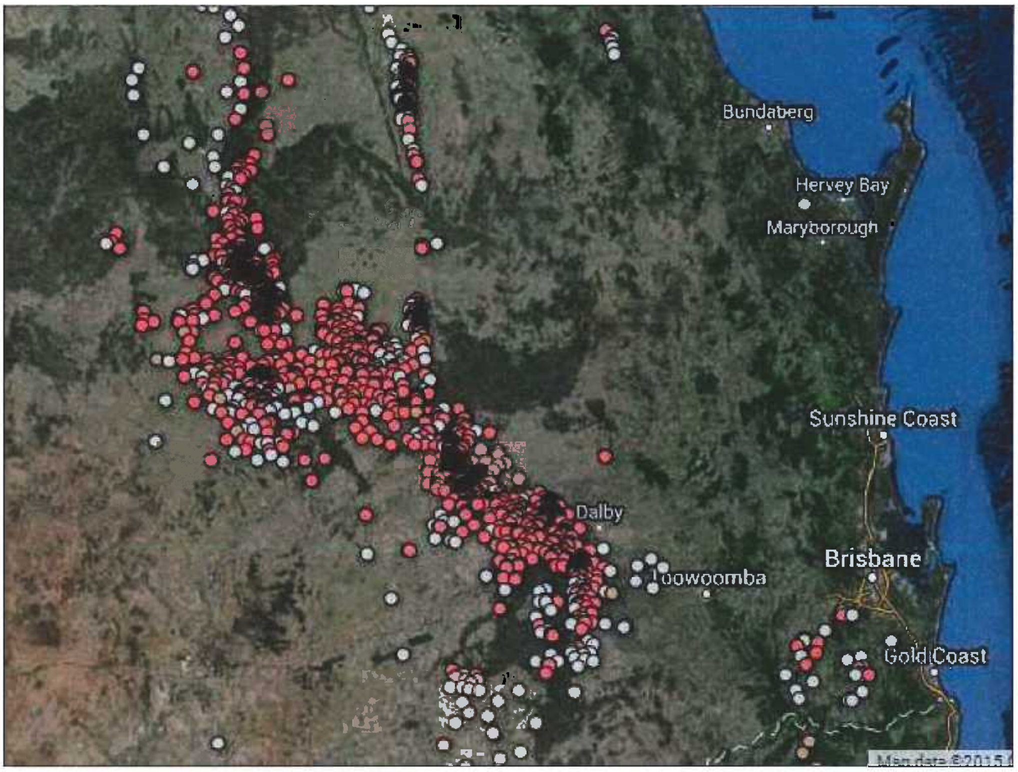

Figure 3. CSG Wells in the Darling Downs[16]

Australians have never before had to live and raise children amidst industrialised gas fields - in landscapes dominated by gas wells, roads, pipes, flares, wastewater ponds, and pumping and compression stations.

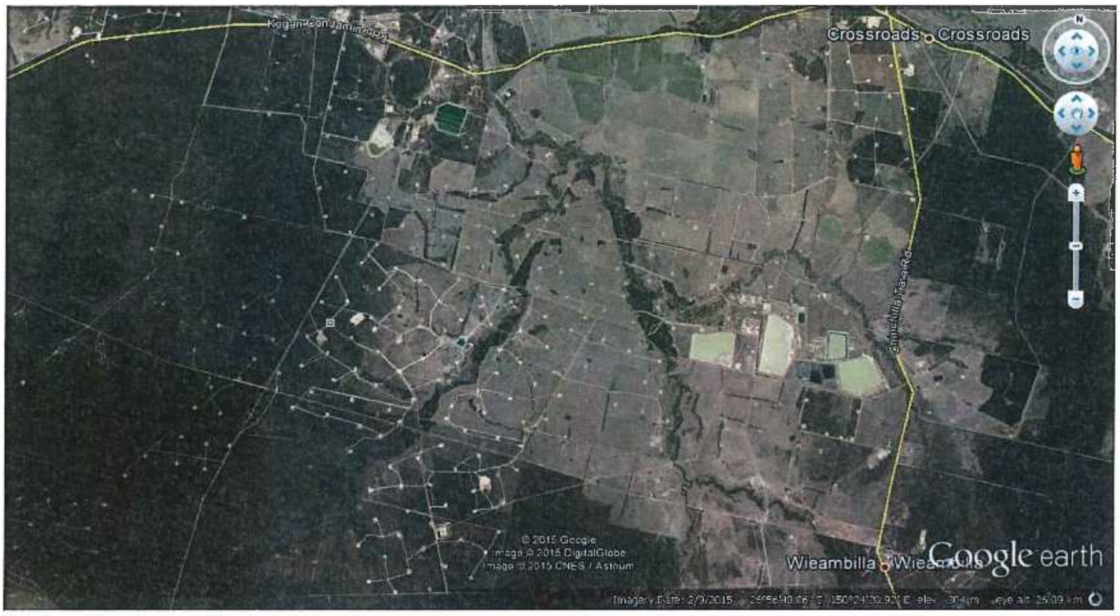

Figure 4. A Darling Downs Gasfield

NPI Data for Gas Industry Air Pollution in the Darling Downs

NPI data is available for many industries and facilities across Australia.

This report is concerned exclusively with NPI reported air emissions from the following twenty gas industry operations (ANZSIC Gas and Oil Extraction, Code 070) identified as being in the Darling Downs: Silver Springs Gasfield (Surat), Daandine Operations (Via Dalby), Tipton Operations (Via Dalby), Kogan Gas Field (Via Dalby), Combabula and Reedy Creek (Yuleba North), Condabri (Miles), Peat (Southshire), South Denison (Westgrove), Spring Gully (Durham Downs), Talinga (Condamine South), ATP676 (Via Miles), ATP852 (Via Wandoan), Kenya Processing Plant (ATP620) and Compressor Stations (Via Tara), Ruby Jo/Jordan (Via Tara), Windibri Processing Plant (PL201) and Compressor Stations (Condamine), Woleebee Creek (Via Tara), "Fairview Coal Seam Methane Field" (Injune), "Moonie" (Moonie), "Roma" (Roma), and "Scotia" (Wandoan).

This report does not consider NPI documented air-pollution in the Darling Downs created by coal and gas fired power plants, coal mines, CSG water treatment plants, or other gas and oil industry associated facilities.

Substances reported in NPI data "are those that, when emitted at certain levels, have the potential to be harmful to human health or the environment. Australian state and territory governments have legislated that industry will report these emissions on an annual basis. Reportable NPI substances are listed in the NPI Guide.....".[17]

Dangerous substances used or liberated by unconventional gas mining can escape into air, soil, and water systems during most stages of the gas production process - from exploration drilling, production testing, well completion, processing, venting, flaring, and waste water storage, through to transportation and supply of the processed gas.

NPI data provides a partial accounting that tends to underestimate the total air pollution created by the unconventional gas industry. Industry reporting is limited to pollutants emitted during field development and normal operation activities, including the industrial processing of CSG. Emissions associated with gas exploration are not reportable under the NPI.

NPI substances have minimum reporting thresholds[18], and the NPI website presents data to two significant figures, for example showing a reported value of 52,366,968 kg as 52,000,000 kg.[19]

NPI data includes CSG-related air pollution from:

- fugitive emissions from general leaks;
- fugitive emissions from storage tanks, including evaporative losses from filling and transfer operations as well as standing losses;
- particulate matter generated by a number of sources including the movement of vehicles, drilling, and wind erosion of exposed areas;
- vented waste gas;
- gas dehydration; and
- fuel combustion including flaring, on-site power generation and on-site vehicles.

NPI data does NOT include CSG-related air pollution from:

- emissions from a facility of a substance at less than reportable thresholds;
- emissions associated with gas exploration;
- the release of greenhouse gases, such as carbon dioxide and methane;
- the "enhanced diffusion of gas from soils" due to changes in subsurface strata caused by horizontal drilling, hydraulic fracturing, and groundwater extraction.[20]

Further, NPI data does NOT include CSG-related soil and water pollution due to:

- the disposal of drilling muds;
- the mixing of subterranean water from different geologic strata due to coal seam depressurisation and fracturing of rock layers; or
- the contamination of aquifers by substances used in or liberated by gas mining.

A comparison of NPI data for the reporting years 2011/12 and 2013/14 indicated marked increases in quantities of air pollutants emitted by particular CSG processing facilities in the Darling Downs.[21] According to Dr Mariann Lloyd-Smith:

> "Particulate matter (PM) for the QGC's Kenya Processing Plant (ATP620) and Compressor Stations near Tara, rose from 5,400 kg of PM10 and PM2.5 in 2011/12 to 342,000 kg in 2013-2014 (63 times greater than 2011/12)...In 2013-14, QGC's other Windibri Processing Plant (PL201) and Compressor Stations reported the extraordinary figure of 1,316,000 kg for their total particulate matter emissions. QGC's report for their Ruby Jo Tara field for 2013-14, showed their emissions for the poisonous carbon monoxide had doubled to 1,600,000 kg while nitrous oxides were reported at 810,000 kg, well up from the previous reporting year's 230,000 kg".[22]

Table 1 (attached as Appendix A) presents NPI data for reportable emissions for the year 2013/14 for the 20 Darling Downs gas industry facilities identified in this report.

Table 2 (attached as Appendix B) presents the total amounts, in kilograms, of reported emissions of NPI substances by gas industry facilities in the Darling Downs for 2013/14.

Understanding the Scale of CSG Air Pollution in the Darling Downs

An appreciation of the quantity of pollutants released into the atmosphere by CSG processing is essential for any assessment of health risks, but statistics involving millions of kilograms of gases, liquids, and solids are difficult to comprehend or imagine. To aid understanding of the scale of pollution documented by the NPI, the data in Table 2 was analysed in various ways.

For liquid pollutants, the standard 20 litre plastic drum (Height 39 cm, Width 28 cm, Depth 21 cm), familiar to most country and many city people, was used to represent data in a more imaginable form.

Appendix C presents the rationale and formula used to convert kilograms of pollutants to volumes in litres, and Table 3 lists the specific gravities listed by the NPI for the 41 specified VOC substances.

Table 4 (attached as Appendix D) presents the total kilograms of liquid VOCs emitted by gas industry operations in the Darling Downs in 2013/14, volume in litres, the number of standard 20 litre drums needed to contain the volume, and the stacked height of those drums in metres.

From Table 4 it can be seen that the stacked height of 20 litre drums required to store the total amount of VOCs emitted into the air by CSG production in the Darling Downs in 2013/14 would be somewhere between the minimum to maximum possible heights of 12.42 to 43.47 kilometres (or 1.4 times to 4.9 times the height of Mt Everest).

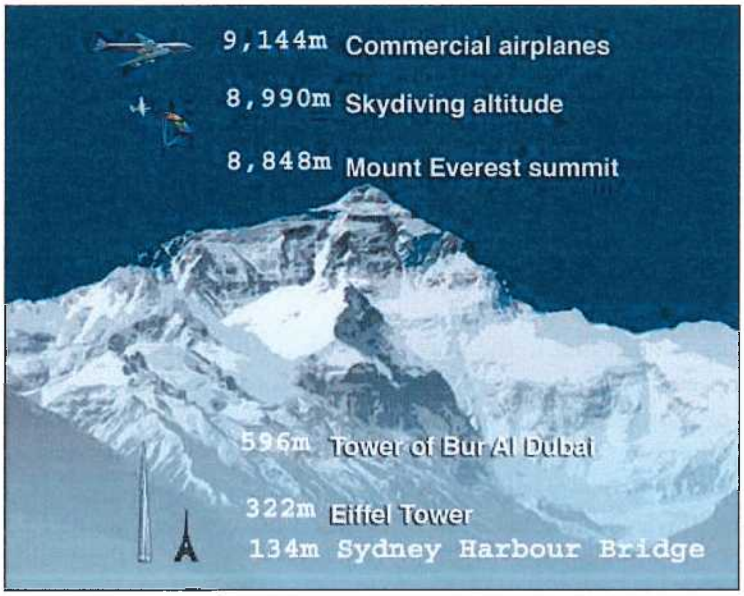

Figure 5. Height of Mt Everest

Table 5 (see Appendix E) presents the 2013/14 NPI data for the quantity of some air pollutants produced during CSG processing in the Darling Downs as total kilograms, kilograms per head of population (Darling Downs population = 251,893), and kilograms per day (n = 365).

From Table 5 it can be seen that in 2013/14 for each man, woman and child in the Darling Downs, CSG processing emitted about 5.5 kg of VOCs, over 83 kg of carbon monoxide and oxides of nitrogen, and more than 9.2 kg of particulates.

From Table 5 it can also be seen that, on average, each day during 2013/14, 3.79 tonnes of VOCs, 57.5 tonnes of carbon monoxide and oxides of nitrogen, and more than 6.37 tonnes of particulates were released into the Darling Downs atmosphere.

The Darling Downs includes many populous non-mining areas, such as Toowoomba, Warwick and Goondiwindi, and CSG facilities are concentrated in a portion of the area. NPI data were analysed for the smaller, more CSG concentrated area shown in Figure 6.

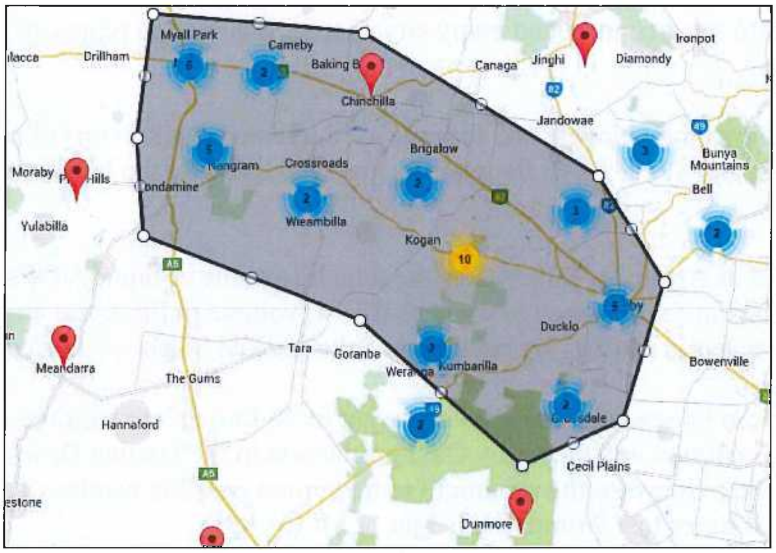

Figure 6. Darling Downs area with more concentrated CSG activity

Table 6 (see Appendix F) presents the 2013/14 NPI data for the 9 CSG facilities that lie within the area indicated in Figure 6.

Table 7 (see Appendix G) presents the 2013/14 NPI data for pollutants emitted by the nine CSG facilities that lie within the area indicated in Figure 6, as total tonnes, kilograms per head of population (sub area population = 18,358) and kilograms per day (n = 365).

From Table 7 it can be seen that in the year 2013/14, for the indicated sub area of the Darling Downs where the nine CSG facilities operated, 5,790 tonnes of Carbon Monoxide, 6,767 tonnes of Oxides of Nitrogen, 2,018 tonnes of particulates, 563 tonnes of VOCs, and 157 tonnes of Formaldehyde were emitted into the atmosphere.

This annual pollution was equivalent to average per day air emissions of 15.86 tonnes of Carbon Monoxide, 18.5 tonnes of Oxides of Nitrogen, 5.5 tonnes of particulates, 1.54 tonnes of VOCs, and 0.425 tonnes of Formaldehyde.

For the 18,358 people who live in the indicated sub-area of the Darling Downs, in the year 2013/14, their per person "share" of CSG air pollution was 315.4 kilograms of Carbon Monoxide, 368.6 kilograms of Oxides of Nitrogen, 110 kilograms of particulates, 30.7 kilograms of VOCs, and 8.6 kilograms of Formaldehyde.

The CSG industry in the Darling Downs is a "work in progress", with plans to expand the number of wells and processing capacity a number of times over in coming years.[23]

To give an idea of potential future levels of air pollution from CSG processing in the Darling Downs, Table 8 (see Appendix H) presents figures for a hypothetical fourfold increase of the 2013/14 NPI data for kilograms of pollutant per head of population and per day (from Table 5) and for height of storage drums (from Table 4).

From Table 8 it can be seen that a hypothetical four-fold increase of the 2013/14 NPI data would result in yearly emissions into Darling Downs air of 5,535.54 tonnes of VOCs, 52 tonnes of Acetaldehyde, 4.3 tonnes of Cyclohexane, 1.3 tonnes of Toluene, 27 tonnes of Hexane, 6.9 tonnes of Xylene, 83,910 tonnes of Carbon monoxide and Oxides of nitrogen, 967 tonnes of Formaldehyde, and 9, 300 tonnes of particulates.

With a hypothetical fourfold increase in CSG air pollution, on average, each day, more than 15 tonnes of VOCs, 2.65 tonnes of formaldehyde, 229.9 tonnes of carbon monoxide and oxides of nitrogen, and 25.48 tonnes of particulates would be released into Darling Downs air.

From Table 8 it can be seen that a hypothetical fourfold increase in CSG air pollution in the Darling Downs would result in an average annual per person "share" of nearly 22 kg of VOCs, about 333 kg of carbon monoxide and oxides of nitrogen, and about 37 kg of particulates.

Storing a hypothetical fourfold increase in Total VOC annual emissions would require a stack of 20 litre drums that stood somewhere between a minimum possible height of over 49.7 kilometres (5.6 times the height of Mt Everest) and a maximum possible height of more than 173.8 kilometres (19.6 times the height of Mt Everest).

It is clear that significant and increasing amounts of pollutants are being discharged into Darling Downs air from the processing of CSG.

To address the question of whether this pollution represents a significant threat to human health, a brief review of the health effects of some pollutants assessed by the NPI will be followed by a discussion of methods for assessing and potentially managing health risks.

Is CSG Air Pollution in the Darling Downs a Risk to Human Health?

In her final report on CSG health impacts[24], Prof O'Kane noted that:

> "All industrial activities will impact the environment. The crucial question then becomes: what is the likelihood and consequence of different events occurring, i.e. what are the risks of CSG activities?" (Page 5).

The following section briefly reviews the health effects of exposure to some of the NPI identified air pollutants being released by CSG processing in the Darling Downs.

Health Impacts of Exposure to Some CSG Pollutants

Volatile organic compounds (VOCs). During the 2013/14 reporting year, 1,383 tonnes of VOCs were emitted into air above the Darling Downs, at an average daily rate of 3.79 tonnes. This represented a yearly "share" of about 5.5 kilograms of VOCs for every person in the Darling Downs.

In the area where CSG activity is concentrated (see Table 7), 5.63 tonnes of VOCs were emitted in the 2013/14 reporting year, at a daily average of 1.54 tonnes. Each person's yearly "share" of VOCs was 30.7 kilograms.

Some VOCs are very toxic and bioactive, and exposure can cause eye, nose, and throat irritation, headaches, visual disorders, memory impairment, loss of coordination, nausea, and damage to liver, kidneys, and the central nervous system.[25] The US EPA noted that some VOCs can cause cancer and other serious, irreversible health effects, including neurological problems and birth defects.[26]

Some VOCs are known to cause cancer in animals, or in humans (e.g., formaldehyde), or are suspected human carcinogens (e.g., chloroform). VOCs are ingredients in ozone, smog, and fine particle pollution.[27]

Benzene, toluene, ethylbenzene, and xylene (BTEX). During the 2013/14 reporting year, over 2.2 tonnes of BTEX chemicals were emitted into Darling Downs air, at an average daily rate of 6.02 kilograms. This represents a yearly "share" of about 8.7 grams for every person in the area. 127.5 twenty litre drums, a stack about 49.7 metres high, would be needed to contain one year of BTEX emissions into the Darling Downs' air.

Benzene and toluene are particularly problematic VOCs because they tend to be activated into other substances and impact on certain tissues in unique ways.[28] Short-term health effects of exposure include dizziness, headache, loss of coordination, respiratory distress, and skin, eye, and nose and throat irritation. Long-term health effects of exposure to BTEX chemicals include kidney, liver, and blood system damage.

Acetaldehyde. During the 2013/14 reporting year, 13 tonnes of acetaldehyde were emitted into air above the Darling Downs, at an average daily rate of over 35.5 kilograms. This represents a yearly "share" of about 52 grams for every person in the area. About 825 twenty litre drums, a stack about 322 metres high, would be needed to contain one year of acetaldehyde emissions.

The primary acute effect of acetaldehyde exposure is irritation of the eyes, skin, and respiratory tract. At higher exposure levels, erythema, coughing, pulmonary edema, and necrosis may also occur. Acetaldehyde is considered a probable human carcinogen. No information is available on the reproductive or developmental effects of acetaldehyde in humans, but animal studies suggest that acetaldehyde may be a potential developmental toxin.[29] Acetaldehyde exposure may also cause: slowed mental response and dizziness; damage to the mouth, throat and stomach; accumulation of fluid in the lungs and chronic respiratory disease; kidney and liver damage; and skin reddening, swelling, and sensitisation.

Formaldehyde. During the 2013/14 reporting year, over 241.8 tonnes of formaldehyde were emitted into air above the Darling Downs, at an average daily rate of over 662 kilograms. This represents a yearly "share" of 960 grams for every person in the area.

In the area where CSG activity is concentrated (see Table 7), 157.7 tonnes of formaldehyde were emitted in the 2013/14 reporting year, at a daily average of 432 kilograms. Each person's yearly "share" of formaldehyde was 8.6 kilograms.

Exposure to low levels of formaldehyde irritates the eyes, nose and throat, and can cause allergies affecting skin and lungs. Higher exposure levels can cause throat spasms and a build up of fluid in the lungs, leading to death. Contact can burn eyes and skin, leading to permanent damage. Formaldehyde is classified as a known human carcinogen by the International Agency for Research on Cancer (IARC) and as a probable human carcinogen by the US EPA.[30]

Carbon monoxide. During the 2013/14 reporting year, over 8,788 tonnes of carbon monoxide were emitted into air above the Darling Downs, at an average daily rate of 24 tonnes. This represents a yearly "share" of about 34.9 kilograms for every person in the Darling Downs.

In the area where CSG activity is concentrated (see Table 7), 5,790 tonnes of carbon monoxide were emitted in the 2013/14 reporting year, at a daily average of 15.9 tonnes. Each person's yearly "share" of carbon monoxide was 315.4 kilograms.

Carbon monoxide is rapidly absorbed into the bloodstream from the lungs, and cleared from the body slowly. Inhalation of low levels of carbon monoxide (200 parts per million for 2-3 hours) can cause headache, dizziness, light-headedness and fatigue. Exposure to higher concentrations (400 ppm) can cause sleepiness, hallucinations, convulsions, collapse, loss of consciousness, and death. Exposure can also cause personality and memory changes, mental confusion and loss of vision. Long term chronic health effects can occur from exposure to low levels of carbon monoxide, resulting in heart disease and damage to the nervous system. Exposure of pregnant women to carbon monoxide may result in low birth weights and other defects in offspring.

Oxides of Nitrogen. During the 2013/14 reporting year, over 12,189 tonnes of oxides of nitrogen were emitted into air above the Darling Downs, at an average daily rate of over 33.4 tonnes. This represents a yearly "share" of over 48.4 kilograms for every person in the Darling Downs.

In the area where CSG activity is concentrated (see Table 7), 6,767 tonnes of oxides of nitrogen were emitted in the 2013/14 reporting year, at a daily average of 18.54 tonnes. Each persons yearly "share" of oxides of nitrogen was 368.6 kilograms.

Exposure to low levels of oxides of nitrogen can irritate eyes, nose, throat and lungs, and produce coughing, shortness of breath, tiredness and nausea. Exposure can also result in a build up of fluid in the lungs for 1-2 days after exposure. Breathing high levels of oxides of nitrogen can cause rapid burning, spasms, and swelling of tissues in the throat and upper respiratory tract, reduced oxygenation of tissues, a build up of fluid in lungs, and possibly death.

Ethylene glycol. During the 2013/14 reporting year, 15.6 tonnes of Ethylene glycol were emitted into air above the Darling Downs, at an average daily rate of 42.8 kilograms. This represents a yearly "share" of about 62 grams of Ethylene glycol for every person in the Darling Downs.

A human respiratory toxicant and teratogen (i.e., an agent that causes malformation of an embryo or foetus) in animal tests. Associated with increased risks of spontaneous abortion and sub-fertility in female workers. When ethylene glycol breaks down in the body, it forms chemicals that crystallise, collecting in the kidneys and affecting kidney function. It also forms acidic chemicals in the body, affecting the nervous system, lungs and heart.[31]

Sulfur dioxide. During the 2013/14 reporting year, 6.33 tonnes of sulfur dioxide were emitted into air above the Darling Downs, at an average daily rate of 17.34 kilograms. This represents a yearly "share" of about 25 grams of sulfur dioxide for every person in the Darling Downs.

Exposure causes irritation of the eyes, nose and throat, choking and coughing. Exposure of the skin or eyes to liquid sulfur dioxide can cause severe burns. Other health effects include headache, general discomfort and anxiety. Repeated or prolonged exposure to moderate concentrations may cause inflammation of the respiratory tract, wheezing and lung damage. It has also proved to be harmful to the reproductive systems of experimental animals and caused developmental changes in their newborn.

Particulate Matter 2.5 μ ($PM_{2.5}$) and 10.0 μ (PM_{10}). During the 2013/14 reporting year, over 2,325 tonnes of particulates were emitted into air above the Darling Downs. Each day during the 2013/14 reporting period, on average, more than 5.48 tonnes of PM_{10} and 892 kilograms of $PM_{2.5}$ particulate matter were released into Darling Downs' air. This represents a yearly "share" of 7.94 kilograms of PM_{10} and 1.29 kilogram of $PM_{2.5}$ for every person in the Darling Downs.

In the area where CSG activity is concentrated (see Table 7), 2,018.92 tonnes of particulate matter were emitted in the 2013/14 reporting year, at a daily average of 5.53 tonnes, and each person's yearly "share" was 109.97 kilograms.

Particulate matter, and especially the finer $PM_{2.5}$ which is roughly 40 times smaller than the width of a human hair, can be drawn deep into the lungs, where it sets up inflammatory foci and spreads damage throughout the body. The chemical properties vary depending on the sources of particles. Ultra-fine particles ($PM_{0.1}$) can penetrate cells and change genetic material.

Recent epidemiological research suggests that there is no threshold for particulates at which health effects do not occur, and risks are highest for sensitive groups such as the elderly and children.

According to Dr Mariann Lloyd-Smith, Senior Advisor with the National Toxics Network, "The adverse effects of particulate matter are well documented and there is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur."[32]

It is clear that the CSG-related air pollution in the Darling Downs involves large quantities of dangerous substances. The following section discusses scientific methods for determining whether these environmental pollutants pose a significant risk to human health.

Scientific Methods for Assessing Health Risks

In the Darling Downs 5.5% of Queensland's population, living in the same Condamine River catchment system, are being exposed to unknown, variable doses of a complex mix of newly introduced, dangerous pollutants.

In their report[33] commissioned by the NSW Chief Scientist and Engineer, Vaneckova and Bambrick (2014) noted that:

> "Given that any effects of CSG mining on population health are likely to be geographically widespread (e.g., over a water catchment), diffuse (indirect, operating through multiple pathways) and non-specific (many potential sources of exposure each with several potential health outcomes), determining these effects presents a challenge. As large numbers of people could be exposed, however, even a very small effect can be significant in terms of public health" (Page 8).

In decreasing levels of power to determine likely causal connection between symptoms of illness and exposure to a pollutant, available scientific methods for assessing health risks include controlled pre-to post drilling comparisons, epidemiological studies, and environmental and health impact assessments.

Pre- to post-drilling research – The lamentable lack of baseline health data. The negligent failure of industry and government to obtain baseline health measurements prior to the commencement of CSG operations in the Darling Downs, as well as every other extant gasfield, has denied the Australian people the ability to compare health statistics obtained prior to, and after, the establishment of CSG gas fields.

Perversely, gas companies seek to benefit by arguing that the lack of baseline health data means that it cannot be "proved" that an observed deleterious post-drilling health effect represents a change from pre-drilling conditions.

But the lack of baseline data also makes it impossible for gas companies to ever prove that their industry is safe.

When pressed to do so, the gas industry cannot provide any data that comes close to scientific "proof" that their operations are safe.[34] Even if it wished to, the CSG industry in the Darling Downs could not satisfy the requirement imposed on pharmaceutical and other companies that they prove the safety of their operations and/or product before the public is exposed.

Certainly, the nature and scale of air pollution created by the processing of CSG in the Darling Downs indicates that gas industry operations can not be assumed a priori to be safe.

Given the lack of baseline health data, the safety of air pollution from CSG processing in the Darling Downs can only be addressed scientifically with long-term epidemiological studies and desktop Environmental Impact Statements and Health Impact Assessments.

Epidemiological studies. When it is not possible to compare baseline to post-drilling health data, scientists have to rely on epidemiological studies to examine patterns of disease in defined populations.

By their nature, epidemiological studies tend to be long term, difficult to undertake, and provide only correlational information. According to Prof O'Kane[35]:

> "Causation and correlation in an epidemiological study can be difficult to show. This is due to many factors including: obtaining an accurate assessment of exposure by individuals or the community; small population sizes exposed; varied and mild health effects; chronic low exposures in sensitive individuals; lifestyle; socioeconomic status; and alternative potential exposure sources such as combustion heating and power generators. Failure of a study to control for these factors adequately means that its ability to attribute a particular symptom to a specific chemical or industrial activity is limited" (Page 28).

Prof O'Kane[36] denied the local relevance of the rapidly growing body of US epidemiological research documenting health impacts due to pollutants from shale gas fields. Specifically, Prof O'Kane argued that US research "Cannot be directly compared to Australian scenarios" because of differences in "surface and subsurface environments and gas composition", the greater use of fracking in shale and tight sands mining, and variations in the composition of gas (Page 28).

And, according to Prof O'Kane, even if the US health studies were relevant, "While there are some reports of health effects, the studies have been unable to find any clear link between CSG and health impacts" and "Many of the studies have methodological problems ..." (Page 28).

It is arguable that Prof O'Kane's grounds for dismissing US epidemiological research as irrelevant to the Australian experience are not valid. Prof O'Kane in her reports explicitly acknowledges that the "methodological problems" are unavoidable features of epidemiological research, and this feature does not constitute grounds for ignoring this data.

Air pollution is likely to be an important illness vector in US gas fields, and similar types of air pollution are likely to be produced by the industrial processing of gas extracted from shale and coal seams. Research indicates that similar hazardous substances are liberated during gas extraction from coal and shale seams.[37]

Promoters of the US shale gas industry argue that mining for shale gas is inherently safer than CSG mining because it takes place at a much greater depth, further away from aquifers used by humans. And in the Northern Rivers, Metgasco's planned gasfield from Bentley to Casino would tap a 2 km deep tight sands formation which, according to the NSW Office of Coal Seam Gas[38], would require extensive fracking and aquifer depressurisation during production.

A growing body of US epidemiological research points to the high risk of severe health impacts from operating gas fields in populated areas, especially for children. For instance, McKenzie et al (2013)[39] found a relationship between heart and neural tube defects in newborn children and the distance that their mothers lived from gas wells, and Kassotis et al (2013) [40] reported a strong association between unconventional gas mining and the presence of moderate to high levels of hormone-disrupting chemicals in the Colorado River and aquifer systems used for human consumption.

The number of published peer-reviewed studies of the environmental and health impacts of shale and tight gas development has increased from 6 in 2009 to 154 in 2014. 96 percent of the studies that directly assessed health impacts (n = 47) reported potential public health risks or actual adverse health outcomes. A number of major epidemiological studies are underway.[41]

Although much research has subsequently appeared, my 2013 report "Self-help Risk Management Tools: A Report on the Health Impacts of CSG and Shale Gas Mining"[42] provides an introductory review of the epidemiological research on unconventional gas mining impacts on health.

Dr Geralyn McCarron's (2013) important study "Symptomology of a Gas Field: An Independent Health Survey in the Tara Rural Residential Estates and Environs"[43] found markedly elevated levels of symptoms suggestive of nervous system damage in children in the Tara area of the Darling Downs.

The Compendium prepared by Concerned Health Professionals of New York[44] is a fully referenced compilation of scientific, medical, and journalistic findings demonstrating risks and harms of fracking. As the Compendium authors note:

> "A growing body of peer-reviewed studies, accident reports, and investigative articles is now detailing specific, quantifiable evidence of harm and has revealed fundamental problems with the entire life cycle of operations associated with unconventional drilling and fracking."

The New York State Department of Health's Review of High Volume Hydraulic Fracturing for Shale Gas Development, December 2014,[45] which was the basis for the Governor of New York State's recent decision to ban fracking, provides a good review of the epidemiological literature.

Many decades passed before epidemiological studies provided the critical mass of evidence needed to motivate politicians to manage the health impacts of leaded petrol, cigarettes, and asbestos.

Today, like asbestos, tobacco and leaded petrol in the past, the unconventional gas industry is allowed to operate and expand in the Darling Downs when there is no scientific evidence that it is safe, no proper assessment of the health risks, and we have good reasons to suspect that operating industrialised gas fields in populated areas is dangerous.

Health Impact Assessments (HIA). Presumably, there are Environmental Impact Statements (EIS), if not HIAs, for the Darling Downs CSG facilities that report to the NPI. Such reports are computer-based, "screening" exercises that do not involve any direct real-world study of health impacts, and do not obtain data from potentially affected people.

According to Prof O'Kane[46] HIAs aim "to determine the risk to human health from a potential environmental impact, if relevant chemicals, their toxicity, concentrations and exposure pathways are known" (Page 29), but are unable "to provide a definitive risk level for an adverse health outcome for an individual in an at-risk population, such as people with particular sensitivities to chemicals" (Page 28).

The potential utility of HIAs is limited because most chemicals used in unconventional gas mining have not been assessed for their toxicity, persistence, or long-term health impacts. Further, there has been no assessment of new compounds that form when mining chemicals interact with other substances or with natural catalysts such as sunlight, water, air, and radioactive elements. Consequently, for many CSG-related pollutants, guidelines for safe levels of exposure do not exist, are inadequately researched, or provide ratings which do not address all potential health impacts.

As AGL's Environmental Health Impact Assessment (EHIS) for a proposed extension to their Camden CSG operation explained, "It is noted that there are a number of chemicals where no suitable human health guidelines are available or relevant, hence the evaluation of these chemicals has been undertaken on a qualitative basis only."[47]

A further problem with HIA methodology is the one-at-a-time consideration of individual substances, when in reality the people of the Darling Downs are being exposed to a complex mix of dangerous pollutants.

As the AGL EHIS explained the process:

> "Once an estimate of exposure has been developed it was compared to appropriate National or International health protective guidelines to determine if the Project poses a risk with regard to each of the hazards. If the exposure from the Project is less than the guideline then there is no unacceptable risk."[48]

That is to say, if any one of the many pollutants being emitted into the Darling Downs air is deemed to be present at a level below the adopted guideline's cut-off point, then it is concluded that that substance has no health impact. This process relies on the dubious assumption that there are no cumulative, interactive, or magnifying effects from exposure to multiple substances.

As US toxicologist Dr David Brown (2013)[49] explained, gas field toxicology is complicated and poorly understood because: not all chemicals are identified; chemicals can interact in complex unknown ways; one agent can greatly increase the toxicity of another agent; agents have multiple physiological actions on various target organs; health effects of exposure to many chemicals is unknown; certain chemicals can alter the biological processing of other chemicals; substances that inhibit metabolism or excretion magnify the effects of other chemicals; some agents change the physiologic distribution of other chemicals; some agents can cause chemicals that would not normally do so to enter the brain; and medications can affect the impact of toxic substances.

While US research programs[50,51,52] are under way to examine the health impacts of simultaneous exposure to multiple pollutants, we are many years away from a scientific understanding of the health impacts from exposure to the multiple pollutants being released into the air above the Darling Downs.

Can CSG Air Pollution Health Risks be Managed?

The essential requirement for effective management of health risks posed by CSG air pollution in the Darling Downs is that the people who live there, and especially the children, are not exposed to illness causing doses of the mix of persistent, bio-accumulative, toxic, carcinogenic, mutagenic, teratogenic, and hormone disrupting pollutants that are being emitted in ever-increasing volumes into their air.

In the Darling Downs about 20 percent of the population are children 14 years and younger. Children are more vulnerable to gasfield pollutants than adults, and they are often the first to become ill. Relative to adults, children are closer to the ground and are more likely to be active outside. Children drink more water, breathe more air, and eat more food per kilo of body weight then do adults. Children have a longer "shelf-life", and their living longer than adults puts them at greater risk from illnesses such as cancer that take years to develop. As was the case with thalidomide, a child is particularly sensitive to gasfield pollutants during critical stages of development.

Effective management of CSG-related health risks will not be straightforward. Some of the pollutants identified by the NPI data can seriously injure health in even minute quantities, measured in parts per billion.

To be truly effective, risk management has to protect the health of children, as well as infants and the yet to be born.

Is Dilution the Solution?

According to Prof O'Kane[53], "The most effective way of preventing community exposure to contaminants is to prevent as far as possible the release of contaminants into the environment in the first place", but "as is the case in a wide range of industrial and resource activities, the release of some contaminants is inevitable", "because some of the CSG activities by virtue of the activity itself will release contaminants to the environment" (Page 30).

CSG activities inevitably involve emissions of pollutants into the environment and "a second level of risk mitigation is required"[54] (Page 31) which, as Prof O'Kane explained, usually relies on the environmental dilution of pollutants such that people are not exposed to clinically significant doses:

> "Dosage is critical in considering human health risks and effects, with most pathways leading to dilution resulting in a decrease in exposure for a person" (Page iv).
>
> "Assessing health risks from pollution relies on understanding the toxicity of the pollutant and the amount that reaches the community or individual over a given period of time" (Page 1).
>
> "If contaminants do enter the water, soil or air, in most cases these will undergo dilution that occurs naturally within the environment. This mechanism helps limit exposure to neighbouring individuals or communities ....." (Page 31).

As Prof O'Kane noted[55], "Exposure pathways can be understood through the modelling of water and air movement, or ecological webs, which requires knowledge of the local environment and the potential contaminants" (Page iv).

According to Prof O'Kane, for the so-called "solution by dilution" method of risk management to work, "it is imperative that cumulative impacts be modelled prior to any new activity taking place to assess the receiving environment's capacity to dilute contaminants of concern" (Page 31). "Cumulative impacts and, for populations, cumulative exposure must be accounted for when approving new projects and establishing licence conditions" (Page 31).

The modelling of "ecological webs" and movement of contaminants that Prof O'Kane describes as essential is a complex and difficult process.

In their paper prepared at Prof O'Kane's request, Vaneckova and Bambrick (2014)[56] concluded:

> "In summary, identifying health impacts associated with industries that affect the environment can be complex. The health effects may be difficult to detect ... the same exposure may produce diverse symptoms, for example from skin problems to digestive problems, so that these are not readily linked; the geographic area affected may extend well beyond the immediate well surrounds and not make intuitive sense or may be difficult to link to other cases ... Constant monitoring of sources of exposure, such as potential contamination of air, water and soil, and data collected specifically for this purpose may therefore be required" (Page 24).

Similarly, in a paper commissioned by Prof O'Kane, Rayner and Utembe (2013) [57] argued:

> "These impacts need to be both assessed and monitored; requiring a combination of measurements and models. For example, if a pollutant is released into the atmosphere, we wish to calculate the exposure of people or the environment as a function of meteorological conditions and the chemical properties of the pollutant" (Page 1).

But as Rayner and Utembe (2013) [58] pointed out, the monitoring, assessment, and modelling of the dispersion of pollutants in the atmosphere relies on an accurate and comprehensive description of emissions:

> "A forward atmospheric model can only be as accurate as the description of the emissions in the model domain. Currently there are significant gaps in knowledge concerning fugitive emissions from CSG and other unconventional natural gas resources (Tait et. al., 2013)" (Page 8).

Some gas industry promoters tout "dilution" as the "solution" to the problem of CSG water, soil, and air pollution. They assume that the vastness of the atmosphere above ensures that almost any amount of pollution will be dissipated to a harmless level.

But air pollution from CSG processing does not dissipate evenly upward into the atmosphere where it is transported elsewhere. Rather, CSG air pollution tends to concentrate in particular areas depending on such factors as wind direction, time of day, season, type of pollutant, factory location, surrounding topography, and many other factors.

As Rayner and Utembe (2013)[59] pointed out, "The trapping of pollutants near the ground at night is a difficult phenomenon to model" and during some nights, especially in cooler seasons, the air, with any smoke or other pollutant in it, can settle into lower areas, concentrating rather than dissipating.

In reality, the extremely complex monitoring, assessment, and modelling that is required to establish that "dilution" is protecting people from pathogenic doses of pollutants does not currently exist, and is unlikely to be put in place any time soon by government or industry.

In the absence of such scientific evidence, the people who have to live and raise families amidst the booming gas industry in the Darling Downs deserve better than regulators assuming without evidence that "dilution" protects everyone from the massive amounts of pollutants being emitted into the air around them.

If "dilution" is not a reliable "solution" for managing the health risk from CSG air pollution, are there any other means, current or potentially available, for protecting the people who live in the Darling Downs Condamine River catchment?

In her Final Report[60], Prof O'Kane concluded that under certain conditions "the technical challenges and risks posed by the CSG industry can in general be managed"(Page iv). The following discussion examines whether the implementation of management processes described by Prof O'Kane could possibly eliminate or mitigate risks to health from CSG air pollution in the Darling Downs.

Prof O'Kane's Recommended Risk Management Processes

At issue is whether the lack of consideration of NPI data on CSG air pollution undermines Prof O'Kane's general conclusion that CSG health risk can be successfully managed.

The omission of an analysis of NPI air pollution data from Prof O'Kane's investigation could be a consequence of the exclusion policy in Section 1.2.2 of her report[61] which states that "risks common to other industrial activity, such as other natural gas and mining industries" were "considered beyond the scope in this report".

Prof O'Kane does not detail the kinds of risks that were deemed to be "within" or "beyond" the scope of her investigation. Prof O'Kane gives no justification for ignoring the potential health impacts of CSG-related air pollution documented in NPI data. It is not apparent why the fact that "other natural gas and mining industries" also create air pollution mitigates, or renders irrelevant, the potential health impacts from air pollutants emitted during CSG production. Nor is it apparent that the air pollution that necessarily accompanies the operation of industrialised gas fields with thousands of wells and processing facilities across populated rural landscapes is a risk "common to other industrial activity" (Page 3).

An analogous situation would be for an investigation into the health risks from a large scale expansion of the aluminium industry into populated areas to completely ignore the air pollution created by smelters because similar manufacturing processes were involved in the production of other metals.

In Tables 1 and 3 of her report, "Managing environmental and human health risks from CSG activities"[62], Prof O'Kane identified CSG-related air pollution as potentially arising from:

a) Drilling, well integrity and fracture stimulation ("Could have air quality impacts where volatiles escape from water");
b) Seam depressurisation ("Could affect air quality through gas escape ... Could have air quality impacts");
c) Spills and leaks ("Could affect air quality", "Cumulative issues of air emissions from leaking pipes and equipment or uncovered ponds");
d) Escaping CSG from coal seam or from infrastructure; and
e) From incomplete combustion of methane as CSG is flared.

In Table 3, titled "Summary of possible exposure pathways", Prof O'Kane opined that potentially hazardous substances "Released with escaping CSG from coal seam or from infrastructure ... From incomplete combustion of methane as CSG is flared", could be controlled by "Air monitoring and modelling", "Topography/weather and distance to well site (dispersion)", and "controls to prevent contamination in the first place".

Further, in Table 3, Prof O'Kane concluded that these problems were unlikely to be a result of CSG operations in New South Wales because escaping gas in NSW was likely to have "low concentrations" of hazardous chemicals, but noted that a "decline in local air quality" was possible "from other sources typical of any form of development such as traffic, engines used to run the well or other equipment at site, bushfires" (Page 27).

In her Final Report[63], Prof O'Kane concluded that "the technical challenges and risks posed by the CSG industry can in general be managed through:

- careful designation of areas appropriate in geological and land-use terms for CSG extraction;
- high standards of engineering and professionalism in CSG companies;
- creation of a State Whole-of-Environment Data Repository so that data from CSG industry operations can be interrogated as needed and in the context of the wider environment;
- comprehensive monitoring of CSG operations with ongoing automatic scrutiny of the resulting data;
- a well-trained and certified workforce; and
- application of new technological developments as they become available" (Page iv).

Prof O'Kane opined that "CSG extraction and related technologies are mature and Australia is well equipped to manage their application" (Page 9). She expressed the belief that, if Government and industry approached issues with "eyes wide open, a full appreciation of the risks, complete transparency, rigorous compliance, and a commitment to addressing any problems promptly", and took advantage of "new technology developments", then CSG production would become "increasingly safer and more efficient over time" (Page iv).[64]

Later in her Final Report[65], Prof O'Kane additionally noted that:

> "Management of potential risks associated with CSG, as with other industries, requires effective controls; high levels of industry professionalism; systems to predict, assess, monitor and act on risks at appropriate threshold conditions; legislation; regulation; research; and commitment to rapid remediation, continuous improvement and specialist training" (Page 10).
>
> "The Review studied the risks associated with the CSG industry in depth and concludes that – provided drilling is allowed only in areas where the geology and hydrogeology can be characterised adequately, and provided that appropriate engineering and scientific solutions are in place to manage the storage, transport, reuse or disposal of produced water and salts – the risks associated with CSG exploration and production can be managed" (Page 10).

Prof O'Kane's recommendations for managing health risk from CSG activities fall into five general categories of "the maturity of the industry", professional standards, scientific research, technological development, and regulation.

On the maturity of the CSG industry. It is not apparent what Prof O'Kane meant to imply with her comment that "CSG extraction and related technologies are mature". Nor is it clear whether the "maturity" of the Australian CSG industry is likely to facilitate or hinder the proper management of health risks from air pollution in the Darling Downs, and other populated gas fields.

Prof O'Kane[66] is correct to note that "CSG production has been happening at significant levels in North America … for two decades and in NSW for 13 years …" (Page 8), but this does not of itself indicate "maturity", that is to say, that the industry is fully and properly developed.

In the US, the unconventional gas industry boomed after the Bush and Cheney Administration's 2005 Energy Policy Act exempted oil and gas producers from the requirements of the Safe Drinking Water Act - the notorious "Halliburton loophole". It seems unlikely that the industry would be as established as it is in the US if it had had to comply with existing environmental laws. The current scale and political power of the US shale gas industry does not guarantee that operating industrialised gas fields in populated or environmentally sensitive areas is safe.

Asbestos fibre-reinforced cement sheets were used as house siding in the late 19th century. By the 1930s scientists had linked asbestos to cancer, but the serious risk to health posed by asbestos fibres was not widely acknowledged until the 1970s, and asbestos was not banned in Australia until 2003. Would it have been appropriate or informative to describe the asbestos building products industry as "mature" in 1900, a decade or so after its invention, or in 1930, some 30 years later, when scientists understood that it is carcinogenic, or at some other time?

It is not apparent that Prof O'Kane's perception that CSG technology is "mature" has any relevance to the question of whether it is actually safe to operate industrialised gas fields in populated areas such as the Darling Downs.

Professional standards of engineering and quality of workforce. Improved professional standards, engineering expertise, and workforce skills would be worthwhile achievements likely to reduce the incidence and severity of accidents, spills, and leaks during the drilling, operation, and retirement of CSG wells.

However, it is not apparent that improved skill sets amongst gas company management and employees could have any impact on the nature and scale of the air pollution created during CSG processing.

Scientific research, air monitoring and modelling, a data repository. Prof O'Kane suggested that risks to health from contact with gasfield pollutants could be managed with appropriate scientific research that models water and air movements, the "receiving environment's capacity to dilute contaminants", and the real-life exposure of people to pollutants.

If properly implemented, the scientific enterprise outlined by Prof O'Kane could inform proper risk assessment and management processes. Unfortunately, nothing like this level of scientific assessment and monitoring is taking place, and it seems unlikely that it will be implemented anytime soon.

To date, most investigations of CSG related health risks have been ad hoc and reactive to complaints, rather than proactive and motivated by a genuine desire to protect people from harm.

In New South Wales, where the Government's Gas Plan, like Prof O'Kane's investigation on which it is based, takes no account of CSG air pollution as documented by NPI data, there is little to no real chance that the appropriate assessment and modelling of air movements, or the environment's capacity to dilute contaminants, or the levels of people's exposure to airborne pollutants, will ever occur.

An oft used tactic of gas industry spruikers is to repeatedly deny that the CSG industry can have any adverse impact on health or the environment. When confronted with scientific evidence, they simply ignore all contrary data and continue to repeat the claim that CSG is in all ways safe. For them, it follows that if there is no risk, or that the risk can be managed as suggested by Prof O'Kane, then risk assessment and management is straightforward. If there is nothing much to assess, there is nothing much to manage.

It seems possible that if the scientific assessment and monitoring programmes recommended by Prof O'Kane were implemented, they might find that CSG air pollution is such that this industry should not operate anywhere that people live, farm, and raise families.

Technological developments. It seems likely that air pollution of the kind and quantity documented by NPI data is an unavoidable consequence of the drilling, pumping, compressing, dehydrating, storing, and transporting involved in the industrial mining and processing of CSG.

Prof O'Kane[67] cited "new technology developments" in the fields of information and communications, numerical modelling, geophysics and petroleum engineering, and new materials as likely to make CSG operations "increasingly safer and more efficient over time" (Page iv).

It is not apparent how any of these developments would significantly decrease the quantity of CSG related air pollution, or effectively manage or even reduce the risk to health of these emissions in the Darling Downs.

Regulations and legislation to prevent or manage contamination. The absence of analysis of NPI CSG air pollution data in Prof O'Kane's investigation has profound implications for the NSW Government's "Gas Plan" [68], which is based on the recommendations from her report[69], and consequently impacts on the assessment and management of CSG-related risks to human health in NSW and elsewhere in Australia.

The suggestion made by a spokesman for Minister Roberts that the NSW Environment Protection Authority will regulate CSG air pollution "through a range of regulatory and economic incentive tools and programs"[70] indicated that the NSW Government has no appreciation of the nature and scale of the escalating health threat from CSG-related air pollution.

If the science that policymakers rely on does not recognise the health threat from exposure to CSG air pollutants created during industrial processing, then it is inevitable that regulators will also be blind to the problem.

Concluding Comments

Even if you can't see it, and the NSW Chief Scientist and Engineer does not consider it, air pollution from CSG processing does exist, and it is a serious threat to community health worthy of consideration.

Prof O'Kane[71] extols an appropriate risk assessment and management attitude in which problems are approached with "eyes wide open, a full appreciation of the risks" (Page iv). Prof O'Kane received submissions that referred to NPI air pollution data, and she does not make clear why this source of health risk was deemed unworthy of consideration and outside the parameters of her investigation.

The industry and the NSW Government have interpreted as a green light Prof O'Kane's[72] conclusion that, "the risks associated with CSG exploration and production can be managed" (Page 10). But can these optimistic conclusions stand if the escalating and massive amounts of dangerous pollutants being emitted into the air on the Darling Downs are taken into account?

It could reasonably be argued that the CSG air pollution documented in NPI data are a necessary and unavoidable consequence of the industrial processing of CSG.

As Prof O'Kane[73] noted, "Whether these (identified CSG-related) risks are acceptable or not depends on the level or (sic) risk Government, in consultation with the wider community, deems acceptable" (Page 5).

If after a genuine risk assessment, the Government and community deem that health impacts resulting from CSG air-pollution are acceptable, then appropriate investments should be made in medical, hospital, hospice, and other health services that the community will require.

If the Government and community decide that the costs from CSG air pollution production in terms of ill-health, lost production, increased mortality, and developmentally disabled children are not acceptable, then it may be that the only effective management intervention would be to prevent the pollution from occurring in the first place. But then there could be no CSG industry in populated areas. The Darling Downs would need to be depopulated to safely operate heavily industrialised CSG gas fields there.

Perhaps the crux of the matter lies in Prof O'Kane's conclusion that the risks posed by the CSG industry can be managed through, amongst other things, "careful designation of areas appropriate in geological and land-use terms for CSG extraction".

The CSG industry has been controversial, and has fostered the greatest social and environmental movement in Australia's history, because it seeks to operate in populated productive rural areas. Populated areas with their established road and other infrastructure, and proximity to workers, centres of population, and transport facilities, provide obvious financial benefits to mining companies.

But the benefits for industry of operating in populated areas can only be achieved if the community bears the burden of ill-health and suffering, and all the other economic and social costs that come from being forced to live in industrialised gas fields.

The lesson that might ultimately be learnt from NPI data is that landscape scale, heavily industrialised unconventional gas fields should not operate where people live, farm, and raise children.

The people of the Darling Downs were unlucky to be living where the CSG industry took root in Australia. No more communities, and no more children, should be exposed to the risk of potentially catastrophic health consequences from CSG air-pollution.

Governments need to protect the precious country and communities that are the heritage of all Australians.

***

APPENDICES

Appendix A

Table 1

2013/14 NPI Data for Reportable Emissions from the 20 Darling Downs' Gas Industry Facilities Cited in this Report

Facility Name	Substance	Air emissions (kg)
Silver Springs Gasfield (Surat)	Oxides of Nitrogen	326,034.05
	Carbon monoxide	43,404.24
	Particulate Matter 10.0µ	4,694.86
	Particulate Matter 2.5µ	4,676.45
	Total VOCs	19,527.63
	Cyclohexane	313.46
	Toluene	144.44
	n-Hexane	1,373.87
	Xylenes	60.85
Daandine Operations Via Dalby	Formaldehyde	18,670.00
	Oxides of Nitrogen	1,271,137.14
	Carbon monoxide	1,015,170.03
	Total VOCs	41,939.08
	Particulate Matter 10.0µ	6,521.75
	Particulate Matter 2.5µ	68.69
	Sulfur dioxide	270.27
Tipton Operations (Via Dalby)	Formaldehyde	19,714.70
	Oxides of Nitrogen	1,007,512.16
	Carbon monoxide	703,941.91
	Total VOCs	44,394.83
	Sulfur dioxide	285.95
	Particulate Matter 10.0µ	6,580.10
	Particulate Matter 2.5 µ	124.70
Kogan Gas Field (Via Dalby)	Sulfur dioxide	23.03
	Carbon monoxide	16,791.90
	Total VOCs	3,557.82
	Oxides of Nitrogen	25,507.14
	Particulate Matter 10.0µ	3,247.96
	Particulate Matter 2.5 µ	17.66
Combabula & Reedy Creek	Particulates 2.5 µ	67,820.00
(Yuleba North)	Particulate Matter 10.0µ	69,520.00
	Oxides of Nitrogen	964,820.00
	Total VOCs	70,834.00
	Carbon monoxide	216,300.00
	Toluene	88.80
	Sulfur dioxide	238.00
	Xylenes	62.00
Condabri (Miles)	Particulates 2.5 µ	93,170.00
	Particulate Matter 10.0 µ	94,990.00
	Oxides of Nitrogen	1,148,330.00
	Carbon monoxide	963,600.00

	Total VOCs	77,530.00
	Toluene	94.17
	Sulfur dioxide	254.80
	Xylenes	65.62
Peat (Southshire)	Sulfur dioxide	67.90
	Total VOCs	11,601.00
	Carbon monoxide	49,400.00
	PAHs	0.02
	Oxides of Nitrogen	75,300.00
	Particulate Matter 10.0µ	6.84
	Particulate Matter 2.5 µ	6.84
South Denison (Westgrove)	Total VOCs	319,040.00
	Cyclohexane	698.30
	n-Hexane	2,734.30
	Carbon monoxide	125,349.00
	Sulfur dioxide	73.48
	Oxides of Nitrogen	93,831.00
	Particulate Matter 10.0 µ	2,172.00
	Particulate Matter 2.5 µ	2,168.50
Spring Gully (Durham Downs)	Formaldehyde	82,100.00
	Acetaldehyde	13,000.00
	Total VOCs	299,170.00
	Oxides of Nitrogen	1,633,510.00
	Carbon monoxide	985,310.00
	Particulate Matter 10.0µ	24,290.00
	Particulate Matter 2.5 µ	23,740.00
	Sulfur dioxide	1,268.77
	Xylenes	307.08
Talinga (Condamine South)	Formaldehyde	47,100.00
	Total VOCs	167,630.00
	Oxides of Nitrogen	1,001,330.00
	Carbon monoxide	574,010.00
	Particulates 2.5 µ	17,595.00
	n-Hexane	1,231.00
	Particulate Matter 10.0µ	18,015.00
	Sulfur dioxide	747.33
	Xylenes	183.88
ATP676 (Via Miles)	Sulfur dioxide	15.30
	Carbon monoxide	52,725.84
	PAHs	0.00
	Total VOCs	4,070.20
	Oxides of Nitrogen	57,316.64
	Formaldehyde	320.42
	Particulate Matter 10.0 µ	3,228.96
	Particulate Matter 2.5 µ	3,165.66
ATP852 (Via Wandoan)	Sulfur dioxide	15.04
	Carbon monoxide	16,222.14
	Total VOCs	4,631.15
	Oxides of Nitrogen	62,896.65
	Particulate Matter 10.0 µ	4,400.23
Kenya Processing Plant	Formaldehyde	34,757.27
(ATP620) & Compressor	Total VOCs	89,465.02

Stations (Via Tara)	Oxides of Nitrogen	711,953.52
	Carbon monoxide	411,363.79
	Particulates 10.0 μ	331,572.17
	Particulate Matter 2.5 μ	11,706.48
	Sulfur dioxide	557.16
Ruby Jo/Jordan (Via Tara)	Carbon monoxide	1,628,286.91
	Particulates 2.5 μ	34,897.27
	Formaldehyde	3,130.81
	Particulate Matter 10.0 μ	35,595.13
	Oxides of Nitrogen	806,656.92
	Total VOCs	43,778.61
	Sulfur dioxide	162.73
Windibri Processing Plant	Formaldehyde	34,037.47
(PL201) & Compressor	Particulates 10.0 μ	1,342,839.52
Stations (Condamine)	Total VOCs	90,665.03
	Oxides of Nitrogen	737,224.06
	Carbon monoxide	424,381.73
	Particulate Matter 2.5 μ	15,557.42
	Sulfur dioxide	568.84
	Xylenes	130.33
Woleebee Creek (Via Tara)	Particulates 2.5 μ	21,385.52
	Carbon monoxide	345,724.25
	Oxides of Nitrogen	382,999.81
	Total VOCs	27,344.70
	Sulfur dioxide	100.86
	Formaldehyde	1,996.11
	Particulate Matter 10.0μ	21,813.18
"Fairview Coal Seam	Oxides of Nitrogen	1,527,150.00
Methane Field" (Injune)	Carbon monoxide	968,292.00
	Particulates 2.5 μ	18,592.00
	Total VOCs	31,683.00
	Ethylene glycol	6,377.00
	Particulate Matter 10.0 μ	18,928.00
	Sulfur dioxide	904.68
"Moonie" (Moonie)	Total VOCs	28,761.00
	Xylenes	904.00
	Ethylbenzene	155.80
	n-Hexane	1,434.10
	Cyclohexane	71.00
	Carbon monoxide	20,894.64
	Oxides of Nitrogen	107,510.00
	Particulate Matter 10.0 μ	6,656.00
	Particulate Matter 2.5 μ	6,525.00
	Sulfur dioxide	625.00
"Roma" (Roma)	Carbon monoxide	99,208.00
	Sulfur dioxide	15.00
	Oxides of Nitrogen	54,729.00
	Particulate Matter 10.0 μ	2,218.00
	Particulate Matter 2.5 μ	2,175.00
	Total VOCs	5,389.00
"Scotia" (Wandoan)	Carbon monoxide	127,766.00
	Sulfur dioxide	150.00

	Ethylene glycol	9,247.00
	Oxides of Nitrogen	193,487.00
	Particulate Matter 10.0 μ	2,256.00
	Particulate Matter 2.5 μ	2,216.00
	Total VOCs	2,872.00

Appendix B

Table 2

Total Amounts (in kilograms) of Reported Emissions of NPI Substances for the Cited 20 Darling Downs' Gas Industry Facilities for the Year 2013/14

Pollutant	Kilograms
Liquids	
Total VOCs[a]	1,383,884.07
Cyclohexane	1,082.76
Toluene	327.41
n-Hexane	6,773.27
Acetaldehyde	13,000.00
Ethylene Glycol	15,624.00
Xylenes	1,713.76
Ethylbenzene	155.80
Gases	
Formaldehyde	241,826.78
Carbon monoxide	8,788,142.38
Oxides of Nitrogen	12,189,244.54
Sulfur dioxide	6,329.14
Solids	
Particulates 2.5 μ	325,608.19
Particulates 10 μ	1,999,545.70

[a] Of the 41 substances listed in NPI Total VOCs, 37 are liquids at room temperature and four are liquids at lower temperatures: Chloroethane (liquid at -14°C), Formaldahyde (-20°C), Ethylene oxide (10°C) and Vinyl chloride monomer (-20°C).

Appendix C

In the NPI Guide[74] for industry the formula for converting litres of each substance into kilograms is *mass* (in kilograms) = *volume* (in litres) multiplied by *specific gravity* (kilogram per litre).

For this report, the volume for each NPI liquid pollutant was calculated using the formula *volume* (in litres) = *mass* (in kilograms) divided by *specific gravity* (kilogram per litre). The volume of each pollutant was then converted to the number of standard 20 litre drums that would be required to contain that amount of substance.

In NPI data, "Total VOCs" (total volatile organic compounds) refers to 41 specified substances of various specific gravities. The data does not specify the relative contribution of each substance to Total VOCs, and therefore it is not valid to use a mean value of specific gravities to calculate volume of Total VOCs. For this report, the minimum and maximum possible volumes of Total VOCs were calculated using the lowest (i.e., 1,3-Butadiene) and highest (i.e., 1,2-Dibromoethane) specific gravity values of the 37 of the 41 VOCs that are liquid at room temperature. Total VOCs includes 4 substances that are liquids at lower temperatures.

Table 3

Specific Gravities for NPI Volatile Organic Compounds in Kilograms per Litre

Acetaldehyde	0.788	Ethyl butyl ketone	0.820
Acetic acid	1.053	Ethylbenzene	0.870
Acetone	0.791	Ethylene oxide	
Acetonitrile	0.787	Formaldehyde (gas)	1.067
Acrolein	0.839	Glutaraldehyde	
Acrylonitrile	0.806	n-Hexane	0.660
Acrylic Acid	1.062	Methanol	0.79
Aniline (benzenamine)	1.022	2-Methoxyethanol	0.966
Benzene	0.879	**1,3 – Butadiene**	0.621
2-Methoxyethanol acetate	1.01	Methyl ethyl ketone	0.805
Chloroethane (gas)	2.22	Methyl isobutyl ketone	0.801
Chloroform	1.484	Methyl methacrylate	1.015
Cumene	0.862	Styrene	0.906
Cyclohexane	0.778	1,1,2,2- Tetrachloroethane	1.587
1,2- Dibromoethane	2.172	Tetrachloroethylene	1.62
1,2-Dichloroethane	1.257	Toluene (methylbenzene)	0.866
Dichloromethane	1.316	1,1,2- Trichloroethane	1.442
Ethanol	0.789	Trichloroethylene	1.46
2-Ethoxyethanol	0.931	Vinyl Chloride Monomer	0.911
2-Ethoxyethanol acetate	0.975	Xylenes	0.86
Ethyl acetate	0.902		

Appendix D

Table 4

Total Weights, Volume, Number of 20 Litre Drums, and Height of Stacked Drums, for NPI Liquid Pollutants Released into the Atmosphere by Darling Downs' Gas Industry Operations in 2013/2014

Liquid Pollutant	Kg	Volume in Litres[a]	Number of Drums	Height in Metres[b]
Total VOCs – Max Vol[c]	1,383,884.07	2,228,476.76	111,423.84	43,455.30
Total VOCs – Min Vol	1,383,884.07	637,147.36	31,857.37	12,424.37
Cyclohexane	1,082.76	1,391.72	69.59	27.14
Toluene	327.41	378.07	18.90	7.37
n-Hexane	6,773.27	10,262.53	513.13	200.11
Acetaldehyde	13,000.00	16,497.46	824.87	321.70
Ethylene Glycol[d]	15,624.00	13,888.00	694.40	270.82
Xylenes	1,713.76	1,992.74	99.64	38.86
Ethylbenzene	155.80	179.08	8.95	3.49

[a] Calculated as: *volume* (in litres) = *mass* (in kilograms) divided by *specific gravity* (kilogram per litre).
[b] Height of liquid to the bottom of the drum cap = 0.39 m
[c] Maximum and Minimum volumes of Total VOCs were calculated using the lowest and highest specific gravity values of the 37 NPI VOC substances that are liquid at room temperature.
[d] Ethylene glycol specific gravity = 1.125

Appendix E

Table 5

2013/14 NPI Data for the Quantity of Some Air Pollutants from Gas Processing in the Darling Downs as Total Kilograms, Kilograms per Head of Population, and Kilograms per Day

Pollutant	**Kg**	**Kg / Head**	**Kg / Day**
Liquids		(n = 251,893)	(n = 365)
Total VOCs	1,383,884.07	5.49	3,791.46
Cyclohexane	1,082.76	0.0043	2.97
Toluene	327.41	0.0013	0.90
n-Hexane	6,773.27	0.027	18.56
Acetaldehyde	13,000.00	0.052	35.62
Ethylene Glycol	15,624.00	0.062	42.80
Xylenes	1,713.76	0.0068	4.70
Ethylbenzene	155.80	0.00062	0.43
Gases			
Formaldehyde	241,826.78	0.96	662.54
Carbon monoxide	8,788,142.38	34.89	24,077.10
Oxides of Nitrogen	12,189,244.54	48.39	33,395.19
Sulfur dioxide	6,329.14	0.025	17.34
Solids			
Particulates 2.5μ	325,608.19	1.29	892.08
Particulates 10μ	1,999,545.70	7.94	5,478.21

Appendix F

Table 6

2013/14 NPI Air Emissions in Tonnes for Nine CSG Facilities that Lie Within the Area Indicated in Figure 6

Facility Name			Pollutant (tonnes)			
	Carbon Monoxide	Nitrogen Oxides	Particulates 2.5 µ	Particulates 10 µ	VOC's	Formalde-hyde
QGC ATP676	52.73	57.32	3.17	3.23	4.07	0.33
Condibri	963.60	1,148.33	93.17	94.99	77.53	
Daandine	1,015.17	1,271.14	0.07	6.52	41.94	18.67
QGC Kenya	411.36	711.95	11.71	331.57	89.47	34.76
Arrow Kogan	16.79	25.51	0.018	3.25	3.56	
RubyJo/Jordan	1,628.29	806.66	34.90	35.60	43.78	3.13
Talinga	574.01	1,001.33	17.60	18.02	167.63	47.10
Arrow Tipton	703.94	1,007.51	0.12	6.58	44.39	19.71
QGC Windibri	424.38	737.22	15.56	1,342.84	90.66	34.04
Total	5,790.27	6,766.97	176.32	1,842.60	563.03	157.74

Appendix G

Table 7

2013/14 NPI Data for Pollutants Emitted by the Nine CSG Facilities that Lie Within the Area Indicated in Figure 6 as Total Tonnes, Kilograms per Head of Population (Sub area population = 18,358) and Kilograms per Day (n = 365)

Pollutant	Tonnes	Pollutant per head per year (kg)	Kg / Day (365 days)
Carbon Monoxide	5,790.27	315.40	15,863.75
Nitrogen oxides	6,766.97	368.61	18,539.64
Particulate 2.5	176.32	9.6	483.07
Particulate 10	1,842.60	100.37	5,048.21
VOC's	563.03	30.67	1,542.55
Formaldehyde	157.74	8.59	432.16

Appendix H

Table 8

Projected Quantity of Air Pollutants from CSG Processing in the Darling Downs Assuming a Fourfold Increase, Expressed as per Head of Population per Year, Average Kilograms per Day, and Height of Storage Drums

Pollutant	**Kg**	**Kg/Head/Yr**	**Kg/Day**
Liquids		÷ 251,893	÷ 365
Total VOCs	5,535,536.28	21.98	15,165.85
Acetaldehyde	52,000.00	0.21	142.47
Cyclohexane	4,331.04	0.017	11.87
Toluene	1,309.64	0.0052	3.59
n-Hexane	27,093.08	0.11	74.23
Xylenes	6,855.04	0.027	18.78
Ethylbenzene	623.20	0.0025	1.71
Gases			
Carbon monoxide	35,152,569.52	139.55	96,308.41
Oxides of Nitrogen	48,756,978.00	193.56	133,580.76
Formaldehyde	967,307.12	3.84	2,650.16
Solids			
Particulates 2.5µ	1,302,432.76	5.17	3,568.31
Particulates 10µ	7,998,182.80	31.75	21,912.83

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