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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> "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

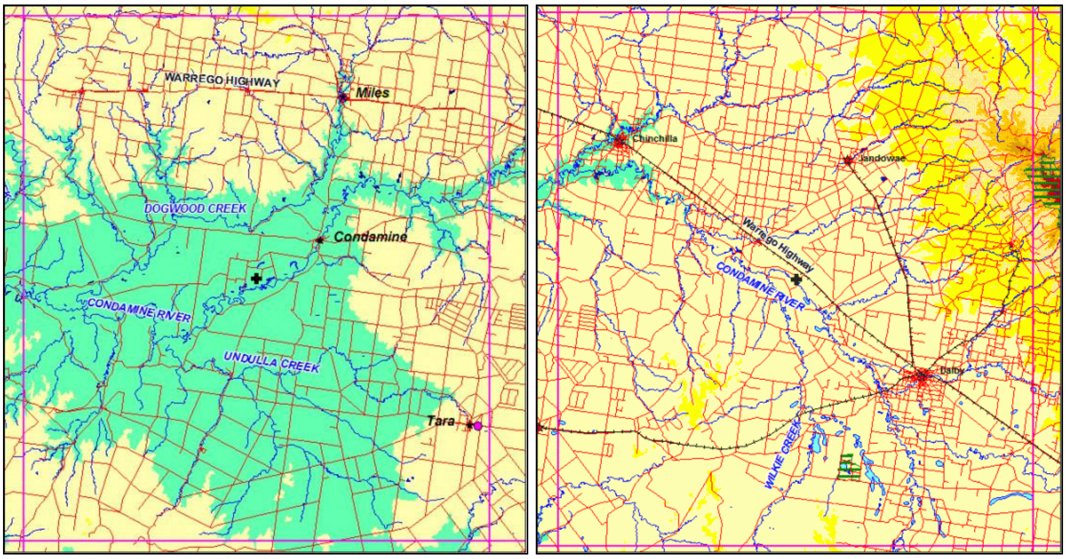

Figure 2. Royal Geographic Society Maps – “Condamine”[13] and “Western Downs”[14]

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.

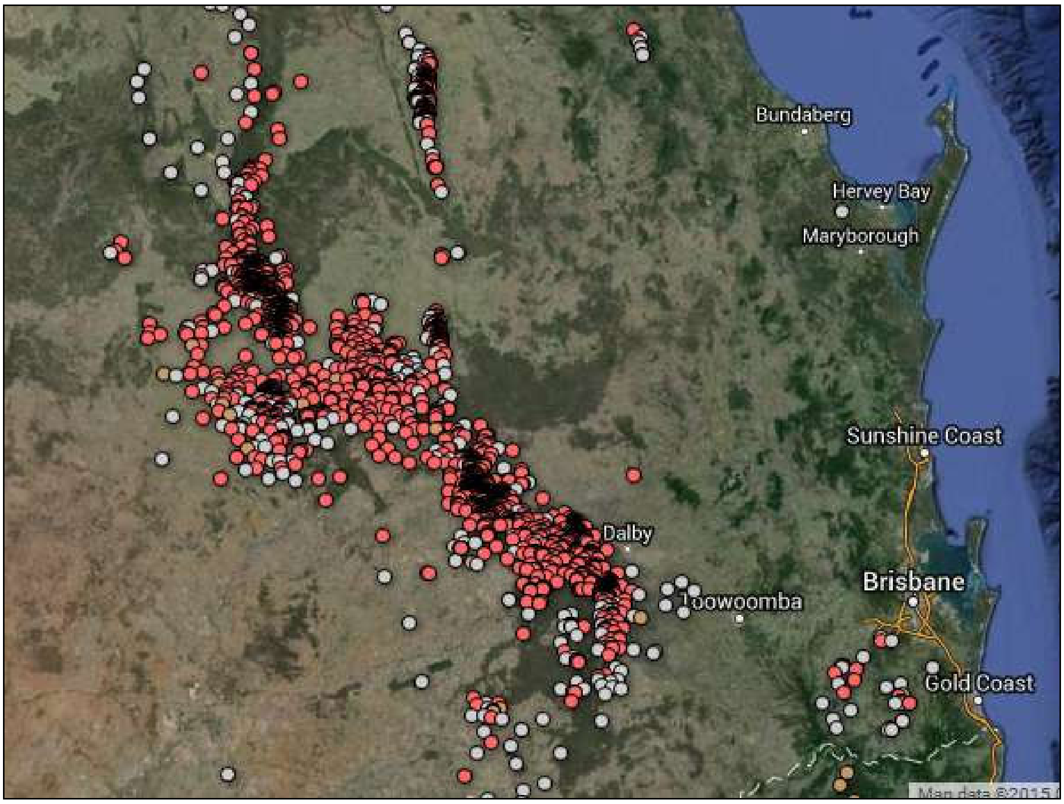

Figure 3. CSG Wells in the Darling Downs[16]

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.

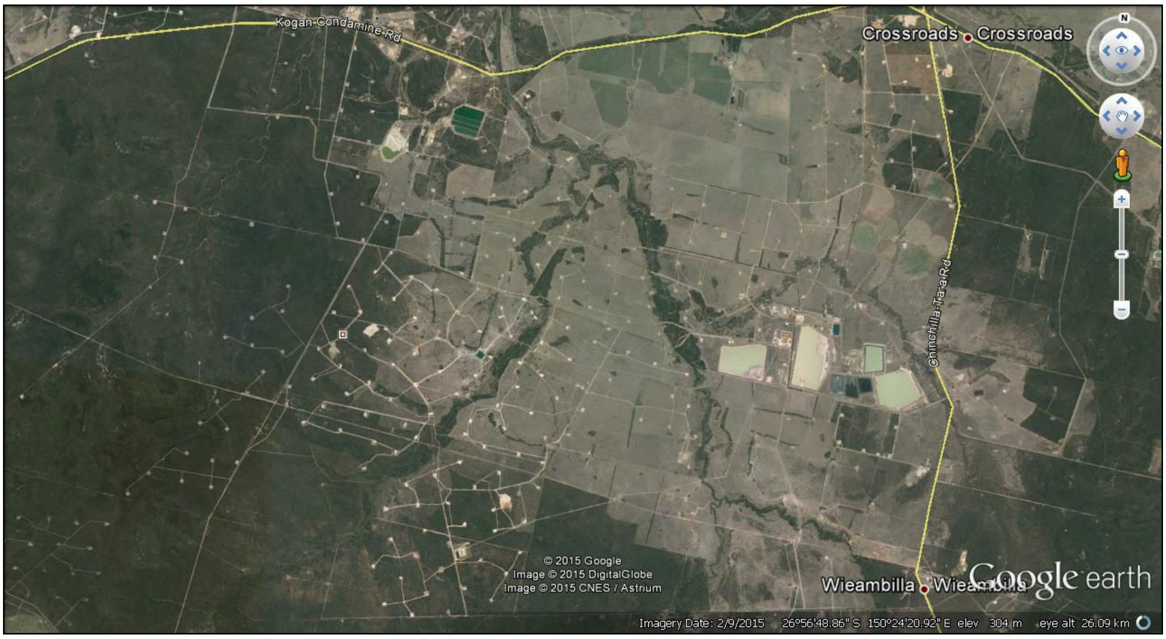

Figure 4. A Darling Downs Gasfield

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).

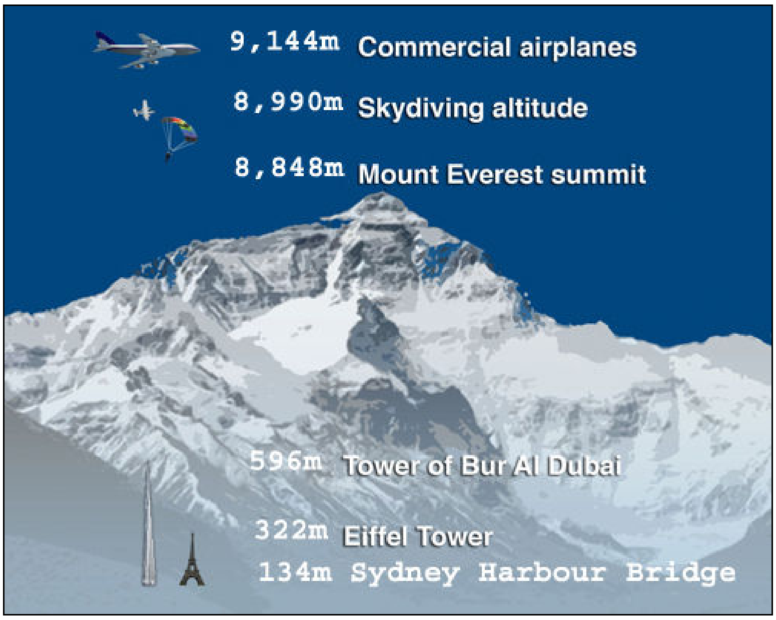

Figure 5. Height of Mt Everest

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.

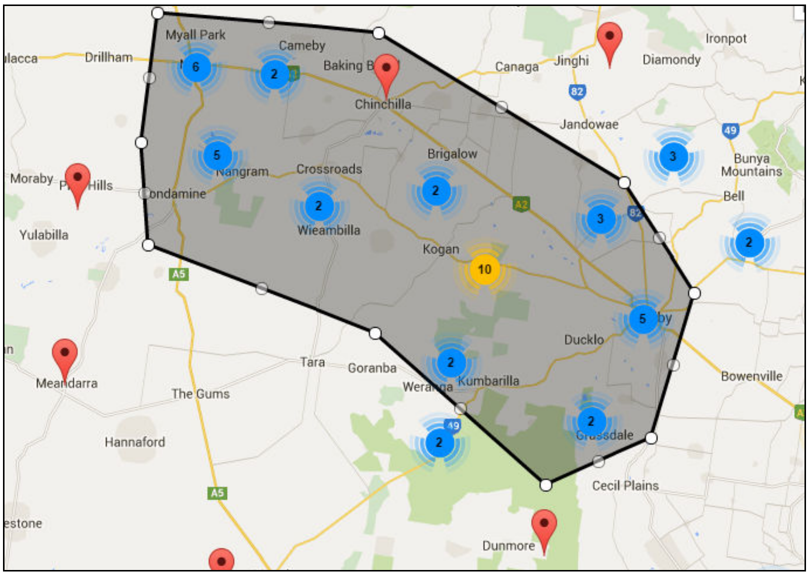

Figure 6. Darling Downs area with more concentrated CSG activity

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 -14ºC), Formaldahyde (-20ºC), Ethylene oxide (10ºC) and Vinyl chloride monomer (-20ºC).

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 s*pecific 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 s*pecific 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 s*pecific 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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