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# Ambient air quality in the Surat Basin, Queensland

## Overall assessment of air quality in region from 2014 -2018

Sarah J. Lawson, Jennifer C. Powell, Julie Noonan, Erin Dunne and David Etheridge

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# Glossary

### Units of measurement

mg $m^{-3}$ - milligrams per cubic metre (1 milligram = one thousandth of a gram)

µg $m^{-3}$ – micrograms per cubic metre (1 microgram = one millionth of a gram)

ng $m^{-3}$ – nanograms per cubic metre (1 nanogram = 1 billionth of a gram)

ppm – parts per million by volume

ppmC – parts per million of volume of gaseous carbon contained in one million volumes of air

ppb – parts per billion by volume

### Nomenclature

Aldehyde – a class of VOCs (volatile organic compounds)

Ambient air – outdoor air

BTX –benzene, toluene, xylenes (a subset of VOCs)

Coarse PM fraction – particles with an aerodynamic diameter of between 2.5 and 10 µm

CSG - Coal Seam Gas. A type of natural gas extracted from coal seams.

Detection Limit – the lowest measurable concentration of a pollutant for a particular analytical technique

Dust- primary particles emitted directly from source such as soil, crustal material and/or organic matter

Fine PM fraction – particles with an aerodynamic diameter of < 2.5 µm ($PM_{2.5}$)

Gas processing facility –facility which compresses and dries gas

Gathering networks –network of pipes which carry gas and water to treatment and processing facilities

Pipeline compressor stations – facilities which compress gas along a gas pipeline

Sensitive receptor – includes but is not limited to a dwelling, library, childcare centre, medical centre, or a public park

TEOM - tapered element oscillating microbalance

Tracer –a gas or particle measurement used as a proxy for other atmospheric constituents not directly measured, or used to indicate the likely impact of a specific pollution source

Vegetation fires – includes forest and grass fires (both prescribed fires and wild fires) and agricultural burning

VOC – volatile organic compound

Water treatment facility – facility which treats produced water from the wells

Wellhead gas and water – gas and water sampled from the separator at an individual CSG wellhead

## Abbreviations

APLNG – Australia Pacific Liquefied Natural Gas

BTEX – a subset of VOCs including benzene, toluene, ethylbenzene and xylenes

CO – carbon monoxide

$CO_2$ – carbon dioxide

$CH_4$ – methane

DES – Department of Environment and Science, Queensland

DEHP – Department of Environment and Heritage Protection, Queensland, now DES

DNRM – Department of Natural Resources and Mines, Queensland, now DNRME

DNRME- Department of Natural Resources, Mines and Energy

DSITI – Department of Science, Innovation Technology and Innovation, Queensland, now DES

EIS – Environmental Impact Statement

GPF – gas processing facility

$H_2S$ – hydrogen sulphide

NEPM – National Environment Protection Measure

$NO_x$ – nitrogen oxides, includes nitric oxide (NO) and nitrogen dioxide ($NO_2$)

$NO_2$ – nitrogen dioxide

NPI – National Pollutant Inventory

$O_3$ – ozone

$PM_{2.5}$ – particles with an aerodynamic diameter of < 2.5 µm

$PM_{10}$ – particles with an aerodynamic diameter of < 10 µm

PM – particulate matter

TVOC – total volatile organic compounds

TSP – total suspended particles

VOC – volatile organic compounds

WTF – water treatment facility

# Executive summary

A comprehensive ambient air quality study has been undertaken in the Surat Basin near Condamine, Miles and Chinchilla in Queensland. The purpose of the study was to assess air quality in this region and to investigate the influence of coal seam gas (CSG) activities on air quality. This report presents an overall assessment of air quality from the entire monitoring program from 2014-2018. A more detailed analysis of monitoring data from 2014-2018 is provided in previous reports (Lawson et al., 2018 a,b, see https://gisera.csiro.au/project/ambient-air-quality-in-the-surat-basin/).

## Measurements undertaken

Air quality measurements were made at 5 ambient air monitoring stations including 3 gas field sites (Hopeland, Miles Airport and Condamine) and 2 regional sites (Tara Region and Burncluith), see Figure 1 and Figure 2. Gas field stations were located between 1 and 5 km from gas processing facilities, between 100 – 450 m from operating CSG wells and had 15 - 25 wells within a 2 km radius. The regional sites were 10-20 km away from major potential CSG-related emission sources.

Continuous measurements were made at ambient air monitoring stations from 2015 - 2018 except for Condamine which was decommissioned in mid-2017. Pollutants were selected for monitoring based on a review of the composition of CSG and CSG-emission sources in the region (Lawson et al., 2017). Pollutants measured continuously included nitrogen oxides ($NO_x$), carbon monoxide (CO), ozone ($O_3$) (gas field and regional sites) and methane ($CH_4$), carbon dioxide ($CO_2$) and particles including $PM_{2.5}$ (particles < 2.5 µm), $PM_{10}$ (particles < 10 µm) and total suspended particles (TSP) (gas field sites only). Meteorology was measured at all sites. Since August 2016 preliminary air quality data from the monitoring sites (including ozone, nitrogen dioxide, carbon monoxide, $PM_{2.5}$, $PM_{10}$ and TSP) has been streamed to the Department of Environment and Science (DES) website under South West Queensland region (https://www.ehp.qld.gov.au/air/data/search.php).

Two-weekly integrated measurements of 54 individual volatile organic compounds (VOCs), aldehydes and hydrogen sulphide were measured during 2014- 2016 at a network of 10 Passive sampling sites, including gas field and regional sites, and in Chinchilla township.

## Overall summary of findings from monitoring program 2014 - 2018

Air quality measurements from the 5 ambient air monitoring sites were compared to relevant air quality objectives including the Queensland Government Environment Protection (Air) Policy) (EPP 2008), the Ambient Air Quality National Environment Protection Measure (NEPM 2016), and the Queensland Government Department of Environment and Science (DES) Nuisance Dust Guidelines for TSP (MFE 2016). Passive gas measurements of VOCs, aldehyde and hydrogen sulphide were assessed against the Air Toxics NEPM (NEPM 2011) and the Queensland Government Air EPP (EPP 2008). Where no Australian objectives were available, the Texas Commission on Environmental Quality Air Monitoring Comparison Values (AMCV) and Effects Screening Levels (ESLs) were used instead (Texas 2016).

During the study there were no exceedances of relevant air quality objectives for any of the gaseous pollutant measured, including carbon monoxide, nitrogen dioxide and ozone as well as individual VOCs, aldehydes and hydrogen sulphide. Concentrations of all these pollutants were well below air quality objectives in almost all cases except for 3 occasions where the 4 hour average ozone concentration was >80% of the air quality objective.

From 2015 - 2018 there were a total of 7 $PM_{2.5}$ exceedances, 3 $PM_{10}$ exceedances and 18 TSP exceedances of 24 hour average air quality objectives at gas field sites. There were no exceedances of annual air quality objectives. An investigation of these 28 exceedance events found that smoke from vegetation fires was the main source of $PM_{2.5}$ exceedances, while a combination of vegetation fire smoke and dust, unsealed roads/CSG activities, regional dust and cattle farming were identified as the most likely sources of the $PM_{10}$ and TSP exceedances. Many of these sources are typical of other rural areas in Queensland. There were a further 48 events investigated with concentrations > 80% of the air quality objectives (predominantly $PM_{2.5}$, $PM_{10}$, TSP events) which had similar sources to the PM exceedance events. Identifying likely sources of exceedances in this work focussed only on the dominant source/s, rather than all possible contributing sources.

Emissions from the CSG industry are likely to have contributed to several of the TSP and $PM_{10}$ 24 hour average exceedance events. In all cases airborne soil was the most likely source of the TSP and $PM_{10}$ from vehicles driving on unsealed roads or other CSG development or operational activities. There were several events where it was challenging to identify the source of the airborne soil and dust. This was particularly the case at the Miles Airport and Hopeland sites which are surrounded not only by CSG infrastructure and activities but are either on, or are adjacent to pastoral properties. These sites are likely to be influenced by both CSG-related and agricultural activities, including traffic on unsealed roads.

CSG in the study area is ~98% methane (Lawson et al., 2017) and due to their low concentrations in the CSG, other trace components such as benzene, toluene and xylenes (BTX) and hydrogen sulphide would be expected to quickly dilute to ambient levels once CSG is released to air (Lawson et al., 2018). An investigation of 30 of the largest methane concentration events during the study suggested that the CSG industry likely contributed to 80% of the largest concentration events observed. However, none of these methane events were associated with an air quality exceedance for other pollutants measured. Methane itself does not have an air quality objective as it is not considered to pose a risk to human health in the ambient environment.

Monitoring of VOCs at the gas field sites showed very low levels of BTX concentrations, typical of other rural areas in Australia (Lawson et al., 2018). BTX had the highest detection frequency and concentrations at the Chinchilla township site, and ratio analysis indicated the likely source was predominantly motor vehicles, as well as domestic and commercial sources within the town. Hydrogen sulphide was not detected in any sample over the study period. Formaldehyde, acetaldehyde and carbon tetrachloride were frequently detected in gas field, regional and Chinchilla samples at background concentrations typical of other parts of Australia (Lawson et al., 2018a).

To conclude, this study found that air quality in the region is well within relevant air quality objectives for the majority of the time for a wide range of gaseous pollutants that are potentially emitted by CSG activities. CSG activities are a likely contributor to infrequent coarse particulate matter ($PM_{10}$ and TSP) events in the study area along with a range of other regional activities and sources which are typical of rural areas. CSG activities were not found to contribute to infrequent fine particle ($PM_{2.5}$) events in the region, which were mainly the result of smoke from vegetation fires.

### Implications and next steps

This was the first comprehensive study to assess air quality in a region of intensive CSG production in Australia over several years. The study provides the largest contribution to air quality data for the Surat Basin region to date, and gives important information about the levels and sources of air pollutants in the region. Ambient monitoring data and CSG source and composition data will be available for use in current and future health studies (including the GISERA health study - Keywood et al., (2018) and environmental studies (including the GISERA Environmental Impacts of Hydraulic Fracturing study -Dunne et al., (2017)). Data collected in this study will also be used to validate the performance and output of air quality models, and has been utilised in the development of CSIRO's air quality model as part of this project (Lawson et al., 2017). Air monitoring data can also be used by government agencies to better understand air pollutant levels and sources in the region and to inform future policy development. Study outputs can also be used by stakeholders to inform decision making around the need for future monitoring in the region.

The CSIRO modelling study is the final output for this project and will provide an estimate of the contribution of CSG-related emissions to total air pollutant levels. The model will also explore how the CSG industry contributes to the pollutant levels over a larger spatial area (300 km by 300 km) than is covered by the monitoring sites.

While the measurements of air quality undertaken at ambient monitoring sites for this CSIRO project were scheduled to finish at the end of February 2018, industry funding is likely to extend air quality monitoring at the Tara Region, Hopeland and Miles Airport sites until the end of 2018. This additional monitoring and associated reporting of this data is beyond the scope of this project.

# 1 Study Background

A comprehensive ambient air quality study has been undertaken in the Surat Basin near the townships of Condamine, Miles and Chinchilla in Queensland (Figure 1). This study incorporates two components: an ambient air quality measurement network and an air quality modelling study. The purpose of the study was two-fold:

1) to measure and assess air quality,

2) to investigate the influence of coal seam gas (CSG) activities on air quality in this region.

The purpose of this Section is to provide background information about the monitoring program including the ambient air monitoring station network (Section 1.1 – 1.5) and passive gas monitoring network (Section 1.6 – 1.8).

A detailed overview of the rationale for site selection and pollutant selection is given in Lawson et al., (2017). A brief overview was provided in Lawson et al., (2018a, b) and is reproduced here.

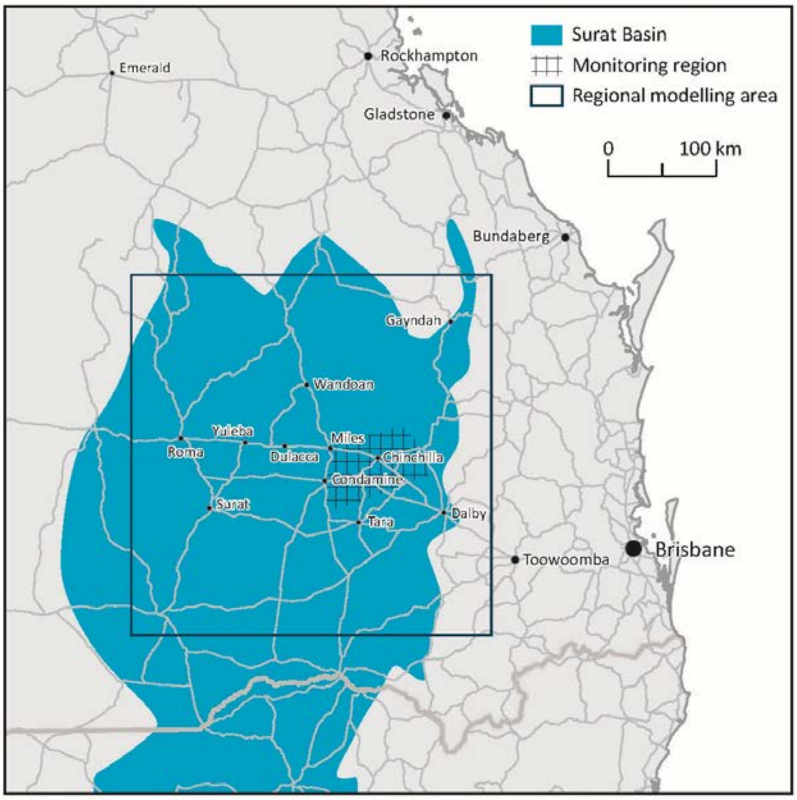


**Figure 1 Study area (source: Lawson et al., 2017)**

## 1.1 Ambient air monitoring station locations

Air quality measurements were made at 5 ambient air monitoring stations including 3 gas field sites and 2 Regional sites. An analysis of data collected from the 5 air monitoring stations was provided in previous reports (Lawson et al., 2018a for data from 2016-2017 and Lawson et al., 2018b for data from 2017-2018).

Gas field stations Hopeland, Miles Airport and Condamine were located in the Condamine-Miles-Chinchilla area (Figure 2). Measurements started at Hopeland, Miles Airport and Condamine in January 2015, July 2015 and March 2016 respectively. The gas field stations were located between 1 and 5 km from gas processing facilities (GPFs) (Orana, Condabri Central and Condabri South) and were located between 100 – 450 m from commissioned CSG wells. Gas field stations had between 15 and 25 wells within a 2 km radius (Table 1).

These stations were selected to be situated in, or close to the area that was expected to experience the largest impact of CSG emissions, based on preliminary dispersion modelling by Day et al., (2015). This modelling used a nominal methane emission rate from all areas with current and projected CSG operations to predict the future methane concentrations in the Surat Basin. Other factors considered when locating gas field air quality monitoring stations included a) suitable access, mains power and security b) that emission sources lie in different directions from the site allowing impacts from different sources (CSG-related and other) to potentially be identified, c) to be in the vicinity of homes and townships and d) to comply with Australian Standard requirements for monitoring sites.

The 2 regional stations, Tara Region/Ironbark (26 km SSE of Condamine township) and Burncluith (20 km NE of Chinchilla) were 10-20 km away from major potential CSG-related emission sources. These stations were commissioned as part of the GISERA Regional Methane Flux project in November 2015 and July 2015 respectively (Etheridge et al., 2017), and were utilised for air quality measurements in this project since June 2016.

The Condamine station was decommissioned in June 2017 to be moved to another site within the study area which was closer to a sensitive receptor. This relocation of the Condamine station is still underway as of July 2018.

The Hopeland, Miles Airport, Burncluith and Tara Region/Ironbark sites complied with Australian Standard (AS/NZ 3580.1.1:2016) siting requirements for monitoring sites (AS/NZ 2016). This Standard prescribes general guidelines for locating monitoring equipment including sampling inlet heights, and minimum distances to nearby pollutant sources or objects which may interfere with measurements of ambient air.

The Burncluith site was on a residential property and has a house chimney within 50 m to the south east of the site. This is only expected to influence the data intermittently (at night in winter, and in south easterly or light winds) and was expected to predominantly cause peaks in the carbon monoxide measurement. The Burncluith site also had trees within 10 m to the north but the air sampling inlet height of 10 m above ground ensured a clear sky angle of 120 degrees. This site therefore met the recommended inlet positioning objective in the Australian Standard.

The Condamine site did not meet all the siting requirements of the standard due to a small tree (approx. 4 m high) 3 m to the south east of the station. The inlet height at Condamine was 3.5m which is lower than required by AS/NZ 3580.1.1:2016 to overcome possible interference of the tree. However, wind measurements at the Condamine monitoring site, made via a 10 m mast some 6 m above the top of the tree, showed winds from the south east were infrequent at this site (see A.6). As such the tree was not expected to have a large impact on measurements.

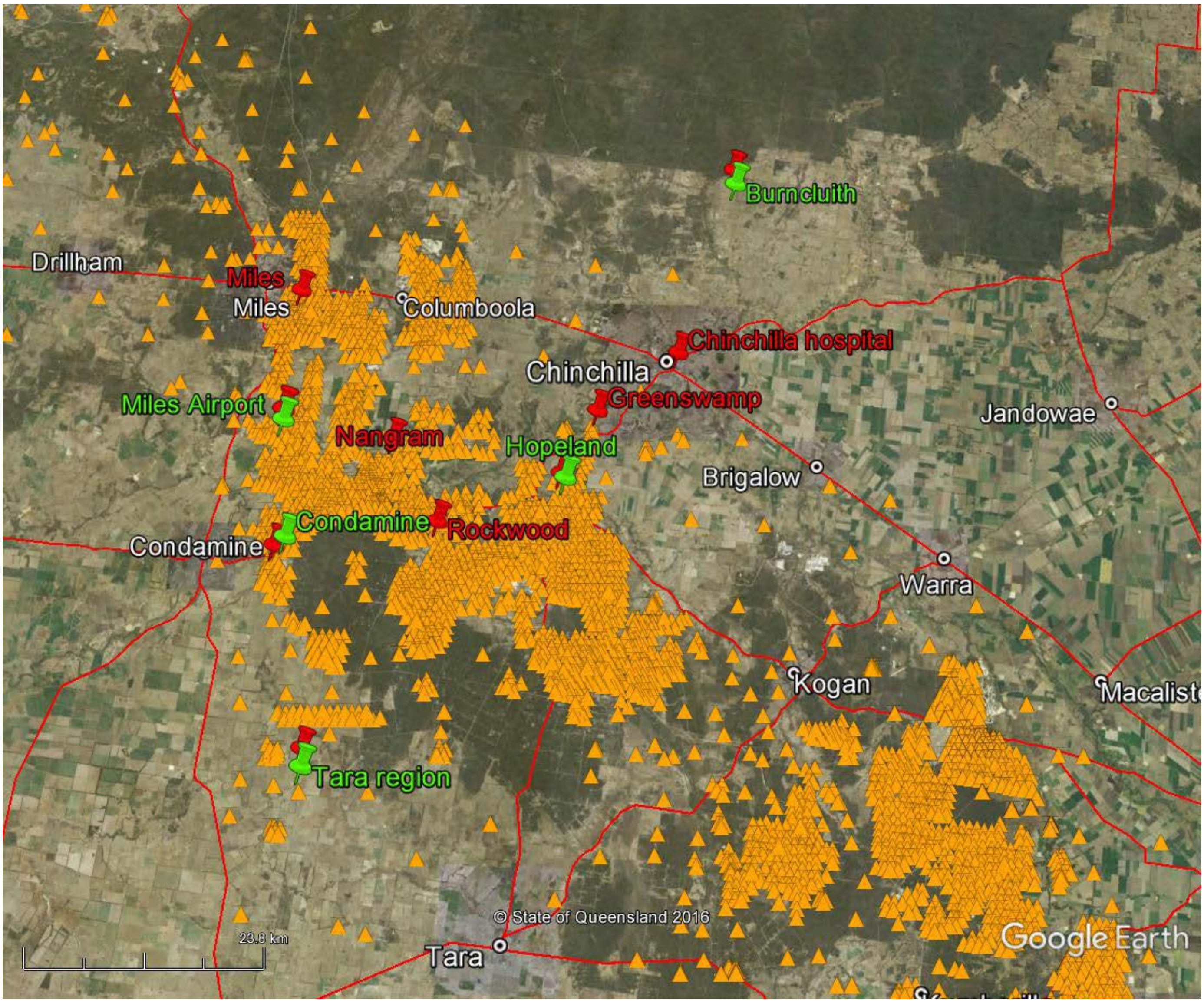


**Figure 2 Location of monitoring sites. Town names in white text, green pins are ambient air monitoring sites, red pins are passive gas sites, orange triangles are CSG wells. Source: Lawson et al., (2017).**

**Table 1 Summary of ambient air quality station locations, nearby emission sources and proximity and status of nearby wells.**

| Station name | Date AQ measurements undertaken* | Location of station | Emission sources < 5 km | Gas wells drilled within 2 km radius at time measurements commenced | Gas wells drilled within 2 km radius as of March 2016 |
|---|---|---|---|---|---|
| Hopeland | January 2015 – February 2018 | Gas fields | Orana GPF (< 5 km SE)<br>Nearest well 100 m | 1<br>(0 commissioned)[1] | 15<br>(14 commissioned) |
| Miles Airport | July 2015 – February 2018 | Gas fields | Condabri Central GPF (1.5 km NW)<br>Miles Airport (3.5 km E)<br>Feedlot (2. 3km NE/E)<br>Nearest well 450 m | 20<br>(all commissioned) | 20<br>(all commissioned) |
| Condamine | March 2016 – June 2017 | Gas fields | Condabri South GPF (1 km SE)<br>Condamine township (8 km E)<br>Nearest well 230 m | 25<br>(23 commissioned) | 25<br>(24 commissioned) |
| Tara Region (Ironbark) | June 2016 – February 2018 | Regional | Nearest well 1 km | 1<br>(plugged and abandoned) | 1<br>(plugged and abandoned) |
| Burncluith | June 2016 – February 2018 | Regional | Dwelling | 0 | 0 |

[1]Commissioned refers to operational wells

*note that that for some sites, there was not continuous data coverage during the measurement period stated. The Tara Region site had low data capture due to power issues, see Section 1.4.

## 1.2 Ambient air monitoring stations -Pollutants measured

A review of the current state of knowledge was undertaken (Lawson et al., 2017) to determine which pollutants to include in the monitoring program. Pollutants were selected where the review of emission sources and characteristics showed evidence that:

a) the CSG industry is a potential source (identified using source data, industry Environmental Impact Statements, National Pollutant Inventory data, inspection of gas infrastructure) and/or

b) CSG activities are likely to elevate pollutant levels above background levels

c) the pollutant has been identified as a key pollutant within the Australian Government National Environment Protection (Ambient Air Quality and Air Toxics) Measures, and in discussions around Australia's new National Clean Air Agreement,

d) the pollutant can be used as a tracer for emissions from certain sources / activities. For example, methane can be used as a tracer for CSG emissions, while CO and $CO_2$ can be used as tracers for combustion sources (Lawson et al., 2017).

Based on the above considerations the following parameters were selected for measurement in this study (see also Table 2)

- Gas field ambient air quality stations– nitrogen oxides ($NO_x$), carbon monoxide (CO), ozone ($O_3$), particles < 2.5 µm and < 10 µm ($PM_{2.5}$ and $PM_{10}$), total suspended particles (TSP), methane ($CH_4$), total VOCs (TVOC), carbon dioxide ($CO_2$) and meteorology (temperature, humidity, solar radiation, wind speed and direction).
- Regional ambient air quality stations– nitrogen oxides, carbon monoxide, ozone and meteorology. Measurements of carbon dioxide, carbon monoxide (Burncluith) and meteorology were provided for use in this study by the GISERA Regional Methane Flux project (Day et al., 2015, Etheridge et al., 2017, Luhar et al., 2018). Particle measurements were not made at regional sites due to budget constraints.
- Radiello passive sites, including gas field, regional and Chinchilla township sites: 46 individual VOCs, 8 individual aldehydes and hydrogen sulphide (see Section 1.6 – 1.8)

A summary of measurement technique and analytical methods is presented in A.1.

Four of the 6 objective pollutants identified in the Ambient Air NEPM were measured at gas field sites : nitrogen dioxide), photochemical oxidants (as ozone), carbon monoxide (CO) and particles (as $PM_{2.5}$, $PM_{10}$). Four of the 5 air toxics covered by the Air Toxics NEPM were measured at the passive sampler sites including benzene, toluene, xylenes, and formaldehyde (see Section 1.6 – 1.8).

A brief description of the CSG industry-related sources of the pollutants measured is provided in Table 2 below.

**Table 2 Air Measurements selected for gas field and regional stations. Source: Study Design Report, Lawson et al., 2017**

| Pollutant/parameter | Gas fields stations | Regional stations | CSG industry-related Sources |
|---|---|---|---|
| Nitrogen oxides ($NO_x$) | Yes | Yes | gas fired engines<br>gas flaring<br>diesel exhaust |
| Carbon monoxide (CO) | Yes | Yes^ | gas fired engines<br>gas flaring<br>diesel exhaust |
| Ozone ($O_3$) | Yes | Yes | n/a<br>Secondary pollutant (precursors $NO_x$, VOCs, $CH_4$) |
| Particles < 2.5 µm and < 10 µm ($PM_{2.5}$ and $PM_{10}$) | Yes | No | gas fired engines, gas flaring, diesel exhaust associated with transport, drilling, generators, dust associated with vehicles, maintenance and construction activities |
| Methane ($CH_4$) | Yes | Yes* | Major component of CSG (venting/fugitive emissions) |
| Total VOCs | Yes | No | gas fired engines, gas flaring, diesel and petrol vehicles, CSG venting/fugitive emissions |
| Carbon dioxide ($CO_2$) | Yes | Yes* | Source tracer (combustion and biological processes) |
| Meteorology (solar radiation, wind speed, wind direction, rainfall, temperature, humidity) | Yes | Yes* | Assists in determination of sources and ventilation of airshed |

^measurement made at Burncluith as part of GISERA Regional Methane fluxes project and made available for use in this project

* measurements made at Tara Region (Ironbark) and Burncluith sites as part of GISERA Regional Methane Flux project. Methane data from Regional sites have been reported as part of the GISERA Regional Methane Flux Project (Day et al 2015, Etheridge et al 2017, Luhar et al 2018)

## Carbon monoxide

Carbon monoxide is a gas formed from incomplete combustion of carbon-containing fuel. Carbon monoxide was identified as a key pollutant in CSG Industry Environmental Impact Statements (EIS) (QGC 2010, APLNG 2010). CSG related sources include combustion of gas in flares and engines, and diesel engine emissions. Carbon monoxide is also emitted from many other sources of combustion including bushfires, other industry (for example power plants), and motor vehicles.

### Nitrogen dioxide

Nitrogen dioxide ($NO_2$) is a gas produced mainly from fuel combustion, including combustion of diesel, biomass, gas, and coal, as well as from natural processes. Nitrogen oxides ($NO_x$) which includes both nitrogen dioxide, nitric oxide (NO) and some other gases is a key pollutant identified in CSG industry EIS (QGC 2010, APLNG 2010). CSG related sources include combustion of gas via flaring and gas combustion engines and diesel engine emissions.

### Ozone

Ground level ozone is a secondary pollutant, meaning that it is not directly emitted to the atmosphere but rather is formed through reactions in the atmosphere. Ozone formation requires the presence of precursors VOCs, and nitrogen oxides, and sunlight.

### $PM_{2.5}$, $PM_{10}$ and TSP

The mass concentration of particles <2.5 µm in size ($PM_{2.5}$) and the mass of particles <10 µm in size ($PM_{10}$) as well as total suspended particles (TSP) were measured at the three gas field sites. Airborne primary particles are emitted directly from the source (e.g. dust, diesel and smoke emissions), while secondary particles are formed from reactions of gas phase precursors in the atmosphere. Particles have been identified by CSG industry EIS as a key pollutant (QGC 2010, APLNG 2010). CSG related sources of particles include diesel exhaust, combustion and dust emissions, relating mostly to construction activities, along with gas fired boilers, engines and flares. Other sources of particles in the study area include agricultural sources and fires. $PM_{2.5}$, the smallest size fraction measured in this study, is emitted mainly from combustion and also forms as a secondary pollutant. The larger size fraction, $PM_{10}$ includes particles from all the $PM_{2.5}$ sources as well as from other non-combustion sources including wind-blown dust. TSP, the largest size fraction incorporates all $PM_{2.5}$ and $PM_{10}$, and includes larger particles such as those from earthworks and construction.

### Methane

Methane is an odourless gas that typically makes up 96-98% of CSG composition in the study region (Lawson et al., 2017). Emissions of CSG may occur from several sources including from wells, pipelines, gathering networks, separators, processing facilities and storage facilities and from ground and river seeps or legacy boreholes that may not be directly related to the CSG production industry. CSG emissions occur both via intentional release (for example pneumatically driven gas and water separators on well heads) and unintentional release for example via leaks.

Methane is considered non-toxic at ambient concentrations and only poses a risk to human health when at very high concentrations where it can act as an asphyxiant or explosive hazard. Consequently, there are no ambient air quality objectives for methane. Methane was included in this study as a tracer for other components of CSG which do have air quality objectives such as VOCs present in trace quantities in CSG. In addition to CSG, methane is also emitted from other sources such as livestock, combustion and coal mines.

The methane data from the Regional sites (Burncluith and Tara Region/Ironbark) were collected as part of the GISERA Regional Methane Flux project (Day et al., 2015; Etheridge et al., 2017, Luhar et al., 2018), and data were reported as part of that project. Determination of the regional emissions of methane in the study area was addressed as part of the GISERA Regional Methane flux project (see https://gisera.csiro.au/project/methane-seepage-in-the-surat-basin/).

### Total volatile organic compounds (TVOC)

Total volatile organic compound (TVOC) measurements were made at the 3 gas field sites. VOCs are a group of gases which are relatively short lived and participate in photochemical reactions in the atmosphere. The TVOC measurement method employed in this study (see A.1) provided an approximation for the sum of all individual VOCs present. In the study region, CSG-related emissions of VOCs include fuel and gas combustion, and some VOCs such as ethane and propane are present in small quantities in CSG and so are likely to be associated with leaking and venting of CSG (Lawson et al., 2017). Other sources of VOCs in the study area include vegetation and soils, vegetation fires, agriculture and domestic commercial sources.

Hydrocarbons, a subset of VOCs, are identified as a key group of pollutants in the APLNG and QGC EIS (QGC 2010, APLNG 2010). Total VOC measurements may provide an indication of whether an elevation of VOCs from combustion or CSG leakage and venting occurs.

Data capture for TVOC measurement was very low with insufficient data captured (<75%) due to several instrumental issues (see Lawson et al., 2018b). Where valid data was captured, the concentration was always below the minimum reportable concentration of 1 ppmC. The passive Radiello VOC sampling employed in this study during 2014 - 2016 provided a more sensitive (sub-ppb), reliable method, capable of measuring the concentration of over 50 individual VOCs, including NEPM air toxics and has been presented in a previous report for this project (Lawson et al., 2018a). Subsequent passive Radiello sampling was undertaken from October 2016 – September 2017 at some existing sites and 10 new sites. Data from some of these sites has been reported as part of the GISERA project Investigating air, water and soil impacts of hydraulic fracturing (Dunne et al., 2018).

## 1.3 Ambient air monitoring stations - Role of measurement service providers, data quality procedures and indicative data

The instruments used to measure air quality at the 5 ambient air quality stations were operated by Ecotech Pty Ltd (see A.1 for instrument details). Ecotech is a NATA (National Association of Testing Authorities) accredited laboratory and as such meets all objectives of ISO17025 for competence of a laboratory to carry out sampling, tests and calibrations using validated test methods. Ecotech was responsible for instrument installation, calibration and maintenance. Ecotech performed daily data checks on all the instruments remotely to ensure correct operation of instruments. If data checks identified issues with instrument performance, these were conveyed to Ecotech field technicians who visited the sites to repair instruments as soon as practicable. CSIRO also undertook an independent daily check of instrument performance remotely for all sites, and conveyed issues to Ecotech for action.

Ecotech was responsible for quality checking and processing data each month. Ecotech quality checked and validated data by flagging data affected by instrument faults, calibrations and other maintenance activities, ensuring compliance with relevant Australian Standards. Ecotech then provided monthly validated data to CSIRO who compared all raw and validated datasets, and independently assessed any adjustments to data (for example due to changes in instrument performance) or removal of data. The final validated data used in this report has been approved by CSIRO. Data that was removed due to issues with instrument performance or other issues are not presented in this report or previous reports from this study. See Lawson et al., (2018a, b) for more details about data quality procedures.

Some data which has been used in this report does not comply with Australian Standard measurement methods due to all requirements of the Australian Standard method not being met. This indicative data has been assessed as being of acceptable quality for use in this report using instrument checks, calibrations, and comparing data obtained with other co-located or nearby instruments (see Appendix A.1 in Lawson et al 2018a,b for more details).

In some cases a measurement method was used other than the Australian Standard method (see A.1 for list of measurement techniques). $PM_{10}$ and $PM_{2.5}$ measurements were made with an optical technique (Fidas) which was used because it provided a cost effective means of simultaneously measuring real-time TSP, $PM_{2.5}$ and $PM_{10}$. While the Fidas it is not an Australian Standard Method for $PM_{2.5}$ and $PM_{10}$, it has shown good agreement with Standard methods in European and UK locations (TUV 2015). CSIRO undertook a particle method comparison for $PM_{10}$ and $PM_{2.5}$ at the Miles Airport site which showed good agreement between $PM_{10}$ measured with the Fidas and a method equivalent to Australian Standard methods (see A.3 in Lawson et al., 2018b for full details). Concentrations of $PM_{2.5}$ during the comparison period were too low to compare methods. As such, the $PM_{10}$ data in this study can be considered equivalent to data obtained by Australian Standard methods. For $PM_{2.5}$, good agreement shown between the Fidas in other techniques in European and UK studies, and provisional data from another recent particle comparison in the Surat Basin (see A.3 in Lawson et al., 2018b) suggests but cannot confirm equivalency to Australian standard methods.

A comparison of the Fidas versus the Australian Standard Method was not undertaken for TSP. TSP was assessed to be a lower priority for comparison due to TSP not being a criteria air pollutant in the NEPM (NEPM 2016). A further reason that a method comparison was not undertaken for TSP is due to the particle diameter size ranges sampled and measured by the Fidas (up to 18 µm) and the Australian Standard method (up to 100 µm) (AS/NZS

3580.9.3:2015) being non-equivalent. As such, the TSP data from this study can only be considered indicative and cannot be considered equivalent to the Australian Standard Method (AS/NZS 3580.9.3:2015). It is likely that for very localised dust events with large airborne particles >10 µm, the Fidas would have measured a lower concentration of TSP than would have been measured by the Australian standard method. As such is possible that there were some 24 hour concentrations of TSP which were below the TSP guideline when measured with Fidas, but would have exceeded the guideline if measured by the Australian Standard Method. Many such events would be expected to be captured by the protocol of investigating TSP events which were >80% of the nuisance dust guideline (MFE 2016) - see Section 2.

## 1.4 Ambient air monitoring stations: reasons for low data capture at some sites

There were several challenges associated with making air quality measurements during this study which led to intermittent loss of data at Hopeland, Miles Airport and Condamine, and more significant loss of data at the Tara Region site. The amount of data captured by each instrument was affected by power failures, instrument faults, maintenance activities and instrument performance issues. Reasons for data loss are discussed below.

### Power and air conditioner failures

Power failures at the monitoring sites tended to be more common in summer and associated with storms, however power failures also sometimes occurred in the winter months. Power outages led to air conditioner failures resulting in overheating of instruments causing failure and damage. The rectification of multiple problems (mains power supplies, air conditioner repair, repairs of instruments on site, or sent back to manufacturer) would sometimes lead to several weeks of data loss. Access to sites for repairs and maintenance by technicians was sometimes limited due to wet weather, and one of the sites were also on private property which required additional permissions prior to accessing the site.

### Unreliable power at Tara Region site

Data capture at Tara Region site was very low during 2017 - 2018 with insufficient data captured (<75%) for every month except February 2017.

There were significant issues with intermittent failure of the power supply to the site. The cause of the power failure was due to technical issues at the site which took longer to resolve than anticipated due to the remoteness of the site and limited existing power infrastructure at the site. Power issues were resolved in January 2018. The low data capture for Tara Region did not impact the project’s ability to meet scientific objectives as there is good data coverage from Burncluith, the other regional site

### Instrument faults

The instruments used to measure air quality at the 5 ambient air quality stations were operated by Ecotech Pty Ltd (see A.1 for instrument details). In case of instrument faults, Ecotech provide technicians who repaired the instrument on site, or removed the instrument and sent it away for repair. In some cases there was data loss due to delays in technicians attending the sites to repair or replace the instruments.

### Controlled Power shutdown

Data loss at Hopeland in June - July 2017 occurred due to the power being shut off during the decommissioning of a groundwater bore in the vicinity of the site switch board.

## 1.5 Ambient air monitoring stations - Live data streaming

Since 25th August 2016, preliminary air quality data from the ambient air quality sites has been streamed to the Department of Environment and Heritage Protection website, now the Department of Environment and Science (DES) website, under South West Queensland region: https://www.ehp.qld.gov.au/air/data/search.php

At the time of streaming, data has not undergone data validation procedures (see above). Data streamed includes carbon monoxide, nitrogen dioxide, ozone and $PM_{2.5}$, $PM_{10}$ and TSP (Hopeland, Miles Airport, Condamine) and carbon monoxide, nitrogen oxides and ozone (Burncluith and Tara Region). These pollutants were selected for live streaming because there are air quality standards associated with each pollutant (Air NEPM), providing context for the reported concentrations. Data was displayed both as measured concentration values and as an air quality index values (0-100) with corresponding colour coded categories (very good, good, fair, poor, very poor). The index value is the pollutant concentration expressed as a proportion of the Ambient Air Quality NEPM standard (see Table 4). This live data streaming allowed comparison of the air quality in the South West region with other parts of Queensland.

Data streaming from some sites was still occurring at the time of publication of this report however CSIRO's role in data validation ceased as of February 2018 and as such pertains to the data published in the present report and accompanying reports Lawson et al. (2018a, 2018c).

Validated carbon monoxide, ozone, nitrogen dioxide, $PM_{2.5}$, $PM_{10}$ and TSP data from this study is available to download from the Queensland Government website https://data.qld.gov.au/dataset

## 1.6 Passive Gas Monitoring Network – measurement locations

In this study, passive gas sampler measurements were made via a network of passive Radiello samplers (Figure 3). The Radiello passive samplers were deployed at or within 2 km of the gas field ambient air monitoring sites, as well as at an additional 4 sites in and around the gas fields (Nangram, Rockwood, Greenswamp and Miles/Condabri North). Radiello passive samplers were also deployed at the two regional air quality station sites (Burncluith and Tara Region) and in the Chinchilla township. The locations of the 10 passive sampler sites as of January 2016 are shown in Figure 2. The gas field passive sampler sites were located within 500 m of Condabri North GPF (Miles/Condabri North passive site), within 1 km of Condabri South GPF (Condamine passive site), within 1.5 km of Condabri Central GPF (Miles Airport passive site), 3 km from Talinga GPF (Rockwood passive site) and within 4 km of Orana GPF (Hopeland passive site). The Greenswamp passive sampler site was located within 50 m of a Condamine River gas seep. All of the gas field sites with the exception of Greenswamp had between 12- 31 gas wells within a 2 km radius.

In contrast at the regional passive sampler sites there were few emission sources nearby. At the Chinchilla township site the main likely emission sources was motor vehicles and domestic and commercial sources associated with the town.

The 10 passive sampler sites are summarised in Table 3. This table lists the proximity of the sites to wells and other potential emission sources.

**Figure 3 Radiello samplers deployed in the field**

**Table 3 Air quality station and Radiello passive sampler monitoring locations including category (Gas field, Regional or Chinchilla), nearby gas infrastructure and other potential emission sources**

| Locations | Air Quality Station | Passive Radiello | Gas wells ≤ 2 km as of March 2016 | Other sources |
|---|---|---|---|---|
| **Gas field sites** | | | | |
| Hopeland | Y | Y | 15 | GPF <4 km |
| Miles Airport | Y | Y | 12* | GPF 1.5 km<br>Airport<br>Feedlot |
| Condamine | Y | Y | 25 | GPF 1 km<br>Township 7 km<br>Road 300 m |
| Miles (Condabri North) | N | Y | 31 | GPF 500 m<br>Township 3 km |
| Nangram/Monreagh | N | Y | 17 | n/a |
| Rockwood /Talinga | N | Y | 27 | GPF 3 km |
| Greenswamp | N | Y | 0 | Road 700 m |
| **Regional sites** | | | | |
| Tara Region | Y | Y | 1 | n/a |
| Burncluith | Y | Y | 0 | Dwelling |
| **Chinchilla** | | | | |
| Chinchilla | N | Y | 0 | Vehicles<br>Domestic and commercial sources |

***refers to location near sensitive receptor**

## 1.7 Passive gas network – pollutants measured

A review of CSG emission sources in the study area identified that the CSG industry is a source of several VOCs, aldehydes and hydrogen sulphide (Lawson et al., 2017). Unprocessed coal seam gas is 96 - 98 % methane with the remainder mostly comprised of nitrogen and carbon dioxide. A review of CSG related emission sources (Lawson et al., 2017) showed that CSG contains trace (~0.01%) levels of VOCs including ethane and propane, with lower levels of VOCs and inorganic gases identified in the NEPM and EPP such as benzene, toluene, xylenes and hydrogen sulphide (< 1 ppm or < 0.0001%). However because emissions of CSG may occur from several sources including during well construction, production, transport and storage phases via venting and emissions from wells, pipelines, separators, compressors, and storage facilities, it is important to understand the contribution that the CSG industry may make to the regional emissions of VOC and hydrogen sulphide. Measurements of emission gases from gas fired compressors and engines at Talinga GPF shows that gas combustion is a source of a wide range of VOCs including aldehydes and BTX (Lawson et al., 2017). It is important to note that these VOCs may also be emitted from other CSG-related sources not characterised in Lawson et al. (2017) – for example emissions from gas flaring, use of diesel generators and engines, mobile sources such as motor vehicles, and well drilling and hydraulic fracturing.

Radiello passive samplers were deployed to measure VOCs, aldehydes and hydrogen sulphide that are potentially emitted from the CSG industry. VOC passive samplers were deployed at 10 sampling sites in the study area from September 2014- January 2016 and aldehyde and hydrogen sulphide passive samplers were deployed for 7 months from June 2015 – January 2016.

45 species are reported from the VOC sampler, 8 species are reported from the aldehyde sampler and 1 species is reported from the hydrogen sulphide sampler.

The passive sampler technique allowed measurement of 4 of the 5 gases listed in the Air Toxics NEPM (benzene, toluene and xylenes and formaldehyde), and several additional VOCs and inorganic gases, including hydrogen sulphide and chlorinated gases, included in the National Pollutant Inventory (NPI). A list of all gases measured with the Radiello technique is provided in A.1.3. A detailed analysis of Radiello passive sampler measurements made in this study from 2014 - 2016 was provided in Lawson et al., (2018a). Radiello passive data from this study will be made available via the GISERA website at https://gisera.csiro.au/project/ambient-air-quality-in-the-surat-basin/

## 1.8 Passive gas network - Role of measurement service providers and CSIRO/QA QC – data management

In this study the Radiello passive samplers were deployed and analysed by environmental consultants SGS Leeder (Lawson et al., 2017). SGS is a NATA-accredited laboratory which meets all criteria of AS ISO/IEC 17025-2005 for competence of a laboratory to carry out sampling, tests and calibrations using validated test methods. Each passive sampler was exposed to air for approximately two weeks, providing an average concentration of gases over the two week deployment. After exposure the absorbing cartridges were packed in a sealed container and sent to a laboratory where the gases were extracted and the mass on each cartridge determined. Using the exposure time, and experimentally determined sampling rate for each gas, the concentrations of gases that were present in the air during sampling was calculated.

CSIRO undertook independent measurements of VOCs and aldehydes alongside the Radiello passive samplers at Hopeland ambient air monitoring station in June - July 2015. CSIRO measurements indicated low levels of VOCs and aldehydes at Hopeland during the method comparison. Overall the level of agreement between techniques supports the suitability of the Radiello passive sampler technique for monitoring VOCs and aldehydes in the study area (Lawson et al., 2018a).

# 2 Summary of air pollution events over the entire study (2014 – 2018)

During this study air quality in the study region in the Surat Basin was well within air quality objectives for the majority of the time. There were no exceedances of air quality objectives (Table 4) for a wide range of gaseous pollutants measured at the ambient air monitoring stations, or in the passive gas network during the study (see Lawson et al., 2018a). There were infrequent 24 hour average exceedances of $PM_{2.5}$, $PM_{10}$ and TSP air quality objectives at the gas field sites during the study.

The purpose of this section is to summarise the number and likely source of the infrequent $PM_{2.5}$, $PM_{10}$, TSP and ozone pollution events observed at air monitoring stations during the course of this study (from 2015 – 2018). A pollution event is defined as an exceedance of an air quality objective, or an event where the pollutant concentration was greater than (>) 80% of the relevant air quality objective. The main types of sources contributing to these pollution events will be discussed. The number of 24 hour average exceedances of the air quality objectives for $PM_{2.5}$ and $PM_{10}$ during this study, and the likely sources contributing to these exceedances, will be compared to the number of exceedances (and their likely sources) at other sites in Queensland.

This section will also summarise and discuss the main sources contributing to the largest methane concentration events observed at the gas field sites. Methane events were identified from maximum hourly average concentrations and defined as one or a series of peaks that occurred in the same wind direction/similar wind conditions, no more than 12 hours apart (for more details see Lawson et al., 2018b). Note that there is no air quality objective for methane. The likely influence of CSG-related activities on $PM_{2.5}$, $PM_{10}$, TSP, ozone and methane events is discussed. For a detailed analysis of individual pollution events see Lawson et al., 2018a (2015-2016) and Lawson et al., 2018b (2017-2018).

## 2.1 Number of events by monitoring site

This section summarises the total number of events by site, by pollutant and by year over the entire study period.

Note that measurements were made during only part of some calendar years in some cases (in particular Condamine which measured for part of 2016 and part of 2017), as detailed in the footnotes of each table. Measurements were made for two complete calendar years at Hopeland and Miles Airport (2016 and 2017). The duration of $PM_{2.5}$ measurements was 29 months at Hopeland and Miles Airport and 15 months at Condamine.

The air quality objectives used to assess pollutant concentrations are given below (Table 4)

**Table 4 Air quality objectives used to assess concentrations in this report including NEPM (2016), EPP air (2008) and DES TSP guidelines based on MFE (2016).**

| Air pollutant | Averaging Period | Objective |
|---|---|---|
| Carbon monoxide | 8-hour | 9 ppm (not to be exceeded on more than one day per year)[a,b] |
| Ozone | 4-hour<br>1-hour | 0.08 ppm (one day per year)[a,b]<br>0.10 ppm (one day per year)[a,b] |
| Nitrogen dioxide | Annual<br>1-hour | 0.03 ppm[a,b]<br>0.12 ppm (one day per year)[a,b] |
| $PM_{10}$ | Annual<br>24-hour | 25 µg $m^{-3}$ [a]<br>50 µg $m^{-3}$ [a,b] |
| $PM_{2.5}$ | Annual<br>24-hour | 8 µg $m^{-3}$ [a,b]<br>25 µg $m^{-3}$ [a,b] |
| TSP | Annual<br>24-hour | 90 µg $m^{-3}$ [b]<br>60 µg $m^{-3}$ (high sensitivity environment) [c] |

[a] NEPM (2016)
[b] EPP (Air) (2008) Queensland
[c] DES TSP guidelines based on MFE (2016)

## 2.2 Exceedances of TSP, $PM_{10}$ and $PM_{2.5}$

There were no exceedances of the annual air quality objective for $PM_{10}$ $PM_{2.5}$ or TSP at any site during this study.

Table 5 shows the number of 24 hour average exceedances of $PM_{10}$ for each site, for each year of the study. Over the entire study period there was 1 exceedance of the $PM_{10}$ objective at Hopeland in 2016, 2 exceedances of the $PM_{10}$ objective at Miles Airport in 2015 and 2017, and no exceedances at Condamine.

**Table 5 number 24 hour average exceedances of $PM_{10}$ for each site, for each year of the study**

| $PM_{10}$ exceedances* | | | | |
|---|---|---|---|---|
| | **averaging period** | **Hopeland[1]** | **Miles Airport[1]** | **Condamine[2]** |
| 2015 | 24 hour | 0 | 1 | nm |
| 2016 | 24 hour | 1 | 0 | 0 |
| 2017 | 24 hour | 0 | 1 | 0 |
| 2018 | 24 hour | 0 | 0 | nm |
| total | | 1 | 2 | 0 |

***Air EPP objectives and NEPM objectives**

**[1] measurements from Sep 2015 – Feb 2018, [2]measurements from Mar 2016 – June 2017**

**nm= not measured**

Table 6 shows the number of 24 hour average exceedances of $PM_{2.5}$ for each site, for each year of the study. Over the entire study period there were 3 exceedances of the $PM_{2.5}$ objective at Hopeland in 2015 (1) and 2016 (2), 3 exceedances of the $PM_{10}$ objective at Miles Airport in 2015, 2016 and 2017 and 1 exceedance of $PM_{2.5}$ at Condamine in 2016.

**Table 6 number of 24 hour average exceedances of $PM_{2.5}$ for each site, for each year of the study**

| $PM_{2.5}$ exceedances* | | | | |
|---|---|---|---|---|
| | averaging period | Hopeland[1] | Miles Airport[1] | Condamine[2] |
| 2015 | 24 hour | 1 | 1 | nm |
| 2016 | 24 hour | 2 | 1 | 1 |
| 2017 | 24 hour | 0 | 1 | 0 |
| 2018 | 24 hour | 0 | 0 | nm |
| total | | 3 | 3 | 1 |

***Air EPP objectives and NEPM objectives**

**[1] measurements from Sep 2015 – Feb 2018, [2]measurements from Mar 2016 – June 2017**

**nm= not measured**

Table 7 shows the number of 24 hour average exceedances of TSP for each site, for each year of the study. Over the entire study period there were 2 exceedances of the TSP objective at Hopeland in 2016 (1) and 2017 (1), 12 exceedances of the TSP objective at Miles Airport in 2015 (1), 2016 (4), 2017 (4) and 2018 (3) and 4 exceedances of the TSP objective at Condamine in 2016 (2) and 2017 (2).

The likely sources of these exceedances is discussed in Section 2.3.

**Table 7 number of 24 hour average exceedances of TSP for each site, for each year of the study.**

| TSP exceedances* | | | | |
|---|---|---|---|---|
| | Averaging period | Hopeland[1] | Miles Airport[1] | Condamine[2] |
| 2015 | 24 hour | 0 | 1 | nm |
| 2016 | 24 hour | 1 | 4 | 2 |
| 2017 | 24 hour | 1 | 4 | 2 |
| 2018 | 24 hour | 0 | 3 | nm |
| total | | 2 | 12 | 4 |

***DES TSP guideline based on MFE (2016)**

**[1] measurements from Sep 2015 – Feb 2018, [2]measurements from Mar 2016 – June 2017**

**nm= not measured**

### 2.2.1 Events >80% of air quality objective for TSP, $PM_{10}$ and $PM_{2.5}$ and ozone

A number of events where pollutant concentrations were > 80% of a relevant air quality objective were also identified and investigated in recognition that an exceedance may have occurred closer to the pollutant source but not at the monitoring station.

Table 8 shows the number of occasions where concentrations of $PM_{10}$ were > 80% of the 24 hour average air quality objectives of $PM_{10}$ for each site, for each year of the study. Over the entire study period there were 2 events where the 24 hour average $PM_{10}$ concentration was greater than (>) 80% of the air quality objective at Hopeland in 2016 and 2017, 3 events at Miles Airport in 2016 (2) and 2017 (1) and 2 events at Condamine in 2016 and 2017.

**Table 8 number of occasions where concentrations of $PM_{10}$ were greater than (>) 80% of the 24 hour air quality objectives of $PM_{10}$ for each site, for each year of the study**

| $PM_{10}$ >80% of objective* | | | | |
|---|---|---|---|---|
| | averaging period | Hopeland[1] | Miles Airport[1] | Condamine[2] |
| 2015 | 24 hour | 0 | 0 | nm |
| 2016 | 24 hour | 1 | 2 | 1 |
| 2017 | 24 hour | 1 | 1 | 1 |
| 2018 | 24 hour | 0 | 0 | nm |
| total | total | 2 | 3 | 2 |

***Air EPP objectives and NEPM objectives**

**[1] measurements from Sep 2015 – Feb 2018, [2]measurements from Mar 2016 – June 2017**

**nm= not measured**

Table 9 shows the number of occasions where concentrations of $PM_{2.5}$ were > 80% of the 24 hour average air quality objective for $PM_{2.5}$ for each site, for each year of the study. Over the entire study period there were 5 events where the 24 hour average $PM_{2.5}$ concentration was greater than (>) 80% of the air quality objective at Hopeland in 2015 (2), 2016 (1) and 2017 (2), 3 events at Miles Airport in 2015 (1) and 2017 (2) and 2 events at Condamine in 2016 and 2017.

**Table 9 number of occasions where concentrations of $PM_{2.5}$ were greater than (>) 80% of the 24 hour average air quality objective for $PM_{2.5}$ for each site, for each year of the study.**

| $PM_{2.5}$ >80% of objective* | | | | |
|---|---|---|---|---|
| | averaging period | Hopeland[1] | Miles Airport[1] | Condamine[2] |
| 2015 | 24 hour | 2 | 1 | nm |
| 2016 | 24 hour | 1 | 0 | 1 |
| 2017 | 24 hour | 2 | 2 | 1 |
| 2018 | 24 hour | 0 | 0 | nm |
| total | | 5 | 3 | 2 |

***Air EPP objectives and NEPM objectives**

**[1] measurements from Sep 2015 – Feb 2018, [2]measurements from Mar 2016 – June 2017**

**nm= not measured**

Table 10 shows the number of occasions where concentrations of TSP were greater than (>) 80% of the 24 hour average air quality objectives of TSP for each site, for each year of the study. Over the entire study period there were 3 events where the 24 hour average TSP concentration was greater than (>) 80% of the air quality objective at Hopeland in 2016 (2) and 2018 (1), 21 events at Miles Airport in 2015 (2), 2016 (4), 2017 (11) and 2018 (4), and 4 events at Condamine including 2016 (2) and 2017 (2).

The likely sources of these events >80% of the air quality objective is discussed in Section 2.3.

**Table 10 number of occasions where concentrations of TSP were greater than (>) 80% of the 24 hour average air quality objectives of TSP for each site, for each year of the study.**

| TSP >80% of objective | | | | |
|---|---|---|---|---|
| | averaging period | Hopeland[1] | Miles Airport[1] | Condamine[2] |
| 2015 | 24 hour | 0 | 2 | nm |
| 2016 | 24 hour | 2 | 4 | 2 |
| 2017 | 24 hour | 0 | 11 | 2 |
| 2018 | 24 hour | 1 | 4 | nm |
| total | | 3 | 21 | 4 |

***DES TSP guideline based on MFE (2016)**

**[1] measurements from Sep 2015 – Feb 2018, [2]measurements from Mar 2016 – June 2017**

**nm= not measured**

Table 11 shows the number of occasions where 4 hour average concentrations of ozone were greater than (>) 80% of the 4 hour air quality objectives of ozone for each site, for each year of the study. Over the entire study period there were 2 events where the 4 hour ozone concentration was greater than (>) 80% of the air quality objective at Miles Airport in 2016 and 2016 and 1 event at Burncluith in 2017.

**Table 11 number of occasions where 4 hour average concentrations of ozone were greater than (>) 80% of the 4 hour air quality objectives of ozone for each site, for each year of the study.**

| ozone >80% of objective | | | | | | |
|---|---|---|---|---|---|---|
| | averaging period | Hopeland[1] | Miles Airport[2] | Condamine[3] | Burncluith[4] | Tara Region[5] |
| 2015 | 4 hour | 0 | 0 | nm | nm | nm |
| 2016 | 4 hour | 0 | 1 | 0 | 0 | 0 |
| 2017 | 4 hour | 0 | 1 | 0 | 1 | 0 |
| 2018 | 4 hour | 0 | 0 | 0 | 0 | 0 |
| total | | 0 | 2 | 0 | 1 | 0 |

***Air EPP objectives and NEPM objectives**

**[1] measurements from Sep 2015 – Feb 2018, [2]measurements from July 2015 – Feb 2018**

**[3]measurements from Mar 2016 – May 2017 [4] measurements from June 2016-Feb 2018 [5] measurements from June 2016 – Feb 2018, however due to site power issues, data available from only 5 months in 2017 and <1 month in 2018**

**nm= not measured**

### 2.2.2 Summary

This study found that air quality in this region is well within air quality objectives for the majority of the time. There were no exceedances of a wide range of gaseous pollutants measured during the study. For annual air quality objectives, there were no exceedances or >80% events for any pollutant measured.

There were infrequent exceedances of 24 hour average $PM_{2.5}$, $PM_{10}$ and TSP air quality objectives at the gas field sites during the study.

$PM_{10}$ 24 hour average exceedances occurred at a rate of between 0 and 1 exceedance per year at gas field sites and 24 hour average $PM_{10}$ events with concentrations >80% air quality objective occurred at a rate of between 0 and 2 events per year for gas field sites, noting that this includes some partial calendar years.

$PM_{2.5}$ 24 hour average exceedances occurred at a rate of between 0 and 2 exceedances per year and 24 hour $PM_{2.5}$ events >80% air quality objective occurred at a rate of between 0 and 2 events per year for gas field sites, noting that this includes some partial calendar years.

TSP 24 hour average exceedances occurred at a rate of between 0 and 4 exceedance events per year, and 24 hour average TSP events >80% air quality objective occurred at a rate of between 0 and 11 events per year for gas field sites, noting that this includes some partial calendar years. For TSP there were higher number of exceedances and >80% events at the Miles Airport sites, both per year and by total number over the entire study period. A summary of the most likely sources influencing the air quality exceedances and events at Miles Airport and other sites is provided in the following Section 2.3.

There were no exceedances of ozone air quality objectives. Ozone 4 hour average events > 80% air quality objective occurred at a rate of between 0-2 per year.

## 2.3 Likely sources influencing events by site

This section summarises all events identified over the entire study period from 2015 - 2018 according to the likely identified main air pollutant emission source/s. A total of 106 events were investigated and are summarised here, including 28 events which exceeded air quality objectives ($PM_{2.5}$, $PM_{10}$ and TSP), 48 events with concentrations > 80% of the air quality objectives ($PM_{2.5}$, $PM_{10}$, TSP and ozone) and the 30 largest methane events.

There are likely to be multiple sources contributing to a concentration of any pollutant at typical ambient or baseline levels. However on some occasion a dominant source/s can make a large contribution, leading to an overall concentration which may exceed air quality objectives, or increase the pollutant concentration to higher than typical levels. The identification of likely sources in this work focuses only on the dominant source/s that were identified during events, rather than all possible contributing sources. For a detailed analysis of individual pollution events see Lawson et al., 2018a (2015-2016) and Lawson et al., 2018b (2017-2018).

### 2.3.1 Protocol used to investigate likely sources of events

Note that this study did not include the measurement of chemical composition of particles. The likely main emission source/s for each particle, ozone and methane event was investigated and identified according to a qualitative protocol that uses a combination of wind speed and direction, source locations, and pollutant correlation and ratios. A summary of the protocol used to identify main air pollutant emission source/s during events is given below. For more details on the protocol please see Lawson et al., (2018b). Exceedances and >80% events are shown for TSP, $PM_{10}$, $PM_{2.5}$ (gas field sites only) and ozone, while the 10 largest methane concentration events are shown for each gas field site.

The steps taken to investigate the likely dominant source/s of pollutants for each event included:

1) Define the date, time and duration of the event period, including the time that peak pollutant concentrations occurred during the event

2) Determine the predominant wind direction/s and wind speed during the peak pollutant concentrations

3) In the case of particle mass, determining whether the PM was mainly in the small or fine size fraction ($PM_{2.5}$, particles <2.5 µm) or coarse size fraction (PM in the range of 2.5 µm – 10 µm, calculated from $PM_{10}$ – $PM_{2.5}$). Coarse particles are typically associated with airborne dust and soil (crustal material), whereas fine particles are associated with smoke and secondary aerosols and fine dust.

4) Identify the other measured pollutants whose concentrations correlated with the pollutant that was the subject of the event.

5) Calculate an average ratio of the exceeding pollutant or methane to any other correlating pollutants during the peak concentration period and examine whether this ratio indicates a particular emission source (vegetation fires, dust, cattle, CSG combustion etc.)

Previous studies have examined the ratios of $PM_{2.5}$ to carbon monoxide ($PM_{2.5}/CO$) and carbon monoxide to carbon dioxide ($CO/CO_2$) which are emitted in smoke from vegetation fires (Andreae and Merlet, 2001; Akagi et al., 2011) and the ratios of methane to carbon dioxide ($CH_4/CO_2$) which are emitted in the breath of cattle (Bai et al., 2014). These published ratio data were used to identify possible sources. The absence of a correlation between pollutants can also be used to rule out sources.

6) Identify possible sources of the exceeding pollutant and other correlating pollutants upwind of the measurement location, and determine the distance from the measurement location to potential sources. For example, Geoscience Australia's Sentinel website, and NASA Worldview website (see Appendix C.1) as well as information from local fire authorities and landholders was used to provide information on the locations and occurrence of fires and smoke in the study region. Likewise, the Queensland Globe database was used to identify CSG infrastructure (GPFs, pipelines, wells) as well as other potential pollutant sources such as feedlots.

7) Investigate other relevant information, for example whether exceedances occurred at other sites that day. Exceedances at multiple sites can indicate a regional source/event.

8) Identify the likely dominant source(s) of the pollutant during the event, recognising that there may not be sufficient information to identify a likely source for each event, or that more than one source may have contributed.

In cases where the major methane peak did not correlate with any other pollutants (e.g. carbon dioxide which could indicate cattle, carbon monoxide which could indicate combustion), and potential CSG emissions sources were identified upwind, the source of the methane peak was attributed as likely being from intentional or unintentional release of un-combusted CSG from CSG activities/infrastructure. While methane emissions from terrestrial seeps or legacy boreholes could be a source of the methane observed in these cases, CSG-related activities or infrastructure are considered to be a more likely source, given the high density of CSG infrastructure (wells, gathering networks, GPFs, WTF, compressor stations) in close proximity to these gas field sites (see Table 1).

### 2.3.2 TSP events

Figure 4 shows the number of 24 hour average TSP exceedance events for Hopeland, Miles Airport and Condamine according to the likely identified dominant source/s (left) and all events for these 3 sites, including exceedances and events> 80% the air quality objective (right). The colour in the columns corresponds to the likely identified source/s.

Figure 4 shows that there were several dominant sources which contributed to TSP events observed at the gas field sites. The categories can be summarised as follows:

Smoke – smoke from vegetation fires. While particles in smoke are mainly in the small size fraction, particles of any size contribute to TSP. Hopeland was the only measurement site where smoke was the main contributor to a TSP event.

Smoke and dust - a combination of smoke from vegetation fires and dust from several different sources depending on the event, including unsealed roads and/or CSG activities, regional dust events (large scale windblown dust) and dust from unknown sources

Dust from roads/CSG activities, regional dust – dust event from either local unsealed roads and/or CSG activities, or regional dust (large-scale windblown dust event)

Dust from cattle farming – particles associated with farming of cattle which may be due to movement of cattle, agitation of soil etc.

Dust from cattle farming and unknown - particles associated with farming of cattle and dust of unknown source

Dust (unknown source) –Dust of unknown source is likely to be airborne soil and may be related to CSG activities/vehicles, unsealed roads and/or agricultural activities/equipment (cannot be determined) As such, where airborne soil events occurred, whether the soil was emitted from agricultural related vehicles/equipment, or CSG related vehicles/equipment could not be determined and the events were identified as 'unknown dust'

The term 'dust' here refers to primary particles emitted directly from source such as soil, crustal material and/or organic matter.

In some cases a single identified main source of TSP was identified, such as smoke from vegetation fires, and dust from cattle farming, however in many cases there were more than one source identified as likely contributing to the event, for example both smoke from vegetation fires and dust.

Figure 4 show that the same types of sources contributed to TSP events at each site whether these events were exceedances, or >80% events. The influence of TSP from cattle farming was unique to the Miles Airport site.

#### Influence of CSG industry on TSP events

CSG activities were likely to have contributed to several TSP events at the Condamine and Miles Airport sites (dust from roads/CSG activities category). The CSG industry/unsealed roads were identified as the likely cause in these events when CSG infrastructure and/or unsealed roads servicing CSG infrastructure were upwind of the measurement site during a TSP event. In these cases the particles were the large size fraction, most likely indicating airborne soil.

In addition CSG industry activities including vehicle traffic could potentially have contributed to dust events of unknown source at Hopeland, Miles Airport and Condamine. While these unknown dust events were characterised by particles mainly in the large size fraction, suggesting airborne soil, the activity causing the soil to become airborne was challenging to determine, particularly at the Miles Airport and Hopeland sites which have CSG infrastructure surrounding the sites but are also likely influenced by nearby agricultural activities including traffic on unsealed roads.

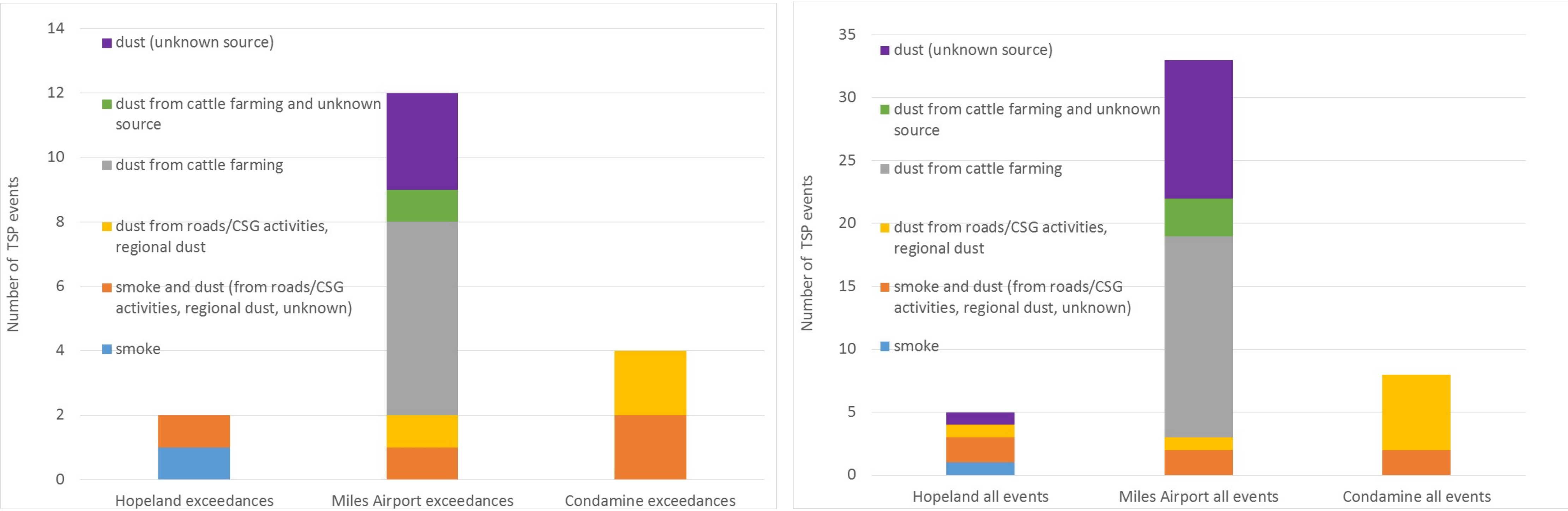


**Figure 4 Dominant sources identified as contributing to TSP events observed at the gas field sites for exceedance events (left) and all events (right). Note that this summarises only the dominant likely sources identified, not all possible contributing sources**

### 2.3.3 $PM_{10}$ events

Figure 5 shows the number of 24 hour average $PM_{10}$ exceedance events for Hopeland, Miles Airport and Condamine according to likely identified dominant source/s (left) and for all events, including exceedances and events> 80% the air quality objective (right). The colour in the columns corresponds to the likely identified source/s.

Overall the dominant sources of $PM_{10}$ were identified as being similar to TSP. This is because the TSP measurement also includes all $PM_{2.5}$ and $PM_{10}$ particles, and during $PM_{10}$ events, particles were predominantly in the larger size fraction, indicating the particles were dust/airborne soil.

Overall there were ~6 times less $PM_{10}$ events at the gas field sites than TSP events. As for TSP events, Miles Airport was the only site where the influence of cattle farming was identified as contributing to $PM_{10}$ events. As for TSP, Hopeland was the only site where smoke from a vegetation fire was the main identified contributor to a $PM_{10}$ event.

#### Influence of CSG industry on $PM_{10}$ events

The CSG industry was identified as likely contributing to the dust component of a single smoke/dust $PM_{10}$ event at Condamine. However for reasons described above, the likely source/s of the 'unknown' component of dust in other events which are likely airborne soil may be related to CSG activities, unsealed roads and or/agriculture. As such the influence of the CSG industry on these events cannot be confirmed.

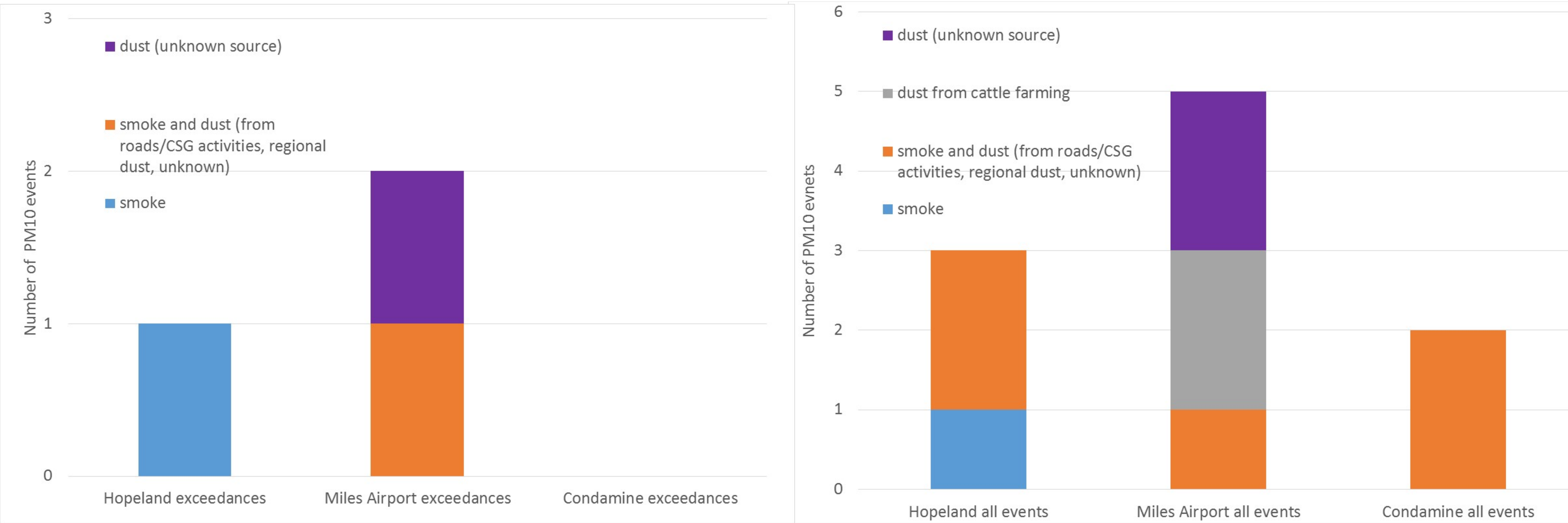


**Figure 5 Dominant sources identified as contributing to $PM_{10}$ events observed at the gas field sites for exceedance events (left) and all events (right). Note that this summarises only the dominant likely sources identified, not all possible contributing sources**

### 2.3.4 $PM_{2.5}$ events

Figure 6 shows the number of 24 hour average $PM_{2.5}$ exceedance events for Hopeland, Miles Airport and Condamine according to likely identified dominant source (left) and for all events, including exceedances and events> 80% the air quality objective (right). The colour in the columns corresponds to the likely identified source/s.

All of the likely dominant sources of $PM_{2.5}$ 24 hour average exceedances were identified as smoke from vegetation fires. The main source/s of $PM_{2.5}$ differs to the main sources of TSP and $PM_{10}$, because the fine particles in $PM_{2.5}$ are predominantly produced from combustion (e.g. fuel, vegetation) and secondary formation processes. Figure 6 shows that for all events there were some occasions when dust and smoke were identified as likely contributing to the observed $PM_{2.5}$ events. There was one event where dust of unknown origin was identified as the main source of $PM_{2.5}$. This event occurred alongside 24 hour average exceedances of $PM_{10}$ and TSP at the same site. While soil is made up mainly of particles in the large size range, a smaller proportion of airborne soil particles are likely to be in the fine ($PM_{2.5}$) size range, and during large dust events, this possibly led to $PM_{2.5}$ levels which were >80% of the air quality objective.

Overall $PM_{2.5}$ exceedances occurred slightly more frequently than $PM_{10}$ exceedances during the study. There were higher number of TSP exceedances than both $PM_{2.5}$ and $PM_{10}$ exceedances.

#### Influence of CSG industry on $PM_{2.5}$ events

Vegetation fires and regional dust events were identified as the main source of all but one $PM_{2.5}$ events during the study. The CSG industry may have contributed to the remaining event (>80% of air quality objective), along with other sources of airborne dust such as agriculture and traffic on unsealed roads.

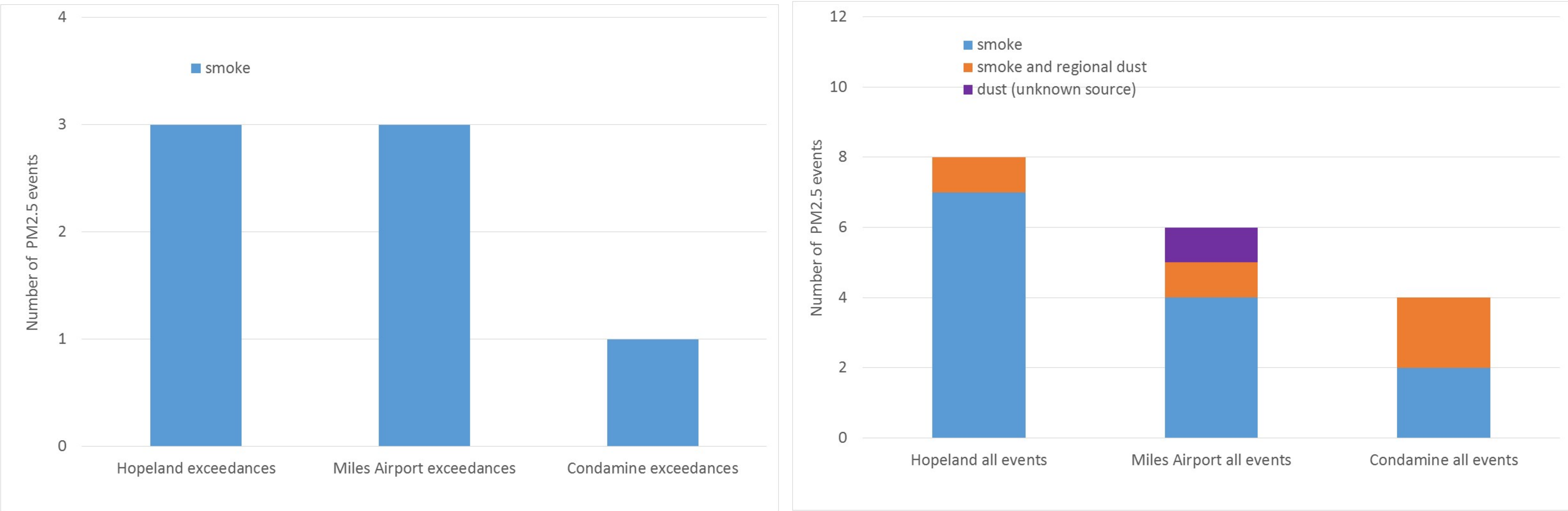


**Figure 6 Dominant sources identified as contributing to $PM_{2.5}$ events observed at the gas field sites for exceedance events (left) and all events (right). Note that this summarises only the dominant likely sources identified, not all possible contributing sources**

### 2.3.5 Methane events

The ten largest methane concentration events for each of the gas field sites were identified and examined (5 events from 2015-2016 and 5 events from 2017-18). The largest events were identified primarily based on hourly concentrations of methane and were investigated according to the protocols described in Section 2.3.1. There is no air quality standard for methane as it is not considered hazardous to human health at ambient concentrations. Instead methane in this study was used as a tracer for other components that may be present in CSG such as VOCs and hydrogen sulphide.

Figure 7 shows that CSG-related sources or activities were likely responsible for 50% of the largest Hopeland methane events, 80% of the largest Miles Airport events (with one event attributed to CSG-related activities and minor cattle influence) and 100% of the largest Condamine methane events. The influence of CSG-related activities on methane events seen at all sites is likely due to the close proximity of the gas field stations to CSG-infrastructure. The sites are located between 1 and 5 km from GPFs, have between 15 and 25 wells and associated gathering networks within a 2km radius and are 100 – 450 m from commissioned CSG wells. There were no exceedances of air quality objectives for other pollutants coinciding with any of the largest methane events identified.

Identifying the type of CSG-related activity or infrastructure most likely for the largest methane events (for example wells, gathering networks, GPFs, WTFs) was not possible. However, in all but one case the methane observed was likely to be un-combusted CSG released intentionally or accidently from CSG infrastructure, rather than combusted CSG (e.g. from flaring, gas fired engines), due to an absence of combustion marker gases alongside the methane.

At Hopeland and Miles Airport there were 5 and 1 methane event/s respectively where the source could not be determined. These events were likely due to build-up of methane in the boundary layer overnight, leading to concentrations higher than typical ambient levels. The source/s of this methane is unknown but could be from CSG-related sources, cattle, other sources or most likely a combination of sources.

#### Influence of CSG industry on methane events

The largest methane events were, in most cases, likely to be from activities or sources relating to the CSG industry, particularly at Condamine and Miles Airport. It is possible that emissions from the CSG industry could also be contributing to some or all of the events at Hopeland and Miles Airport which could not be identified. There were no exceedances of air quality objectives for other pollutants alongside any of the largest methane events identified.

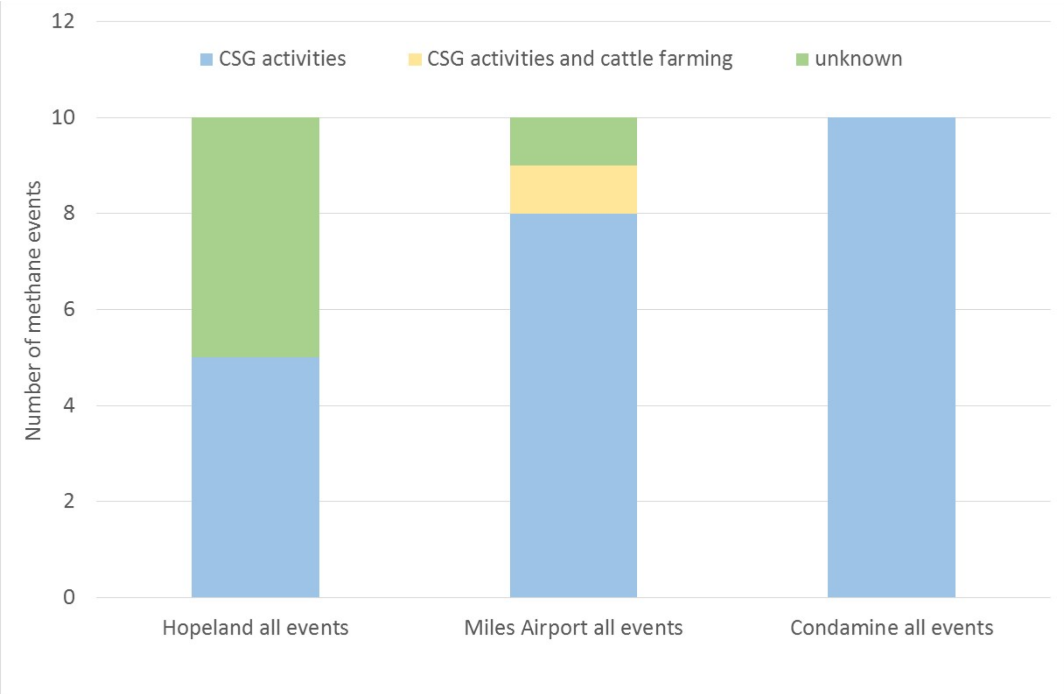


**Figure 7 Likely dominant source of the ten largest methane events for each of the gas field sites. Note that this summarises only the dominant likely source/s identified, not all possible contributing sources**

### 2.3.6 Ozone events

There were 3 occasions during the study where the 4 hour average ozone concentration was >80% of the air quality objective. These events occurred on two different days at Miles Airport and one at Burncluith. The 4 hour average concentration which was >80% of the air quality objective occurred in the afternoon during each event.

The ozone events were regional in nature, in that all or most of the 5 ambient monitoring sites showed a similar pattern of ozone concentration on the day of the event, and had higher than typical ozone, even though concentrations at other sites did not exceed the >80% of the air quality objective.

The cause/s of the 2 ozone events at Miles Airport is unknown. The ozone event at Burncluith is likely related to regional vegetation smoke to the north of the site, which contains the precursors (VOCs and $NO_x$) required for ozone to form in sunlight. However factors such as atmospheric mixing and meteorology also have a large influence on ozone formation.

#### Influence of CSG industry on ozone events

The influence of emissions from the CSG-industry on the 3 ozone events >80% of air quality objective could not be determined. However CSG-related emissions are unlikely to be a major contributor to the ozone precursors, given that for all 3 events ozone concentrations (and in one case precursor emission concentrations - $NO_x$) were enhanced across all monitoring sites, including regional sites. A regional smoke event was identified as a likely source of ozone precursor emissions in the Burncluith event.

## 2.4 Comparison of exceedance numbers with other Queensland sites

The purpose of this section is to provide some context about how the number of $PM_{2.5}$ and $PM_{10}$ exceedances in this study compare to number of exceedances in other parts of Queensland. This study also compares the source/s contributing to air quality exceedances in this study with sources in other areas. The number and source of exceedances of $PM_{2.5}$ and $PM_{10}$ in the study area are compared with three other sites in the Queensland air monitoring network, Jondaryan and Cannon Hill in the South East Queensland air monitoring network, and Moranbah in the MacKay air monitoring network. The number of TSP exceedances in this study have not been compared to other sites in the Queensland air monitoring network. This is because the TSP measurements from this study are unlikely to be equivalent to TSP measurements made at the other sites in the network due to different instruments deployed for TSP (Fidas in this study, TEOM in the Queensland monitoring network) resulting in different particle size ranges measured (see Section 1.3).

The Jondaryan site is in a rural inland location was located on the eastern side of Jondaryan township in South Eastern Queensland, and was installed to assess particle emissions from the Jondaryan Rail Loading Facility which is less than 1 km from the town. The Jondaryan Rail Loading Facility is a bulk handling facility for transporting coal by train from the Darling Downs to the Port of Brisbane. $PM_{2.5}$ and $PM_{10}$ continuous measurements were made at the air monitoring station at Jondaryan from March 2014 to August 2016. The Jondaryan site was ~120 km south east of the gas field sites in this study.

The Moranbah station in the Mackay network is in a rural inland location and measures particles to assess the impact of coal mining operations in the Moranbah community and surrounding area. $PM_{10}$ measurements were established in March 2011 and have continued to the present time. The Moranbah station is ~600 km to the north-north-west of the gas field sites from this study.

The Cannon Hill monitoring station in Brisbane is situated next to the metropolitan rail line used to transport coal to the Port of Brisbane. The site is located in an urban area approximately 5km from the Brisbane CBD. The Cannon Hill site is ~270km east-south-east of the gas field sites in this study. $PM_{2.5}$ and $PM_{10}$ continuous measurements commenced in February 2014 and have continued to the present time.

Jondaryan, Cannon Hill and Moranbah stations were chosen for comparison for the following reasons. Jondaryan and Moranbah were chosen as they are rural sites which may experience impacts from nearby industry (coal loading rail facility in Jondaryan, coal mining near Moranbah). In this way, they have some similarity with the gas field sites in this study, which are located in rural areas and may be impacted by emissions from CSG infrastructure and activities. It is important to note that particle impacts on air quality from coal loading and coal mining will not be equivalent to particle impacts from CSG activities. However data from Jondaryan and Moranbah have been assessed as suitable for comparison with the gas field sites, due to the limited number of rural monitoring sites in the Queensland air quality monitoring network, which tend to be located in urban areas with higher population density.

The Cannon Hill site was chosen because it provides measurements of $PM_{2.5}$ and $PM_{10}$ but in an urban environment in South East Queensland with higher population density than the gas field sites in this study. This site also has potential impact of the coal rail corridor nearby, but none of the exceedances at this site have been linked to rail transport (DSITI 2016, 2017).

The Jondaryan, Moranbah and Cannon Hill sites were also chosen because they have $PM_{2.5}$ and $PM_{10}$ measurements in years which overlap the measurement period of this study (2015 - 2018). This is desirable because factors such as rainfall, winds and synoptic weather conditions may vary year to year, leading to differences in frequencies of, for example, wind blown dust events, or inversion events. Meteorological statistics for gas field sites and wind roses for gas field and regional sites are provided from the entire study period in Appendix B.

Table 12- Table 13 below show the number of 24 hour average exceedances of $PM_{10}$ and $PM_{2.5}$ per year at the Hopeland, Miles Airport, Condamine, Jondaryan, Moranbah and Cannon Hill sites. The number of exceedances at different sites is compared and the likely sources discussed.

### 2.4.1 $PM_{10}$ 24 hour average exceedances and types of sources impacting

**Table 12 Comparison of number of $PM_{10}$ 24 hour average exceedances**

| | averaging period | Hopeland[1] | Miles Airport[2] | Condamine[3] | Jondaryan[4] | Moranbah[5] | Cannon Hill[6] |
|---|---|---|---|---|---|---|---|
| 2015 | 24 hour | 0 | 1 | nm | 7 | 4 | 1 |
| 2016 | 24 hour | 1 | 0 | 0 | 3 | 0 | 0 |
| 2017 | 24 hour | 0 | 1 | 0 | nm | 7 | 0 |
| 2018 | 24 hour | 0 | 0 | nm | nm | 1 | 0 |

**Measurements summarised from [1]Sep 2015 – Feb 2018, [2] Sep 2015 – Feb 2018, [3] Mar 2016 - June 2017 [4]March 2014 - August 2016, [5]Jan 2014-Feb 2018 [6]Feb 2014-Feb 2018**

- Where parallel measurements are available, Jondaryan and Moranbah typically had higher number of $PM_{10}$ exceedances per year (0-7) than gas field sites (0-1) (Hopeland, Miles Airport and Condamine) and Cannon Hill (0-1) (Table 12)
- Gas field sites had a similar number of $PM_{10}$ exceedances per year (0-1) as Cannon Hill (0-1)
- At Jondaryan, $PM_{10}$ exceedances were attributed to windblown dust, unsealed local roads and other activities involving ground disturbance, particles from the nearby rail wagon coal loading facility, bushfires and unknown sources.
- At Moranbah, $PM_{10}$ exceedances were attributed to windblown dust, vegetation fires and unknown sources
- At Cannon Hill, the single $PM_{10}$ exceedance was attributed to dust from rail track reconditioning word
- Overall, the Hopeland, Miles Airport and Condamine gas field sites had some similar sources contributing to $PM_{10}$ exceedances as the rural Jondaryan and Moranbah sites (windblown dust/unsealed roads, vegetation fires) but fewer number of $PM_{10}$ exceedances.

### 2.4.2 $PM_{10}$ annual exceedances

- There were no annual $PM_{10}$ exceedances at any gas field or comparison site, except for Moranbah in 2017. This was attributed to due to the impact of occasional high regional $PM_{10}$ episodes such as bushfire smoke events in July and September 2017 (DSITI 2018).

### 2.4.3 $PM_{2.5}$ 24 hour average exceedances and types of sources impacting

**Table 13 Comparison of number of 24 hour $PM_{2.5}$ exceedances**

| | averaging period | Hopeland[1] | Miles Airport[2] | Condamine[3] | Jondaryan[4] | Cannon Hill[5] |
|---|---|---|---|---|---|---|
| 2015 | 24 hour | 1 | 1 | nm | 2 | 0 |
| 2016 | 24 hour | 2 | 1 | 1 | 0 | 1 |
| 2017 | 24 hour | 0 | 1 | 0 | nm | 0 |
| 2018 | 24 hour | 0 | 0 | nm | nm | 0 |

Measurements from [1]Sep 2015 -Feb 2018, [2] Sep 2015- Feb 2018, [3] Mar 2016 - June 2017 [4]March 2014 - August 2016, [5]Jan 2014-Feb 2018

- Where parallel measurements are available, gas field sites had similar number of $PM_{2.5}$ exceedances per year (0-2) as Jondaryan (0-2), while Cannon Hill had 0-1 per year (Table 13). There are no $PM_{2.5}$ measurements at Moranbah
- At Jondaryan, $PM_{2.5}$ exceedances were attributed to bushfire smoke
- At Cannon Hill, the single $PM_{2.5}$ exceedance was attributed to a likely regional smoke event
- Overall, the Hopeland, Miles Airport and Condamine gas field sites had similar numbers of $PM_{2.5}$ 24 hour average exceedances per year as the Jondaryan and Cannon Hill sites. Smoke from bushfires or vegetation fires was the attributed source of the $PM_{2.5}$ exceedances at all sites.

### 2.4.4 $PM_{2.5}$ annual exceedances

There were no $PM_{2.5}$ annual exceedances at any site

### 2.4.5 Summary

Overall, the sites in this study had similar number of 24 hour average $PM_{2.5}$ exceedances per year as the comparison sites at Jondaryan (rural with industry influence) and Cannon Hill (urban/rail corridor). The sites in this study had fewer 24 hour average $PM_{10}$ exceedances per year than comparison sites at Jondaryan and Moranbah (rural with industry influence) and a similar number of $PM_{10}$ exceedances to the Cannon Hill (urban/rail corridor) site. As such, the number of exceedances per year were broadly similar to comparison sites.

Many sources contributing to exceedances at sites in this study were common to the comparison sites- for $PM_{10}$; windblown dust/unsealed roads, smoke from vegetation fires; $PM_{2.5}$ - smoke from bushfires/vegetation fires.

# 3 Overall findings from monitoring study

The purpose of this section is to summarise the main findings of this study and provide context to the findings. Section 3.1 summarises the overall air quality at the ambient air stations and passive gas monitoring sites, Section 3.2 discusses the impact of both regional and local sources on pollution events while Section 3.3 discusses the likelihood of CSG-related activities contributing to pollution events observed. Finally, in Section 3.4 and 3.5 upcoming modelling outputs, and significance of this study and next steps are discussed.

## 3.1 Air quality at ambient monitoring stations and passive gas sites

The main findings from the ambient air quality sites and passive gas monitoring sites is provided below. A detailed presentation and analysis of all the data from this study is provided in Lawson et al., (2018a) (data form 2014-2016) and Lawson et al (2018b) (data from 2017- 2018).

### Ambient air monitoring stations

Comparison of air monitoring data from the 3 gas field and 2 regional monitoring stations with air quality objectives showed that air quality was generally very good during the study period from 2015 - 2018.

There were no exceedances of annual air quality objectives for any pollutant measured at the gas field or regional ambient air monitoring stations (carbon monoxide, nitrogen dioxide, ozone, $PM_{2.5}$, $PM_{10}$ or TSP). There were no exceedances of any relevant air quality objectives for any gaseous pollutant (carbon monoxide, nitrogen dioxide ozone) at gas field or regional sites. Concentrations were almost always well below air quality objectives. There were 3 occasions (2 at gas field sites, 1 at regional site) when the 4 hour average concentration of ozone was >80% of the relevant air quality objective. In all 3 occasions, ozone was elevated across gas field and regional sites.

Particle concentrations ($PM_{2.5}$, $PM_{10}$ or TSP) were in most cases also well below air quality objectives, except for occasional exceedances of 24 hour average air quality objectives. From 2015 - 2018 there were 7 $PM_{2.5}$ exceedances, 3 $PM_{10}$ exceedances and 18 TSP exceedances of 24 hour average air quality objectives at gas field sites. Smoke from vegetation fires was identified as the main source of $PM_{2.5}$ exceedances, while a combination of vegetation fire smoke and dust, unsealed roads/CSG activities, regional dust and cattle farming were identified as the most likely sources of the $PM_{10}$ and TSP exceedances. Many of these sources are typical of other rural areas in Queensland (see Section 2.4). The identification of likely sources in this work focuses only on the dominant source/s that were identified during events, rather than all possible contributing sources.

### Passive gas measurements

Ambient measurements of 54 individual VOCs and aldehydes as well as hydrogen sulphide via the Radiello passive sampler network also showed a very good level of air quality from September

2014 - January 2016. VOCs and aldehyde passive measurements were assessed against the Air Toxics NEPM (NEPM 2011) and the Queensland Government Air EPP (EPP 2008). Where no Australian objectives were available, the Texas Commission on Environmental Quality Air Monitoring Comparison Values (AMCV) and Effects Screening Levels (ESLs) were used instead (Texas 2016). There were no exceedances of any relevant air quality objectives at any of the 7 gas field sites, 2 regional sites or the Chinchilla township site. Concentrations at all sites were consistently well below air quality objectives. There was less than one year of data of aldehydes and hydrogen sulphide to compare to annual air quality objectives, but given the concentrations observed it would be reasonable to assume the objective would be met.

Of the 54 targeted gases able to be measured by the Radiello passive samplers, 31 were measured above the detection limit in one or more of the passive samples from the gas field, regional and Chinchilla sites. Conversely, 23 gases which were not able to be detected in any of the samples, including hydrogen sulphide.

Gases most frequently detected (present in ≥80% of the samples from gas field, regional and/or Chinchilla sites) were benzene, toluene and xylenes (BTX), carbon tetrachloride, formaldehyde and acetaldehyde. BTX was detected more frequently at the Chinchilla site and the benzene/toluene ratio at Chinchilla was similar to other Australian urban and rural environments, indicating the source of BTX at the Chinchilla site is likely due predominantly to motor vehicles and domestic commercial sources. BTX concentrations in the study area were similar to other rural areas in Australia. Carbon tetrachloride, formaldehyde and acetaldehyde were detected evenly and at similar concentrations across gas field, regional and Chinchilla sites. These gases were observed at background concentrations typical of other parts of Australia and do not indicate the presence of a local source (Lawson et al., 2018a).

CSIRO undertook independent measurements of VOCs and aldehydes alongside the Radiello passive sampler measurements made by consultants at Hopeland monitoring station in June - July 2015. The overall good agreement between techniques provides support for the use of the Radiello passive sampler technique for monitoring VOCs and aldehydes in this study.

## 3.2 Regional and local sources

During this study the source of some of the exceedance events were regional in nature, where an emission source(s) impacted the pollutant concentrations in an area over hundreds of kilometres. Smoke and regional dust events are examples of regional sources in this study which caused exceedances for $PM_{2.5}$, $PM_{10}$ and TSP at multiple sites, while a regional smoke event was linked to elevated ozone concentrations. In other cases, the source of $PM_{2.5}$, $PM_{10}$ or TSP was a local event which occurred upwind of the measurement site and did not impact other monitoring sites. Examples include a vegetation fire, a local dust event (e.g. vehicle driving on unsealed road near monitoring site) and particles from cattle farming. In some cases, both local and regional sources contributed to an exceedance on the same day, for example a regional smoke event combined with a local dust event at Condamine leading to a 24 hour average exceedance of the nuisance dust guideline for TSP (see Lawson et al., 2018a, Section 4.5.2). For methane, which was measured as a tracer for CSG-related emissions, all the events attributed to the CSG industry (80% of events) were local in nature.

## 3.3 Influence of the CSG industry on pollution events

Emissions from the CSG industry were identified as likely contributing to several TSP and $PM_{10}$ 24 hour average events at gas field sites. In all cases airborne soil was the most likely source of TSP and $PM_{10}$, likely from vehicles driving on unsealed roads or other CSG development or operational activities. There were several other 'unknown' dust events throughout the study which were characterised by particles mainly in the large size fraction, suggesting airborne soil. However, the activity leading to the event could not be identified as being related to CSG-related activities or other activities. This was particularly the case at the Miles Airport and Hopeland sites which are surrounded not only by CSG infrastructure but are either on, or are adjacent to pastoral properties. These sites are likely to be influenced both by agricultural and CSG-related activities. As such the CSG industry activities were likely to have contributed to some of the 'unknown' events but this cannot not be confirmed.

Methane does not have an air quality objective, and is included in this study as a tracer for other species from CSG-related sources which do have air quality objectives. Of the 30 largest methane events observed, 80% were identified as likely from CSG-related activities or sources. None of these methane events were associated with an air quality exceedance for other pollutants measured. The type of CSG-related activity or infrastructure most likely for the largest methane events could not be identified. However, in all but one case the methane observed was likely to be un-combusted CSG released intentionally e.g via venting, or accidently, rather than combusted CSG (e.g. from flaring, gas fired engines). The remaining 20% of methane events investigated of unknown origin were likely due to build-up of methane in the stable boundary layer overnight, leading to concentrations higher than typical ambient levels. In these cases, the source/s of the methane was unknown but is most likely a combination of sources including CSG-related sources, cattle, and other sources.

Gas composition measurements shows that CSG in the study area is ~98% methane (Lawson et al., 2017). Other components such as BTX and hydrogen sulphide are at trace concentrations which would be expected to quickly dilute to ambient levels once CSG is released to air (Lawson et al., 2018a). Radiello passive sampler monitoring of BTX at the gas field sites supported this, with a low frequency of samples detecting BTX (~30%) and no samples detecting hydrogen sulphide. Where detected, BTX was at low levels, typical of other rural areas in Australia (Lawson et al., 2017). BTX had the highest detection frequency and concentrations at the Chinchilla township site, and ratio analysis indicated the source is likely predominantly motor vehicles, as well as domestic and commercial sources within the town.

The influence of CSG-related emissions on the 3 ozone events >80% of air quality objective could not be determined. However CSG-related emissions are unlikely to be a major contributor to the ozone precursors, given that for all 3 events ozone (and in one case precursor emissions) were enhanced across all monitoring sites (including regional sites). A regional smoke event was a likely source of precursor emissions in the Burncluith event (Section 2.3.6).

To conclude, this study found that air quality in the region was well within relevant air quality objectives for the majority of the time for a wide range of gaseous pollutants which are potentially emitted by CSG activities. Emissions from the CSG industry were likely to have contributed to the majority of the largest methane concentration events, however none of these methane events coincided with an air quality exceedance for other pollutants measured. Where detected, VOC and aldehyde concentrations in the gas fields were generally very low and well below relevant air quality objectives, typical of other rural locations. CSG activities were a likely contributor to infrequent coarse particulate matter ($PM_{10}$ and TSP) events along with a range of other regional activities and sources which are typical of rural areas. CSG-related dust emissions were in all cases attributed to airborne soil, emitted through vehicles driving on unsealed roads or other CSG development or operational activities.

## 3.4 Air quality modelling outputs

The air quality modelling component of this study will investigate the impact of CSG-related emissions on ozone and other pollutant concentrations by running the model with and without CSG-related emissions. This will give an estimate of the contribution of CSG-related emissions to total air pollutant levels. This differs from the approach used here, in which the CSG-related contribution was investigated only during pollution events (Lawson et al., 2018a, b). The model will also explore how the CSG industry contributes to the pollutant levels over a larger spatial area than is covered by the monitoring sites (300 km by 300 km).

## 3.5 Significance of this study and next steps

This was the first comprehensive study to assess air quality in a region of intensive CSG production in Australia over several years. The study provides the largest contribution to air quality data for the Surat Basin region to date, and gives important information about the levels and sources of air pollutants in the region. Pollutants were selected for monitoring based on a review of CSG-emission sources and composition in the region. Composition data used in the review including gas composition, composition of gas combustion emissions and water composition are available in Lawson et al., (2017). The outcome of the review was that a wide range of air pollutants were selected for monitoring, making the suite of measurements at the gas field sites among the most comprehensive in the Queensland air quality monitoring network. Data from the monitoring sites, including ozone, carbon monoxide, nitrogen dioxide, $PM_{2.5}$, $PM_{10}$ and TSP, was live streamed to allow community, government and industry to see in near real time how air quality in this region compares to other parts of Queensland and air quality objectives.

Ambient monitoring data and CSG source and composition data from this study will be available for use in current and future health studies (including the GISERA health study – Keywood et al., 2018) and environmental studies (including the GISERA Environmental Impacts of hydraulic fracturing study - Dunne et al., 2017). Data collected in this study will also be used to validate the performance and output of air quality models, and has been utilised in the development of CSIRO's air quality model as part of this GISERA project, described above.

Trends in air pollutant levels during the study could not be assessed with the time period of measurements and was not considered in the scope of this study. However this study does provide air pollutant data during a period of increasing CSG production levels in the region, and so can provide data against which future measurements can be compared.

This work will be available to government agencies to better understand air pollutant levels and pollution sources in the region and to inform future policy development. Study outputs can also be used by stakeholders to inform decision making around the need for future monitoring in the region.

While the measurements of air quality undertaken for this CSIRO project were scheduled to finish at regional and gas field sites at the end of February 2018, industry funding will likely extend air quality monitoring at the Tara Region sites and Hopeland and Miles Airport sites until the end of 2018. This additional monitoring, including reporting of data, is beyond the scope of this project.

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CONTACT US

**t** 1300 363 400
+61 3 9545 2176
**e** csiroenquiries@csiro.au
**w** www.csiro.au

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**CSIRO Oceans and Atmosphere**
Sarah Lawson
**t** +61 3 9239 4400
**e** **sarah.lawson**@csiro.au
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