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Ambient air quality in the Surat Basin, Queensland

Final data summary: January 2017 - February 2018

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Acknowledgments

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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

L - litre

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

Radiological surveys – measurement of radiation levels and assessment of radiation hazards in a given area

Sales gas – gas which has been processed by the gas processing facility

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

SVOC – semi volatile organic compound

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 CSG wells

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

Abbreviations

APLNG – Australia Pacific Liquefied Natural Gas

BTX – a subset of VOCs including benzene, toluene and xylenes

CO – carbon monoxide

CO_2 – carbon dioxide

CH_4 – methane

DES – Department of Environment and Science

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

Executive summary

A comprehensive ambient air quality study has been undertaken in the Surat Basin near the townships of Condamine, Miles and Chinchilla in Queensland. The purpose of the study was two-fold:

1) to measure and assess air quality, and

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

This report summarises data from the second half of the Surat Basin ambient air monitoring study (2017 - 2018) with the previous data (2014 - 2016) summarised in Lawson et al., (2018a). An overall assessment of air quality for the entire study period is provided a separate report (Lawson et al., 2018c).

Air quality measurements were made at 5 ambient air monitoring stations including 3 gas field sites and 2 regional sites (Figure 1 and Figure 2). The gas field stations were named Hopeland, Miles Airport and Condamine and measurements started in January 2015, July 2015 and March 2016 respectively. The gas field stations were located between 1 and 5 km from gas processing facilities (Orana, Condabri Central and Condabri South) and were located 100 – 450 m from operating CSG wells. Gas field stations had between 15 and 25 wells within a 2 km radius.

The 2 regional stations were incorporated into the study to investigate air pollution levels outside the gas field region. Regional stations were named Tara Region/Ironbark (26 km SE of Condamine township) and Burncluith (20 km NE of Chinchilla township). These sites 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 2015 and have been utilised for air quality measurements in this project since June 2016.

Along with meteorological variables the following pollutants were measured at the monitoring sites in this study:

• 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)
- meteorology (temperature, humidity, solar radiation, wind speed and direction).

• Regional ambient air quality stations:

- nitrogen oxides
- carbon monoxide (Burncluith data provided by GISERA Regional methane flux project)
- ozone
- meteorology (provided by GISERA Regional methane flux project)

Data reported here was collected during monitoring at Miles Airport, Hopeland and Burncluith from January 2017 - February 2018. The Condamine gas field station was decommissioned in June 2017 to be relocated to another site in the study area – this relocation is still underway. The Tara Region site suffered significant data loss during 2017 - 2018 due to technical issues resulting in unreliable power at this remote site. Power issues were resolved January in 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) (Air EPP), the National Environment Protection Measure (NEPM), and the Queensland Government Department of Environment and Science (DES) Nuisance Dust Guidelines for TSP.

During the period January 2017 – February 2018:

• There were no exceedances of carbon monoxide, nitrogen dioxide or ozone air quality objectives at any of the regional or gas field sites.

• There was 1 exceedance of the 24 hour average $PM_{2.5}$ objective, and 1 exceedance of the 24 hour average PM_{10} objective at the gas field sites. There were 10 exceedances of the 24 hour TSP nuisance dust objective at the gas field sites.

• There were no $PM_{2.5}$, PM_{10} or TSP measurements undertaken at the Regional sites.

A protocol which uses a combination of wind speed and direction, source locations, and pollutant correlations and ratios was developed to investigate the cause / source(s) of the 12 exceedances. Identifying likely sources of exceedances in this work focussed only on the dominant source/s, rather than all possible contributing sources. Based on these investigations, the most likely dominant cause or source/s of the exceedance events were as follows:

• The $PM_{2.5}$ exceedance was attributed to smoke from regional vegetation fire/s;

• The PM_{10} exceedance was attributed to a combination of a regional dust event and regional vegetation fire

• Three TSP events were attributed to a combination of regional dust and regional vegetation fire, 4 TSP events were attributed to cattle farming, 1 TSP event was attributed to dust from unsealed roads/CSG operational or development activities, and 1 TSP event was attributed to a regional dust event. The source/s of 1 event could not be determined.

A further 28 events where pollutant concentrations were greater than 80% of a relevant air quality objective were identified and investigated in recognition that an exceedance may have occurred closer to the pollutant source but not at the monitoring station. Most (26) of these events were 24 hour average concentrations of $PM_{2.5}$, PM_{10}, TSP. The same protocol was also used to determine the most likely cause or source(s) of these events with the findings as follows:

- The levels of carbon monoxide and nitrogen dioxide were always less than 80% of the air quality objectives at the regional and gas field sites
- $PM_{2.5}$ levels that were >80% of 24 hour average air quality objective were attributed to smoke from vegetation fires, a combination of smoke from vegetation fires and dust
- PM_{10} levels that were >80% of the 24 hour average air quality objective were attributed to smoke from a combination of vegetation fires and dust, particles associated with cattle farming;
- TSP levels that were >80% of the 24 hour average air quality objective were attributed to regional dust, particles associated with cattle farming, unsealed roads and/or CSG development or operational activities, source undetermined.
- Ozone levels that were >80% of the 4 hour average air quality objective were attributed to emissions from a regional fire, and source/cause undetermined.

Methane emissions and implications for air quality

CSG in the study area is approximately 98% methane (Lawson et al., 2017). There is no air quality objective for methane, instead methane was measured at the gas field sites as a tracer for other components in CSG which have air quality objectives, such as VOCs and hydrogen sulphide. The 2017 annual average methane concentration at the gas field sites was 1.9 ppm, comparable to methane concentrations of 1.8 ppm measured at the two regional sites as part of the GISERA Regional Methane Flux study (Luhar et al., 2018). Determination of the regional emissions of methane in the study area was addressed as part of the GISERA Regional Methane Flux study (Day et al., 2015, Etheridge et al., 2017, Luhar et al., 2018).

The 5 largest methane events at each of the 3 gas field sites from 2017 - 2018 were identified and the potential source(s) investigated, making a total of 15 methane events investigated during this period. Nine of the 15 methane events investigated were attributed to sources or activities associated with the CSG industry, 1 was attributed to a combination of the CSG industry and cattle farming, and the source of the remaining 5 could not be determined. None of the methane events investigated coincided with an exceedance of an air quality objective for any of the other pollutants measured. Eight of the 9 methane events attributed to CSG-related sources were likely due to the release of un-combusted CSG from gas infrastructure, while the remaining event may have been related to gas combustion.

In summary, air pollutant concentrations across the Surat Basin monitoring network during 2017-2018 were generally well below air quality objectives for the majority of the time. There were a number of infrequent exceedances of 24 hour air quality objectives for particles, particularly TSP. The sources of the particles identified were typical of rural areas, including smoke from vegetation fires, windblown dust, unsealed roads, particles associated with agriculture, and CSG-related activities at one site.

An overall assessment of air quality in region over the entire study period (2014 – 2018) is provided in a separate report (Lawson et al., 2018c). 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 ambient monitoring sites 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 reporting of 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 is 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 Section 1 of this report is to provide background information about the monitoring program including the ambient air monitoring station network.

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) and is reproduced here.

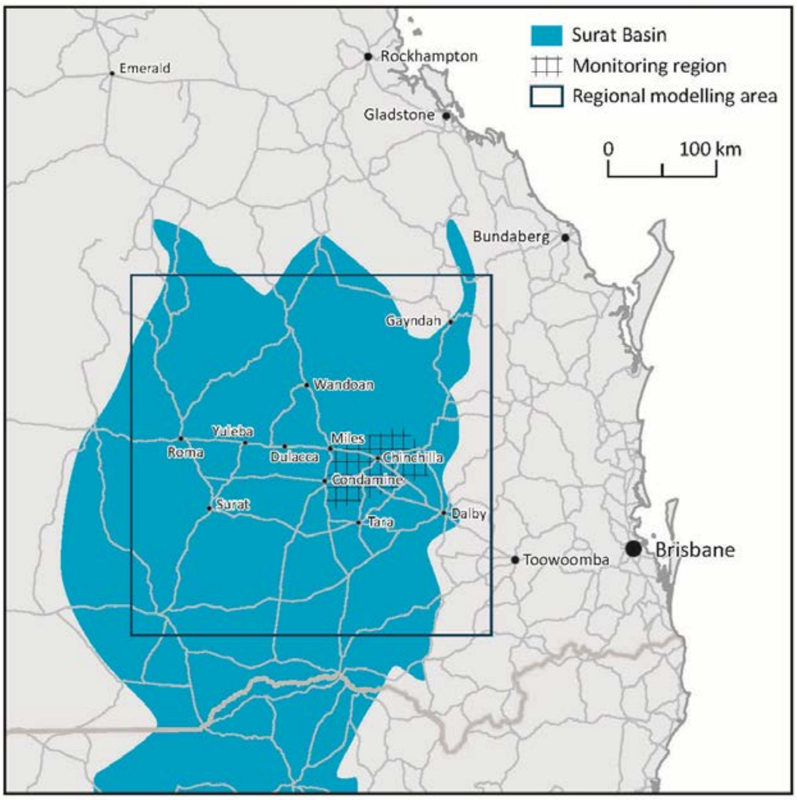

Figure 1 Study area (source: Lawson et al., 2017)

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 from 2015 - 2016 was reported in Lawson et al. (2018a).

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 is expected to experience the largest impact of CSG emissions of methane, 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 (AS/NZ 3580.1.1:2016).

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, and have been 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. The decision was made to move Condamine rather than Hopeland or Miles Airport, because Condamine was the most recently installed station (~ 1 year prior) while Miles Airport and Hopeland had been already running for 2+ years, and having uninterrupted measurements at these sites with a longer data record was desirable. Further, the Condamine site was not compliant with the Australian Standard for monitoring sites (see 1.1.1 below) due to a tree within 10m of the site. The Condamine site was a similar distance to major gas infrastructure and had a similar number of surrounding gas wells as the Miles Airport site. In addition, analysis of the number of exceedances across the 3 gas field sites showed broadly similar numbers of PM_{10}, $PM_{2.5}$ and TSP exceedances per year at Hopeland, Miles Airport and Condamine. As such it was considered that all three gas field sites were representative of pollution levels in the gas fields study area, and as such one station could be moved elsewhere without compromising the objectives of the project. This relocation of the Condamine station is still underway.

1.1.1 Compliance with AS/NZ 3580.1.1 2016

The Hopeland, Miles Airport, Burncluith and Tara Region/Ironbark sites complied with Australian Standard 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 located on a residential property and had a house with a chimney within 50 m to the south east of the monitoring site. Emissions of smoke from this chimney were only expected to influence the data intermittently (at night in winter, and in south easterly or light winds) and would 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 meets 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 SE are infrequent at this site (see A.6.3). As such the tree was not expected to have a large impact on measurements made at this site.

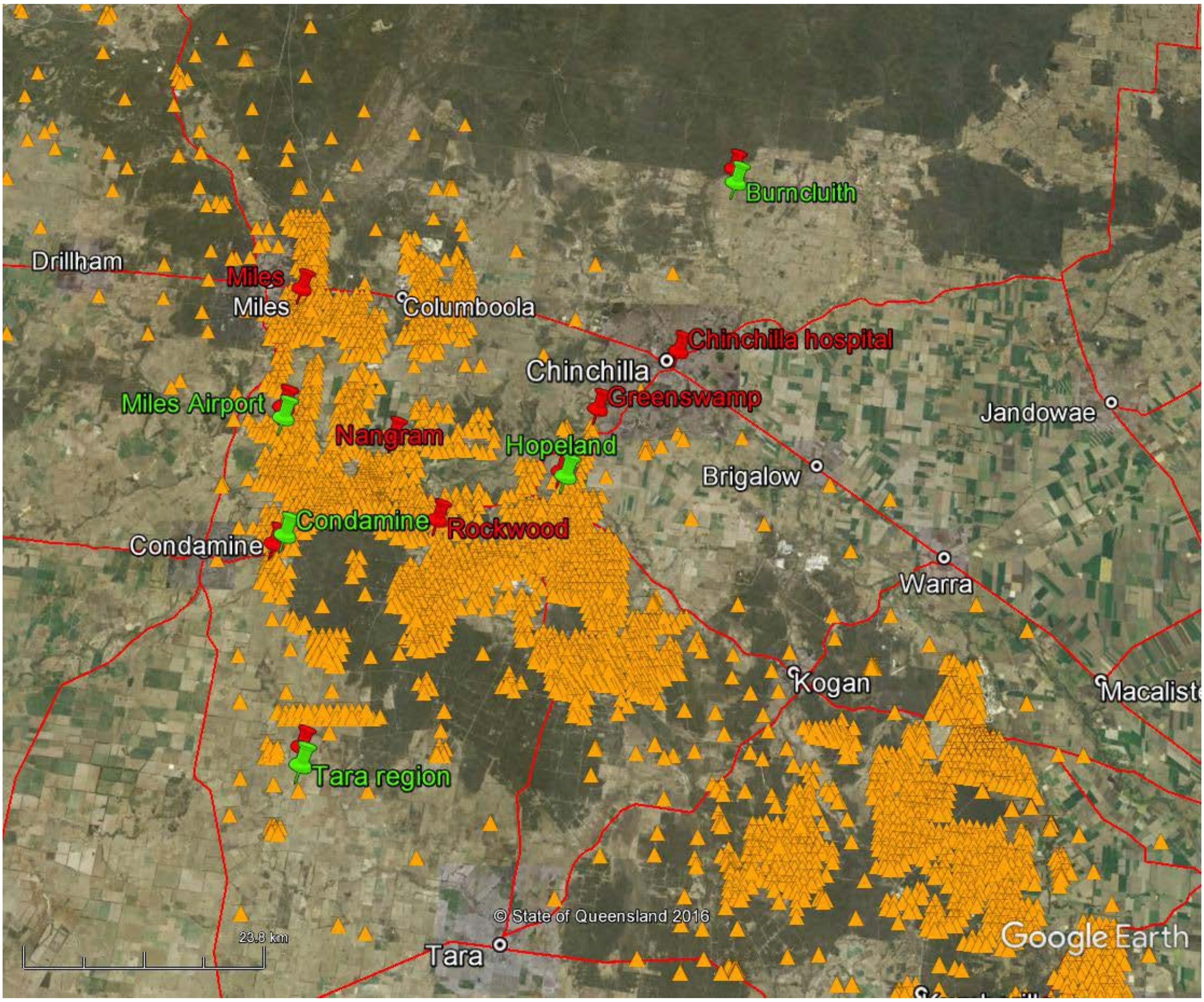

Figure 2 Location of monitoring sites. Town names in white text, green pins are ambient air monitoring sites, red pins are passive gas sites, orange triangles are CSG wells. Source: Lawson et al., (2017).

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) Nearest well 100 m	1 (0 commissioned)[1]	15 (14 commissioned)
Miles Airport	July 2015 – February 2018	Gas fields	Condabri Central GPF (1.5 km NW) Miles Airport (3.5 km E) Feedlot (2. 3km NE/E) Nearest well 450 m	20 (all commissioned)	20 (all commissioned)
Condamine	March 2016 – June 2017	Gas fields	Condabri South GPF (1 km SE) Condamine township (8 km E) Nearest well 230 m	25 (23 commissioned)	25 (24 commissioned)
Tara Region (Ironbark)	June 2016 – February 2018	Regional	Nearest well 1 km	1 (plugged and abandoned)	1 (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 (ozone), 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 are being 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). There were no particle measurements at Regional sites due to budget constraints.

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 are measured at Gas field sites : nitrogen dioxide), photochemical oxidants (as ozone), carbon monoxide (CO) and particles (as $PM_{2.5}$, PM_{10}).

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
Oxides of nitrogen (NO_x)	Yes	Yes	gas fired engines gas flaring diesel exhaust
Carbon monoxide (CO)	Yes	Yes^	gas fired engines gas flaring diesel exhaust
Ozone (O_3)	Yes	Yes	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 Fluxe 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 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) are 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 volatile organic compounds (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 particulates 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). Potential 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 but also from other non-combustion sources including wind-blown dust. TSP, the largest size fraction includes all $PM_{2.5}$ and PM_{10} particles, 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 not necessarily 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. Terrestrial seeps or legacy boreholes are another possible source of methane in the study area.

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 air toxics 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) was collected as part of the GISERA Regional Methane Flux project (Day et al., 2015; Etheridge et al., 2017), 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 are made at the 3 Gas field sites. VOCs are a group of gases which are relatively short lived, exist as gases at ambient temperatures and participate in photochemical reactions in the atmosphere. The TVOC measurement method employed in this study (see A.1) provides 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 which 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.

In addition to the TVOC measurement at the Gas field sites, during 2014 – 2016 a network of passive VOC samples was deployed over the study area which provided fortnightly integrated measurements of individual VOCs, the results from which were previously reported in Lawson et al., (2018a).

1.3 Ambient air monitoring stations - Role of measurement service providers and CSIRO/QA QC – data management

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-accredited laboratory which means it meets all objectives of ISO17025 for competence of a laboratory to carry out sampling, tests and calibrations using validated test methods. Ecotech were responsible for instrument installation, calibration, operation 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 were 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, assessing compliance with relevant Australian Standards. Ecotech then provided monthly validated data to CSIRO who then 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 was approved by CSIRO. Data that was removed due to issues with instrument performance or other issues are not presented in this report. The reasons for removal of data for each measurement and each site are provided in the footnotes of the data summary tables for each pollutant and more details can be found in A.2.

Data availability (%) reported are based on the proportion of the total month that validated data was captured. Data statistics (including average and maximum concentrations) are only reported in the monthly statistics tables for each pollutant when the monthly data availability exceeded 75%, as per NEPM technical paper no. 5 (PRC 2001). All valid data (even for months where data availability was below 75%) are included in the time series plots.

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 A.2 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 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 Section 2.2 for summary and Appendix A.3 for full details). Concentrations of $PM_{2.5}$ during the comparison were too low to compare methods, while a comparison was not undertaken for TSP as it was considered a lower priority for method comparison than PM_{10} and $PM_{2.5}$ as it is not a NEPM criteria pollutant (NEPM 2016). 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 in higher ambient concentrations (see A.3) suggests but cannot confirm equivalency to Australian standard methods. TSP concentrations obtained using the Fidas cannot be considered an equivalent method to the Australian Standard gravimetric method (AS/NZS 2015) and TSP data are indicative only.

1.4 Reasons for low data capture at monitoring sites

The amount of data captured by each instrument was affected by power failures, instrument faults, maintenance activities and instrument performance issues. Overall there was a lower data capture at the monitoring sites during 2017-2018 than during the previous period (2015 – 2016) reported in Lawson et al., (2018). Reasons for this are discussed below. Specific reasons for monthly data capture rates of <75% data are listed for each pollutant for each month in Sections 2 and 3, with detailed explanations provided in Appendix A.2.1.

Power and air conditioner failures – Hopeland and Miles Airport

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. In some cases, as occurred at Miles Airport in August - September 2017 and Hopeland in March - April 2017, power outages led to air conditioner failures at the monitoring station 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 has not impacted the project's ability to meet scientific objectives as there is good data coverage from Burncluith, the other regional site.

Controlled Power shutdown

Data loss at Hopeland in June - July 2017 occurred due to the power being turned off as a groundwater bore in the vicinity of the site switch board had to be decommissioned.

Instrument faults

The instruments used to measure air quality at the 5 ambient air quality stations are operated by Ecotech Pty Ltd (see A.1 for instrument details). In case of instrument faults, Ecotech provide technicians who repair 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.

1.5 Live data streaming

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

At the time of streaming, data had not undergone data validation procedures (see above). Data streamed included carbon monoxide, nitrogen dioxide, ozone and $PM_{2.5}$, PM_{10} and TSP (Hopeland, Miles Airport, Condamine) and carbon monoxide, nitrogen oxides, 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 15). This live data streaming allowed comparison of the air quality in the SW 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 https://data.qld.gov.au/dataset

2 Data summary: Carbon monoxide, nitrogen dioxide, ozone, $PM_{2.5}$, PM_{10} and TSP measurements– gas field and regional sites

The purpose of this section is to

- Present air quality objectives used for assessing pollutant concentrations
- Compare pollutant concentrations with air quality objectives, and document any exceedances
- Present statistics and time series plots of each pollutant concentration

Data from gas field and regional sites from January 2017 - February 2018 are presented. For occasions where measured concentrations exceeded ambient air quality objectives, an analysis of the likely source of each exceedance is presented in Section 4. Carbon monoxide, nitrogen dioxide, ozone, $PM_{2.5}$, PM_{10} and TSP data from 2015 – 2016 is presented in Lawson et al., (2018a).

2.1 Summary of measured ambient concentrations

2.1.1 Carbon monoxide

The NEPM/EPP 8-hour air quality objective for carbon monoxide is 9 ppm. The concentrations measured across all sites were well below the NEPM/EPP standard (9 ppm) with 8 hourly average values ranging from 0.1 – 0.5 ppm. There were no exceedances of the Air EPP/NEPM (air) 8-hour average air quality objective for carbon monoxide at any of the sites in this study from January 2017 to February 2018. A time series showing the maximum 8-hour concentration of carbon monoxide at the three gas field and 2 regional sites is shown in Figure 3. All values were well below the air quality objective.

Summary statistics for the carbon monoxide concentrations observed at the gas field and regional sites for each month from January 2017 to February 2018 are shown in Table 6 and Table 7, including the maximum 8 hour value, the average 8 hour the and average 1 hour value for each month. Note that the 1 hour average values do not have a relevant air quality objectives for comparison and are provided for additional information. CO measurements at the Condamine site ceased when the site was decommissioned in June 2017. Carbon monoxide measurements from Burncluith were made as part of the GISERA Regional Methane Flux project (Day et al., 2015, Etheridge et al., 2017, Luhar et al., 2018) and data has been provided for use in this project.

Where data availability was <75% for a month, the specific reason is provided in the footnote of the table. More details on reasons for low data availability is provided in A.2.

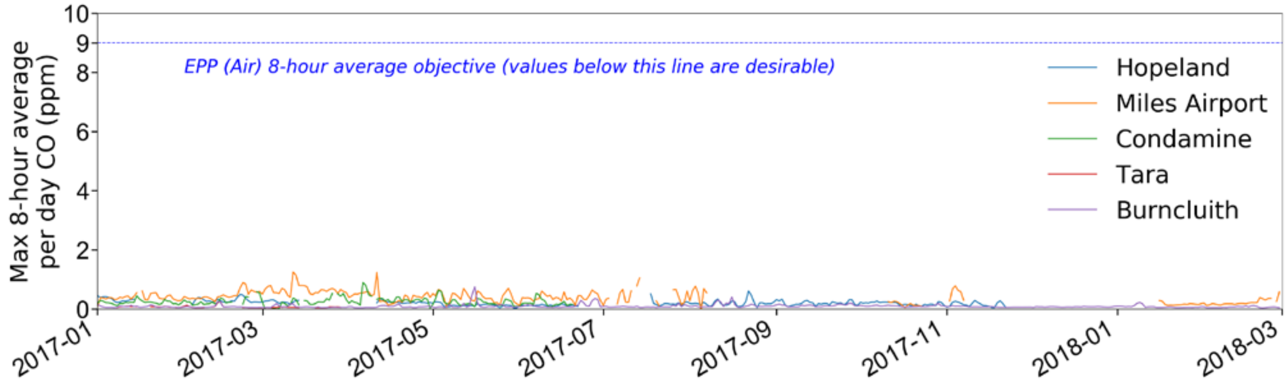

Figure 3 Daily maximum 8 hour averages for carbon monoxide for all 5 sites

Table 3 Ambient concentrations of carbon monoxide. Monthly maximum and average 8-hour concentrations and monthly 1-hour average concentration for all sites for 2017 (ppm).

CO - 2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hopeland												
Max 8-hour	-	0.5	-	-	0.2	-	-	0.6	0.3	0.3	-	-
Average 8-hour	-	0.2	-	-	0.1	-	-	0.1	0.1	0.1	-	-
Average 1-hour	-	0.2	-	-	0.1	-	-	0.1	0.1	0.1	-	-
% Data Avail	40[a,e]	82	42[a,d]	62[d]	93	68[a]	42[a]	96	96	95	61[b]	0[b]
Miles Airport												
Max 8-hour	0.6	0.9	1.2	1.2	0.7	0.6	-	-	-	-	-	-
Average 8-hour	0.3	0.4	0.5	0.3	0.3	0.3	-	-	-	-	-	-
Average 1-hour	0.3	0.4	0.5	0.3	0.3	0.3	-	-	-	-	-	-
% Data Avail	85	95	93	89	85	93	38[b]	18[a,d]	0[a,b]	35[b]	16[b]	0[b]
Condamine												
Max 8-hour	0.4	-	0.5	0.9	0.6	0.5	-	-	-	-	-	-
Average 8-hour	0.2	-	0.1	0.2	0.1	0.1	-	-	-	-	-	-
Average 1-hour	0.2	-	0.1	0.2	0.1	0.1	-	-	-	-	-	-
% Data Avail	93	68[a]	84	82	94	92	-	-	-	-	-	-
Burncluith												
Max 8-hour	0.2	0.3	0.2	0.2	0.8	0.4	0.2	0.4	0.2	0.2	0.1	0.1
Average 8-hour	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Average 1-hour	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
% Data Avail	97	99	96	96	96	100	99	100	100	98	99	99
Tara Region												
Max 8-hour	-	-	-	-	-	-	-	-	-	-	-	-
Average 8-hour	-	-	-	-	-	-	-	-	-	-	-	-
Average 1-hour	-	-	-	-	-	-	-	-	-	-	-	-
% Data Avail	46[a]	62[e]	66[a,e]	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure

Table 4 Ambient concentrations of carbon monoxide. Monthly maximum and average 8-hour concentrations and monthly 1-hour average concentration for all sites for 2018 (ppm).

CO - 2018	Jan	Feb
Hopeland		
Max 8-hour	-	-
Average 8-hour	-	-
Average 1-hour	-	-
% Data Avail	0[b]	0[b]
Miles Airport		
Max 8-hour	-	0.6
Average 8-hour	-	0.2
Average 1-hour	-	0.2
% Data Avail	46[b]	83
Burncluith		
Max 8-hour	0.2	0.1
Average 8-hour	0.1	0.1
Average 1-hour	0.1	0.1
% Data Avail	100	99
Tara Region		
Max 8-hour	-	-
Average 8-hour	-	-
Average 1-hour	-	-
% Data Avail	0[a,e]	0[a,e]

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure

2.1.2 Nitrogen dioxide

The Air EPP/NEPM (air) 1-hour air quality objective for nitrogen dioxide is 120 ppb (0.120 ppm). The concentrations measured across all sites were well below the NEPM/EPP standard (120 ppb or 0.120 ppm) with hourly average values ranging from 0.001 – 0.004 ppm. The annual air quality objective for nitrogen dioxide is 30 ppb (0.03 ppm) and the measured annual averages were well below this, ranging between 0.002- 0.003 ppm. There were no exceedances of the annual and 1-hour average air quality objectives for nitrogen dioxide at any of the sites in this study from January 2017 to February 2018.

A time series showing the maximum 1-hour concentration of nitrogen dioxide at the three gas field and two regional sites is shown in Figure 4. All values were well below the air quality objectives. Summary statistics of the nitrogen dioxide concentrations for each month from January 2017 to February 2018 are shown in Table 5 and Table 6, including the maximum 1-hour and average 1-hour concentration for each month, as well as the annual average. Nitrogen dioxide measurements ceased at Condamine when the site was decommissioned in June 2017.

Where data availability was <75% for a month, the specific reason is provided in the footnote of the table. More details on reasons for low data availability is provided in A.2.

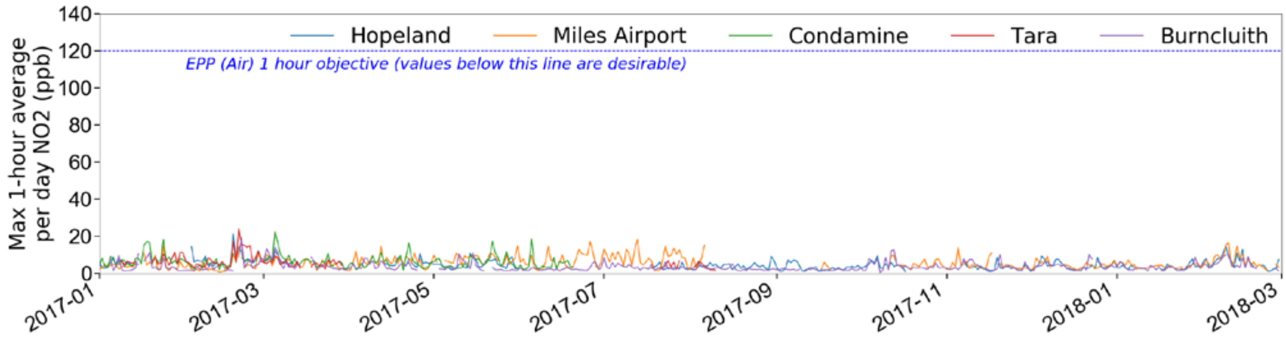

Figure 4 Daily maximum 1 hour concentration of nitrogen dioxide for all sites. Note that concentrations in this figure are in parts per billion (ppb) (where 1 ppb = 0.001 ppm)

Table 5 Ambient concentrations of nitrogen dioxide. Annual average and monthly maximum and average 1-hour concentrations (ppm) for all sites for 2017.

NO_2 - 2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hopeland												
Max 1-hour	-	0.021	-	-	0.011	-	-	0.009	0.007	-	0.009	0.009
Average 1-hour	-	0.004	-	-	0.002	-	-	0.001	0.001	-	0.001	0.002
% Data Avail	44[a]	88	42[a,d]	57[d]	93	68[a]	42[a]	96	96	49[e]	75	91
Annual Average	0.002											
Miles Airport												
Max 1-hour	0.015	0.017	0.01	0.014	0.015	0.017	0.018	-	-	-	0.014	0.009
Average 1-hour	0.001	0.001	0.002	0.002	0.003	0.003	0.003	-	-	-	0.002	0.002
% Data Avail	88	95	93	95	78	96	96	19[a,d]	9[a,b]	62[b]	87	80
Annual Average	0.002											
Condamine												
Max 1-hour	0.018	-	0.022	0.016	0.017	0.018	-	-	-	-	-	-
Average 1-hour	0.003	-	0.003	0.002	0.002	0.002	-	-	-	-	-	-
% Data Avail	96	68[a,e]	88	84	96	94	-	-	-	-	-	-
Annual Average	-											
Burncluith												
Max 1-hour	-	0.019	0.014	0.008	0.011	0.006	0.009	0.005	0.003	0.013	0.01	0.01
Average 1-hour	-	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.002
% Data Avail	73[a,f]	75	80	75	75	92	91	91	87	92	92	81
Annual Average	0.002											
Tara Region												
Max 1-hour	-	0.024	-	-	-	-	-	-	-	-	-	-
Average 1-hour	-	0.004	-	-	-	-	-	-	-	-	-	-
% Data Avail	53[a]	90	73[a,b]	0[a]	0[a]	0[a]	27[a]	22[a]	0[a]	0[a]	0[a]	0[a]
Annual Average	-											

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure

Table 6 Ambient concentrations of nitrogen dioxide. Annual average and monthly maximum and average 1-hour concentrations (ppm) for all sites for 2018

NO_2 - 2018	Jan	Feb
Hopeland		
Max 1-hour	-	0.015
Average 1-hour	-	0.002
% Data Avail	62[b]	85
Annual Average	-	
Miles Airport		
Max 1-hour	0.007	0.016
Average 1-hour	0.002	0.003
% Data Avail	95	84
Annual Average	-	
Burncluith		
Max 1-hour	0.009	-
Average 1-hour	0.001	-
% Data Avail	91	68[e]
Annual Average	-	
Tara Region		
Max 1-hour	-	-
Average 1-hour	-	-
% Data Avail	0[a,e]	0[a,e]
Annual Average	-	

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure

2.1.3 Ozone

The Air EPP/NEPM (air) 1-hour and 4- hour air quality objectives for ozone are 100 ppb (0.1 ppm) and 80 ppb (0.08 ppm) respectively. The measured concentrations across all sites were generally well below the NEPM/EPP objective values (100 ppb or 0.1 ppm) with hourly average values of 0.02 – 0.03 ppm. There were no exceedances of the 1-hour and 4-hour average air quality objectives for ozone at any of the sites in this study from January 2017 to February 2018. Ozone measurements ceased at Condamine when the site was decommissioned in June 2017.

Time series showing the maximum 4-hour and maximum 1-hour concentration of ozone at the three gas field and two regional sites is shown in Figure 5 and Figure 6. Summary statistics of the ozone concentrations for each month from January 2017 to February 2018 are shown in Table 7 and Table 8, including the maximum and average 1-hour and maximum and average 4-hour concentrations for each month.

Where data availability was <75% for a month, the specific reason is provided in the footnote of the table. More details on reasons for low data availability is provided in A.2.

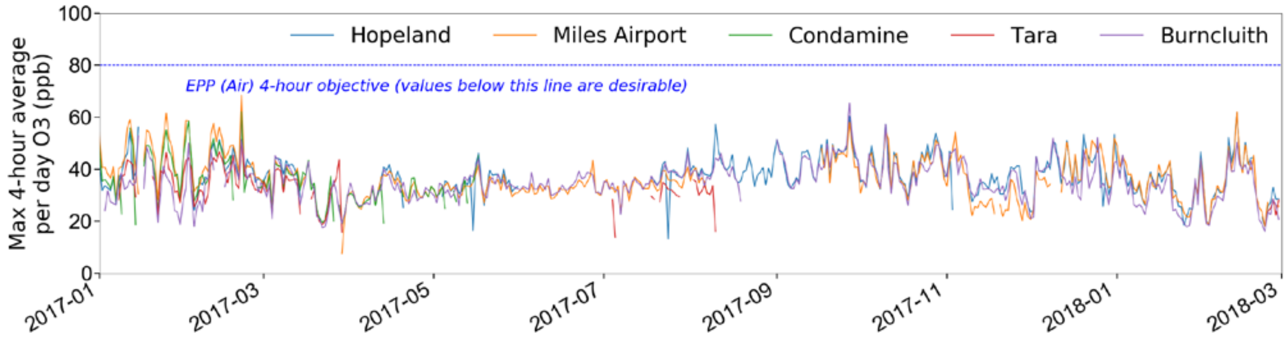

Figure 5 Daily maximum 4-hour concentrations of ozone for all sites. Note that concentrations in this figure are in parts per billion (ppb) (where 1 ppb = 0.001 ppm)

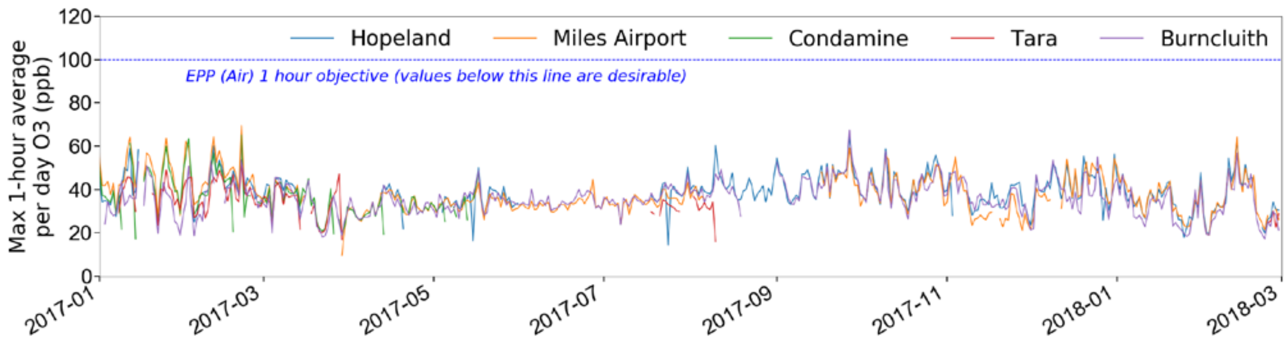

Figure 6 Daily maximum 1 hour average concentration of ozone for all sites. Note that concentrations in this figure are in parts per billion (ppb) (where 1 ppb = 0.001 ppm)

Table 7 Ambient concentrations of ozone. Monthly maximum and average 4-hour and 1-hour concentrations (ppm) at all sites for 2017.

O_3 - 2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hopeland												
Max 4-hour	-	0.063	-	-	0.046	-	-	0.057	0.06	0.057	0.047	0.053
Max 1-hour	-	0.064	-	-	0.05	-	-	0.06	0.065	0.059	0.048	0.056
Average 4-hour	-	0.028	-	-	0.023	-	-	0.027	0.032	0.03	0.026	0.029
Average 1-hour	-	0.029	-	-	0.023	-	-	0.028	0.033	0.03	0.026	0.029
% Data Avail	43[a]	87	42[a,d]	27[b,d]	82	68[a]	38[a]	95	94	94	79	90
Miles Airport												
Max 4-hour	0.062	0.069	-	0.039	0.042	0.043	0.041	-	-	0.055	0.054	0.052
Max 1-hour	0.064	0.07	-	0.04	0.043	0.045	0.044	-	-	0.056	0.055	0.054
Average 4-hour	0.03	0.031	-	0.023	0.023	0.024	0.024	-	-	0.03	0.022	0.027
Average 1-hour	0.031	0.031	-	0.023	0.023	0.024	0.024	-	-	0.03	0.023	0.028
% Data Avail	88	95	51[b]	95	94	95	93	17[a,d]	42[a]	93	87	80
Condamine												
Max 4-hour	0.056	-	0.043	-	-	-	-	-	-	-	-	-
Max 1-hour	0.061	-	0.045	-	-	-	-	-	-	-	-	-
Average 4-hour	0.026	-	0.022	-	-	-	-	-	-	-	-	-
Average 1-hour	0.026	-	0.022	-	-	-	-	-	-	-	-	-
% Data Avail	76	71[a]	86	62[b]	27[b]	-	-	-	-	-	-	-
Burncluith												
Max 4-hour	0.053	0.052	0.045	0.04	0.044	0.039	0.047	-	0.065	0.057	0.048	0.052
Max 1-hour	0.053	0.054	0.046	0.042	0.049	0.04	0.048	-	0.067	0.058	0.048	0.055
Average 4-hour	0.023	0.025	0.022	0.023	0.024	0.024	0.024	-	0.034	0.03	0.027	0.027
Average 1-hour	0.023	0.025	0.023	0.023	0.024	0.025	0.025	-	0.035	0.03	0.027	0.028
% Data Avail	77	79	89	92	91	91	91	53[e]	93	93	92	89
Tara Region												
Max 4-hour	-	0.051	-	-	-	-	-	-	-	-	-	-
Max 1-hour	-	0.052	-	-	-	-	-	-	-	-	-	-
Average 4-hour	-	0.025	-	-	-	-	-	-	-	-	-	-
Average 1-hour	-	0.025	-	-	-	-	-	-	-	-	-	-
% Data Avail	53[a]	90	73[a]	0[a]	0[a]	0[a]	26[a]	21[a]	0[a]	0[a]	0[a]	0[a]

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure

Table 8 Ambient concentrations of ozone. Monthly maximum and average 4-hour and 1-hour concentrations (ppm) at all sites for 2018.

O_3 - 2018	Jan	Feb
Hopeland		
Max 4-hour	0.047	0.062
Max 1-hour	0.048	0.063
Average 4-hour	0.024	0.025
Average 1-hour	0.024	0.025
% Data Avail	91	86
Miles Airport		
Max 4-hour	0.049	0.062
Max 1-hour	0.05	0.064
Average 4-hour	0.025	0.025
Average 1-hour	0.025	0.025
% Data Avail	94	84
Burncluith		
Max 4-hour	0.045	0.05
Max 1-hour	0.047	0.057
Average 4-hour	0.022	0.023
Average 1-hour	0.023	0.023
% Data Avail	91	90
Tara Region		
Max 4-hour	-	-
Max 1-hour	-	-
Average 4-hour	-	-
Average 1-hour	-	-
% Data Avail	0[a]	15[a]

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure

2.2 Particles ($PM_{2.5}$, PM_{10}, TSP)

Particle measurements were made at the three gas field sites (Hopeland, Miles Airport and Condamine) but were not made at the two regional sites (Burncluith and Tara Region) due to budget constraints. Particle measurements ceased at Condamine when the site was decommissioned in June 2017.

2.2.1 Particle measurement method comparison

The PM instrumentation (Fidas – see A.1) deployed at the Gas field sites was selected because it provided a cost effective means of simultaneously measuring real-time $PM_{2.5}$, PM_{10} and TSP.

While the Fidas it is not an Australian Standard Method for $PM_{2.5}$ and PM_{10}, it has shown good agreement for $PM_{2.5}$ and PM_{10} with Standard methods in four European and UK urban locations (TUV 2015). However, because measurements using optical techniques such as the Fidas may be influenced by the composition of particles in the environment it is measuring, it was desirable to test the performance of the Fidas for $PM_{2.5}$ and PM_{10} in Australian rural conditions relevant to this study. Note that a method comparison for TSP was not undertaken, as this 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 Australian Standard Method (AS/NZS 3580.9.3:2015).

CSIRO made independent measurements of $PM_{2.5}$ and PM_{10} alongside the existing particle instrumentation (Fidas) at the Miles Airport site for 6 months in 2017. CSIRO deployed a Teledyne-API dual channel Model 602 BetaPLUS Particle Measurement System based on beta attenuation (herein called BAM) which produces data equivalent to Australian Standard Methods (AS/NZS 3580.9.11.2008 (PM_{10}) and AS/NZS 3580.9.12:2013 ($PM_{2.5}$)).

The method comparison at Miles Airport site found good agreement between PM_{10} measured with the Fidas, (which measures particles at the 3 gas field sites), and the BAM. A comparison of paired data captured by Fidas and BAM indicated that the two measurement techniques agreed within their stated uncertainties at the 95% confidence level. The R^2, or coefficient of determination was 0.74 indicating a reasonable correlation between the two techniques. This confirms the Fidas is a suitable technique for monitoring PM_{10} in this study.

A method comparison could not be undertaken for $PM_{2.5}$ due to the low concentrations of $PM_{2.5}$ at the Miles Airport site during the comparison period. However provisional data from 2017 measurements in the Surat Basin showed good agreement between the Fidas and other techniques for $PM_{2.5}$ at higher ambient concentrations and details of this comparison and final results will be made available at the end of 2018 at https://gisera.csiro.au/project/air-water-and-soil-impacts-of-hydraulic-fracturing-phase-2/. Validation of the Fidas technique for $PM_{2.5}$ against standard methods in UK and Europe provides confidence in the suitability of the Fidas for monitoring $PM_{2.5}$ (TUV 2015).

For TSP, the difference in 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) means that TSP data from this study can only be considered indicative and cannot be considered equivalent to Australian Standard Method (AS/NZS 3580.9.3:2015).

For all full description of the particle method comparison for PM_{10} and $PM_{2.5}$ see Appendix A.3.

2.2.2 PM_{10}

A plot of daily 24 hour average PM_{10} concentrations are shown in Figure 7 for the 3 gas field sites with the Air (EPP) (2008) 24-hour air quality objective of 50 µg m^{-3} shown. Concentrations were well below the air quality objective (50 µg m^{-3}) for the majority of time with a single exceedance of the 24 hour average objective occurring at one site (Miles Airport) during 2017-2018. Table 9 and Table 10 show summary statistics of maximum 24-hour and average 1-hour PM_{10} concentrations for each month from January 2017 to February 2018, as well as the 2017 annual average. The Condamine site was decommissioned in June 2017. Note that the 1-hour average values do not have a relevant air quality objectives for comparison and are provided for additional information.

Where data availability was <75% for a month, the specific reason is provided in the footnote of the table. More details on reasons for low data availability is provided in A.2.

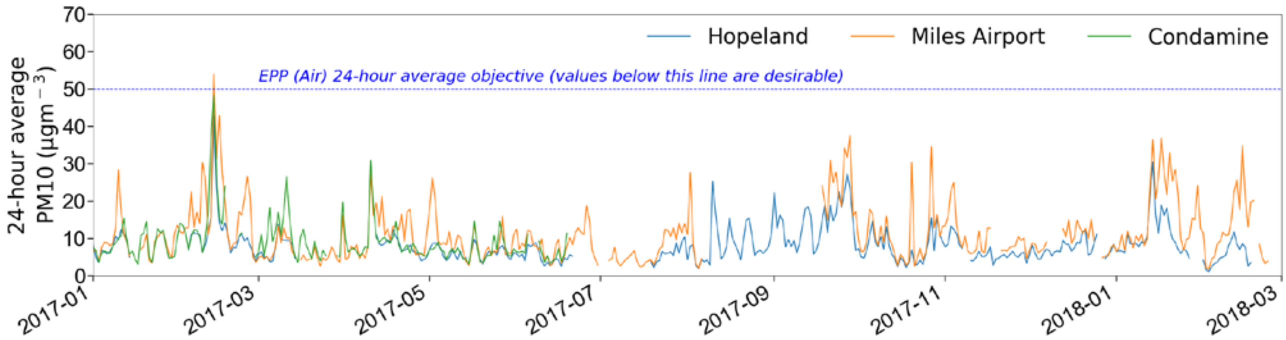

Figure 7 24 hour average PM_{10} concentrations from Gas field sites

Table 9 Ambient concentrations of PM_{10}. Monthly maximum 24-hour average and monthly average 1-hour average concentrations (µg m^{-3}) at all sites for 2017.

PM_{10} - 2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hopeland												
Max 24-hour	-	42.7	-	-	9.7	-	-	25.3	27.3	15.8	13.3	12
Average 1-hour	-	11.6	-	-	6.2	-	-	8.3	14.5	7.3	6.4	7.3
% Data Avail	46[a]	92	44[a,d]	65[d]	98	71[a]	44[a]	100	100	99	97	96
Annual Average	8.2											
Miles Airport												
Max 24-hour	28.4	54	16.2	27.2	26.3	18.7	14.1	-	-	34.6	25	15.1
Average 1-hour	9.3	18.6	6.4	10.9	9.1	8.6	6.7	-	-	10.4	10	9.6
% Data Avail	92	99	97	100	100	99	92	19[a,d]	44[a]	100	91	84
Annual Average	10.6											
Condamine												
Max 24-hour	15.4	48.3	26.5	30.9	14.6	11.4	-	-	-	-	-	-
Average 1-hour	8	15.1	9.9	9	7	6.6	-	-	-	-	-	-
% Data Avail	100	79	92	100	100	88	0[g]	0[g]	0[g]	0[g]	0[g]	0[g]
Annual Average												

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure

Table 10 Ambient concentrations of PM_{10}. Monthly maximum 24-hour average, monthly average 1-hour average and annual average concentrations (µg m^{-3}) at all sites for 2018

PM_{10} - 2018	Jan	Feb
Hopeland		
Max 24-hour	30.5	-
Average 1-hour	10.6	-
% Data Avail	94	66[b]
Annual Average	-	
Miles Airport		
Max 24-hour	36.9	34.9
Average 1-hour	16.7	12.2
% Data Avail	100	88
Annual Average	-	

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure

2.2.3 $PM_{2.5}$

A plot of daily 24-hour average $PM_{2.5}$ concentrations are shown in Figure 8 for the three gas field sites with the Air (EPP) (2008) 24-hour air quality objective (25 µg m^{-3}) shown. Concentrations were generally well below the air

quality objectives for the majority of the time with a single exceedance of the 24 hour average objective occurring at a single site (Miles Airport). Table 11 and

Table 12 show summary statistics of maximum 24-hour and average 1 hour $PM_{2.5}$ concentrations for each month from January 2017 to February 2018, as well as the annual average for 2017. The Condamine site was decommissioned in June 2017. Note that the 1-hour average values do not have a relevant air quality objective for comparison and are provided for additional information.

Where data availability was <75% for a month, the specific reason is provided in the footnote of the table. More details on reasons for low data availability is provided in A.2.

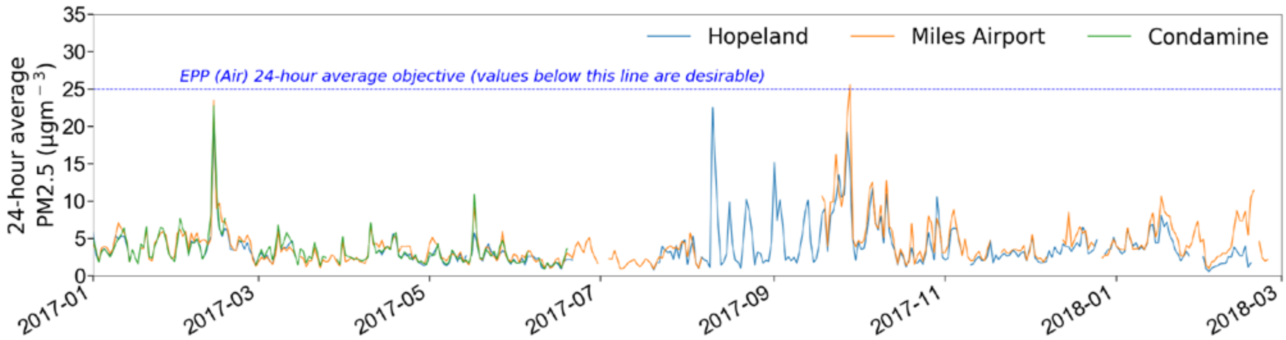

Figure 8 Daily 24 hour average $PM_{2.5}$ concentrations from Gas field sites

Table 11 Ambient concentrations of $PM_{2.5}$. Monthly maximum 24-hour average and monthly average 1-hour average concentrations (µg m^{-3}) at all sites for 2017

$PM_{2.5}$ - 2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hopeland												
Max 24-hour	-	20.6	-	-	5.7	-	-	22.5	19.2	11.8	6.4	6.5
Average 1-hour	-	5	-	-	2.8	-	-	4.4	7.1	4.7	3	3.6
% Data Avail	46[a]	92	44[a,d]	65[d]	98	71[a]	44[a]	100	100	99	97	96
Annual Average	4.0											
Miles Airport												
Max 24-hour	7.1	23.5	5.9	6.7	9.2	5.1	4.6	-	-	12.7	8.8	8.5
Average 1-hour	4.1	5.8	2.6	3.2	3.2	2.6	2.5	-	-	5.4	3.7	4.2
% Data Avail	92	99	97	100	100	99	92	19[a,d]	44[a]	100	91	84
Annual Average	4.0											
Condamine												
Max 24-hour	6.6	22.8	6.8	7.1	10.9	3.6	-	-	-	-	-	-
Average 1-hour	3.8	5.9	3.3	3	3	1.9	-	-	-	-	-	-
% Data Avail	100	79	92	100	100	88	-	-	-	-	-	-
Annual Average	-											

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure

Table 12 Ambient concentrations of $PM_{2.5}$. Monthly maximum 24-hour average, monthly average 1-hour average and annual average concentrations (µg m^{-3}) at all sites for 2018

$PM_{2.5}$ - 2018	Jan	Feb
Hopeland		
Max 24-hour	8.1	-
Average 1-hour	4.3	-
% Data Avail	94	66[b]
Annual Average	-	
Miles Airport		
Max 24-hour	10.7	11.4
Average 1-hour	5.3	4.7
% Data Avail	100	88
Annual Average	-	

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure

2.2.4 TSP

A plot of daily 24-hour average TSP concentrations are shown in Figure 9 for the three gas field sites with the DES 24-hour nuisance dust guideline (60 µg m^{-3}) shown. Concentrations were generally below the nuisance dust guideline for most of the time, with 10 exceedances of the 24 hour average guideline (MFE 2016). Table 13 and Table 14 show summary statistics of max 24 hour and average 1 hour TSP concentrations for each month from January 2017 to February 2018, as well as the annual average for 2017. Note that the 1 hour average values do not have a relevant air quality objectives for comparison and are provided for additional information.

Where data availability was <75% for a month, the specific reason is provided in the footnote of the table. More details on reasons for low data availability is provided in A.2.

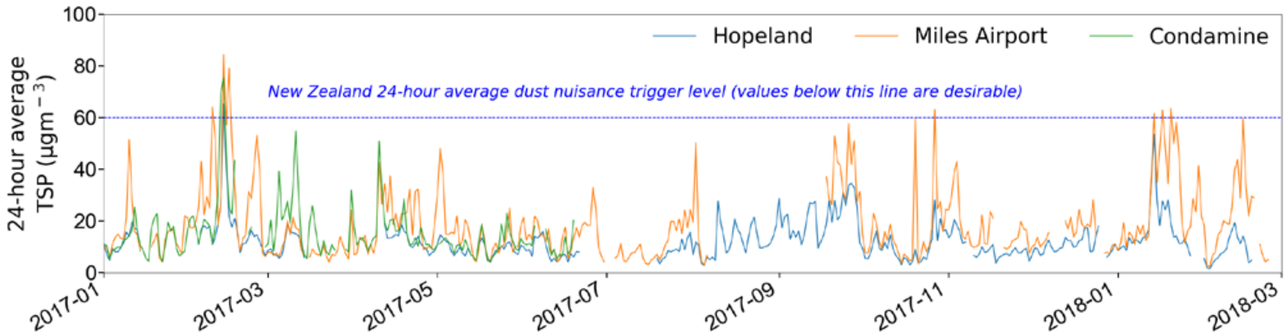

Figure 9 Daily 24 hour average TSP concentrations from Gas field sites

Table 13 Ambient concentrations of TSP. Monthly maximum 24-hour average and monthly average 1-hr average concentrations ($\mu g\ m^{-3}$) at all Gas field sites for 2017

TSP - 2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hopeland												
Max 24-hour	-	65.2	-	-	14.6	-	-	27.6	34.5	28.1	20.6	18
Average 1-hour	-	17.9	-	-	9.2	-	-	12	21.5	9.5	9.5	10.5
% Data Avail	46[a]	92	44[a,d]	65[d]	98	71[a]	44[a]	100	100	99	97	96
Annual Average	12.1											
Miles Airport												
Max 24-hour	51.5	84.4	24.3	42.7	48.1	32.9	24.4	-	-	63.1	43.1	28.1
Average 1-hour	14.5	33.1	10.1	18.9	15.1	14.3	10.6	-	-	15.5	16.8	15.1
% Data Avail	92	99	97	100	100	99	92	19[a,d]	44[a]	100	91	84
Annual Average	17.3											
Condamine												
Max 24-hour	25.4	75.4	54.7	50.8	23	20.1	-	-	-	-	-	-
Average 1-hour	12	25.1	17.9	16	10.8	11.3	-	-	-	-	-	-
% Data Avail	100	79	92	100	100	88	-	-	-	-	-	-
Annual Average	-											

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure

Table 14 Ambient concentrations of TSP. Monthly maximum 24-hour average, monthly average 1-hr average and annual average concentrations ($\mu g\ m^{-3}$) at all Gas field sites for 2018

TSP - 2018	Jan	Feb
Hopeland		
Max 24-hour	53.7	-
Average 1-hour	16.4	-
% Data Avail	94	66[b]
Annual Average	-	
Miles Airport		
Max 24-hour	63.6	59.5
Average 1-hour	28.8	19.7
% Data Avail	100	88
Annual Average	-	

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure

2.3 Summary of compliance with air quality objectives

The air quality objectives used to assess the pollutant concentrations are presented in Table 15. Air quality objectives for carbon monoxide, ozone, nitrogen dioxide, $PM_{2.5}$ and PM_{10} are all based on the values from the Queensland Air EPP (2008) and the Australian NEPM (2016). In the absence of a relevant Australian objective the air quality objective for TSP is based on the New Zealand Ministry for the Environment's nuisance trigger level for high sensitivity areas (MFE 2016), and the use of this objective is recommended by Queensland's Department of Environment and Science (DES).

Table 15 Air quality objectives used to assess concentrations in this report including NEPM (2016), EPP air (2008) and DES TSP guidelines based on MFE (2016).

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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	0.08 ppm (one day per year)[a,b]
	1-hour	0.10 ppm (one day per year)[a,b]
Nitrogen dioxide	Annual	0.03 ppm[a,b]
	1-hour	0.12 ppm (one day per year)[a,b]
PM_{10}	Annual	25 µg m^{-3} [a]
	24-hour	50 µg m^{-3} [a,b]
$PM_{2.5}$	Annual	8 µg m^{-3} [a,b]
	24-hour	25 µg m^{-3} [a,b]
TSP	Annual	90 µg m^{-3} [b]
	24-hour	60 µg m^{-3} (high sensitivity environment) [c]

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

Table 16 shows the number of exceedances for of the relevant carbon monoxide, nitrogen dioxide, ozone, $PM_{2.5}$ and PM_{10} objective for the time period covered in this report (2017-2018). There were no exceedances for carbon monoxide, nitrogen dioxide or ozone at any sites. There were no exceedances of any annual average air quality objectives for any pollutant measured.

There was one PM_{10} exceedance of the 24 hour average objective and one $PM_{2.5}$ exceedance of the 24 hour average objective, both at the Miles Airport site. Note that PM_{10} and $PM_{2.5}$ were not measured at the Regional sites. Table 17 shows the number of times 24-hour TSP concentrations exceeded the air quality guideline for 2017 - 2018, the period covered by this report (2017-2018). There were a total of 10 exceedances of the 24 hour TSP guideline, 7 exceedances at Miles Airport, 2 exceedances at Condamine and 1 exceedance at Hopeland.

Table 18 shows the 24-hour exceedance values for PM_{10}, $PM_{2.5}$ and TSP according to site. In Section 4 the results of investigations into the circumstances that led to any exceedances is presented.

Due to the different particle size ranges measured by the Fidas (up to 18 µm) and the Australian Standard Method (AS/NZS 3580.9.3:2015) (up to 100 µm), 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 nuisance dust guideline when measured with Fidas, but would have exceeded the guideline if measured by the Australian Standard Method (AS/NZS 3580.9.3:2015). Many such events are expected to be captured by the protocol of investigating TSP events which were at a concentration >80% of the nuisance dust guideline (MFE 2016) – see Section 4 for investigation of these events.

Table 16 Number of exceedances of Air EPP objectives and NEPM standards for carbon monoxide, nitrogen dioxide, ozone, PM_{10} and $PM_{2.5}$ for the period covered in this report, January 2017 to February 2018

Air pollutant	Averaging Period	Exceedances				
		Hopeland	Miles Airport	Condamine	Burncluith	Tara Region
Carbon monoxide	8-hour	0	0	0	0	0
Nitrogen dioxide	Annual	0	0	0	0	0
	1-hour	0	0	0	0	0
Ozone	4-hour	0	0	0	0	0
	1-hour	0	0	0	0	0
PM_{10}	Annual	0	0	0	nm	nm
	24-hour	0	1	0	nm	nm
$PM_{2.5}$	Annual	0	0	0	nm	nm
	24-hour	0	1	0	nm	nm

nm = not measured

Table 17 Number of times 24 hour TSP concentrations exceeded the DES- recommended air quality guideline (MFE 2016) for 2017-2018, the period covered by this report.

Air pollutant	Averaging Period	Above objectives				
		Hopeland	Miles Airport	Condamine	Burncluith	Tara Region
TSP	Annual	0	0	0	nm	nm
	24-hour	1	7	2	nm	nm

nm = not measured

Table 18 Exceedance concentrations for PM_{10}, $PM_{2.5}$ and TSP (values are 24 hour average in µg m^{-3}).

	PM_{10} Air EPP/NEPM 24h standard is 50 µg m^{-3}			$PM_{2.5}$ Air EPP/NEPM 24h standard is 25 µg m^{-3}			TSP MFE 24h standard is 60 µg m^{-3}		
Date	**Hopeland**	**Miles Airport**	**Condamine**	**Hopeland**	**Miles Airport**	**Condamine**	**Hopeland**	**Miles Airport**	**Condamine**
9/2/17								64.1	
12/2/17									69.2
13/2/17		54.0					65.2	84.4	75.4
15/2/17								79.0	
28/9/17					25.6				
27/10/17								63.1	
14/1/18								61.6	
17/1/18								62.9	
20/1/18								63.6	

2.4 Summary

Time series plots and statistical tables were presented for the concentration of carbon monoxide, nitrogen dioxide and ozone from all five sites and $PM_{2.5}$, PM_{10} and TSP from the three gas field sites for January 2017 to February 2018.

At all five sites air quality was generally very good. There were

- no exceedances of ambient air quality objectives concentrations for carbon monoxide, nitrogen dioxide or ozone; and
- no exceedances of annual air quality objective concentrations for any of the pollutants measured.

At the gas field sites there was the occasional exceedance of air quality objectives, including

- 1 exceedance of the 24-hour air quality objective concentration for $PM_{2.5}$ (Air EPP/NEPM (air);
- 1 exceedance of the 24-hour air quality objective concentration for PM_{10} (Air EPP/NEPM (air), and
- 10 exceedances of the 24-hour TSP nuisance dust guideline (MFE).

An investigation of the likely contributing source(s) of $PM_{2.5}$, PM_{10} and TSP to the air quality exceedances is presented in Section 4.

3 Data summary: methane and total VOCs measured at gas field sites

The purpose of this section is to present statistics and time series plots of methane and total VOC concentrations from the three gas field sites for the period January 2017 to February 2018.

An analysis of the likely source of the 5 largest methane concentration events for each site is presented in Section 4.

3.1 Methane

There is no ambient air quality objective for methane, instead methane was measured in this study as a tracer for other components of CSG which do have air quality objectives such as air toxics including volatile organic compounds (VOCs) that were potentially present in trace quantities in CSG. Figure 10 shows a time series of hourly methane concentrations from the three gas field sites from January 2017 to February 2018. Table 19 and Table 20 show methane statistics from the same period including maximum and average monthly values, as well as annual average values. Note that the Condamine site was decommissioned in June 2017.

The 2017 annual average methane concentration for the gas field sites was 1.9 ppm and is similar to the 2017 annual average at Regional Sites Ironbark/Tara Region and Burncluith of 1.8 ppm (Luhar et al., 2018). It should be noted that methane measurements reported here cannot be directly compared with the methane measurements from Burncluith and Tara Region (Ironbark) reported in Etheridge et al., (2017), Luhar et al., (2018) and other reports from that study for the reasons outlined below.

The methane measurement systems employed at the gas field sites were designed to detect relatively large changes in methane concentrations which may be caused by emissions from local CSG sources. The measurement systems employed for this purpose could detect changes in methane of 0.1 ppm. In contrast, in the GISERA Regional Methane Flux project, high sensitivity methane measurement systems were employed to allow detection of very small changes in methane (down to about 1 ppb, or 0.001 ppm) between sites and over time. As such, methane concentrations between the gas field sites and regional sites can only broadly be compared to the level of 0.1 ppm due to differences in the instrument and method sensitivities.

The background concentrations of methane at this latitude vary seasonally by about ±20 ppb (0.02 ppm). At the gas field sites the background concentration of methane of ~ 1.9 ppm can be seen in Figure 10, with higher concentrations visible in the form of peaks. The largest hourly average methane concentration observed from January 2017 to February 2018 was 15.7 ppm and occurred at Miles Airport on 7th January 2018. The five largest methane events at gas field sites were identified using maximum hourly methane concentrations (Section 4.1.2) and are investigated in Section 4.4 along with implications for air quality. It should be noted that the regional stations were deployed in locations that would not be affected by local and large sources of methane, to allow the regional emissions to be determined. As such, methane data from the Regional sites has smaller amplitude spikes in concentrations (Etheridge et al., 2017, Luhar et al., 2018) than reported here for the gas field sites.

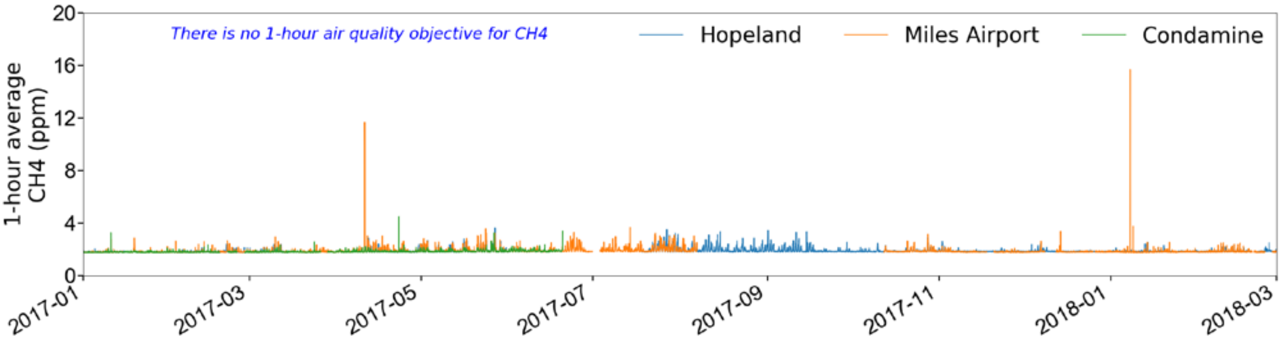

Figure 10 time series of hourly methane data at the gas field sites

Table 19 Ambient concentrations of methane. Monthly maximum and average 1-hour average and annual average concentrations (ppm) at the three gas field sites for 2017

CH_4 - 2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hopeland												
Max 1-hour	-	2.4	-	-	3.6	-	-	3.3	3.4	2.9	2.6	2.5
Average 1-hour	-	1.8	-	-	1.9	-	-	2.0	1.9	1.9	1.8	1.8
% Data Avail	46[a]	92	44[a,d]	65[d]	98	71[a]	44[a]	100	100	100	100	96
Annual Average	1.9											
Miles Airport												
Max 1-hour	2.8	2.7	2.9	11.7	3.5	3.3	3.7	-	-	-	2.2	3.4
Average 1-hour	1.8	1.8	1.8	1.9	2.0	1.9	2.0	-	-	-	1.8	1.8
% Data Avail	92	100	97	99	100	99	92	19[a]	0[a]	63[b]	91	84
Annual Average	1.9											
Condamine												
Max 1-hour	3.3	2.3	2.6	4.5	3.2	3.4	-	-	-	-	-	-
Average 1-hour	1.8	1.8	1.8	1.8	1.9	1.9	-	-	-	-	-	-
% Data Avail	100	79	91	99	100	98	-	-	-	-	-	-
Annual Average	-											

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure

Table 20 Ambient concentrations of methane. Monthly maximum and average 1-hour average and annual average concentrations (ppm) at the three gas field sites for 2018

CH_4 - 2018	Jan	Feb
Hopeland		
Max 1-hour	2.5	2.5
Average 1-hour	1.8	1.8
% Data Avail	100	91
Annual Average	-	
Miles Airport		
Max 1-hour	15.7	2.5
Average 1-hour	1.8	1.8
% Data Avail	100	88
Annual Average	-	

a=power outage, b= instrument fault, c=instrument commissioned during month, d=air conditioning failure, e=calibration out of tolerance, f=communication / logger failure, g=station decommissioned

3.2 Total Volatile Organic Compounds (TVOC)

Volatile organic compounds are a large group of organic gases (100s of species), four of which are prescribed in the air toxics NEPM (benzene, toluene, xylenes, formaldehyde) with an additional five prescribed in the Queensland EPP (air). At the 3 gas field sites a measurement method was employed that provides an approximation for the sum of all individual VOCs present (TVOC) and the results are presented as parts per million of Carbon (ppmC). There are no state or federal air quality objectives for TVOC. VOCs have been detected in trace levels in CSG and CSG combustion emissions (Lawson et al., 2017) and total VOC measurements were included in the present study to provide an indication of whether an elevation of VOCs from combustion or CSG leakage and venting may have occurred.

Data capture was below 75% for all months of the period covered by this report except for June 2017 at Miles Airport. Several instrumental issues resulted in invalid data and low data capture rates for the TVOC measurement. Issues included power outages, hydrogen generator flow faults and span checks not meeting calibration tolerances set out in AS/NZS 3580.11.1-2013. Another limitation of the instrument is that the TVOC is calculated as the difference between sequential measurements of [Methane+TVOC] and [methane]. During periods where methane levels are rising and falling faster than the time it takes for the sequential measurement, noisy positive and negative TVOC readings occur which are invalidated if they fall below -1 ppm.

The only month of reportable data was for June 2017 at Miles Airport, where the monthly mean and maximum 1 hour concentrations were lower than the lowest reportable measurement concentration of 1 ppmC. As the only month of reportable data, this is considered an indicative concentration of TVOC.

A passive Radiello VOC sampling was employed in an earlier phase of this study during 2014 – 2016. This method 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). Overall, the VOC concentrations from the two Radiello passive sampler measurement studies reported concentrations of VOCs that were well below long-term air quality guidelines.

Summary

- Gas field average annual average methane concentrations for 2017 of 1.9 ppm compare to concentrations observed at the Regional sites of 1.8 ppm as part of the GISERA Regional Methane Flux project, reported in Etheridge et al., (2017). Note that due to differences in measurement systems, concentrations can only broadly be compared to the level of 0.1 ppm. Peaks of methane above the background concentration occur at each of the gas field sites throughout the time series. The five largest methane concentration events at each site are investigated further in Section 4.
- Several instrumental issues resulted in invalid data and low data capture rates for the TVOC measurements. The only month with an acceptable data capture rate was June 2017 at Miles Airport where monthly mean and maximum 1 hour concentrations were lower than the lowest reportable measurement concentration of 1 ppmC. As the only month of reportable data during this measurement period, this is considered an indicative concentration of TVOC.
- VOC concentrations from two previous VOC measurement studies in this region (Lawson et al., 2018a, Dunne et al., 2018) reported concentrations of VOCs that were well below long-term air quality guidelines.

4 Investigation of events

In this section events are identified, and the protocol for investigating the circumstances that resulted in these events is described. The results of the investigations are summarised and implications for air quality are discussed.

4.1 Identification of events

4.1.1 Exceedances of air quality objectives, or concentrations >80% of air quality objectives

Events were identified for the measured pollutants for which air quality objectives or guidelines exist (carbon monoxide, nitrogen dioxide, ozone, $PM_{2.5}$, PM_{10}, TSP) in the following way:

- any exceedances of air quality objectives were identified as events. See Table 16 and Table 17 for a summary of the type and number of exceedances at each site
- pollutant concentrations greater than (>) 80% of the air quality objective, were also identified as events in recognition that an exceedance may have occurred closer to the pollutant source or near the monitoring site.

There were 40 events identified, 38 of which were related to exceedances or concentrations >80% of the 24 hour average $PM_{2.5}$ /PM_{10}/TSP air quality objectives at the gas field sites. The remaining two events were related to concentrations > 80% of the 4 hour average ozone air quality objective. A summary of the dates, location and type of exceedance (red text) or concentration > 80% (black text) are shown in Table 21 as well as the air quality objectives, and 80% value of the objectives for ozone, PM_{10}, $PM_{2.5}$ and TSP. Note that there were no annual average exceedances of air quality objectives.

Table 21 Date and site of exceedances and concentrations > 80% of Air EPP/NEPM air quality objective. $PM_{2.5}$, PM_{10} and TSP are 24-hour average ($\mu g\ m^{-3}$), O_3 is 4-hour average (ppm). Red text indicate concentration exceeded air quality objectives, black text indicates concentration > 80% of air quality objectives

	Hopeland			Miles Airport				Condamine			Burncluith
	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP	O_3	$PM_{2.5}$	PM_{10}	TSP	O_3
Air quality objective	25[a,b]	50[a,b]	60[c]	25[a,b]	50[a,b]	60[c]	0.080[a,b]	25[a,b]	50[a,b]	60[c]	0.080[a,b]
80% of objective	20[a,b]	40[a,b]	48[c]	20[a,b]	40[a,b]	48[c]	0.064	20[a,b]	40[a,b]	48[c]	0.064[a,b]
	$\mu g\ m^{-3}$			$\mu g\ m^{-3}$			ppm	$\mu g\ m^{-3}$			ppm
10/1/17						51.5					
9/2/17						64.1					
10/2/17						51.5					
12/2/17										69.2	
13/2/17	20.6	42.7	65.2	23.5	54.0	84.4		22.8	48.3	75.4	
14/2/17						57.1					
15/2/17					42.9	79.0					
16/2/17						50.5					
21/2/17							0.069				
25/2/17						53.0					
11/3/17										54.7	
10/4/17										50.8	
2/5/17						48.1					
2/8/17						50.3					
10/8/17	22.5										
21/9/17						52.8					
26/9/17						57.7					
27/9/17				21.3							0.065
28/9/17				25.6		51.0					
20/10/17						59.6					
27/10/17						63.1					
14/1/18			53.7			61.6					
17/1/18						62.9					
18/1/18						48.7					
20/1/18						63.6					
21/1/18						49.7					
22/1/18						58.2					
15/2/18						59.5					

[a] NEPM (2016)

[b] Air (EPP) (2008) Queensland

[c] DES TSP guidelines based on MFE (2016)

4.1.2 Identification of largest methane concentration events

Methane does not have an air quality objective and was measured in this study as a tracer for CSG activities and for other components relevant to air quality that are potentially present in CSG emissions. As such, the analysis of methane events undertaken here aims to explore the likely sources of methane in the study area, and relate this, where possible, to implications for air quality.

The 5 largest methane events from each of the gas field sites from 2017 - 2018 have been identified and investigated as follows:

- As a first step, the largest events were identified from the maximum hourly average concentrations
- For some of these events, several smaller peaks above baseline accompanied the largest peak when there were similar wind directions at the one site, or under similar wind conditions (e.g. light and variable). These peaks were considered to be part of the same "event" when: the magnitude of the smaller peak was >10% of the largest peak above baseline for that event, and, they occurred within 12 hours of the largest peak
- Events include a baseline or near baseline value either side of the first and last peak associated with that event

As such, the identification of the 5 largest methane events from each site is semi-quantitative/approximate which is suitable for an exploratory analysis. Table 22 shows the dates and the maximum 1-hour average concentrations observed during the 5 highest methane events at each of the gas field sites. The two largest 1-hour methane concentrations were recorded at Miles Airport (15.7 and 11.7 ppm) with the remaining 13 largest hourly concentrations across all three sites in the range of 2.6 – 4.5 ppm.

Table 22 Dates and maximum 1 hour average concentrations observed during 5 highest methane events at Gas field sites (ppm). These values were used to identify the 5 largest methane events from each site

End of max 1 h peak, date, time (5 m time)	Max 1 h average methane concentration (max 5 min average) (ppm)		
	Hopeland	Miles Airport	Condamine
10/01/2017 21:00 (20:45)			3.3 (4.8)
24/03/2017 03:00 (02:05)			2.6 (2.8)
11/04/2017 00:00 (00:05)		11.7 (18.2)	
23/04/2017 03:00 (02:35)			4.5 (12.7)
23/05/2017 23:00 (22:25)		3.5 (5.1)	
26/05/2017 00:00 (00:00)			2.6 (3.3)
27/05/2017 00:00 (26/5/2017 23:15)	3.6 (4.4)		
27/05/2017 07:00 (07:10)			3.2 (3.7)
14/07/2017 08:00 (06:55)		3.7 (4.5)	
27/07/2017 08:00 (07:40)	3.5 (3.7)		
15/08/2017 08:00 (07:40)	3.3 (3.9)		
1/09/2017 06:00 (07:05)	3.4 (4.1)		
14/09/2017 23:00 (23:00)	3.3 (5.0)		
7/01/2018 23:00 (22:05)		15.7 (50.9)	
8/01/2018 23:00 (22:40)		3.8 (8.1)	

4.2 Protocol for investigating likely source of pollutants during events

This section describes the protocol that was used to investigate the likely sources or circumstances that led to the events identified in the previous section.

4.2.1 Exceedances of air quality objectives or concentrations> 80% of air quality objectives ($PM_{2.5}$, PM_{10} and TSP and ozone events)

Where several peaks in an event occurred from the same wind direction, only the source of the largest peak was investigated. However where two or more peaks contributed to event and appear to be from different sources, then these peaks were investigated and reported separately in Section 4.4.

The steps taken to investigate the likely source of events included:

1) Define the event period, including the date and time. Define the time and peak concentrations of the pollutant which exceeded, or were > 80% of the relevant air quality objective

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. Pollutants were only stated as being correlated where the coefficient of determination (R^2) was R^2>0.4 and the correlation was statistically significant at a 95% confidence interval.

For instance, $PM_{2.5}$, carbon monoxide (CO) and carbon dioxide (CO_2) are emitted during combustion. Correlations between $PM_{2.5}$ and carbon monoxide and carbon dioxide can be used to identify sources of $PM_{2.5}$ exceedances associated with smoke from fires. Likewise, methane and carbon dioxide are emitted from cattle and correlations between these pollutants can be used to identify sources of PM_{10} and TSP peaks due to dust from cattle farming activities. The absence of a correlation between pollutants can also be used to rule out sources.

5) Calculate an average ratio of the exceeding pollutant to any other correlating pollutants during the peak concentration period and examine whether this ratio indicates a particular emission source (fires, dust, cattle, CSG combustion etc.). Correlating pollutants were plotted against one another, and the ratio was the slope of the linear relationship between the two. Note that where the wind direction changed significantly mid-way through an event and pollutant concentrations decreased after the wind direction change, only the ascending concentration data were used to calculate ratios of the exceeding pollutant to other pollutants.

The use of emission ratios can be used to identify a likely source where the species used are unlikely to be significantly influenced by removal or production from the time they are emitted from the source, to when they are measured at the ambient air monitoring quality site. 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) in smoke (Andreae and Merlet, 2001; Akagi et al., 2011) and the ratios of methane to carbon dioxide (CH_4/CO_2) in the breath of cattle (Bai et al 2014). These published ratio data will be used to here to identify possible sources.

Note that in events where CO_2 and CH_4 were elevated alongside elevated TSP but not correlated with TSP, and the ratio of CH_4/CO_2 suggested cattle, cattle farming was determined as the most likely source of the TSP. This is because CO_2 and CH_4 are emitted predominantly from the breath of cattle, which is a different process to the production of TSP, which is created by soil or dust becoming airborne due to agitation of soil through movement of vehicles, animals etc. As such TSP associated with cattle farming may not be expected to correlate with CO_2 and CH_4 concentrations from cattle farming.

Also note that the ratio of CO_2/CH_4 has been used in this study to suggest the influence of cattle over short-lived events of a few hours, but is not be a reliable indicator of cattle-related emissions over longer periods. This is because CO_2 is exchanged between the atmosphere and the biosphere including uptake by plants during the day and release at night. As such, over longer time periods, the uptake and release of CO_2 is likely to lead to changes in the measured ratio.

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 A.4) 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.

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

7) 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.

4.2.2 Protocol for investigating methane events

The steps taken to investigate the likely source of methane events is very similar to the protocol for investigating $PM_{2.5}$, PM_{10} and TSP events and included:

1) Define the date and duration of the methane event. Methane events are defined as one or a series of peaks that occurred in the same wind direction/similar wind conditions, no more than 12 hours apart (Section 4.1.2). The average concentration over the duration of the event, as well as the maximum hourly and maximum 5 or 15 minute concentrations are also reported. Note that the highest time resolution validated data was used (either 5 or 15 minute), depending on availability.

2) Determine predominant wind direction(s) and speed during the peak methane concentration

3) Identify other pollutants whose concentrations correlated with methane concentrations. Methane and other pollutants were only stated as being correlated where the coefficient of determination (R^2) was $R^2>0.4$ and the correlation was statistically significant at a 95% confidence interval.

4) Calculate an average ratio of methane to any other correlating pollutants during the peak concentration period and examine whether this ratio indicates a particular emission source (cattle, CSG combustion, un-combusted CSG etc). Methane was plotted against any correlating pollutants and the ratio was the slope of the linear relationship between the two.

5) Identify possible sources of methane and other correlating pollutants upwind of the measurement location, and identify the distance from the measurement location to point sources.

6) Identify the likely dominant source of methane during the event. Note that there may not be sufficient information to identify a likely source for each event.

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).

4.3 Methane events – implications for air quality

CSG in the study area is 96-98% methane (Lawson et al., 2017) and emissions of CSG may occur from several sources including from wells, pipelines, gathering networks, separators, processing facilities and storage facilities. CSG emissions occur both through intentional release (e.g. pneumatically driven gas and water separators on well heads) and unintentional release (e.g. via leaks in infrastructure). Methane does not have an air quality objective, and was included in this study as a tracer for other components potentially present in CSG which do have air quality objectives such as VOCs and hydrogen sulphide.

To understand the air quality impact of the likely CSG-related methane events, the composition of undiluted CSG can be used to estimate the concentrations of other components such as VOCs and hydrogen sulphide during the peak methane concentrations observed. This analysis assumes that the methane observed was CSG.

Hydrogen sulphide is sometimes detected in CSG at trace levels and it is a prescribed air pollutant in the Queensland EPP (Air). Based on previously report CSG composition analysis we assumed a concentration of 0.2 ppm hydrogen sulphide (Lawson et al., 2017,) in CSG. The ambient concentration of methane in the air resulting from CSG emission would need to be 540,00 ppm for the hydrogen sulphide concentration to be approaching the 24 hour EPP air quality objective value of 110 ppb. Assuming a maximum concentration of 1 ppm of benzene in the CSG (limit of detection for benzene in CSG analysis reported previously in Lawson et al., 2017) the ambient concentration of methane would need to be 1300 ppm for benzene to be approaching the annual air quality objective of 1.4 ppb (Texas AMCV). The highest hourly average methane concentration observed during this study was well below these values at 25 ppm (Lawson et al., 2018a). While gas composition data used in this analysis cannot be considered representative of all CSG-related sources in the study region (Lawson et al., 2017a), this does provide a good indication of the relative levels of methane that would need to be observed in the air for the other gas components to approach air quality objectives.

As such, it is likely given the ambient methane levels observed in this study that components such as BTX and hydrogen sulphide are rapidly diluted to concentrations well below the NEPM/EPP air quality objectives when CSG is emitted to air. The Radiello monitoring data reported in Lawson et al., (2018) found low detection frequencies of BTX at gas field sites and did not detect hydrogen sulphide in any sample in the study region, which supports this conclusion.

4.4 Summary of events

This section briefly summarises the most likely source of pollutants during events summarised in Section 4.1.

A summary of the dominant sources most likely responsible for events is given below for each site. Table 23 ($PM_{2.5}$, PM_{10}, TSP and ozone) and Table 24 (methane) lists the events by date and site and the sources most likely responsible for the observed pollutant levels.

It should be noted that in most cases 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 will make a large contribution to the concentration leading to an overall concentration which exceeds air quality objectives. The analysis below explores and attempts to identify only the dominant source/s during events, rather than all possible contributing sources.

Table 23 ($PM_{2.5}$, PM_{10}, TSP and ozone) and Table 24 (methane) lists the sources most likely responsible by date and site. In Table 23 red text indicates an exceedance and black text indicates the concentration was >80% of the relevant air quality objective.

An analysis of each individual event including supporting information is provided below including exceedance events (Table 25 – Table 27), events with $PM_{2.5}$, PM_{10}, TSP concentrations > 80% of air quality objectives (Table 28 – Table 30), ozone events > 80% of air quality objectives (Table 31) and methane events (Table 32 – Table 35).

Overall the most likely dominant source of air pollutants identified for the observed events were:

- Regional vegetation fires which emitted smoke resulting in $PM_{2.5}$, PM_{10} and TSP events at multiple sites on the same day
- Regional vegetation fires which emitted smoke along with regional dust from airborne soil or other particles, resulting in $PM_{2.5}$, PM_{10} and TSP events at multiple sites on the same day
- Regional fire/s which emitted pollutants which reacted to form ozone
- Cattle farming activities which emitted dust resulting in local PM_{10} and TSP events

- CSG operational or development activities and/or vehicle traffic which emitted dust resulting in local TSP events
- CSG activities or infrastructure which emit un-combusted CSG (~98% methane).

For some events, the source of the pollutant exceedance could not be determined with the available information and remains unknown. For example there were several local PM_{10} and TSP events which may have been due to airborne dust emitted from unsealed roads from wind or vehicle traffic, or agricultural activities, but the specific source could not be identified.

The following provides a summary of events and their likely sources for each site:

Hopeland

1 x TSP exceedance due to regional dust and regional vegetation fire

1 x 24-hour event with $PM_{2.5}$ concentration >80% of air quality objective, attributed to a combination of regional vegetation fire and regional dust

1 x 24-hour event with $PM_{2.5}$ concentration >80% of air quality objective, attributed to a regional vegetation fire

1 x 24-hour event with PM_{10} concentration >80% of air quality objective, attributed to a combination of regional vegetation fire and regional dust

1 x 24-hour with TSP > 80% nuisance dust guideline attributed to regional dust

4 x methane events of unknown source, 1 x methane event attributed to emissions of CSG from CSG activities/infrastructure

Miles Airport

1 x 24-hour $PM_{2.5}$ exceedance events attributed to regional vegetation fire

1 x 24-hour PM_{10} exceedance attributed to regional dust and regional vegetation fire

4 x 24-hour TSP exceedance of nuisance dust guidelines attributed to particles from cattle farming activities, 1 x 24 hour exceedance attributed to regional dust and regional vegetation fire, 1 x 24 hour exceedance attributed to regional dust and 1 x 24 hour exceedance with source unknown

1 x 24-hour event with $PM_{2.5}$ concentration > 80% of air quality objective attributed to regional dust and regional vegetation fire, 1 x 24 hour event attributed to regional vegetation fire

1 x 24-hour event with PM_{10} concentration > 80% of air quality objective attributed to cattle farming

8 x 24-hour events with TSP > 80% nuisance dust guidelines attributed to particles associated with cattle farming, 1 x 24 hour event attributed to particles associated with cattle farming and an unknown source, 5 x 24 hour events with source unknown

1 x regional ozone event with 4-hour average concentrations >80% of air quality objective, source unknown

3 x methane events attributed to emissions of CSG from CSG activities/infrastructure, 1 x methane event attributed to emissions of CSG from CSG activities/infrastructure and particles associated with cattle farming, and 1 x methane event with source unknown

Condamine

1 x 24 hour TSP exceedance due to unsealed roads and/or CSG development or operational activities, 1 x 24 hour TSP exceedance attributed to regional dust and regional vegetation fire

1 x 24-hour event with $PM_{2.5}$ concentration > 80% of air quality objective, attributed to regional dust and regional vegetation fire

1 x 24-hour event with PM_{10} concentration > 80% of air quality objective, attributed to regional dust and regional vegetation fire

2x 24-hour events with TSP > 80% nuisance dust guidelines attributed to unsealed roads and/or CSG development or operational activities

5 x methane events attributed to emissions of CSG from CSG activities/infrastructure

Burncluith

1 x regional ozone event with 4-hour average concentrations >80% of air quality objective attributed to regional vegetation fire

Table 23 most likely sources responsible for each exceedance (red text) and >80% event (black text) for 2017-2018. $PM_{2.5}$, PM_{10} and TSP exceedances are 24-hour average concentration values, ozone is 4 hour average value. Identifying sources of events focussed only on the dominant source/s, rather than all possible contributing sources.

	Hopeland			Miles Airport				Condamine			Burncluith
	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP	O_3	$PM_{2.5}$	PM_{10}	TSP	O_3
10/120/17						Cattle farming					
9/2/2017						Cattle farming					
10/2/2017						Cattle farming and unknown					
12/2/2017										Unsealed roads and/or CSG development or operational activities	
13/2/2017	Regional dust and vegetation fire*	Regional dust and vegetation fire*	Regional dust and vegetation fire	Regional dust and vegetation fire*	Regional dust and vegetation fire*	Regional dust and vegetation fire		Regional dust and vegetation fire*	Regional dust and vegetation fire*	Regional dust and vegetation fire	
14/2/2017						Unknown					
15/2/2017					Cattle farming	Cattle farming					
16/2/2017						Cattle farming					
21/2/2017							Unknown regional				
25/2/2017						Cattle farming					
11/3/2017										Unsealed roads and/or CSG development /operational activities	

	Hopeland			Miles Airport				Condamine			Burncluith
	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP	O_3	$PM_{2.5}$	PM_{10}	TSP	O_3
10/4/2017										Unsealed roads and/or CSG development or operational activities	
2/5/2017						Cattle farming					
2/8/2017						Cattle farming					
10/8/2017	Regional vegetation fire*										
21/9/2017						unknown					
26/9/2017						unknown					
27/9/2017				Regional vegetation fire*							Regional vegetation fire
28/9/2017				Regional vegetation fire*		Regional vegetation fire and unsealed roads and/or CSG development or operational activities					
20/10/2017						unknown					
27/10/2017						unknown					
14/1/2018			Regional dust			Regional dust					

	Hopeland			Miles Airport				Condamine			Burncluith
	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP	O_3	$PM_{2.5}$	PM_{10}	TSP	O_3
17/1/2018						Cattle farming					
18/1/2018						Cattle farming					
20/1/2018						Cattle farming					
21/1/2018						Cattle farming					
22/1/2018						Cattle farming					
15/2/2018						unknown					

***these $PM_{2.5}$ and PM_{10} exceedances would be classed as being associated with exceptional events according to NEPM protocols (NEPM 2016)**

Table 24 summary of the sources attributed to the largest 5 methane events from each of the gas field sites in this study from 2017-2018. Identifying likely sources of events in this work focussed only on the dominant source/s, rather than all possible contributing sources.

Date	Max 1 h average methane concentration (ppm)		
	Hopeland	Miles Airport	Condamine
10/01/2017			Emissions of CSG from CSG activities/infrastructure
24/03/2017			Emissions of CSG from CSG activities/infrastructure
11/04/2017		Emissions of CSG from CSG activities/infrastructure	
23/04/2017			Emissions of CSG from CSG activities/infrastructure
23/05/2017		unknown	
26/05/2017			Emissions of CSG from CSG activities/infrastructure
27/05/2017	unknown		Emissions of CSG from CSG activities/infrastructure
14/07/2017		Emissions of CSG from CSG activities/infrastructure and cattle farming	
27/07/2017	unknown		
15/08/2017	unknown		
1/09/2017	unknown		
14/09/2017	Emissions of CSG from CSG activities/infrastructure		
7/01/2018		Emissions of CSG from CSG activities/infrastructure	
8/01/2018		Emissions of CSG from CSG activities/infrastructure	

4.4.1 Analysis of events with exceedances of air quality objectives

Table 25 Hopeland - $PM_{2.5}$ and PM_{10} exceedances of the Air (EPP) Objectives and TSP exceedances of the DES nuisance dust limit values (MFE 2016)

Event date	Event time (average and peak) and concentrations	Wind at time of peak concentra tion	Species correlated	Possible sources in study area	Emission ratio interpretation	Sources identified upwind	Other info	Likely source
13/2/17	TSP 65.2 µg m^{-3} (24-hr av) 5 min peak = 166.9 µg m^{-3} at 03:40	SW 1-3 m s^{-1}	PM is mainly large fraction TSP and O_3 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	n/a	CSG wells and gathering network Agriculture Unsealed roads GPF 10km to SSW Hotspots in previous 24 hours indicate fires about 570 km S of Hopeland Smoke over study area visible on satellite image	Landholder reports hazy conditions but no local fires TSP exceedance Hopeland, Miles Airport, Condamine PM_{10} exceedance Miles Airport PM_{10}>80% of EPP guideline Hopeland, Condamine $PM_{2.5}$ >80% EPP objective at Hopeland, Miles Airport, Condamine	Information available suggests regional dust event and regional smoke event from vegetation fire

For PM events, the PM species ($PM_{2.5}$, PM_{10}, TSP) were always correlated with one another, and so PM correlations are not explicitly stated

Table 26 Miles Airport - $PM_{2.5}$ and PM_{10} exceedances of the Air (EPP) Objectives and TSP exceedances of the DES nuisance dust limit values (MFE 2016)

Event date	Event time (average and peak) and concentrations	Wind at time of peak concentration	Species correlated	Possible sources in study area	Emission ratio interpretation	Sources identified upwind	Other info	Likely source
9/2/2017	TSP 64.1 µg m^{-3} (24-hr av) 5 min peak = 1515.1 µg m^{-3} at 19:55	E 2 m s^{-1}	PM mostly large fraction TSP and CH_4 correlate TSP and CO_2 correlate CO_2 and CH_4 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio consistent with cattle	Feedlot 2 km Agriculture CSG wells and gathering network Unsealed roads	No other exceedances	Information available suggests particles associated with cattle farming
13/2/2017	PM_{10} 54.0 µg m^{-3} (24-hr av) 5 min peak = 129.9 µg m^{-3} at 01:10 TSP 84.4 µg m^{-3} (24-hr av) 5 min peak = 249.7 µg m^{-3} at 01:10	SW 3-6 m s^{-1}	PM is mainly large fraction at peak TSP, PM_{10} correlates with ozone	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities combustion	n/a	Hotspots in previous 24 hours indicate fires about 570 km S of Miles Airport Smoke over study region visible on satellite image Agriculture CSG wells and gathering network Unsealed roads	Landholder reported hazy conditions but no local fires TSP exceedance Hopeland, Miles Airport, Condamine PM_{10} exceedances Miles Airport PM10>80% of EPP guideline Hopeland, Condamine $PM_{2.5}$ >80% EPP objective at Hopeland. Miles Airport, Condamine	Information available suggests regional dust event and regional smoke event from vegetation fire

15/2/2017	TSP 79.0 µg m^{-3} (24-hr av) 5 min peak = 1549.5 µg m^{-3} at 20:40 1850-22:20	ESE 1-8 m s-1	PM is mainly large fraction TSP correlates with CH_4 TSP correlates with CO_2 correlates with CH_4	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio consistent with cattle	Feedlot 2 km Agriculture CSG wells and gathering network Unsealed roads	PM10 >80% EPP objective Miles Airport	Information available suggests particles associated with cattle farming
28/9/2017	$PM_{2.5}$ 25.6 µg m^{-3} (24-hr av) 5 min peak = 73.7 µg m^{-3} at 04:10 0:00-9:40	NNE 3-6 m s^{-1}	PM is mainly small fraction No CO_2, CO, NO_x or CH_4 data	Combustion	n/a	Hotspots in previous 24 hours indicate fires about 250-290 km NW of Miles Airport and 90 km NE of Miles Airport Smoke approaching Barakula State forest visible on satellite image	PM2.5/CO ratios at Hopeland indicate vegetation fire (but no exceedance)	Information available suggests regional vegetation fire
27/10/2017	TSP 63.1 µg m^{-3} (24-hr av) 5 min peak = 380.3 µg m^{-3} at 03:55 2nd peak 19:05, 281 µg m^{-3} 1 (5 min)	WSW 2-3 m s^{-1} 2nd peak SSW 2 m s^{-1}	Mainly large fraction TSP and CO_2 correlate (first peak) No other correlations	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	n/a	CSG wells and gathering network CSG infrastructure (water treatment ponds) 1.5km to W Agriculture Unsealed roads	No other exceedances	Could not be determined with available data
14/01/2018	TSP 61.6 µg m^{-3} (24-hr av)	S-SSW 1-6 m s^{-1}*	PM mainly large fraction	Airborne dust and soil from unsealed roads, agriculture	n/a	CSG wells and gathering network Agriculture	TSP>80% DES dust limit at Hopeland	Information available suggests regional dust event

	5 min peak = 233.7 µg m^{-3} at 20:55		No correlations No CO data	activities, CSG activities		Unsealed roads		
17/01/2018	TSP 62.9 µg m^{-3} (24-hr av) 1st 5 min peak = 831.0 µg m^{-3} at 20:00 2nd 5 min peak = 582.6 at 21:15	N-ENE 0-2 m s^{-1}*	PM mainly large fraction First peak: CO_2 and CH_4 elevated alongside TSP but not correlated with TSP Second peak: CH_4 and CO_2 and TSP correlate All peaks: CO_2 and CH_4 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio consistent with cattle	Feedlot 2 km Agriculture CSG wells and gathering network Unsealed roads	No other exceedances	Information available suggests particles associated with cattle farming
20/01/2018	TSP 63.6 µg m^{-3} (24-hr av) 5 min peak = 1561.0 µg m^{-3} at 20:05 19:45 – 21:25	ENE 2 ms^{-1}*	PM is mainly large fraction CO_2 and CH_4 elevated alongside TSP but not correlated with TSP CO_2 and CH_4 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio consistent with cattle	Feedlot 2 km Agriculture CSG wells and gathering network Unsealed roads	No other exceedances	Information available suggests particles associated with cattle farming

For PM events, the PM species ($PM_{2.5}$, PM_{10}, TSP) were always correlated with one another, and so PM correlations are not explicitly stated

***Where wind data from ambient air quality site was unavailable due to instrument calibration or error, wind data from the nearest alternative measurement site was used instead. Alternative sites included Burncluith, Miles township and a private property ~5 km north of Hopeland ambient air quality station. Wind data from these alternative sites was found to be broadly comparable with wind data from gas field sites, where parallel measurements were available.**

Table 27 Condamine - $PM_{2.5}$ and PM_{10} exceedances of the Air (EPP) Objectives and TSP exceedances of the DES nuisance dust limit values (MFE 2016)

Event date	Event time (average and peak) and concentrations	Wind at time of peak concentration	Species correlated	Possible sources in study area	Emission ratio interpretation	Sources identified upwind	Other info	Likely source
12/2/2017	TSP 69.2 µg m^{-3} (24-hr av) 1st 5 min peak =378.3 µg m^{-3} at 15:45 2nd 5 min peak = 475.1 µg m^{-3} at 22:40	1st peaks W -SW 2-6 m s^{-1} plus several smaller peaks from W 2nd peak N 2 m s^{-1}	1st peak PM is mainly large fraction. No correlations 2nd peak PM is mainly large fraction CH_4 and TSP correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	n/a	CSG wells and gathering network Unsealed roads Agriculture	Short lived and sharp peaks suggests local source/s	Information available suggests particles associated with unsealed roads/CSG development or operational activities
13/2/2017	TSP 75.4 µg m^{-3} (24-hr av) 5 min peak = 226.8 µg m^{-3} at 00:15	SW 2-4 m s^{-1}	PM is mainly large fraction TSP correlates with O_3	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	n/a	CSG wells and gathering network Unsealed roads Agriculture Hotspots in previous 24 hours indicate fires about 560 km S of Condamine. Smoke over study area visible on satellite image	Landholder reports hazy conditions but no local fires TSP exceedance Hopeland, Miles Airport, Condamine PM_{10} exceedances Miles Airport PM_{10}>80% of EPP guideline Hopeland, Condamine $PM_{2.5}$ >80% EPP objective at Hopeland. Miles Airport, Condamine	Information available suggests regional dust event and regional smoke event from vegetation fire

For PM events, the PM species ($PM_{2.5}$, PM_{10}, TSP) were always correlated with one another, and so PM correlations are not explicitly stated

4.4.2 Analysis of events with concentrations >80% of air quality objectives

Table 28 Hopeland – $PM_{2.5}$ and PM_{10} greater than 80% of the Air (EPP) Objectives (>80% EPP objective) and TSP greater than 80% of the DES nuisance dust limit values (>80% DES dust limit) MFE (2016)

Event date	Event time (average and peak) and concentrations	Wind at time of peak concentration	Species correlated	Possible sources in study area	Emission ratio interpretation	Sources identified upwind	Other info	Likely source
13/2/2017	$PM_{2.5}$ 20.6 µg m^{-3} (24-hr av) 5 min peak = 49.6 µg m^{-3} at 20:20 PM_{10} 42.7 µg m^{-3} (24-hr av) 5 min peak = 95.9 µg m^{-3} at 03:40	SW-SSW 4-6 m s^{-1} SW 2-3 m s^{-1}	PM is half fine fraction $PM_{2.5}$ and CO correlate PM is mainly large fraction PM_{10} and O_3 correlate	Combustion Airborne dust and soil from unsealed roads, agriculture activities, CSG activities Combustion	$PM_{2.5}$/CO ratio indicates vegetation fire	Hotspots in previous 24 hours indicate fires about 570 km S of Hopeland Smoke over study area visible in satellite image GPF 10km to SSW	TSP exceedances Miles Airport, Hopeland PM_{10} exceedances Miles Airport $PM_{2.5}$ >80% EPP objective at Hopeland. Miles Airport PM_{10} >80% EPP objective at Hopeland, Condamine	Information available suggests regional dust event and regional smoke event from vegetation fire
10/8/17	$PM_{2.5}$ 22.5 µg m^{-3} (24-hr av) 5 min peak = 71.9 µg m^{-3}	NNE 1-3 m^{s-1}	PM mainly fine fraction $PM_{2.5}$ and CO correlate until 19:30	Combustion	$PM_{2.5}$/CO ratio indicates vegetation fire	Hotspots in previous 24 hours indicate fires about 75 km NNE and about 90 km NNW of Hopeland Smoke visible heading S and SE	Elevated $PM_{2.5}$ continues until ~8am the following morning (11/8) No data at Miles Airport or Condamine, CO elevated Burncluith	Information available suggests regional smoke event from vegetation fire

	at 18:25		$PM_{2.5}$ and NO_x correlate until 19:30			towards study area on satellite images		
14/1/18	TSP 53.7 µg m^{-3} (24-hr av) 5 min peak = 161.9 µg m^{-3} at 20:25	S 3-7 m s^{-1}*	PM is mainly large fraction No correlations No CO, NOx data	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	n/a	CSG wells and gathering network Agriculture Unsealed roads GPF 10km to SSW	TSP exceedance Miles Airport (TSP peak at similar time) No data at Condamine	Information available suggests regional dust event

For PM events, the PM species ($PM_{2.5}$, PM_{10}, TSP) were always correlated with one another, and so PM correlations are not explicitly stated

***Where wind data from ambient air quality site was unavailable due to instrument calibration or error, wind data from the nearest alternative measurement site was used instead. Alternative sites included Burncluith, Miles township and a private property ~5 km north of Hopeland ambient air quality station. Wind data from these alternative sites was found to be broadly comparable with wind data from gas field sites, where parallel measurements were available.**

Table 29 Miles Airport – $PM_{2.5}$ and PM_{10} greater than 80% of the Air Quality Objective (>80% EPP objective) and TSP greater than 80% of the DES nuisance dust limit values (>80% DES dust limit), MFE (2016)

Event date	Event time (average and peak) and concentrations	Wind at time of peak concentration	Species correlated	Possible sources in study area	Emission ratio interpretation	Sources identified upwind	Other info	Likely source
10/1/2017	TSP 51.5 µg m^{-3} (24-hr av) 5 min peak = 1068.2 µg m^{-3} at 20:35	E 2 m s^{-1}	PM mainly large fraction TSP correlates with CO_2, CH_4 and NO_x CO_2 and CH_4 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio consistent with cattle	Feedlot 2 km Agriculture CSG wells and gathering network Unsealed roads	Wind direction change to NW/SW halfway during event – TSP concentrations decrease when wind changes No other exceedances	Information available suggests particles associated with cattle farming
10/2/2017	TSP 51.5 µg m^{-3} (24-hr av) 5 min peak = 1634.6 µg m^{-3} at 19:55	E 2 m s-1	PM mainly large fraction CO_2 and CH_4 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio consistent with cattle (upper end of ratio)	Feedlot 2 km (E) Agriculture CSG wells and gathering network Unsealed roads CSG infrastructure (water treatment ponds) (1.5km to W)	Wind direction change to WSW during event- then TSP concentrations keep increasing but CO_2 and CH_4 concentrations decrease No other exceedances	Information available suggests particles associated with cattle farming to E (minor) and other unknown source to WSW
13/2/2017	$PM_{2.5}$ 23.5 µg m^{-3} (24-hr av) 5 min peak = 53.1 µg m^{-3} at 20:20	SW 3-6 m s^{-1}	PM is about half small fraction $PM_{2.5}$ and NO_x correlate	Combustion	n/a	Hotspots in previous 24 hours indicate fires about 570 km S of Miles Airport. Smoke over study area visible on satellite image	Landholder reported hazy conditions but no local fires TSP exceedance Hopeland, Miles Airport, Condamine PM_{10} exceedances Miles Airport	Information available suggests regional dust event and regional smoke event from vegetation fire

							PM_{10}>80% of EPP guideline Hopeland, Condamine $PM_{2.5}$ >80% EPP objective at Hopeland. Miles Airport, Condamine	
14/2/2017	TSP 57.1 µg m^{-3} (24-hr av) 5 min peak = 461.1 µg m^{-3} at 20:20 smaller peaks at 6:45, 8:30 and 18:10	Largest peak: E 3-7 m s-1 smaller peaks: SW/variable 1-4 m s^{-1}	PM mainly large fraction	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CO_2 and CH_4 are not enhanced alongside TSP indicating unlikely to be cattle	Feedlot 2 km Agriculture CSG wells and gathering network Unsealed roads	No other exceedances Short lived (<1 hr) and sharp peaks suggests local sources	Could not be determined with available data
15/2/17	PM_{10} 42.9 µg m^{-3} (24-hr av) 5 min peak = 805.0 µg m^{-3} at 20:40	ESE 1-6 m s^{-1}	PM is mainly large fraction TSP correlates with CH_4, CO_2 CO_2 and CH_4 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities Combustion	CH_4/CO_2 ratio consistent with cattle	Feedlot 2 km (E) Agriculture CSG wells and gathering network Unsealed roads	TSP exceedance Miles Airport	Information available suggests particles associated with cattle farming
16/2/2017	TSP 50.5 µg m^{-3} (24-hr av) 5 min peak = 1039.4 µg m^{-3} at 19:20	E 1-7 m s-1 (E as TSP increasing then S at 7 ms -1 during peak TSP)	PM is mainly large fraction TSP correlates with CO_2 TSP correlates with CH_4 CH_4 and CO_2 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio consistent with cattle	Feedlot 2 km (E) and 5km (SSE) Agriculture CSG wells and gathering network Unsealed roads	No other exceedances	Information available suggests particles associated with cattle farming

25/2/2017	TSP 53.0 µg m^{-3} (24-hr av) 5 min peak = 1057.8 µg m^{-3} at 19:30	E 2-4 m s-1	PM is mainly large fraction CO_2 and CH_4 elevated alongside TSP but not correlated with TSP CO_2 and CH_4 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio consistent with cattle	Feedlot 2 km Agriculture CSG wells and gathering network Unsealed roads	No other exceedances	Information available suggests particles associated with cattle farming
2/5/2017	TSP 48.1 µg m^{-3} (24-hr av) 5 min peak = 527.2 µg m^{-3} at 18:15	ENE 2 ms-1	PM mainly large fraction TSP and CO_2 correlate TSP and CH_4 correlate CO_2 and CH_4 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio consistent with cattle	Feedlot 2 km Agriculture CSG wells and gathering network Unsealed roads	No other exceedances	Information available suggests particles associated with cattle farming
2/8/2017	TSP 50.3 µg m^{-3} (24-hr av) 5 min peak = 618.3 µg m^{-3} at 17:30	E 2 ms -1	PM is mainly large fraction CO_2 and CH_4 elevated alongside TSP but not correlated with TSP CO_2 and CH_4 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio consistent with cattle	Feedlot 2 km Agriculture CSG wells and gathering network Unsealed roads	No other exceedances	Information available suggests particles associated with cattle farming
21/9/2017	TSP 52.8 µg m^{-3} (24-hr av) 5 min peak = 327.2 µg m^{-3} at 20:30	ENE 2 ms-1	Mainly large fraction No NO_x, CO, CO_2 or CH_4 data	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	n/a	Feedlot 2 km Agriculture CSG wells and gathering network Unsealed roads	No other exceedances	Could not be determined with available data

26/9/2017	TSP 57.7 µg m^{-3} (24-hr av) 5 min peak = 298.1 µg m^{-3} at 20:35	S-E-NE 2-4 m s^{-1}	Mainly large fraction No NO_x, CO, CO_2 or CH_4 data	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	n/a	Feedlot 2 km E and 5 km SSE Agriculture CSG wells and gathering network Unsealed roads	No other exceedances Short lived and sharp peaks suggests local source/s	Could not be determined with available data
27/9/2017	$PM_{2.5}$ 21.3 µg m^{-3} (24-hr av) 5 min peak = 30.6 µg m^{-3} at 22:45	NNE 2-4 m s^{-1}*	PM is mainly small fraction No CO_2, CO, NO_x or CH_4 data	Combustion	n/a	Hotspots in previous 24 hours indicate fires about 250-290 km NW of Miles Airport and 90 km NE of Miles Airport	$PM_{2.5}$/CO ratio at Hopeland indicates vegetation fire (no exceedance) O_3 >80% EPP objective at Burncluith	Information available suggests regional smoke event from vegetation fire
28/9/2017	TSP 51.0 µg m^{-3} (24-hr av) 1st 5 min peak = 86 µg m3 at 3:35 2nd 5 min peak =118.5 µg m^{-3} at 13:30	1st peak N 3-8 m s^{-1} 2nd peak NW 4-9 m s-1	1st peak: PM is mainly small fraction 2nd peak: PM is mainly large fraction No CO_2, CO, NO_x or CH_4 data	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	n/a	Hotspots in previous 24 hours indicate fires about 250-290 km NW of Miles Airport and 90 km NE of Miles Airport CSG infrastructure including GPF, WTF 1.5 km (NW) CSG wells and gathering network Unsealed roads Agriculture	$PM_{2.5}$ exceedance at Miles Airport $PM_{2.5}$/CO ratio at Hopeland indicates vegetation fire (but no exceedance)	Information available suggests particles associated with regional smoke event from vegetation fire and unsealed roads/CSG development or operational activities

20/10/2017	TSP 59.6 µg m^{-3} (24-hr av) 1st 5 min peak = 1774.3 µg m^{-3} at 18:40 Smaller peaks at 20:15 and 21:05	1st peak ESE 2 m s^{-1} Smaller peaks NE 1-2 m s^{-1} and SSW 5-7 m s^{-1}	PM is mainly large fraction CO_2 and CH_4 elevated alongside TSP but not correlated with TSP 1st peak: CO_2 and CH_4 correlate Subsequent peaks: no correlations	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio higher than cattle ratio	Feedlot 2 km E and 5 km SSE Agriculture CSG wells and gathering network Unsealed roads	No other exceedances	Could not be determined with available data
18/01/2018	TSP 48.7 µg m^{-3} (24-hr av) 5 min peak = 593.4 µg m^{-3} at 21:30	NE 1-2 m s^{-1}*	PM mainly large fraction TSP and CH_4 correlate TSP and CO_2 correlate TSP and NO_x correlate CH_4 and CO_2 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio consistent with cattle	Feedlot 2 km Agriculture CSG wells and gathering network Unsealed roads	No other exceedances	Information available suggests particles associated with cattle farming
21/01/2018	TSP 49.7 µg m^{-3} (24-hr av) 5 min peak = 1297.1 µg m^{-3} at 19:40	ENE 2-3 ms^{-1}*	PM is mainly large fraction CO_2 and CH_4 elevated alongside TSP but not correlated with TSP CO_2 and CH_4 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio consistent with cattle	Feedlot 2 km Agriculture CSG wells and gathering network Unsealed roads	No other exceedances	Information available suggests particles associated with cattle farming

22/01/2018	TSP 58.2 µg m^{-3} (24-hr av) 5 min peak = 1458.4 µg m^{-3} at 20:05	NE 1-2 m s^{-1}*	PM is mainly large fraction CO_2 and CH_4 elevated alongside TSP but not correlated with TSP CO_2 and CH_4 correlate	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CH_4/CO_2 ratio consistent with cattle	Feedlot 2 km Agriculture CSG wells and gathering network Unsealed roads	No other exceedances	Information available suggests particles associated with cattle farming
15/02/2018	TSP 59.5 µg m^{-3} (24-hr av) 5 min peak = 516.7 µg m^{-3} at 20:35	NNE 0-5 ms^{-1}*	PM is mainly large fraction No correlations	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	CO_2 and CH_4 not correlated suggesting unlikely to be cattle	Agriculture CSG wells and gathering network Unsealed roads	No other exceedances	Could not be determined with available date

For PM events, the PM species ($PM_{2.5}$, PM_{10}, TSP) were always correlated with one another, and so PM correlations are not explicitly stated

***Where wind data from ambient air quality site was unavailable due to instrument calibration or error, wind data from the nearest alternative measurement site was used instead. Alternative sites included Burncluith, Miles township and a private property ~5 km north of Hopeland ambient air quality station. Wind data from these alternative sites was found to be broadly comparable with wind data from gas field sites, where parallel measurements were available.**

Table 30 Condamine – $PM_{2.5}$ and PM_{10} greater than 80% of the Air Quality Objective (>80% EPP objective) and TSP greater than 80% of the DES nuisance dust limit values (>80% DES dustlimit), MFE (2016)

Event date	Event time (average and peak) and concentrations	Wind at time of peak concentration	Species correlated	Possible sources in study area	Emission ratio interpretation	Sources identified upwind	Other info	Likely source
13/2/2017	$PM_{2.5}$ 22.8 µg m^{-3} (24-hr av) 5 min peak = 52.3 µg m^{-3} at 20:25	SSW 3-5 m s^{-1}	PM is mainly fine fraction $PM_{2.5}$ and CO correlate first peak	Combustion	First peak – $PM_{2.5}$/CO ratio indicates vegetation fire	Hotspots in previous 24 hours indicate fires about 560 km S of Condamine Smoke over study area visible on satellite image	TSP exceedances Miles Airport, Hopeland PM_{10} exceedances Miles Airport $PM_{2.5}$ >80% EPP objective at Hopeland. Miles Airport PM_{10} >80% EPP objective at Hopeland, Condamine	Information available suggests regional dust event and regional smoke event from vegetation fire
	PM_{10} 48.3 µg m^{-3} (24-hr av) 5 min peak = 106.2 µg m^{-3} at 01:05	SSW 3-4 m s^{-1}	PM is mainly large fraction PM_{10} correlates with O_3	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities Combustion	n/a			
11/3/2017	TSP 54.7 µg m^{-3} (24-hr av) 5 min peak = 1466.6 µg m^{-3} at 19:00	SW 1 m s^{-1}	PM is mainly large fraction No correlations	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	n/a	CSG wells and gathering network CSG infrastructure (including pond and compressor station -1.5km SW) unsealed roads	No other exceedances Short lived TSP peak (< 1 hour)	Information available suggests particles associated with unsealed roads/CSG development or operational activities

10/4/2017	TSP 50.8 µg m^{-3} (24-hr av) 5 min peak = 160.1 µg m^{-3} at 07:10	SSW 3-4 m s^{-1}	PM is mainly large fraction No correlations	Airborne dust and soil from unsealed roads, agriculture activities, CSG activities	n/a	CSG wells and gathering network CSG infrastructure (including pond and compressor station -1.5km SW, GPF 1.5km SSE) unsealed roads	No other exceedances TSP elevated for most of day	Information available suggests particles associated with unsealed roads/CSG development or operational activities

For PM events, the PM species ($PM_{2.5}$, PM_{10}, TSP) were always correlated with one another, and so PM correlations are not explicitly stated

Table 31 Ozone events >80% EPP objective (4 hour average) for all sites

Event date	Event time (average and peak) and concentrations	Wind at time of peak concentra -tion	Species correlated	Possible sources in study area	Emission ratio interpretation	Sources identified upwind	Other info	Likely source
21/02/2017 Miles Airport	O_3 0.069 ppm (4-hr av from 15:00-18:00) 15:40 72 ppm (5 min peak)	Variable 1-4 m s^{-1}	NO_x correlates with CO_2 and CH_4 CH_4 and CO_2 correlate.	Fires Other sources of VOCs and NO_x	n/a	No significant hotspots that would suggest regional fire event. Elevated NO_x, CO_2, CH_4 previous night from ~1800-08:30 in variable winds. (NO_x peak of 29.6 ppb 5 min at 05:40) (source unknown) O_3 removed completely ~05:00 before increasing to peak levels later that day	Similar O_3 pattern at Hopeland, Burncluith, Condamine and Tara Region in variable winds. Similar pattern of elevated NO_x, CO_2, CH_4 previous night also at Hopeland, Burncluith and Tara Region (no CH_4 data) in variable winds (Condamine incomplete data set for O_3, NO_x, CO_2, CH_4)	Information available suggests regional ozone event (cause unknown)
27/09/2017 Burncluith	O_3 0.065 ppm (4 hour av from 16:00-20:00) 16:25 69 ppm (5 min peak)	NNW - NNE 2-3 m s-1	O_3 and CO correlate	Fires Other sources of VOCs and NO_x	n/a	Hotspots in previous 24 hours indicate fires about 280-320 km NW and 40 km NNE of Burncluith	$PM_{2.5}$ >80% EPP Obj Miles Airport $PM_{2.5}$/CO ratio at Hopeland indicates vegetation fire (no exceedance) O3 shows similar pattern with concentrations higher than usual at Miles Airport, Hopeland (Condamine no data).NO_x not elevated at any site	Information available suggests ozone associated with regional smoke event (vegetation fire)

4.4.3 Analysis of methane events

Table 32 Hopeland methane events

Event date	Event time (average and peak) and concentrations	Wind at time of peak concentra-tion	Species correlated	Possible sources in study area	Emission ratio interpretation	Sources identified upwind	Other info	Likely source
27/05/2017	26/5/2017 18:20 – 27/5/2017 08:40 Average 2.5 ppm 07:10 5 min Peak =4.4 ppm 07:00 3.6 ppm (1 hr av)	SE 0-2 m s^{-1}	No correlations	CSG activities cattle	No correlation of CH_4 with CO_2 or CO indicates unlikely to be cattle or combustion However CH_4 and CO_2 do correlate more broadly overnight.	CSG wells and gathering network GPF 3 km to SE	CH_4 increases overnight for several consecutive nights. Suggests CH_4 trapped in boundary layer, source unknown. CH_4 event Condamine peaks 23:15	Could not be determined with available data
27/07/2017	26/7/2017 19:25 – 27/7/2017 10:25 Average 2.5 ppm 07:40 5 min Peak =3.7 ppm	Light and variable	No correlations	CSG activities cattle	No correlation of CH_4 with CO_2 or CO indicates unlikely to be cattle or combustion However CH_4 and CO_2 do correlate more broadly overnight.	CSG wells and gathering network agriculture	CH_4 increases overnight for several consecutive nights. Suggests CH_4 trapped in boundary layer, source unknown.	Could not be determined with available data

	08:00 3.5 ppm (1 hr av)							
15/08/2017	14/8/2017 20:05 – 15/8/2017 08:20 Average 2.4 ppm 07:40 5 min Peak =3.9 ppm 08:00 3.3 ppm (1 hr av)	SE $<1\ ms^{-1}$	No correlations	CSG activities cattle	No correlation of CH_4 with CO_2 or CO indicates unlikely to be cattle or combustion However CH_4 and CO_2 do correlate more broadly overnight.	CSG wells and gathering network GPF 3 km to SE	CH_4 increases overnight for several consecutive nights. Suggests CH_4 trapped in boundary layer, source unknown.	Could not be determined with available data
1/09/2017	31/8/2017 20:05 -1/9/2017 08:05 Average 2.5 ppm 07:05 5 min Peak =4.1 ppm 06:00 3.4 ppm (1 hr av)	SE $<1\ ms^{-1}$	No correlations	CSG activities cattle	No correlation of CH_4 with CO_2 or CO indicates unlikely to be cattle or combustion However CH_4 and CO_2 do correlate more broadly overnight.	CSG wells and gathering network GPF 3 km to SE	CH_4 increases overnight for several consecutive nights. Suggests CH_4 trapped in boundary layer, source unknown.	Could not be determined with available data

14/09/2017	20:50 – 23:50 Average 2.7 ppm 23:00 5 min Peak =5.0 ppm 23:00 3.3 ppm (1 hr av)	SSW 2 ms^{-1}	No correlations	CSG activities cattle	No correlation of CH_4 with CO_2 or CO indicates unlikely to be cattle or combustion	CSG wells and gathering network GPF 10km to SSW	Short lived and sharp peaks suggests local source	Information available suggests emissions of uncombusted CSG from CSG activities/infrastructure

Table 33 Miles Airport methane Events

Event date	Event time (average and peak) and concentrations	Wind at time of peak concentra -tion	Species correlated	Possible sources in study area	Emission ratio interpretation	Sources identified upwind	Other info	Likely source
11/04/2017	10/4/2017 23:00 – 11/4/2017 2:40 Average 6.9 ppm 00:05 5 min Peak =18.2 ppm 00:00 11.7 ppm (1 hr av)	WSW 1-2m s^{-1}	No correlations	CSG activities Cattle Dam/reservoir	No correlation of CH_4 with CO_2 or CO indicates unlikely to be cattle or combustion	CSG wells and gathering network CSG infrastructure (water treatment ponds) 1.5km to W	n/a	Information available suggests emissions of uncombusted CSG from CSG activities/infrastructure

23/05/2017	23/5/2017 18:40 – 24/5/2017 08:00 Average 2.7 ppm 22:25 5 min Peak =5.1 ppm 23:00 3.5 ppm (1 hr av)	E-NE 1-2 ms^{-1}	CH_4 and CO_2 correlate CH_4 and NO_x correlate (incomplete NO_x and CO dataset)	CSG activities Cattle Dam/reservoir	CH_4/CO_2 ratio consistent with cattle^	Feedlot -2km Agriculture CSG wells and gathering network	Long duration event overnight (14 hrs), consistent with CH_4 trapped in boundary layer.	Could not be determined with available data
14/07/2017	13/7/2017 18:10 - 14/7/2017 08:10 Average 2.2 ppm First peak 18:30 5 min peak = 3.6 ppm Second peak 06:55 5 min Peak =4.5 ppm 08:00 3.7 ppm (1 hr av)	ENE 2-3 ms^{-1}	CH_4 and CO_2 correlate (first peak) TSP elevated but not correlated (first peak) No other correlations No CO data	CSG activities Cattle Dam/reservoir	CH_4/CO_2 ratio consistent with cattle (first peak)	Feedlot -2km Agriculture CSG wells and gathering network	Two sources likely contributing in same wind direction	Information available suggests emissions of uncombusted CSG from CSG and activities/infrastructure (second larger peak) and cattle farming (first peak)

7/01/2018	21:35 – 23:00 Average 16.0 ppm 22:05 5 min Peak =50.9 ppm 23:00 15.7 ppm (1 hr av)	NE 1 ms^{-1}*	CH_4 and NO_x correlate No other correlations No CO data	CSG activities Cattle Dam/reservoir	No correlation of CH_4 with CO_2 indicates unlikely to be cattle or combustion	Feedlot 2km Agriculture CSG wells and gathering network	n/a	Information available suggests emissions of uncombusted CSG from CSG activities/infrastructure
8/01/2018	20:50-22:55 Average 3.7 ppm 22:40 5 min Peak =8.1 ppm 23:00 3.8 ppm (1 hr av)	NNE 1-3 m s^{-1}*	No correlations No CO data	CSG activities Cattle Dam/reservoir	No correlation of CH_4 with CO_2 indicates unlikely to be cattle or combustion	Feedlot 2km Agriculture CSG wells and gathering network	n/a	Information available suggests emissions of uncombusted CSG from CSG activities/infrastructure

Table 34 Condamine methane Events

Event date	Event time (average and peak) and concentrations	Wind at time of peak concentra -tion	Species correlated	Possible sources in study area	Emission ratio interpretation	Sources identified upwind	Other info	Likely source
10/01/2017	19:50 – 21:15 Average 2.8 ppm 20:45 5 min Peak =4.8 ppm 21:00 3.3 ppm (1 hr av)	ENE 2-4 m s^{-1}	CO and NO_x, CO_2 correlate CO, NO_x and CO_2 elevated alongside CH_4 but not correlated with CH_4	CSG activities cattle	n/a	CSG wells and gathering network GPFs 10 km to NE and 13 km to ENE	TSP>80% EPP objective at Miles Airport	Information available suggests emissions of CSG from CSG activities/infrastructure (possible gas combustion)
24/03/2017	23/3/17 20:00 – 24/3/17 05:25 Average 2.0 ppm 02:05 5 min Peak =2.8 ppm 03:00 2.6 ppm (1 hr av)	ENE 3-4 m s^{-1}	No correlations	CSG activities cattle	No correlation of CH_4 with CO_2 or CO indicates unlikely to be cattle or combustion	CSG wells and gathering network GPFs 10 km to NE and 13 km to ENE	n/a	Information available suggests emissions of uncombusted CSG from CSG activities/infrastructure

23/04/2017	01:45 – 03:40 Average 3.5 ppm 02:35 5 min Peak =12.7 ppm 03:00 4.5 ppm (1 hr av)	E-N 1-2 m s^{-1}	No correlations	CSG activities cattle	No correlation of CH_4 with CO_2 or CO indicates unlikely to be cattle or combustion	CSG wells and gathering network GPFs 10 km to NE and 13 km to ENE	n/a	Information available suggests emissions of uncombusted CSG from CSG activities/infrastructure
26/05/2017	25/5/17 21:05 – 26/5/17 03:15 Average 2.3 ppm 25/5/17 23:45 5 min Peak =3.3 ppm 00:00 2.6 ppm (1 hr av)	SW-E 0-2 m s^{-1}	No correlations	CSG activities cattle	No correlation of CH_4 with CO_2 or CO indicates unlikely to be cattle or combustion	GPF 1km S/SE, compressor station 1.5 km SW CSG wells and gathering network GPFs 10 km to NE and 13 km to ENE	n/a	Information available suggests emissions of uncombusted CSG from CSG activities/infrastructure

27/05/2017	26/5/17 20:10 – 27/5/17 07:55 Average 2.3 ppm 26/5/17 23:15 5 min Peak =3.7 ppm 00:00 3.2 ppm (1 hr av)	ENE 1-3 m s^{-1}	PM and CH_4 correlate (PM mostly large fraction)	CSG activities cattle	No correlation of CH_4 with CO_2 or CO indicates unlikely to be cattle or combustion	CSG wells and gathering network GPFs 10 km to NE and 13 km to ENE	CH_4 event Hopeland peaks at 7:10	Information available suggests emissions of uncombusted CSG from CSG activities/infrastructure

5 Conclusion

This report summarises data from the second half of the Surat Basin ambient air monitoring study (2017 - 2018) with the previous data (2014 – 2016) summarised in Lawson et al., (2018a). Data reported here was collected during monitoring at Miles Airport, Hopeland and Burncluith from January 2017-February 2018. The Condamine gas field station was decommissioned in June 2017 to be relocated to another site in the study area – this relocation is still underway. The Tara Region site suffered significant data loss during 2017-2018 due to technical issues resulting in unreliable power at this remote site. Power issues were resolved January 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) (Air EPP), NEPM, and DES Nuisance Dust Guidelines for TSP. During the period January 2017 – February 2018:

• There were no exceedances of carbon monoxide, nitrogen dioxide or ozone air quality objectives at any of the regional or gas field sites.

• There was 1 exceedance of the 24 hour average $PM_{2.5}$ objective, and 1 exceedance of the 24 hour average PM_{10} objective at the gas field sites. There were 10 exceedances of the 24 hour TSP hour nuisance dust objective at the gas field sites.

• There are no $PM_{2.5}$, PM_{10} or TSP measurements undertaken at the regional sites.

A protocol which uses a combination of wind speed and direction, source locations, and pollutant correlations and ratios was developed to investigate the cause / source(s) of the 12 exceedances. Based on these investigations, the most likely cause or source/s of the exceedance events were as follows:

• $PM_{2.5}$ exceedance was attributed to smoke from regional vegetation fire/s;

• PM_{10} exceedance was attributed to a combination of a regional dust event and regional vegetation fire

• Three TSP events were attributed to regional dust and regional vegetation fire, 4 TSP events were attributed to cattle farming, 1 TSP event was attributed to unsealed roads/CSG activities, 1 TSP event was attributed to a regional dust event. The source/s of 1 event could not be determined.

A further 28 events where pollutant concentrations were greater than 80% of a relevant air quality objective were identified and investigated in recognition that an exceedance may have occurred closer to the pollutant source but not at the monitoring station. Most (26) of these events were 24 hour average concentrations of $PM_{2.5}$, PM_{10}, TSP. The same protocol was also used to determine the most likely cause or source(s) of these events with the findings as follows:

- The levels of carbon monoxide and nitrogen dioxide were always less than 80% of the air quality objectives at the regional and gas field sites
- $PM_{2.5}$ levels that were >80% of 24 hour average air quality objective were attributed to smoke from vegetation fires, a combination of smoke from vegetation fires and dust
- PM_{10} levels that were >80% of the 24 hour average air quality objective were attributed to smoke from a combination of vegetation fires and dust, particles associated with cattle farming;
- TSP levels that were >80% of the 24 hour average air quality objective were attributed to regional dust, particles associated with cattle farming, unsealed roads and/or CSG development or operational activities, source undetermined.
- Ozone levels that were >80% of the 4 hour average air quality objective were attributed to emissions from a regional fire, and source/cause undetermined.

Methane emissions and implications for air quality

Methane was measured at the gas field sites as a tracer for CSG related emissions. The 2017 annual average methane concentration at Gas field sites was 1.9 ppm, comparable to methane concentrations measured at the two regional sites as part of the GISERA Regional Methane Flux study (Luhar et al., 2018). The 5 largest methane events at each gas field site from 2017-2018 were identified and the potential source(s) investigated, making a total of 15 methane events investigated. Nine of the 15 methane events investigated were attributed to sources or activities associated with the CSG industry, 1 was attributed to a combination of the CSG industry and cattle farming, and the source of 5 were unknown. None of the methane events investigated were associated with an exceedance of an air quality objective of any of the other pollutants measured. Eight of the 9 methane events attributed to CSG-related sources were likely due to the release of un-combusted CSG, while the remaining event may have been related to gas combustion. Maximum 1 hour concentrations of methane at the Gas field sites were generally lower in 2017-2018 than in 2015-2016.

Overall, air pollutant concentrations during 2017-2018 were generally well below air quality objectives for the majority of the time. There were a number of infrequent exceedances of 24 hour objectives for particles, particularly TSP. The sources of the particles identified were typical of rural areas, including smoke from vegetation fires, windblown dust, unsealed roads, agriculture, and CSG-related activities at one site. While the CSG industry was identified as the likely largest source of methane concentration events observed, these did not result in exceedances of air quality objectives for other pollutants measured.

An overall assessment of air quality in region over the entire study period is provided in a separate report (Lawson et al., 2018c). The CSIRO modelling study will be the final output for this project and will aim to provide an estimate of what contribution CSG-related emissions make to the 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 ambient monitoring sites 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 data reporting, is beyond the scope of this project.

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