12 AIR

12.1 INTRODUCTION

This chapter provides responses to submissions received on the draft EIS related to potential air quality impacts of the Gas Field activities.

Where changes to the project description, as detailed in *Volume 2, Chapters 7* and *11*, have impacted air, these impacts, and measures to mitigate impacts are described.

12.2 RESPONSES TO SUBMISSIONS

Table 3.12.1 provides a summary of the submissions received on air of the Gas Field and a response to those submissions.

Table 3.12.1 Responses to Submissions on the draft EIS

Issue Raised	QCLNG Response	Relevant Submissions(s)
Camps should be considered as sensitive receptors to which the same mitigation measures should be applied as other sensitive receptors.	Modeling of impacts on air quality as presented in this Chapter and in Volume 3, Chapter 12 of the draft EIS, demonstrates that there will be no exceedences on air quality limits, including at camps. All occupational health and safety guidelines will implemented by QGC.	10
Provide information on: • Locations and numbers of the compressor engines and generators; • NOx, CO and VOCs concentrations presented in terms of mg/Nm^3 (dry) at 3% O_2; • The generators stack specifications, fuel type used and emission characteristics	Nominal locations of emissions sources are provided in *Section 12.3.* NOx, CO and VOCs concentrations are presented in terms of mg/Nm^3 (dry) at 3% O_2. Refer to *Section 12.6*. The nominal stack specifications, fuel type used and emission characteristics for emissions sources is presented in *Section 12.6*.	32

12.3 CHANGES TO PROJECT DESCRIPTION

Changes to the Project description are described in *Volume 2, Chapters 7* and *11*. The following changes in the Project description have resulted in a change to the assessment of impacts on air quality:

- power sources for screw compressors at FCSs
- power sources for compressors at CPPs
- power sources for WTPs
- flares at wells
- power for pumping water
- wellhead pressure reduction using either wellhead compressors or available FCS screw compressor capacity.

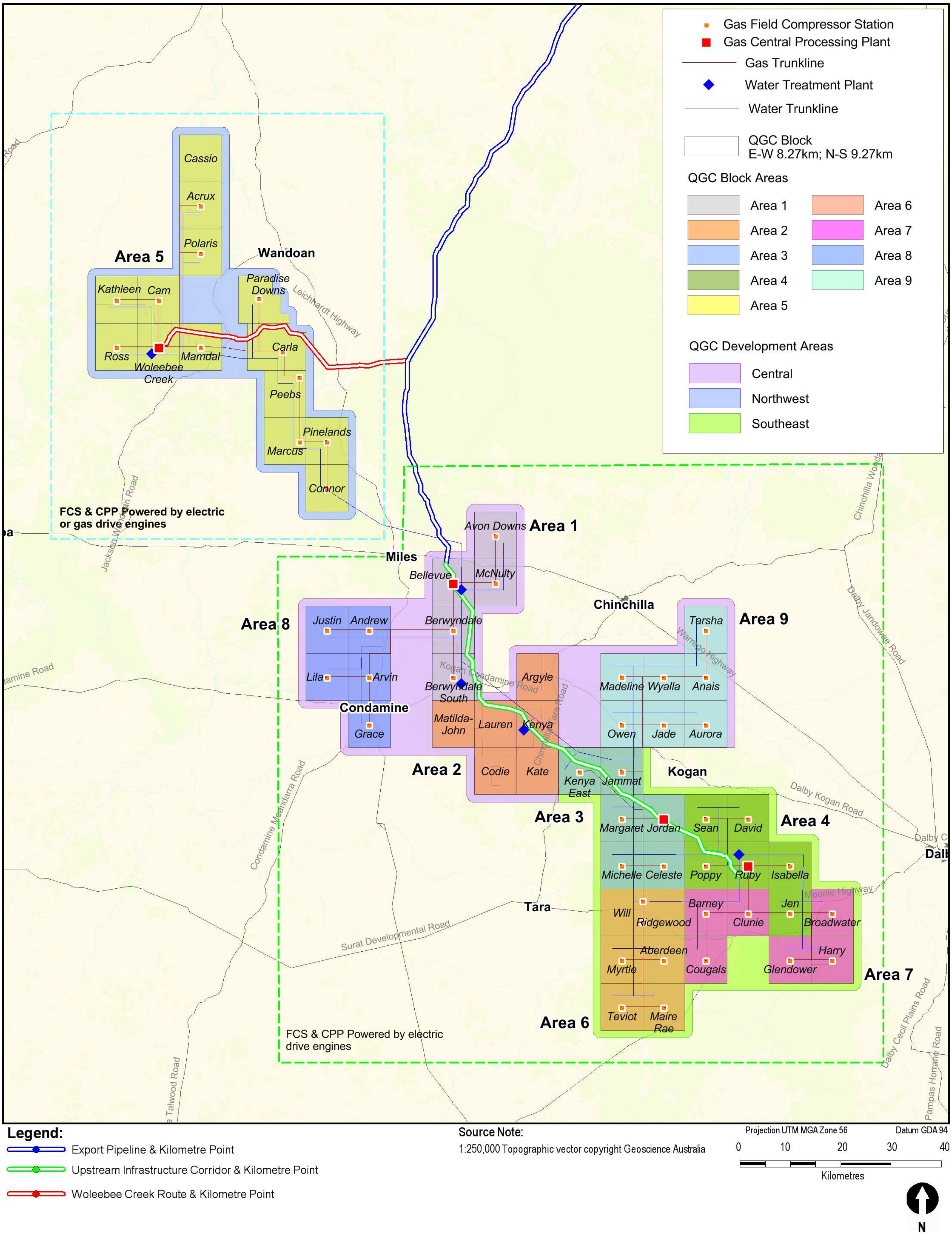
Where changes to Project description are considered insignificant in relation to impacts on air quality, these impacts have not been assessed in the supplementary EIS.

12.3.1 Field Compressor Stations and Central Processing Plants

The draft EIS assumed that all screw compressors at FCSs and reciprocating compressors at CPPs would be powered by gas engines. For the purpose of assessing impacts on air quality, the supplementary EIS assumes a worst case scenario where:

- all compressors at FCSs and CPPs in the Central Development Area (CDA) and South East Development Area (SEDA) will be powered by electric motors or turbines connected to the electricity transmission grid
- all compressors at FCSs and CPPs in the North West Development Area (NWDA) will be powered by gas engines or turbines.

Figure 3.12.1 shows the Development Areas, potential power sources for FCSs and CPPs in each Development Area and the nominal locations of FCSs, CPPs and WTPs in the Gas Field.



QUEENSLAND CURTIS LNG
A BG Group business

ERM
Environmental Resources Management Australia Pty Ltd

Project	Queensland Curtis LNG Project	Title	**Gas Field Areas and Major Facilities**
Client	QGC - A BG Group business		
Drawn: Unidel	**sEIS Volume 3 Figure S3.12.1**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.	
Approved: CDP	File No: QC02-T-MA-00164		
Date: 20.01.10	Revision: Supplementary		

QGC are investigating the option to power WTPs and compressors at FCSs and CPPs in the NWDA with electric motors. Power for electric motors would be sourced from a connection to the grid or decentralised gas turbines. The gas turbines will supply power as an interim measure if a connection to the grid cannot be established in the timeframes required. It is not expected that these turbines would operate for more than 3 years. The air impact modelling described in this chapter includes, as a scenario, the decentralised gas turbine, nominally located in the Woleebee Creek block, as a source of air emissions.

QGC will not assess the impacts of air emissions (other than greenhouse gases) from power sourced from a grid connection. In the NWDA, where there is uncertainty about the potential connection to the grid, QGC has adopted a conservative approach by assuming that compressors will either be powered by:

- gas engines or turbines located at each compressor or
- decentralised gas turbines connected via transmission lines to each compressor.

Table 3.12.2 compares the power sources for compressors between the draft EIS and supplementary EIS. Due to the refinement in engineering design of compressors and engines, the power requirements per screw compressor have declined, although the number of screw compressors has remained similar. The compressors at the CPP have changed from reciprocating to centrifugal with a corresponding decline in the number of compressors required and an increase in the engine capacity required to power each compressor.

For the purpose of modelling emissions in the NWDA it has been assumed that there will be one CPP located in the Woleebee Creek block and 12 FCSs located near the centre of each block. Whilst full field development may see 12 sites for FCS in that area, it is not likely that each FCS will be operating at full capacity (i.e. with maximum of 8 screw compressors) simultaneously. There will be, on average, approximately 4 to 6 screw compressors operating simultaneously at each FCS.

Table 3.12.2 Comparison of Power Sources for FCSs and CPPs

Compressor type	Draft EIS		Supplementary EIS		
	Nominal Engine model or type	Number of engines	Nominal Engine model or type	Area	Number of gas drive engines / turbines
Screw Compressors at FCS	Caterpillar G3512 gas engines with engine capacity of ±2 MW	± 216	Caterpillar G3516 gas engines with engine capacity of ±1 MW or one decentralised GE LMS100 turbine with 100 MW capacity	NWDA	± 70
			Electric drive engines (grid supply) with engine capacity of ±1 MW	CDA & SEDA	± 130
Reciprocating compressors at CPPs	Caterpillar G3608 gas engines, with engine capacity of ±4.6 MW	90	n/a		n/a
Centrifugal compressors at CPPs	n/a	n/a	GE LM2500 gas turbines with engine capacity of ±23 MW or one decentralised GE LMS100 turbine with 100 MW capacity	NWDA	3
			Electric dive turbines (grid supply) with engine capacity of ±23 MW	CDA & SEDA	5

12.3.2 *Water Treatment Plants*

The components of a WTP, including pre-treatment facilities, reverse osmosis (RO) plant, brine concentrator, amendment and blending plant and chemical storage, are as described in the draft EIS.

To provide sufficient excess capacity, WTPs will be sized to treat approximately 175 ML per day. The final locations, configuration and design specifications for WTPs have not been selected. For the purposes of assessing impacts on air quality from WTPs, it has been assumed that there will be 3 WTPs with a combined capacity of 175 ML per day located in the NW, central and SE tenements.

Under the option for 3 WTPs:

- the WTP in NW tenements will have 35 ML per day capacity, be co-located with the CPP in the Woleebee Creek block and be powered by a gas engine
- the WTP in the central tenements will have capacity of approximately 75 ML per day, be located with existing ponds in Kenya block and be powered by a gas engine
- the WTP in the SE tenements will have 65 ML per day capacity, be co-located with the CPP in the Ruby block and be powered by an electric motor connected to the grid.

12.3.3 *Wellhead Pressure Reduction*

The following options (described in *Volume 2, Chapter 7*) to reduce wellhead pressure are under investigation:

- utilisation of the installed compression capacity of screw compressors at the FCSs
- individual compressors with gas engines at wellheads, where required.

Where screw compressors at FCSs are utilized to lower wellhead pressure, this will result in a greater number of screw compressors operating at a FCS towards the end of life of a group of wells. There will be a maximum of eight screw compressors at an FCS at any stage.

Individual wellhead compression provides an alternative mechanism to lower wellhead pressure, by installing a compressor and gas engine at an individual well. Under a worst case scenario, where no screw compressors at FCSs contribute to the lowering of wellhead pressure, then wellhead compression would:

- involve a maximum of 3,600 wells requiring compression simultaneously
- be installed after approximately 5 - 10 years of well operation
- operate for a period of approximately 10 – 20 years

- comprise a single screw compressor and gas engine per well.

In a local area where specific well productivity, the gas resource and configuration characteristics require it, up to 75 per cent of the local wells might have wellhead compression.

The engine size required to power the compressor will depend on the volume of gas that requires compression, estimated at 0.4 mmscf (11,300 m^3) per day. The caterpillar G3304, with engine power at 70 per cent load of approximately 40 kW, has been selected as representative of the type of gas engines that will be required.

12.3.3.1 *Scenarios for Impact Assessment*

In the CDA and SEDA, FCS screw compressors will be powered by electric motors, connected to the grid. Any increase in screw compressors required to lower wellhead pressure in these areas, will not result in an increase in direct Project air emissions as power is sourced from the grid. Screw compressors in the NWDA are assumed to be powered by gas drive engines. Up to eight screw compressors will be required at each FCS to lower wellhead pressure. The impact assessment has considered the following scenario for the assumption that all wellhead pressure reduction is supplied from screw compressors at FCSs:

- no direct air emissions in SEDA and CDA
- in the NWDA, an average of 6 screw compressors operating simultaneously at each FCS to gauge regional air impacts
- In the NWDA, an individual FCS with 8 screw compressors to gauge localised air impacts for FCSs operating with a maximum number of screw compressors.

The worst case scenario for direct air emissions from the Project is when all wellhead pressure reduction is supplied by wellhead compressors powered by a gas engine in the SEDA, CDA and NWDA. Under the assumption that all wellhead pressure reduction is supplied by wellhead compression, the impact assessment has adopted a conservative scenario of approximately 75 per cent of wells (up to 4,500 wells) with a wellhead compressor operating simultaneously. This scenario is not considered likely as it is expected that the majority wellhead pressure reduction will be sourced from screw compressors at FCSs.

Modelling assumes that catalytic reduction technology has been applied to all wellhead compression engines. Catalytic reduction in an engine occurs when hydrocarbons and CO are converted into H_2O and CO_2 and NOx is converted into NO_2. The United States Environmental Protection Agency's (US EPA's) AP-42 document details control technologies for natural gas fired engines. This document states that *"NOx reduction efficiencies are greater than 90% while CO reductions are approximately 90%".* It is also considered that a reduction of 50% in hydrocarbons can be expected with catalytic reduction.

Based on the above information obtained from the US EPA, all modelling assumes catalytic reduction has been incorporated into wellhead compressor engines with the following reduction in air emissions:

- 90 per cent of NO_x
- 80 per cent of CO
- 50 per cent of hydrocarbons

For the purposes of impact assessment it has been assumed that wellhead compressors will be located approximately 750 m apart with 1 in every 4 wells not requiring a wellhead compressor.

12.3.4 *Flaring at Wells*

Flaring will result from a combination of routine, maintenance and emergency flaring. It is estimated that each well will flare 1 mmscf (28,300 m^3) per annum. There are a range of potential flaring scenarios occurring between once every 4 years and twice per year. Flaring events range between 5 minutes and 6 hours except for flaring during pilot well testing and workover rig activities, which are considered to be flaring for routine or maintenance purposes.

Pilot well testing will occur as part of the exploration and appraisal program for the QCLNG project and for these wells (approximately 5 per cent or 300 wells) flaring will occur for up to 6 months. Pilot wells are expected to flare approximately 95 mmscf (2.7 million m^3) per event.

Flaring during workover rig activities occurs once every 2 years for a duration of approximately 3 days. Each workover flaring event will flare approximately 0.5 mmscf (14150 m^3) per day.

Greater than 95 per cent of flaring at wells is attributable to routine or maintenance flaring. To model the maintenance flaring, 50 wells were spread across the entire Gas Field, located in the centre of each block and the average annualised flaring estimate per well was used to calculate emissions of NO_x, CO and hydrocarbons.

The timing of emergency flaring cannot be predicted, but it was assumed that emergency flaring and maintenance flaring do not occur simultaneously. A semi-quantitative assessment of flare emissions at the wells has been carried out for emergencies.

The stack for well site flares will be between 2 and 6 m high and between 150 and 250 mm diameter and designed to comply with all relevant standards.

12.3.5 *Water Pumps*

Each infield storage, regional storage, collection header pond and raw water pond is likely to require a water pump. Over the life of the Project, approximately 150 - 200 infield pumps will be required across the Gas Field, with approximately 40 per cent of pumps operating simultaneously at peak water flows. For the purposes of the supplementary EIS, infield pumps are assumed to be powered by a gas or diesel generator of between 100 – 1,500 kW per pump, with an average of 500 kW. Air emissions have been modeled on using the Waukesha L5794 gas drive engine operating at 70 per cent capacity. It is assumed that there will be approximately 3 water pumps per block for the purpose of emissions modelling.

Based on information obtained from the US EPA (refer *Section 12.3.3*), all modelling assumes catalytic reduction has been incorporated into water pump engines with the following reduction in air emissions:

- 90 per cent of NO_x
- 80 per cent of CO
- 50 per cent of hydrocarbons

12.4 MODELLING SCENARIOS

The impact assessment has been carried out for five scenarios. The selected scenarios cover two regions of the Project area:

- the NWDA
- the SEDA and CDA

The final locations of each emission source have not been defined and will be refined as the Project develops further. The outcome of the assessment is not expected to change substantially as a result of final siting. The locations of emission sources represent nominal locations within the Gas Field, based on expectations of the final location of emissions sources.

12.4.1 Scenario 1

Scenario 1 includes the following emissions sources and corresponding power generation options, from infrastructure located in the NWDA:

- emissions from 1 CPP plant with three GE LM2500 gas turbine driven compressors)
- emissions from 12 FCSs with an average of six G3516 gas-fired reciprocating engines with single stage Ariel screw compressors
- emissions from on GH LM2500 gas turbine for power generation at the WTP
- emissions from CAT G3304 wellhead compression engines (assuming 75 per cent of wells with compressors)
- flare emissions from wells for maintenance
- emissions from water pump Waukesha L5794GSI engines

- background NO_2 emissions from other emitters such as power stations.

There will be between one and eight screw compressors operating at any one FCS. Based on the expected gas throughput there will be an average of six screw compressors at each FCS (assuming that FCS screw compressors are not used for wellhead pressure reduction) and this number has been used in modelling the NWDA to determine regional air impacts.

12.4.2 Scenario 1B

Scenario 1B considers a single FCS with eight screw compressors in the NWDA. Localised air impacts are used to provide a qualitative analysis of the potential air emission should more then one FCS operate with eight screw compressors simultaneously. This may occur should screw compressors at the FCS be used to reduce wellhead pressure.

12.4.3 Scenario 2

Scenario 2 includes all emissions sources in the NWDA as per Scenario 1, with the following power generation options:

- power station used to power CPP and FCSs compressor engines or turbines
- emissions from CAT G3304 well head compression engines (assuming 75 per cent of wells with compressors)
- emissions from water pump Waukesha L5794GSI engines
- flare emissions from wells for maintenance
- background NO_2 emissions from other emitters such as power stations.

12.4.4 Scenario 3

Scenario 3 includes the following emissions sources and corresponding power generation options, from infrastructure located in the CDA and SEDA:

- emissions from a single GE LM2500 gas turbine for power generation at the water treatment plant located in the CDA
- emissions from CAT G3304 wellhead compression engines (assuming 75 per cent of wells with compressors)
- emissions from water pump Waukesha L5794GSI engines
- flare emissions from wells for maintenance
- background NO_2 emissions from other emitters such as power stations.

12.4.5 *Scenario 4*

A semi-quantitative assessment of emergency flaring at the wells has been conducted. Scenario 4 has not been explicitly modelled.

12.5 AIR POLLUTANTS

The air pollutants considered in this supplementary EIS are associated with the combustion of CSG fuel in the gas engines and turbines proposed to be used. The key pollutants identified in the EIS include NO_X, CO and various hydrocarbon species. Sulfur is not present in the CSG in any significant amounts, and therefore sulfur dioxide or any other compounds containing sulfur will not be present in any appreciable quantity in the exhaust emissions of fuel burning equipment.

12.5.1 *Assumptions Made in Modelling Hydrocarbons*

The draft EIS dispersion modelling found that formaldehyde, benzene, ethylchloride, phenanthrene and acrolein to be present in emissions and ground level concentration albeit at very low levels. The assessment of hydrocarbons for the supplementary EIS has focused on these species.

In order to assess the impact of specific hydrocarbon emissions on environmental values, the USEPA AP-42 document *Natural Gas-fired Reciprocating Engines (Chapter 3.1)* has been referenced to determine the potential composition of hydrocarbon emissions associated with the gas-fired reciprocating engine exhaust.

It should also be noted that the AP-42 emission factors have been determined for gas-fired reciprocating engines using natural gas fuel in the United States of America. The natural gas fuel combusted in AP-42 emission tests has a composition that is different to the CSG used in the QCLNG Project.

In particular, it has been found that hydrocarbons such as acrolein do not occur in the exhausts of the engines when fired on CSG because, unlike the natural gas that is used as the basis of the AP-42 emission factors, the CSG does not contain propene the necessary precursor for the formation of acrolein. This was demonstrated in sampling of G3512 and G3608 reciprocating engines, done for the draft EIS, fuelled on CSG (Leeder Consulting, 2009). Consequently, acrolein emission rates have been characterised in this study using the results of Leeder Consulting sampling rather than AP-42.

12.5.2 *Air Quality Standards, Meteorological Data and Background Air Quality*

The following changes have occurred in modeling between the draft EIS and supplementary EIS:

- The air quality standards used remain unchanged.

- Modelling has been upgraded with improved descriptions of the historical meteorological conditions experienced in the area.
- Background NO_2 emissions include an extra power station and minor modifications to modelling to better represents background conditions across the study area.
- Modelling has been carried out with CALPUFF instead of AUSPLUME to better predict ground-level concentrations.

Further information on air quality standards, meteorological data and background air quality is provided in *Appendix 3.3* to the sEIS.

12.6 EMISSIONS SOURCES

Table 3.12.3 presents a summary of the Gas Field emission sources used in the modeling for the supplementary EIS, during both normal and non-normal operations.

12.6.1 Field Compressor Stations

The FCS's that have been included within this assessment are the FCS's located in the NWDA. In this area, 12 FCSs are proposed. The performance characteristics of the Caterpillar G3516 gas engines with single stage Ariel screw compressors, that are considered to be a reasonable approximation of the gas engines that may be used at each FCS, are presented in *Table 3.12.4*. Performance information is presented for normal operating conditions with the gas engines operating at 100% capacity. Each FCS will consist of an average of six screw compressors. *Table 3.12.5* presents the concentrations and emission rates for NO_X, CO and total hydrocarbons, while *Table 3.12.6* presents the rates of formaldehyde, benzene, ethylchloride, phenanthrene and acrolein.

Table 3.12.3 Emission Sources

Unit	No. of process units	Type of source at each unit						Total no. of sources
		Cat G3516 engines	GE LM2500	Waukesha L5794GSI	Cat G3304 engines	LMS100	Flare	
FCS	12	72	0	0	0	0	0	72
CPP	1	0	3	0	0	0	0	3
Water Pumps	170	0	0	170	0	0	0	170
Wellhead pressure reduction, assuming wellhead compression only	6000	0	0	0	4500	0	0	4500
Flares	6000 (wells) 57 (FCS & CPPs)	0	0	0	0	0	6000 / 57	6000 / 57
Power Station[1]	1	0	0	0	0	1	0	1
Water Treatment Plant	2	0	2	0	0	0	0	2

1 Power station would comprise decentralised gas powered turbine, which will only be used as an alternative to gas engines or gas turbines at each FCS or CPP compressor

Table 3.12.4 Performance and Source Characteristics for Caterpillar G3516 Screw Compressors

Parameter	Units	Value[1]
Engine power	bkW	999
Nominal engine efficiency	%	33.7
Nominal fuel consumption	MJ/bkW-hr	10.67
Stack height	m	7.2
Stack diameter	m	0.26
Exhaust gas temperature	^oC	457
Exhaust gas velocity	m/s	25.1
Exhaust mass flow rate (0^oC, 1 Atm, wet)	kg/bkW-hr	6.03
Exhaust gas flow rate (0^oC, 1 Atm, wet)	Nm^3/bkW-hr	4.8
Exhaust gas flow rate (actual stack conditions)	m^3/s	2.1
Normalised exhaust gas flow rate (0^oC, 1 Atm)	Nm^3/s	1.3

1 Source characteristics data obtained from Caterpillar gas engine technical data sheet.

Table 3.12.5 Emissions Data for Caterpillar G3516 Screw Compressors

Parameter	Concentration[1] (mg/Nm^3 at 3% O_2)	Emission rate[1] (g/s)
Oxides of nitrogen (as NO_2)	300	0.558
Carbon monoxide	370	0.699
Non Methane Non Ethane Hydrocarbons (NMNEHC)	60	1.14

1 Information calculated from Caterpillar gas engine technical data sheet.
2 Total hydrocarbons as non-methane hydrocarbons and presented as methane equivalents.

Table 3.12.6 Hydrocarbons Emission Data for Caterpillar G3516 Screw Compressors

Pollutant	Molecular weight	Emission1 factor[1]	Emission Rate (g/s)
Benzene	78.1	4.4×10^{-4}	5.6×10^{-4}
Acrolein[2]	56.06	-	1.24×10^{-5}
Phenanthrene	178.23	1.04×10^{-5}	1.32×10^{-5}
Formaldehyde	30.03	5.28×10^{-2}	6.72×10^{-2}
Ethylchloride	64.52	1.87×10^{-6}	2.38×10^{-6}

1 Source: USEPA AP-42
2 Acrolein emission rate calculated from measurements made by Leeder Consulting, as described in the draft EIS

12.6.2 Central Processing Plant and Water Treatment Plant

The performance characteristics of the GE LM2500 gas turbine that is considered to be a reasonable approximation of the gas turbine that may be located at the CPP in the NWDA and the WTP in the CDA, are presented in *Table 3.12.7*. Pollutant concentrations and emission rates are presented in *Table 3.12.8*. Performance information is presented for normal operating conditions with the gas engine operating at 100% capacity. The CPP will include three turbines and the WTP will include one turbine. *Table 3.12.9* presents the likely contribution to total hydrocarbon emissions assessed for the Project.

Table 3.12.7 Source Characteristics for GE LM2500 Gas Turbine

Parameter	Units	Value[1]
Number of units	-	3
Stack height	m	28.3
Stack diameter	m	3
Exhaust stack temperature	^{o}C	837
Exhaust gas velocity	m/s	30
Exhaust gas flow rate (actual stack conditions)	m^3/s	173.94
Normalised exhaust gas flow rate ($0^{o}C$, 1 Atm)	Nm^3/s	59.24

1 Source characteristics data obtained from Caterpillar gas engine technical data sheet.

Table 3.12.8 Emission Data for GE LM2500 Gas Turbine

Parameter	Concentration[1] (mg/Nm^3 @ 15% O_2)	Emission rate[1] (g/s)
Oxides of nitrogen (as NO_2)	51	3.34
Carbon monoxide	31	2.03
Total Hydrocarbons[2]	30	0.21

1 Information obtained from GE gas engine technical data sheet.
2 As n-propane equivalent.

Table 3.12.9 Hydrocarbons Emission Data for GE LM2500 Gas Turbine

Pollutant	Molecular weight	Emission factor[1] (lb/MMBtu)	Emission rate (g/s)
Benzene	78.1	1.2×10^{-5}	3.42×10^{-4}
Acrolein	56.06	6.4×10^{-6}	1.82×10^{-4}
Formaldehyde	30.03	7.1×10^{-4}	2.02×10^{-2}

1 Source: US EPA AP-42

12.6.3 Wellhead Pressure Reduction

Performance characteristics and emissions data for screw compressors at the FCS, utilized for wellhead pressure reduction, are presented in *Section 12.6.1*.

The performance characteristic of the Caterpillar G3304 gas-fired engine, that is considered to be a reasonable approximation of the gas engine that may be located at a well requiring compression, is presented in *Table 3.12.10*. Pollutant concentrations and emission rates are presented in *Table 3.12.11*. Performance information is presented for normal operating conditions with the gas engine operating at 100% capacity and assuming the installation of catalytic reduction of NO_x, CO and hydrocarbons. *Table 3.12.12* presents the likely contribution from the G3304 to total hydrocarbon emissions assessed for the Project.

Table 3.12.10 Source Characteristics for Caterpillar G3304 Compressors

Parameter	Units	Value[1]
Engine power	bkW	71
LHV input	kW	56.5
Nominal engine efficiency	%	
Nominal fuel consumption	MJ/bkW-hr	11.14
Stack height	m	2
Stack diameter	m	0.105
Exhaust stack temperature	^{o}C	548
Exhaust gas velocity	m/s	25
Exhaust gas flow rate (actual stack conditions)	m^3/s	0.2
Normalised exhaust gas flow rate ($0^{o}C$, 1 Atm)	Nm^3/s	0.07

1 Source characteristics data obtained from Caterpillar gas engine technical data sheet.

Table 3.12.11 Concentration and Emission Data for Caterpillar G3304 Compressors

Parameter	Concentration[1] (g/bkW-hr)	Emission rate[1] (g/s)
Oxides of nitrogen (as NO_2)	2.83	0.06
Carbon monoxide	0.43	0.008
Total Hydrocarbons	1.61	0.03

1 Information obtained from Caterpillar gas engine technical data sheet and assuming catalytic reduction for NOx of 90%, CO of 80% and hydrocarbons of 50%.

Table 3.12.12 Hydrocarbons Emission Data for Caterpillar G3304 Compressors

Pollutant	Molecular weight	Emission factor[1] (lb/MMBtu)	Emission rate (g/s)
Benzene	78.1	1.58×10^{-3}	7.45×10^{-5}
Acrolein[2]	56.06	-	6.24×10^{-7}
Formaldehyde	30.03	2.05×10^{-2}	9.66×10^{-4}

1 Source: US EPA AP-42

2 Acrolein emission rates calculated from measurements made by Leeder Consulting, as described in the draft EIS.

12.6.4 Water Pumps

The performance characteristic of the Waukesha L5794GSI gas-fired engine, that is considered to be a reasonable approximation of the gas engine that may be located at each water pumping station, is presented in *Table 3.12.13*. Pollutant concentration rates are presented in *Table 3.12.14*. Performance information is presented for normal operating conditions with the gas engine operating at 100% capacity. *Table 3.12.15* presents the hydrocarbon emission rates.

Table 3.12.13 Performance and Source Characteristics for the Waukesha L5794GSI Gas Engines

Parameter	Units	Value[1]
Engine power	bkW	1029
Nominal fuel consumption	kJ/bkW-hr	10,625
Stack height	m	2
Stack diameter	m	0.33
Exhaust stack temperature	^{o}C	587
Exhaust gas velocity	m/s	25.3
Exhaust gas flow rate (actual stack conditions)	m^3/s	2.1
Normalised exhaust gas flow rate ($0^{o}C$, 1 Atm)	Nm^3/s	0.67

1 Source characteristics data obtained from Waukesha gas engine technical data sheet.

Table 3.12.14 Concentration and Emission Rates for Waukesha L5794GSI Gas Engines

Parameter	Concentration[1] (g/bhp-hr)	Emission rate[1] (g/s)
Oxides of nitrogen (as NO_2)	1.39	0.49
Carbon monoxide	1.76	0.63
NMHC	0.15	0.05

1 Information obtained from Waukesha gas engine technical data sheet assuming catalytic reduction of NO_x of 90%, CO of 80% and hydrocarbons of 50%

Table 3.12.15 Hydrocarbons Emission Data for Waukesha L5794GSI Gas Engines

Pollutant	Molecular weight	Emission factor[1] (lb/MMBtu)	Emission rate (g/s)
Benzene	78	1.58×10^{-3}	1.03×10^{-3}
Acrolein[2]	56.06	-	6.25×10^{-6}
Formaldehyde	30.03	2.05×10^{-2}	1.34×10^{-2}

1 Source: US EPA AP-42
2 Acrolein emission rates calculated from measurements made by Leeder Consulting, as described in the draft EIS

12.6.5 Decentralised Gas Powered Turbines

The decentralised gas powered turbine will only be used as an alternative to gas engines or gas turbines at each FCS or CPP compressor. It will not be used in conjunction with gas engines or gas turbines located at each compressor.

The performance characteristics of the GE LMS100 gas-turbines, that are considered to be a reasonable approximation of the gas turbine that may be used for supplying power to the CPPs and FCSs in the NWDA, are presented in *Table 3.12.16.* Pollutant concentrations are presented in *Table 3.12.17*. Performance information is presented for normal operating conditions with the gas turbine operating at 100 per cent capacity. *Table 3.12.18* presents the hydrocarbon emission rates.

Table 3.12.16 Performance and Source Characteristics for the GE LMS100 Gas Turbine

Parameter	Units	Value[1]
Nominal fuel consumption	MJ/GJ/hr	868.4
Stack height	m	14.6
Stack diameter	m	3.3
Exhaust stack temperature	^{o}C	414.6
Exhaust gas velocity	m/s	10.2
Exhaust gas flow rate (actual stack conditions)	m^3/s	166
Normalised exhaust gas flow rate ($0^{o}C$, 1 Atm)	Nm^3/s	60.7

1 Source characteristics data obtained from Caterpillar gas engine technical data sheet

Table 3.12.17 Emission Data for the GE LMS100 Gas Turbine

Parameter	Concentration[1] (mg/Nm^3 @ 15% O_2)	Emission rate[1] (g/s)
Oxides of nitrogen (as NO_2)	51	10.3
Carbon monoxide	194	39
Hydrocarbons[2]	20	1.06

1 Information obtained from Caterpillar gas engine technical data sheet
2 As n-propane

Table 3.12.18 Hydrocarbons Emission Data for GE LMS100 Gas Turbine

Pollutant	Molecular weight	Emission factor[1] (lb/MMBtu)	Emission rate (g/s)
Benzene	78	1.2×10^{-5}	1.2×10^{-3}
Acrolein	56.06	6.4×10^{-6}-	6.6×10^{-4}
Formaldehyde	30.03	7.1×10^{-4}	7.36×10^{-2}

12.6.6 Flares

12.6.6.1 Maintenance Flaring

Table 3.12.19 and Table 3.12.20 provide flare characteristics and emission rates per well during routine or maintenance flaring.

Table 3.12.19 Characteristics for the Flares – Maintenance Flaring

Parameter	Units	Well Maintenance
Nominal stack height	m	2
Nominal flare tip diameter	m	0.15
Temperature	^oC	1273
Gas exit velocity (modelled)	m/s	20
Effective stack height (modelled)	m	2.9
Effective flare tip diameter (modelled)	m	0.26
Energy output	GJ/hr	2.3
Exhaust gas mass rate	g/s	0.64
Exhaust Gas flow rate	m^3/s	0.0004

1 From information supplied by QCLNG.
2 From AP-42 Emission Factors.
3 From USEPA Screen 3 Method.

Table 3.12.20 Emission Data for the Flares – Maintenance Flaring

Parameter	Oxides of nitrogen	Carbon monoxide	Total hydrocarbons
Emission factor (g/GJ)[1]	29.2	159.1	60.2
Emission rate (g/s)[2]	0.02	0.1	0.04

1 From AP-42 emission factors
2 From AP-42 emission factors and flare energy output data supplied by QCLNG.

12.6.6.2 Emergency Flaring

Information on the characteristics and emission rates from the flare during emergency operations are presented in *Table 3.12.21 and Table 3.12.22*.

Table 3.12.21 Characteristics for the Flares - Emergency Operations

Parameter	Units	Emergency operations
Nominal stack height	m	2
Nominal flare tip diameter	m	0.15
Temperature	^{o}C	1273
Gas exit velocity (modelled)	m/s	20
Effective stack height (modelled)	m	2.3
Effective flare tip diameter (modelled)	m	0.08
Energy output	GJ/hr	0.2
Exhaust gas mass rate	g/s	0.06
Exhaust Gas flow rate	m^3/s	0.00003

1 From information supplied by QCLNG.
2 From AP-42 Emission Factors.
3 From USEPA Screen 3 Method.

Table 3.12.22 Emission Data for the Flares – Emergency Operations

Parameter	Oxides of nitrogen	Carbon monoxide	Total hydrocarbons
Emission factor (g/GJ)[1]	29.2	159.1	60.2
Emission rate (g/s)[2]	0.002	0.01	0.003

1 From US EPA AP-42 emission factors
2 From US EPA AP-42 emission factors and flare energy output data supplied by QCLNG.

12.7 AIR EMISSIONS

Air emission results for nitrogen dioxide, carbon monoxide and hydrocarbons are presented for all modelling scenarios (*Section 12.4*).

12.7.1 Nitrogen Dioxide

Table 3.12.23 presents the predicted maximum 1-hour and annual average ground-level concentrations of NO_2 resulting from each of scenario 1, 2 and 3 emissions, all in isolation, and including background concentrations. Predicted concentrations have been compared to air quality objectives.

Table 3.12.23 Predicted Concentrations of Nitrogen Dioxide

Scenario	Averaging Period	Incremental predicted maximum concentration (µg/m³)	Predicted maximum concentration with background (µg/m³)	Air quality objective (µg/m³)	Percent of air quality objective (%)
1	1-hour	83	83.3	250	33.3
	Annual	2.6	2.7	62[1] / 33[2]	4.3 / 8.1
1B	1-hour	101.5	101.8	250	40.7
	Annual	1.5	1.6	62[1] / 33[2]	2.6 / 4.8
2	1-hour	25.5	26.1	250	10.5
	Annual	1.9	2.0	62[1] / 33[2]	3.2 / 6.1
3	1-hour	51.8	68.8	250	27.5
	Annual	3.6	3.6	62[1] / 33[2]	6.1 / 10.9

1 EPP(Air) Health and wellbeing objective
2 EPP(Air) Health and biodiversity of ecosystems objective

Scenario 1B models an FCS with 8 screw compressors in isolation. However, due to the distance between compressors, the localized maximum concentration of NO_2 at an FCS is comparable to the expected maximum regional concentrations of NO_2 from all FCSs having 8 screw compressors. This is supported by the data in *Table 3.12.24* which shows that the maximum concentrations for NO_2 for an FCS with 6 or 8 screw compressors in isolation is similar to the maximum concentrations for all emissions sources in Scenario 1.

Table 3.12.24 Scenario Comparison of Predicted Concentration of Nitrogen Dioxide

Pollutant	Averaging Period	Air quality objective (µg/m³)	Incremental predicted maximum concentration (µg/m³)		
			6 screw compressors in isolation	8 screw compressors in isolation	Scenario 1
NO_2	1-hour	250	76.1	101.5	83
NO_2	Annual	62	1.1	1.5	2.6

For scenario 4, the maximum predicted 1-hour average ground-level concentration of NO_2 due to maintenance flaring of wellheads is approximately 2 µg/m³. Under the extreme case of all wells flaring simultaneously, there may be approximately 120 times more wells flaring compared with the maintenance scenario. On this basis, the maximum 1-hour average ground-level concentration of NO_2 would be less than 30 µg/m³. This is 12% of the EPP(Air) objective 250 µg/m³. No other Gas Field activities would be occurring in this extreme case.

The results show that there are no exceedences predicted of the EPP(Air) air quality objective for the 1-hour and annual average ground-level concentration of NO_2 due to Scenario 1, 1B, 2, 3 or 4, assessed in isolation and including background concentrations.

12.7.2 Carbon Monoxide

Table 3.12.25 presents the predicted maximum 8-hour average ground-level concentration resulting from Scenario 1, 2 and 3 emissions in isolation. Background levels of CO are likely to be essentially zero. Hence, background levels are not included in the assessment of impacts, which is consistent with the approach taken in the draft EIS.

Table 3.12.25 Predicted Maximum Concentration of Carbon Monoxide

Scenario	Predicted maximum concentration (µg/m³)	Air quality objective (µg/m³)	Percent of air quality objective (%)
1	134.9	11,000	1.2
1B	121.4	11,000	1.1
2	33.3	11,000	0.3
3	44.8	11,000	0.4

Scenario 1B models an FCS with 8 screw compressors in isolation. However, due to the distance between compressors, the localized maximum concentration of CO at an FCS is comparable to the expected maximum regional CO concentrations from all FCSs having 8 screw compressors. Maximum concentrations of CO for all scenarios are approximately one per cent of air quality objectives.

Scenario 4 has not been explicitly modelled. The potential effect of Gas Field flaring on ground-level concentrations of air pollutants can be inferred from the above scenarios and the emissions information presented in *Section 12.6*. Predicted ground-level concentrations of air pollutants would not exceed air quality limits.

The results show there are no exceedances predicted of the EPP(Air) air quality objective for the 8-hour average ground-level concentration of CO due to scenario 1, 1B, 2, 3 or 4, assessed in isolation.

12.7.3 Hydrocarbons

Formaldehyde, acrolein, benzene, ethylchloride and phenanthrene were selected for modelling as they represented the key air pollutants identified in the draft EIS. Background hydrocarbon levels were not included in the assessment of impacts. This is conventional modelling practice and is consistent with the approach taken in the draft EIS.

Table 3.12.26 presents a summary of maximum ground-level concentrations of key hydrocarbons for scenario 1 in isolation.

Table 3.12.26 Predicted Maximum Hydrocarbons Concentrations for Scenario 1

Pollutant	Averaging Time	Air Quality Guideline (µg/m³)	Predicted maximum concentration (µg/m³)	Percent of air quality objective (%)
Formaldehyde	30-minute	110	18.3	16.7
	24-hour	54	3.0	5.6
Acrolein	1-hour	0.42	0.01	1.4
Benzene	1-hour	29	0.2	0.6
Ethylchloride	1-hour	0.048	0.001	1.1
Phenanthrene	1-hour	0.5	0.003	0.6

The results show there are no exceedances predicted of relevant air quality objectives for ground-level concentrations of hydrocarbons selected for modelling resulting from scenario 1, assessed in isolation. Concentrations of all hydrocarbons, other than formaldehyde, are less 1.5 per cent of the relevant air quality objectives. Formaldehyde concentrations are approximately 17 per cent of 30 minute air quality objectives.

Table 3.12.27 presents a summary of key maximum ground-level concentrations of hydrocarbons for scenario 1B in isolation. Emissions of ethylchloride and phenanthrene are not considered for scenario 1B, based on their low concentrations for scenario 1.

Table 3.12.27 Predicted Maximum Hydrocarbons Concentrations for Scenario 1B

Pollutant	Averaging Time	Air Quality Guideline (µg/m³)	Predicted maximum concentration (µg/m³)	Percent of air quality objective (%)
Formaldehyde	30-minute	110	23.4	21.3
	24-hour	54	3.6	0.1
Acrolein	1-hour	0.42	0.0007	<0.1
Benzene	1-hour	29	0.004	<0.1

Scenario 1B models an FCS with 8 screw compressors in isolation. However, due to the distance between compressors, the localized maximum concentration of hydrocarbons at an FCS is comparable to the expected maximum regional hydrocarbon concentrations from all FCSs having 8 screw compressors.

Concentrations of all hydrocarbons, other than formaldehyde, are less 0.1 per cent of the relevant air quality objectives. Formaldehyde concentrations are approximately 21 per cent of 30 minute air quality objectives.

Table 3.12.28 presents a summary of key maximum ground-level concentrations of hydrocarbons for scenario 2 in isolation. There are no emissions of ethylchloride and phenanthrene resulting from scenario 2.

Table 3.12.28 Predicted Maximum Hydrocarbons Concentrations for Scenario 2

Pollutant	Averaging Time	Air Quality Guideline (µg/m³)	Predicted maximum concentration (µg/m³)	Percent of air quality objective (%)
Formaldehyde	30-minute	110	2.7	2.5
	24-hour	54	0.5	1
Acrolein	1-hour	0.42	0.003	0.6
Benzene	1-hour	29	0.2	0.6

The results show there are no exceedances predicted of relevant air quality objectives for ground-level concentrations of the hydrocarbons selected for modelling resulting from scenario 2, assessed in isolation.

Concentrations of all hydrocarbons, are less 3 per cent of the relevant air quality objectives.

Table 3.12.29 presents a summary of maximum ground-level concentrations of key hydrocarbons for scenario 3 in isolation. There are no emissions of ethylchloride and phenanthrene resulting from scenario 3.

Table 3.12.29 Predicted Maximum Hydrocarbons Concentrations for Scenario 3

Pollutant	Averaging Time	Air Quality Guideline ($\mu g/m^3$)	Predicted maximum concentration ($\mu g/m^3$)	Percent of air quality objective (%)
Formaldehyde	30-minute	110	4.2	3.8
	24-hour	54	0.9	1.7
Acrolein	1-hour	0.42	0.002	0.5
Benzene	1-hour	29	0.3	0.9

The results show there are no exceedances predicted of relevant air quality objectives for ground-level concentrations of the hydrocarbons selected for modelling resulting from scenario 3, assessed in isolation. Concentrations of all hydrocarbons, are less 4 per cent of the relevant air quality objectives.

Scenario 4 has not been explicitly modelled. The potential effect of flaring on ground-level concentrations of air pollutants can be inferred from the above scenarios and the emissions information presented in Section 12.6. Predicted ground-level concentrations of air pollutants would not exceed air quality limits.

12.8 IMPACTS AND MITIGATION MEASURES

Air quality objectives are set at levels that enhance or protect the qualities of the air environment that are conducive to protecting human health and wellbeing, and the health and biodiversity of ecosystems.

In modelling wellhead compressor and water pump gas powered engines, catalytic reduction has been incorporated into the engines with the following reduction in air emissions:

- 90 per cent of NO_x
- 80 per cent of CO
- 50 per cent of hydrocarbons

Based on the modelling results above, there are no exceedences of air quality objectives for any of the modelled air emissions from the Gas Field. Hence, air emissions from the Gas Field are not expected to impact human health or biodiversity. As such, mitigation measures are not proposed for any air emissions.

12.9 CONCLUSION

The supplementary EIS assumes that compressors at the FCSs and CPPs in the CDA and SEDA are powered by electric drive engines or turbines connected to the electricity transmission grid. These engines no longer represent a direct source of air emissions in the Gas Field. The supplementary EIS has introduced emissions sources not described in the draft EIS, namely gas engines for wellhead compressors, water pumps and WTPs and flares at wells.

Compressor engines will be the main sources of air emissions from the Gas Field. Emissions include oxides of nitrogen, carbon monoxide and hydrocarbons. Five scenarios were considered in modelling impacts on air quality covering two regions of the Gas Field, the NWDA and the combined SEDA and CDA. The scenarios selected represented worst-case emissions throughout the Project lifetime.

Modelling demonstrated that there will not be exceedences of air quality objectives for any of the modelled air emissions from the Gas Field. Hence, air emissions from the Gas Field are not expected to impact human health or biodiversity. The overall assessment of impact significance for air is negligible.