UKOG PLC

Title: Waste Gas Management Plan

Document Number: UKOG-EPR-ATON-GMP-008

Revision: 0

0	-	1st Issue Permit Application	01/05/2020	ZG-SS	ZG-TF	TH
Rev.	**Status**	**Reason for Issue**	**Revision Date**	**Written by**	**Reviewed by**	**Approved by**
Revision History						

REVISION DESCRIPTION SHEET

This sheet must be completed in detail, at each revision, once this document has been issued at revision 0.

Details to include revision number, a description of the revision indicating paragraphs and pages that have been revised, together with the date and approved signature.

Revision	Description	Date	Approved by
0	1st Issue Permit Application	01/05/2020	TH

Table of Contents

1. Introduction 5
2. Definitions 6
3. Site Description 7
3.1 Site Location 7
3.2 Environmental Setting 7
4. Establishing Best Available Technique 9
4.1 Proposed Operations and the Identification of Waste Gas Streams 9
4.2 Initial Screening of BAT 10
4.3 Short List of Technologies 12
4.3.1 Harness Natural Gas for Alternative Use 12
4.3.2 Incineration of Natural Gas 13
4.3.3 Cold Venting 14
4.4 Conclusion of Potential Techniques 14
4.5 Quantitative BAT Assessment 16
4.5.1 Well Clean Up 16
4.5.2 Extended Well Test 16
4.6 Qualitative BAT Assessment 16
4.6.1 Shrouded Ground Flare 16
4.6.2 Enclosed Flare 17
4.6.3 Considerations of the Assessment 17
4.6.4 Assessment Matrices 17
4.6.5 Conclusion of Qualitative Assessment 19
4.7 BAT Conclusion 19
5. Management of Gas - Well Testing Operations 21
5.1 PW Well Test - Shrouded Ground Flare 22
5.1.1 Flare Design 22
5.1.2 Combustion Efficiency 22
5.1.3 Flame Length 23
5.2 PW Well Test - 9.5 Enclosed Ground Flare 23
6. Lifting Techniques 24
6.1 Well Lifting - Nitrogen 24
6.1.1 Justification for the use of Nitrogen to Lift Wells 24
6.2 Lifting the Well Using Mechanical Lifting Techniques 26
7. Environmental Management and Monitoring 27
7.1 Odour 27
7.2 Air Monitoring 27

8. Emergency Response Procedures 28

8.1 Spillages 28

8.2 Well Shut In 28

Appendix 1 – Indicative Site Layout Plan with Emission Points 29

Appendix 2 – Air Quality Impact Assessment 31

Appendix 3 – PW Shrouded Flare Design and Emissions Report 33

Appendix 4 – PW Enclosed Flare Design 35

1. INTRODUCTION

UK Oil & Gas PLC (herein referred to as UKOG) is a public limited company that was formed to manage the exploration activities within Petroleum Exploration and Development Licence 331 (PEDL 331). UKOG has operatorship of PEDL 331 within which the proposed Arreton Well Site is located.

UKOG have prepared an application to the Environment Agency seeking permission to undertake a number of permitted activities in accordance with the Environmental Permitting (England and Wales) Regulations 2016 (EPR2016).

This Waste Gas Management Plan (WGMP) is applicable to the Arreton Well Site in accordance with environmental permits and planning consent. It is applicable to UKOG, its contractors and subcontractors and can be used in support of applications to the Environment Agency under EPR2016.

This WGMP has been produced to demonstrate the process which has been undertaken to identify the Best Available Technique with regards to the Initial Flow Test (IFT) (also referred to as Well Clean UP (WCU)) and the Extended Well Test (EWT).

Any subsequent production phases would be covered by a revised WGMP once additional information (as a result of the EWT) has been obtained.

The objective of this WGMP is to ensure that any waste gas that arises as part of the proposed operations is managed in such a way so as to reduce the quantities of gas emitted to air and minimise environmental impacts so far as available techniques allow.

This objective will be achieved by:

- Identifying Waste Gas Streams;
- Undertaking an initial screening process to remove unavailable or unsuitable techniques;
- Establishing Best Available Technique (BAT) to manage identified waste gas streams;
- Implementing a programme of management based on BAT; and
- Reviewing the WGMP and revise where necessary.

2. DEFINITIONS

ALARP:	As Low as Reasonably Practicable
API:	American Petroleum Institute
BAT:	Best Available Technique
BS:	British Standard
Casing:	Steel tubes lining the wall of the borehole
Cold Venting:	The release of unburned gas to atmosphere
Combustion:	A burning process (see also incineration)
DST:	Drill Stem Test
Emissions:	Released into the environment
ESD:	Emergency Shut Down
EWT:	Extended Well Test
Flowrate:	The rate at which fluid passes through per unit of time
GWP:	Global Warming Potential
Hazardous Waste:	As defined by Article 3(2), 7 and Annex III of the Waste Framework Directive
Hierarchy:	In order of priority
Hydrocarbons:	Any class of compounds containing only hydrogen and carbon
Incineration:	The destruction of waste by controlled burning at high temperatures
IFT	Initial Flow Test
Installation:	A stationary technical unit where one or more activities are carried on; and any other location on the same site where any other directly associated activities are carried on
mmscfd:	Million standard cubic feet per day
PEDL:	Petroleum Exploration and Development Licence.
Petroleum:	A complex mixture of naturally occurring hydrocarbon compounds found in rock and takes the form of a solid, liquid or gas
Pipework:	A system of pipes used for transporting natural gas, oil and any other produced fluids to their respective storage vessels onsite
Produced Fluids:	Any fluid produced from a wellbore, a typical example being oil, condensate or formation water
Reservoir:	The rock within which hydrocarbons are encountered and confined to
Sour Gas:	Natural gas with a hydrogen sulphide content of 4ppm or above
Thermocouple:	A sensor used to measure temperature
Turbulence:	Violent or unsteady movement of air
Turndown Rate:	The ration of the maximum capacity to minimum capacity
UK:	United Kingdom
Waste:	Any substance or material that has or no longer has a purpose and, therefore, must be discarded
Well Control:	Equipment and procedures used to prevent or direct the flow of formation fluids
Wellhead:	The system of spools, valves and assorted adapters, which is the interface between the wellbore and surface equipment

3. SITE DESCRIPTION

3.1 Site Location

The proposed well site and associated exploratory operations are being undertaken at the following location[1].

A3056, Arreton, Blackwater,
Isle of Wight,
England,
PO30 3BT,
United Kingdom

National Grid Reference: SZ 52351 86355

3.2 Environmental Setting

The proposed development comprises a new temporary well site set back 400m from the Newport to Sandown Highway (A3056) accessed by a new temporary highway junction and internal vehicular track. Views of the Site from the north, east and south are restricted by the undulating landscape and mature hedgerows that form field boundaries and highway verges.

The wider area has the appearance of a worked landscape supporting intensive agricultural practices, large scale renewable energy installations and non-agricultural commercial uses. The land immediately to the east supports the Wight Farm Anaerobic Digestion Energy Power Station and land to the west supports the Blackwater Quarry and ancillary uses connected to the winning and working of aggregates.

The nearest residential dwellings are 600m to the south-west fronting the A3056. The nearest farmsteads are Great East Standen Manor, and Little Sullens, 700m and 950m to the north respectively. The village of Arreton is 1km to the east, Merstone 1km to the south and Blackwater 1.6km to the west. Rookley is 2.7km to the south-west and Newport is 3.8km to the north-west.

A public right of way abuts the proposed well site before merging with a local bridleway which then merges with the Vectis and Bembridge Trail, running east to west along a ridge line. This ridgeline acts as the southern boundary of the Islands Area of Outstanding Natural Beauty (AONB) designation.

A desktop study was undertaken to identify any designated sites which may be affected by the proposal. The results of the desktop survey using the Multi-Agency Geographic Information for the Countryside (MAGIC) interactive mapping tool have been provided within Table 5.1 below. No National or Local Nature Reserves were identified.

[1] Address determined using Grid Reference Finder.

Designated Site	Search Radius	Name	Approx. Distance
RAMSAR	10km	Solent & Southampton Water	4.14km
Special Area of Conservation	10km	Isle of Wight Downs	8.43km
		South Wight Maritime	7.42km
		Solent Maritime	4.14km
		Briddlesford Copses	2.89km
Special Protection Areas	10km	Solent & Southampton Water	4.14km
Marine Protection Areas	10km	Solent and Dorset Coast	3.20km
		Solent and Southampton Water	4.14km
Sites of Special Scientific Interest	2km	Arreton Down	1.08km
Schedule Ancient Monuments	2km	Bowl Barrow on Arreton Down	1.66km
		Bowl Barrow known as Michael Morey's Hump, and a Highway Commission Barrier on Gallows Hill	1.49km
		Downend Romano-British Villa	1.84km
Sensitive Receptors: Households / Businesses	2km	Power Station	0.25km
		New Barn	0.40km
		Great East Standen Manor	0.55km
		Pyle Cottage	0.57km
		Merstone including Padan Aran Cottage	0.75km
		Conveyors	0.77km
		Roslyn Cottage	0.77km
		The Old Farm house	0.84km
		Arreton	0.86km
		JD Pipes	0.88km
		Longdown	0.96km
		Manor Cottage	0.97km
		Arreton House	0.97km
		Locks Cottage	1.06km
		Perraton Farm	1.13km
		Little East Standen Farm Cottage	1.15km
		Little Birchmore	1.25km
		Little East Standen Farm	1.29km
		Garrets Farm	1.38km
		Black Water	1.41km
		Green Acres Farm	1.41km
		Downend and Adventure Park	1.43km
		Great East Standen Farm	1.45km
		Newport Golf Club - Club House	1.56km
		Birchmore Farm	1.57km
		Burnt House Farm	1.59km
		Fulford	1.66km
		Little Owl Cottage	1.71km
		Redway Dwellings	1.72km
		Stickworth Lodge	1.78km
		Standen House	1.79km
		Durton Farm	1.85km
		Highwood Cottage	1.86km
		Suda Farm	1.88km
		Mornhill	1.89km
		Station House	1.96km
		West Standen Farm	1.96km
Water Features (nearest)	2km	Ephmeral streams tributing to River Medina	0.00km
		SmallPond at Wight Farm Anaerobic Digestion Energy Power Station	0.40km
		Ponds at Conveyors	0.41km
		Small Ponds at Arreton Manor / Vicarage	1.10km
Surrounding Environment (No Designation)	N/A	Wellsite surface and wellsite subsurface soils	-
		Surface water, groundwater and atmosphere	-

Table 3.1: Receptor Details

4. ESTABLISHING BEST AVAILABLE TECHNIQUE

BAT is defined within the Industrial Emissions Directive (2010/75/EU) as *'the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole:*

(a) 'techniques' includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;

(b) 'available techniques' means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;

(c) 'best' means most effective in achieving a high general level of protection of the environment as a whole;'

4.1 Proposed Operations and the Identification of Waste Gas Streams

UKOG are applying for the necessary permissions from both the Environment Agency and the Mineral Planning Authority to drill a single exploration borehole and sidetrack from the Arreton Well Site.

The development will commence with the construction of an access track and the Arreton Well Site. Upon completion of the construction activities UKOG will drill a single borehole, with the potential to further drill a side track, as determined by UKOG.

Upon completion of the drilling phase the well(s) will be the subject of a testing regime known as a well test. The purpose of the well test is to evaluate the commercial viability of the hydrocarbon reservoir, if encountered. The test will be conducted in 2 (two) parts consisting of a IFT and an EWT. During the well test natural gas will be produced. This WGMP has been developed specifically for the management of waste gas as a result of the well testing phase.

During the testing phase, natural gas, oil/condensate and produced water will be brought to surface and flowed through a series of pipework to a three-phase separator which will separate natural gas, oil/condensate and produced water. The oil/condensate shall be stored within its own dedicated storage tank(s), with produced water also being the subject of storage within its own dedicated storage tank(s). Any residual gas emissions from storage tanks has not been considered due to being residual in volume. Such volumes will be the subject of scrubbing prior to release.

Although the exact quantities of natural gas cannot be confirmed, UKOG is proposing to flow gas during the IFT phase at a maximum rate of 0.5mmscfd. An IFT is required to ensure that any wellbore fluids and debris which may impact on the performance of the well are removed prior to the EWT. During this IFT the rate of natural gas produced will fluctuate unpredictably. The duration of the IFT is expected to last no longer than 720 well flow hours which may be accumulated in stages and not in a continuous period of time. The reason for the longer than normal IFT is due to the anticipated target formation being oil bearing with some associated gas, which inevitably take longer to remove any debris and fluid as it is likely a pumping mechanism will be required and the well will not flow under natural conditions.

Once the IFT has been completed, that is wellbore fluids and debris have been removed, the second phase of testing shall commence. An EWT is a longer duration test, which is carried out to assess the commercial viability of the well and establish detailed gas and oil composition. Any composition data acquired during IFT may not be accurate due to being comingled with wellbore fluids. The duration of the EWT will not exceed 90 days.

An Air Quality Impact Assessment has been undertaken on the basis that both testing phases will be undertaken at a rate of no more than 0.5mmscfd to ensure that a worst case assessment has been made. The assessment concluded that both the short term impact and long term impact were negligible. The assessment was modelled on longer IFT and EWT phases, however the limits specified within this document shall be defined within the permit.

In order to establish BAT, it is necessary to identify every point source of natural gas as a waste stream throughout the well testing phase. In addition, the quantity of natural gas from each point source also needs to be understood, as this will be a factor in selecting BAT. A review of the proposed operations has confirmed each natural gas point source and referenced them as point source emissions (PSEs).

Activity	Unit	PSE	EWC	Annual Quantity	
				MMSCF	Tonnes[2]
Initial Flow Test (IFT)	As Determined by BAT	PSE-01	16 05 04*	15	297
Extended Well Test (EWT)	As Determined by BAT	PSE-02	16 05 04*	45	892
Oil Storage & Transfer	Storage Tank(s)	PSE-03	-	Residual Volumes	
Produced Water Tank	Storage Tank(s)	PSE-04	-	Residual Volumes	

Table 4.1: Identification of Waste Gas Streams

4.2 Initial Screening of BAT

The Environment Agency have identified a '*long list of technologies*' within report: **SC170013/R** (the report) which have been summarised below.

- Cold Venting
- Flaring
- Heat Generation
- Power Generation
- Well Reinjection
- Recycling Through to Gas Processing
- Mini Liquefied Natural Gas
- Conversion to Fuels
- Vapour Recovery
- Gas Processing and Natural Gas Liquids Recovery
- Compressed Natural Gas
- Energy Storage

The long list was then screened against the definition of BAT within the report with a number of technologies not currently considered BAT at the time of writing this report, for the exploration phase of the operation. For clarity, BAT as a concept will continue to change as technologies improve or become increasingly available for use within the onshore oil and gas industry.

Table 4.2 provides a list as to what technologies have been identified with the potential of being considered BAT for the onshore oil and gas industry. This WGMP has been produced to assess the techniques considered 'best available' for the two phases of well testing only. Should the development move into production, a separate WGMP and permit variation will be required once the natural gas composition and well characteristics are understood.

To summarise, where a technology/technique has not been considered suitable for the onshore oil and gas industry this is due to one or more of the following reasons:

- The technology was not readily available for supply in England - due to economics or the lack of supplier base;
- The technology was considered unproven or novel;
- There was no widespread market for the product or resource produced; and/or
- The working capacity of the technology did not match the onshore oil and gas sector requirements.

[2] Tonnes derived natural gas conversion conditions of 0.7 specific gravity, 273.15K & 101.325 kPa at 0^{oC}

Techniques for BAT Assessment				
Option	**Technology / Process**	**IFT**	**EWT**	**Reason for Considering / Not Considering**
Cold Venting	Direct Release to atmosphere		✓	Worst impact environmentally with Methane being 28 times greater in global warming potential. Potential for use during very short term low flow.
Flaring	Elevated Flares	✓		Produces a visible flame and excessive noise. May be suitable for sour gas or WCU given its ability to incinerate across a wide range of flow.
	Shrouded Flare	✓	✓	Considered to have a reduced combustion efficiency but able to accommodate variable and unpredictable flow (associated gas).
	Enclosed Flare / Enclosed Burners	✓	✓	Provides the best combustion efficiency and reduced noise and visible flame, but can only operate within a defined range of flow specification.
Heat Generation	Incinerators / Boilers		✓	Natural gas can be used to fuel bath heaters but only once an understanding of gas rates and PVT have been established. Could be considered for oil test only.
Power Generation	Spark Engines		✓	Well understood technology and available to rent/buy in the UK. May need to be used in combination with a flare system. Gas can be used to fuel the generators but only after a significant understanding of gas rate and PVT has been established.
	Gas Turbines			Well understood technology and available to rent/buy in the UK. May need to be used in combination with a flare system. Gas can be used to fuel the turbine but only after a significant understanding of gas rate and PVT has been established. Project is temporary and short term and connection to grid will be excessively disproportionate.
	ORC (heat recovery)			Not available to rent. Used in conjunction with gas turbine.
Well Reinjection	Enhanced Oil Recovery			Would only work for associated gas wells where conditions dictate. No permissions to re-inject in place.
Recycling Through to Gas Processing	Recycling of Waste Gases			Subject to limitations, only after a significant understanding of gas PVT has been established.
	Pipeline Export			Only considered if pre-existing pipelines are present and available.
Mini Liquefied Natural Gas	Liquefaction of Natural Gas			Lack of equipment in the UK. So not considered available.
Conversion to Fuels	Convert Natural Gas to Liquid.			Lack of equipment in the UK together with unproven technology.
Vapour Recovery	Compression to CNG for collection or direct export.			Logistics and lack of equipment in the UK. So not considered available. Direct export only considered if pre-existing pipelines are present and available.
	Compression to CNG for export via a pipeline			Logistics and lack of equipment in the UK. So not considered available. Direct export only considered if pre-existing pipelines are present and available.
Gas Processing / Gas Liquids Recovery	Recovery of NGL from Natural Gas			Lack of equipment in the UK. So not considered available.
Compressed Natural Gas	Compression to CNG for collection or direct export.			Logistics and lack of equipment in the UK. So not considered available. Direct export only considered if pre-existing pipelines are present and available.
Energy Storage	Electricity - Battery Storage			Intermittent gas supply and supply unknown Technology not yet available for short duration testing of gas.
	Thermal - Thermal Storage			Technology not yet available.

Table 4.2: Long List of Technologies

4.3 Short List of Technologies

The technologies which have been considered for a more detailed assessment to establish whether they can be considered BAT are outlined below within each subsection. For clarity this information has been sourced from the Environment Agency Report: **SC170013/R** together with the proposed well testing operations.

To summarise, the tiers for the management of waste gas can be classified as follows:

- Harness natural gas for alternative use;
- Incineration of natural gas by flare; and
- Cold venting of natural gas directly to atmosphere.

4.3.1 Harness Natural Gas for Alternative Use

The preferred method for gas management is to harness the associated gas at the site to produce energy i.e. electrical or heat. This has many benefits including reducing the running cost of the site and reducing overall environmental impact. Following the initial screening process, potentially suitable methods for harnessing natural gas have been identified and assessed further.

4.3.1.1 Onsite Power Generation

Onsite power generation at the site cannot be considered for the IFT phase due to the gas composition and flowrate likely to be inconsistent throughout the IFT leading to inefficient and unsafe combustion.

It is anticipated during the EWT phase that the associated natural gas will reach a steady state with regards to flowrates and pressures. During the initial part of the EWT it is unlikely that the harnessing of associated natural gas can be achieved. Representative samples of gas will need to be taken and analysed to determine the gas composition. With this in mind the use of a temporary 'gas fuelled' generator could be considered part way through the EWT, however by the time the relevant information has been obtained it is likely that the EWT will have been completed and therefore no longer required. Resulting in significant time and effort without any benefit. It is not feasible at this stage to design or order appropriate generators due to having unknown/unreliable gas composition or PVT.

For clarity the IFT operations will not provide the necessary information on the associated gas to inform the selection or specification of a gas generator.

Whilst UKOG recognises its responsibility to reduce both emissions and waste where reasonably practicable, UKOG also recognise and agree with 'conclusion 51' of the BREF note 'Management of Waste from Extractive Industries' which concludes that reduced emissions completions are BAT but may have limited applicability in the exploration phase. To this end, and based on the feasibility outlined above, the harnessing of natural gas via power generation for a IFT or EWT operations cannot be considered further.

Should the development proceed into production operations a revised WGMP and BAT Assessment would be developed and presented with the expectation that the harnessing of natural gas for alternative use can be utilised.

4.3.1.2 Heat Generation

Depending on whether an EWT is being undertaken for natural gas, or oil with associated gas, heat generation may be required in the form of a bath heater. The purpose of the bath heater is to heat up the liquid hydrocarbons and produced water to aid in the separation of each substance. However, where an EWT for gas be undertaken, a bath heater would not be required.

In the event an EWT is undertaken for oil then the use of a duel fuelled bath heater may be considered, however it will need to be compatible with the well test supplier's equipment. It may also be apparent that any associated gas, once analysed and composition understood, does not meet the minimum input requirements of the bath heater.

During the initial part of the EWT it is unlikely that the harnessing of associated natural gas can be achieved. Representative samples of gas will need to be taken and analysed to determine the gas composition and whether it will be suitable for use as fuel for a bath heater. Once the gas sample is determined a further assessment will have to be made to retrofit a new bath heater and redesign the well test spread and break containment. Once this process is designed, reviewed, assessed, procured and installed the EWT will be completed. It may also be the case whereby oil

is produced with little to no associated gas being produced thus negating the need to harness the natural gas. With this in mind the use of a temporary 'gas fuelled' bath heater could be considered part way through the EWT for oil, however there is no guarantee that associated gas will continue to be present within the well at stable flowrates.

For clarity the IFT operations will not provide the necessary information on the associated gas to inform the selection or specification of a gas fuelled bath heater.

It is not feasible at this stage to design or order an appropriate bath heater due to having unknown/unreliable gas composition or PVT, if any. To this end, and based on the feasibility outlined above, the harnessing of natural gas via heat generation for a IFT or EWT operations cannot be considered further.

Should the development proceed into production operations a revised WGMP and BAT Assessment would be developed and presented with the expectation that the harnessing of natural gas for alternative use can be utilised.

4.3.2 Incineration of Natural Gas

Hydrocarbon gases, such as Methane (CH4), have a Global Warming Potential (GWP) twenty-eight (28) times greater than Carbon Dioxide (CO2e), based on a 100-year time horizon, therefore, the incineration of hydrocarbons represents a decreased environmental impact over venting of natural gas. In addition, the venting of large volumes of hydrocarbons presents an increased risk of fire and/or explosion. The use of a flare unit in isolation will only dispose of natural gas.

4.3.2.1 Elevated Pipe Flares

Elevated pipe flares generally have a single burner flare tip, elevated some metres above ground to provide greater dispersion performance. The flare tip is not enclosed nor is it shrouded, resulting in a visible flame and no noise attenuation. Elevated flares are capable of incinerating natural gas with high methane content across a significantly variable range of flowrates and inlet pressures, such as those likely to be experienced during the initial phase of hydrocarbon exploration, such as IFT, where the gas composition, pressure and flow rates are unknown.

Whilst technically feasible, an elevated flare can be used for EWT, however their combustion efficiency and environmental impacts regarding noise and light have meant that their use within onshore oil and gas wells has diminished.

UKOG have identified alternative incineration units which generate a lesser environmental impact. For this reason, an elevated pipe flare shall not be considered further.

4.3.2.2 Shrouded Flare

A shrouded flare, is essentially an open pipe flare, which is designed to incinerate natural gas with high Methane content across a significantly variable range of flowrates and inlet pressures, such as those likely to be experienced during the initial phase of hydrocarbon exploration such as IFT, where the gas composition, pressure and flow rates are unknown. Whilst having a slightly lower combustion efficiency due to not having multiple burners, a shrouded flare provides confidence of natural gas combustion across the significantly variable range of flowrates and inlet pressures.

As a shrouded flare can operate efficiently across a wide operating envelope it is also feasible that it can be used for EWT. However, should the gas flow and pressure would have reached a steady state, additional flare units can be considered which have been designed to operate at higher levels of efficiency.

The shroud placed around the flare tip aids in the reduction of the environmental impact, with respect to noise and visual impact. The size of the shroud is largely dictated by transportation restrictions onshore UK. As stated in National Planning Policy Framework (NPPF), minerals, which includes oil and gas, 'can only be worked where they are found', often resulting in wellsites being located in areas with minimal and restrictive highway infrastructure.

Some shrouded flares have been analysed and assessed during operation to ensure that data on their efficiency is available. Should an enclosed flare be considered UKOG will ensure that evidence of the shrouded flares efficiency (that is, above 98% combustion efficiency) is provided.

A shrouded ground flare has been considered further.

4.3.2.3 Enclosed Flares

Enclosed flares, such as those used in landfill, are designed with either a single or multiple burner, to incinerate natural gas with low methane content, typically around 56% Methane and 31% Carbon Dioxide. These burner tips are limited insofar as inlet pressure and flowrate capabilities, therefore, can only be used for oilfield purposes when there is significant confidence that any associated natural gas pressures and/or flow rate is low.

Enclosed flares have been designed and do exist specifically for oilfield purposes, however, from experience, their environmental performance is based on consistent pressures and flow rates. Enclosed ground flares are more sophisticated than open pipe flares or shrouded ground flares and are not easily modified to accommodate increase in support gas to sustain combustion efficiency.

Sophisticated enclosed ground flares that achieve high environmental performance are designed and constructed to operate in a narrow operating envelope, based on known gas compositions, flow rates and pressures. Evidence to support this being the case is contained within the Mott MacDonald report. In response to a questionnaire, flare manufacturer Zeeco states *'We would not decide on the flare design based on what the customer is doing on their site. We would take their process data and select the best flare to achieve their specified goals. Often we don't know what the application is. We simply look at the gas composition and condition of supply to our battery limit along with the customers desired result and availability of utilities.'*

The IFT operation will enable UKOG to select the most suitable enclosed unit for the period of EWT. However, as they are designed to operate efficiently over a narrow operating envelope, multiple units may be required to provide a wider operating envelope.

An enclosed flare has been considered further.

4.3.3 Cold Venting

Ordinarily, venting of natural gas is only considered in the event that low volumes of natural gas is anticipated and, evidence is available to support the cost of installing a flare for this activity would be disproportionate to the environmental benefit and subject also to the health and safety risks of cold venting having been deemed as being as Low as Reasonably Practicable (ALARP). When determining BAT for onshore oil and gas exploratory operations, the following points are considered with respect to cold venting:

- An increase in environmental impact;
- An increase of the risks associated with health and safety; and
- Minimal cost increase using a unit, which in turn reduces both environmental impact and safety risks.

Cold venting of waste gases can be considered in the event that the volume of waste gas is significantly low and the cost to install a unit is disproportionate to environmental benefit. This would be applicable to activities involving storage and transfer of crude oil where Volatile Organic Compounds (VOCs) may be emitted. Whilst it is feasible to have a feed line from the tank vents to a flare there is a high risk of "blowback" and this could ignite the gas inside the atmospheric stock tanks which in turn could explode causing serious injury and possible fatality. All atmospheric stock tanks should be vented to air via a vent line.

Similarly, there is the potential for natural gas to be temporarily vented during lifting operations involving Nitrogen. This is due to the calorific value of the natural gas being significantly reduced due to the presence of Nitrogen within the gas line. Any proposed gas management technique would need to have the technology available to mitigate against prolonged periods of cold venting, such as the introduction of propane.

4.4 Conclusion of Potential Techniques

Following an appraisal of each available technology initial conclusions have been made as to the BAT for IFT and EWT. This is detailed within Table 4.4 below.

Option	Technology	Considered	Reason
Harness	Onsite Power Generation	No	Not suitable for IFT or early stages of EWT due to unknown gas composition. Potential for use part way through the EWT for gas once the gas composition and flowrate have been established. However, once the correct generator has been identified, supplied and installed the EWT is likely to have been concluded.
	Heat Production	No	Not suitable for IFT or early stages of EWT due to unknown gas composition. Feasible part way through EWT for oil once the associated gas composition and flowrate has been established. However, once the correct bath heater has been identified, supplied and installed the EWT is likely to have been concluded, or the gas volumes may have depleted or no longer meet the input criteria.
Incineration	Elevated Pipe Flare	No	Whilst feasible for use during IFT and EWT due to its ability to operate over a wide operating envelope and incinerate gas safely, the use of an open flare causes environmental impacts such as visual and noise impact.
	Shrouded Flares	Yes	A shrouded flare is suitable for use for both IFT and EWT due to its ability to operate over a wide operating envelope and incinerate gas safely. It provides a slightly reduced environmental impact in comparison to an elevated pipe flare. Combustion efficiency whilst expected to be above 98% can be more difficult to regulate than that of enclosed units. A shrouded flare can be considered for IFT due to its ability to incinerate gas at variable flow rates and pressures efficiently. A shrouded flare may be used for EWT in the event of an oil test, again due to its ability to incinerate inconsistent flowrates efficiently.
	Enclosed Units	Yes	An enclosed unit flare, is not considered for IFT operations due to the units having narrow operating envelopes. Gas may result in being cold vented, if pressure and volumes are too low or too high. For the same reasons, an enclosed unit may not perform efficiently in the event of an EWT for oil, which produces fluctuating volumes of associated natural gas.
Venting	-	No	Potential for significant global warming emissions (Methane). Environmentally beneficial to incinerate at the very least.

Table 4.4: Results of Initial Conclusions

4.5 Quantitative BAT Assessment

4.5.1 Well Clean Up

Following the initial screening process there are currently two (2) incineration techniques which have been identified:

- Incineration of natural gas using a shrouded flare; and
- Incineration of natural gas using an enclosed flare.

Based on the feasibility and suitability alone, the requirement to prepare a Cost Benefit Analysis (CBA) has not been considered for IFT operations. UKOG may consider the use of either a shrouded flare or an enclosed flare. Both incineration units will have a minimum combustion efficiency of 98%.

The direct cost of each option will be the same for either management technique, with exception to the units themselves. A shrouded flare, capable of operating across a wide operational envelope is a cheaper option when compared to that of enclosed flares and provides greater confidence of efficiently incinerating fluctuating gas volumes.

The use of an enclose flare during this phase will likely result in inefficient combustion, due to periods of operating outside of its operational window, resulting in the emission of methane which has an impact potential 28 times greater than that of Carbon Dioxide.

There are no income benefits to either proposal and pollution quantities will remain the same.

4.5.2 Extended Well Test

Following the initial screening process there are currently two (2) incineration techniques which have been identified depending on the conditions of the EWT:

- Incineration of natural gas using a shrouded flare; and
- Incineration of natural gas using an enclosed flare.

Harnessing techniques at this stage have been screened out due to either operational uncertainties, technical feasibility or availability. UKOG are committed to revising this position for future production operations should the testing phase dictate this.

Based on the feasibility and suitability alone, the requirement to prepare a Cost Benefit Analysis (CBA) has not been considered for EWT operations. UKOG may consider the use of either a shrouded flare or an enclosed flare for an oil test. Both incineration units will have a minimum combustion efficiency of 98%.

The direct cost of each option will be the same for either management technique, with exception to the units themselves. A single shrouded flare, capable of operating across a wide operational envelope is a cheaper option when compared to that of enclosed flares and provides greater confidence of efficiently incinerating fluctuating gas volumes.

The use of an enclose flare during this phase can be considered subject to the necessary conditions being met, namely the confidence in associated gas being in a ‘steady state’, this may be achieved in the latter stage of IFT, allowing the use of an enclosed flare during the EWT.

4.6 Qualitative BAT Assessment

This section details the qualitative risk assessment that has been undertaken for assessing the impact each proposed option will pose. The methodology has been utilised from the Environment Agency Report **SC170013/R**.

4.6.1 Shrouded Ground Flare

Shrouded flares are similar to enclosed flares with respect to height and visual impact, subject to the flame being contained within the shroud. Shrouded flares have demonstrated in the past that they are able to incinerate natural gas with high Methane content across a significantly variable range of flowrates and inlet pressures. Whilst typically a shrouded flare will have a lesser combustion efficiency than that of an enclosed ground flare the selected shrouded flare unit shall have a minimum combustion efficiency of 98%. It is expected that the smoke and air quality impact between an enclosed unit and the shrouded flare to be similar, although upon start up there is the potential for limited smoke and flame visibility, however this is expected to be temporary.

4.6.2 Enclosed Flare

Enclosed flares are generally lower in height to that of shrouded flares and are enclosed so go a long way to preventing visible flames. Enclosed units generally provide the best environmental performance in relation to combustion efficiency, specifically for Methane. Enclosed units have specific operating envelopes in which they can operate efficiently.

4.6.3 Considerations of the Assessment

The site is surrounded by the civil parish of Arreton with a population of 988 according to the 2011 census. The site itself is semi-rural with a number of dwellings located throughout the area, surrounded by agricultural fields. The testing operations are anticipated to be in operation for an aggregated period of no more than 1 year. An enclosed unit has been considered a base case with a Score of 0.

4.6.4 Assessment Matrices

The following matrices and calculation of magnitude of risk have been developed with consideration of the Environment Agency Report: SC170013/R. UKOG has considered for the purpose of this qualitative assessment that a base case for the choice of technology used to manage the associated gas as being an enclosed unit, this is consistent with the Environment Agency's position. Table 4.5 represents the scale of impact the proposed use of a shrouded flare will have when considering both its risk and benefit over a number of considerations.

During well testing operations it is not considered that the operations will provide any benefit to the nearby population in the first instance. Given that the site is exploratory, additional infrastructure to either export gas or electricity is not possible and as such it is not expected that the proposed operations will have a significant impact either negative or positive in the first instance.

The development is considered to fall within a general population of 1,001-10,000 based on a 2km radius from the site and a general trend of increase in population. However, the actual number of people affected by using a shrouded flare over an enclosed unit is expected to be much less (1-10), i.e. those in very short proximity to the site. As such this category has been used.

Increase / Decrease of Risk / Benefit	Number of People Likely to be Affected				
	General Population				
	1-10	11-100	101-1000	1001-10k	>10k
	Disadvantaged Groups				
	NA	NA	10-100	101-1000	>1000
Very Small (VS)	NC	VS	S	S	M
Small (S)	VS	S	S	M	M
Modest (M)	S	M	M	M	L
Large (L)	M	M	L	L	VL
Very Large (VL)	M	L	L	VL	VL

Table 4.5: Scale of Impact Matrix

Impact Criteria	Shrouded Flare
Visual	NC
Noise	NC
Land Take	NC
Smoke / Efficiency	VS

Table 4.6: Impact of Shrouded Flare

Having established that the impact on local receptors as being very small when compared to that of an enclosed unit for visual, noise and smoke/combustion efficiency, the next phase is to establish the magnitude of the risk based on the longevity of the impact. The impact score within Table 4.6 is carried forward to Table 4.7 for this assessment.

	Scale of effect.				
	Impact Score				
Duration of effect	VS	S	M	L	VL
Few days / one-off event	VS	VS	VS	S	M
Weeks / Months / Repeated Event	VS	VS	S	M	L
Up to 1 year	VS	S	M	L	VL
1-3 Years	VS	S	M	L	VL
4-6 Years	VS	M	L	L	VL
More than 6 years	VS	M	L	VL	VL

Table 4.7: Magnitude of Risk Matrix

Magnitude Output	Score
Very Large Positive	10
Large Positive	8
Medium Positive	6
Small Positive	4
Very Small Positive	2
Neutral	0
Very Small Negative	-2
Small Negative	-4
Medium Negative	-6
Large Negative	-8
Very Large Negative	-10

Table 4.8: Magnitude Score

The impact of using the shrouded flare when set against the enclosed unit (base case).

Impact Criteria	Enclosed Unit	Shrouded Flare
Visual	0	0
Noise	0	0
Land Take	0	0
Smoke / Efficiency	0	-2

Table 4.9: Result of Analysis

4.6.5 Conclusion of Qualitative Assessment

The result of the Qualitative assessment has demonstrated that the impact of using the shrouded flare as being 'very small negative'.

This assessment considered both the positive and negative impact of choosing a shrouded flare over an enclosed unit. No positive impacts (with respect to receptors) were identified. A single negative impact has been identified in the form of Smoke/Combustion Efficiency.

The Shrouded flare is expected to be 2.7m taller than an enclosed unit on average. However, it is not considered a negative impact on visibility due to the number of persons that would be affected by this slight increase in height. It is also possible that the flame will be visible, although this is of very short duration during start up only.

The shrouded flare is also expected to be slightly noisier than an enclosed unit, largely due to the fact noise generated as part of the combustion process is not contained within a chamber, but only partially enclosed by a shroud. Again, this impact is not considered to be significant enough to increase the risk rating due to the number of receptors likely to be affected.

The footprint of each flare or burner will be similar and will be placed onto a pre-existing wellsite.

The result of the qualitative assessment concluded that the use of the enclosed unit should be used ahead of the shrouded flare where technically feasible.

UKOG conclude, based on the qualitative assessment alone, that an enclosed unit is BAT for both IFT and EWT operations when compared to that of a shrouded unit. However, this is based only on the slightly increased risk based on smoke/efficiency. However, this does not take into account the potential safety implication and has been assessed on environmental impact alone.

4.7 BAT Conclusion

This WGMP has been produced to demonstrate the process which has been undertaken to identify the Best Available Technique with regards to the well testing operations to be conducted. Any subsequent production phases would be covered by a revised WGMP once additional information (during the EWT) has been obtained. This WGMP has been written in line with the Environment Agency Report: SC170013/R 'Waste gas management at onshore oil and gas sites: framework for technique selection'.

Exploration wells will be tested to ascertain whether commercial hydrocarbon rates can be achieved. The test will involve two (2) phases, a IFT and an EWT. The quantities of associated natural gas cannot be confirmed; however, the proposal shall not exceed a volume of 60mmscf.

The Environment Agency has identified a 'long list of technologies' within report: SC170013/R which provided the initial list of technologies that had the potential to be considered BAT. The long list was then screened against the definition of BAT and the proposed operation which resulted in a number of technologies being screened out and not being considered further. For clarity, BAT as a concept will continue to change as technologies improve or become increasingly available for use within the onshore oil and gas industry.

Technologies which have passed through the initial screening process have been considered for a more detailed assessment to establish whether they can be considered BAT. The technologies which were the subject of further assessment were placed onto a short list. Each technology was then assessed for compatibility against the proposed exploration development. It was considered that the incineration of natural gas using either a shrouded flare or an enclosed flare was considered BAT.

A cost benefit analysis was not undertaken as the only consideration was which incineration device could be used for the IFT and EWT. The enclosed unit has a slightly greater combustion efficiency than that of the shrouded flare and neither option can generate revenue for the operator, therefore it can be considered that the environmental cost of the enclosed unit is cheaper than that of the shrouded unit on combustion efficiency alone, without considering rental cost. However, when assessing the feasibility of each option, the shrouded unit is expected to perform better than an enclosed unit due to being able to operate across a wide operating envelope, such features are a necessary

requirement when we consider the IFT and an EWT for oil and the natural gas flowrates and volumes will vary throughout.

A qualitative assessment on the use of both a shrouded flare and an enclosed unit was also undertaken. The enclosed unit (base case) was considered the better option when considering potential impact (noise, visual, land take and smoke) on the local population. The impact was slightly greater with the shrouded flare.

The WGMP has concluded that the BAT for the management of waste gas is incineration. Further assessment has concluded that both a shrouded flare is the most suitable for exploratory operations, subject to test conditions. UKOG have determined the following as BAT:

- A shrouded flare is the BAT for IFT operations, due to its ability to safely incinerate natural gas across a wide operating envelope and manage unpredictable flow rates; and
- A shrouded flare is the BAT for EWT operations for oil, again, due to its ability to safely incinerate associated natural gas across a wide operating envelope and manage unpredictable flow rates throughout the entire EWT for oil.

Should it be identified that the associated gas production rate becomes stable throughout the IFT, then UKOG will consider the use of an enclosed unit.

5. MANAGEMENT OF GAS - WELL TESTING OPERATIONS

Well testing operations will be managed and controlled by the Well Site Supervisor. The Well Site Supervisor is ultimately in charge and responsible for the operations which take place onsite, ensuring that the work is completed in accordance with all regulatory requirements and company policies. The operators of the temporary well testing equipment package report directly to the Well Site Supervisor. Any instructions for operating the equipment are received from the Well Site Supervisor who is also responsible for verifying the information and data being collected.

Prior to operating the flare and temporary well test package, site operatives will be required to commission the equipment in accordance with their standard procedures. The installation and commissioning of the equipment will be recorded. Any issues will also be recorded and will be resolved before operations are allowed to commence. Furthermore, a pre-operational check list will be completed in accordance with the equipment operators and manufacturers requirements. The flare units will be operated within its technical specification at all times.

UKOG will have procedures in place for the management of flare units at the well site specifically for well testing. The procedure will be the subject of Environment Agency approval prior to the commencement of well testing operations.

The exact equipment required during the well test will be dependent on the gas pressure of the well. The flow from the well will be directed via a choke manifold, which is used to control the flow and well pressures and can be adjusted to suit the varying parameters.

Once the flow has passed through the choke manifold and subject to well conditions, the well will flow into a separator. The purpose of the separator is to remove any fluids that may be contained in the gas.

Gas will be flowed from the separator, through a knock out pot, which removes any residual fluids suspended in the gas, which is important in ensuring a good flame within the flare units. Finally, the gas will flow into the flare unit where it will be incinerated. The flaring operation, with its associated fluids knocked-out, will minimise the amount and harmfulness of any residues. Good combustion conditions with the correct temperature, residence time and sufficient turbulence are key to securing this.

Any fluids flowed from the well are captured in an atmospheric gauge tank, with a vent stack system. Atmospheric gauge tanks are used for the storage of well fluids. The atmospheric tank is protected from overpressure and under pressure by an adequately sized vent system.

Throughout the well testing operations, there are a number of elements which can be varied to enable the equipment to operate optimally. The primary locations for varying the parameters are at the choke manifold and the flare.

The choke manifold is a series of valves, which can be restricted to control the flow from the well. The flare is controlled by changing the flow rate and temperature using support fuel where required.

A number of safety devices will be installed as part of the temporary well testing equipment package. Such equipment may include:

- Actuated Valves;
- Pressure Relief Valves; and
- Monitoring equipment including pressure gauges, flow rate and gas composition.

Subject to the relevant well control procedures the well can be shut back in if required and this will occur at specified periods within the testing programme. This enables the build-up of pressure within the wellbore to be monitored during this period.

Natural gas is considered a hazardous material and a review of the Waste Directive Annex III has identified a suitable waste reference code for natural gas. The appropriate waste reference is H3-A, which is classified as highly flammable. There is no corresponding entry within the European Waste Catalogue (EWC) codes, which is considered appropriate for the waste stream. However, the Sector Guidance published by the Environment Agency states that EWC code 16 05 04* should be applied.

An Air Quality Impact Assessment has been undertaken by SOCOTEC UK Limited encompassing the potential impact both IFT and the EWT will have on local air quality. This has been provided within Appendix 2 and concludes that the impact from well testing operations, specifically the incineration of natural gas, is negligible.

Having established that the BAT for the IFT and EWT for oil is a shrouded flare, UKOG have identified a suitable unit which meets both environmental and operational requirements. The flare chosen for this phase of works is the PW Shrouded Ground Flare (PW Flare) (see section 5.1).

However, should the production of associated gas prior to the EWT on the oil become stable then an alternative enclosed flare could be considered (see section 5.2).

5.1 PW Well Test - Shrouded Ground Flare

The PW Well Test Shrouded Ground Flare is currently the only known flare available onshore UK, which can meet the operational requirements of common well testing operations such as well clean up and IFT. The following section sets out the current design and construction of the PW Flare, together with safety considerations and its environmental performance.

Appendix 3 contains a schematic of the PW Flare and an indicative Planning and Instrumentation Diagram for the well test spread.

As part of the well test package a three phase separator will be deployed to site to ensure that the oil and produced water is separated from the natural gas to ensure that a cleaner combustion is achieved. In addition, a knock-out pot will also be deployed to the site for the purpose of removing any residual fluids from the natural gas prior to reaching the Flare unit. Given that the exploratory operations are focused around the testing of natural gas, it is not envisaged that a bath heater will be required.

5.1.1 Flare Design

The flare was manufactured to an open pipe flare design of a single 78mm (3.068”) diameter open pipe flare, elevated 3.1m above ground, with an 8.5m long by 2m diameter steel shroud. The 78mm (3.068”) open pipe flare is concentric within a 356mm (14”) diameter steel pipe, with a pilot line and air assist line running up the outside.

Once installed the total height of the flare is 12.2m once the skid frame has been taken into account. Appendix 3 provides a design of the proposed PW Flare. The PW Flare was designed to work within a wide operating envelope, namely 0.0mmscfd to 6.5mmscfd. Operation of the PW Flare will be restricted through the choke to achieve a flowrate of 0.5mmscfd. It is anticipated, based on previous modelling results that the height of the flame at this flow rate will not exceed the height of the shroud. A prediction of a 6m flame height within an 8.5m shroud at a rate of 2.5mmscfd was observed. This information has been provided within Appendix 3. Should it become apparent that the flame height exceeds the height of the shroud the flowrate can be coked back at the choke.

The height of the PW flare ensure that adequate dispersion is achieved when compared to that of enclosed flare units. The release height of the emissions will be 12.2m.

Both the pilot line and the air assist line extend to the flare tip. The pilot line delivers propane, from tanks located a safe and sufficient distance from the flare, to a continuously lit flame, providing a reliable and secure means of ignition at the flare tip. The air assist line delivers air to the flare tip from an air compressor, generating turbulence and increasing combustion efficiency. The air compressor is a typical mobile design, which is noise attenuated.

To mitigate against the flame entering the outlets, commonly referred to as ‘flash-back’, the flare will be fitted with a ‘quick closing valve’ and fail-safe spring return pneumatic actuator. A thermocouple will be fitted downstream of the outlet and a gas pressure transmitter will be installed within the gas delivery pipe, upstream of the outlet. The thermocouple will detect the presence of an initial ‘flash-back’, sending a signal to the ‘quick closing valve’ to activate closure of the valve.

The pilot line and air assist line are to remain in place, so too are the thermocouples and data logging facility. Propane tanks, which provide a continuous fuel source to the pilot light, will be located at safe and sufficient distance from the flare so as not to be affected by radiant heat emitted from the flare.

5.1.2 Combustion Efficiency

Combustion efficiency of a flare is generally based upon the flares ability to destroy methane, which in turn produces Carbon Dioxide (CO_2) and Water (H_2O). The combustion efficiency of higher hydrocarbons, such as benzene and PAHs, is generally expected to be lower.

Higher combustion efficiency is achieved by increasing the residence time at the flare tip, allowing time for the methane to mix with air, resulting in greater methane destruction.

UKOG understands that the PW Flare has been the subject of assessment by an independent service provider specialising in stack emissions testing. PW Well Test has confirmed that the combustion efficiency observed during past operations was in excess of 99%.

5.1.3 Flame Length

The PW Flare has been used by a number of onshore oil & gas operators for well testing operations. During each use it was recorded by PWWT that the flame height did not exceed the shroud height. No visible plume has been observed during well testing operations.

During use of the flare, the flame length will be continually monitored visually by the dedicated flare operator, who will be positioned immediately adjacent to the flare. Provision will be available on site to mitigate flame visibility should actual performance differ from the predictions not least due to the flare operator being in continuous communication with the choke manifold operator. In this regard, it is important that the flare is not viewed in isolation of the well test package.

Although unlikely, during initial start-up of the IFT, there may be a short period of time when the flame may be slightly visible above the shroud. This is to be expected, as the choke operator adjusts flowrates and pressures in order to establish a consistent flow, control flame height so it is not visible and optimise the combustion temperature.

During well testing operations, the adjustable choke box will be used to control well pressure on a small choke setting. During the IFT, should the flame length start to exceed the shroud height, the flow rate will be reduced at the choke manifold. In turn, this will reduce the inlet flow rate of natural gas to the flare, resulting in a reduction in flame length.

When the well is flowing, the well test package is continuously manned and periodic checks of the flare are undertaken, including temperature and flame condition. A dedicated well test operative will be assigned to continuously monitor the flare during testing operations and shall be in full communication with the dedicated choke manifold operator, advising the choke manifold operator of the flame characteristics. Choke adjustments are normally carried out in $^{4}/_{64}$" increments, with upstream and downstream pressures monitored throughout.

If necessary, due to any safety concerns, the well can be shut in at the choke manifold. The well test package will have an active Emergency Shutdown (ESD) system in operation throughout the well testing operation. All well testing personnel must be trained in its use, including how to shut in the well in the event of an emergency. UKOG is proposing to commission two of the shrouded flares during the initial flow testing. The second flare will be identical to that of the first in terms of appearance and performance. The EWT will require the use of a single PW Flare.

5.2 PW Well Test - 9.5 Enclosed Ground Flare

To demonstrate the commitment to BAT, UKOG will consider the use of the PW 9.5 Enclosed Flare (PW Enclosed Flare) should the associated natural gas flow become stable, consistent and within the flowrate capability of the flare. The maximum capacity for this flare model is 0.25mmscfd.

The flare design is based on a 2-stage burner for a varied range in flow rates. The capacity is restricted by reducing the number of burner nozzles in the second stage. The first stage will contain around 50 burner nozzles. The second stage has been reduced from 50 to 25 burner nozzles to cap capacity whilst keeping the flexibility to allow the unit to maintain efficient combustion.

Once installed the total height of the flare is 9.5m once the skid frame has been taken into account. Appendix 4 provides a design of the proposed PW Enclosed Flare. The PW Flare was designed to work within a specific operating envelope, namely a maximum 250,000scf flowrate with a turndown ratio of 5:1.

To mitigate against the flame entering the outlets, commonly referred to as 'flash-back', the flare will be fitted with a 'quick closing valve' and fail-safe spring return pneumatic actuator. A thermocouple will be fitted downstream of the outlet and a gas pressure transmitter will be installed within the gas delivery pipe, upstream of the outlet.

Full details of the PW Enclosed flare have been provided within Appendix 4.

6. LIFTING TECHNIQUES

6.1 Well Lifting - Nitrogen

To aid in the initial flow of hydrocarbons it is common for Nitrogen (N_2) to be introduced into the wellbore to displace wellbore fluids introduced during drilling or completion operations.

The N_2 will displace any liquids in the tubing or wellbore which reduces the hydrostatic pressure and allows the well to flow.

As the wellbore fluids, N_2 and natural gas rise to surface they will be diverted via temporary pipework to a three-phase separator, which will separate oil, formation water and gas (N_2 and natural gas) from each other. Oil (Inc. condensate) will be transferred via temporary pipework to storage tanks pending collection, with produced water being transferred via separate temporary pipework to separate storage tanks.

In the first instance, following artificial lifting, gas separated from the produced fluid will heavily consist of N_2, with small volumes of natural gas, and will be diverted through temporary pipework to the PW Flare where the following two processes will occur should artificial lifting be used.

1. The volume of N2 to be introduced into the wellbore will depend on the volume of wellbore fluid requiring lifting. Initially the recovered gas mixture will largely be N_2 with entrained natural gas. The gas flow from the well will be cold vented to atmosphere via the stack for a short period of time. Venting through the PW flare allows for greater dispersion.

2. As the lifting operations continue the volume of N_2 will decrease whilst the volume of natural gas will increase. Once a suitable mix of natural gas to oxygen has been achieved (once N_2 has reduced and cannot blanket ignition) the PW Flare pilot light will ignite the gaseous waste stream. The pilot light is always on and will ensure that no unnecessary cold venting will take place by igniting the gas as soon as it is physically possible to do so.

N_2 is an odourless gas and therefore does not directly cause odour issues, however as it will prevent the ignition of natural gas due to providing an 'ignition blanket', meaning that natural gas (although in small quantities) may present an issue of odour at the site albeit for a short duration. An Odour Management Plan has been provided which considers odour and associated management techniques from cold venting.

6.1.1 Justification for the use of Nitrogen to Lift Wells

There have been questions raised from the Environment Agency surrounding the use of nitrogen to undertake 'well lifting' operations. In particular why natural gas (external from the well) cannot be used to displace fluids and lift the well, as this would ensure that cold venting is prevented and all gas is combusted.

Whilst it is technically possible to use Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG) this is likely to be undertaken once appropriate equipment has been installed at the site, such as modified wellheads, annular safety valves and ESD systems, following a successful well test and once the reservoir properties are better understood, i.e. moving into the production phase of a development.

In addition to the infrastructure of exploration wells not being able to accommodate the use of CNG and LNG, they also pose additional risks with regards to health and safety, not least failing to adopt the ALARP principle with regards to the management of risks.

The Health and Safety at Work etc. Act 1974 states inter alia:

*It shall be the duty of every employer to ensure, **so far as is reasonably practicable**, the health, safety and welfare at work of all his employees.*

Without prejudice to the generality of an employer's duty under the preceding subsection, the matters to which that duty extends include in particular—

a) *the provision and maintenance of plant and systems of work that are, **so far as is reasonably practicable**, safe and without risks to health;*

b) *arrangements for ensuring, **so far as is reasonably practicable**, safety and absence of risks to health in connection with the use, handling, storage and transport of articles and substances;*

c) *the provision of such information, instruction, training and supervision as is necessary to ensure, **so far as is reasonably practicable**, the health and safety at work of his employees;*

d) ***so far as is reasonably practicable** as regards any place of work under the employer's control, the maintenance of it in a condition that is safe and without risks to health and the provision and maintenance of means of access to and egress from it that are safe and without such risks;*

e) *the provision and maintenance of a working environment for his employees that is, **so far as is reasonably practicable**, safe, without risks to health, and adequate as regards facilities and arrangements for their welfare at work.*

*It shall be the duty of every employer to conduct his undertaking in such a way as to ensure, **so far as is reasonably practicable**, that persons not in his employment who may be affected thereby are not thereby exposed to risks to their health or safety.*

The Health and Safety Executive have also published document *'Reducing Risks, Protecting People'* which provides the following statement: *'It is useful to note that SFAIRP is not the only qualification. There are other similar qualifications such as 'as low as reasonably practicable' (ALARP); 'as low as reasonably achievable' (ALARA).*

UKOG consider that the use of N_2 as opposed to CNG/LNG demonstrates its commitment to ensuring that risks are managed in accordance health and safety legislation and reinforced by its own moral obligations to ensure that all persons who may be affected by their business activities are safe and that any risks are controlled to ALARP, demonstrating compliance with health and safety legislation.

UKOG consider the transporting, handling and storage of CNG/LNG at an exploratory well site, for introduction into a wellbore for fluid lifting purposes an unnecessary risk, as safer and more cost effective technologies are available to use such as N_2 which is an inert chemical, when compared to flammable and explosive substances.

When comparing the risk of transporting, handling and storing CNG/LNG against the risk of cold venting small quantities of natural gas during the initial stages of nitrogen lifting as a result of using N_2, UKOG are of the strong opinion that the use of N_2 heavily outweighs the benefit of CNG/LNG for exploration operations.

To reduce the amount of cold venting, N_2 use is kept to a minimum by using a phased approach. Firstly, where possible the well is made underbalanced by using a light fluid. Secondly where possible N_2 is displaced into the well from surface to increase the under balance pressure. This keeps the N_2 and natural gas separate. Lastly N_2 is circulated around the well, this is used if there are sufficient quantities of fluid that need to be evacuated prior to the gas reaching the wellbore.

To further reduce the amount of cold venting the N_2 will be stopped once sufficient amount of gas has reached the wellbore to lift the fluid in the well. Once indications of natural gas are observed by measuring the return gas rate and deducting the N_2 rate to verify if this passes the minimum lift capacity. Additional gas gravity sampling can be taken to observe the weight decrease with the presence of natural gas. When the unit starts to light intermittently the N_2 can be periodically be shut off to observe if the well flows naturally. Once flowing, the N_2 will not be required and the natural gas will be burnt within the combustion unit.

6.2 Lifting the Well Using Mechanical Lifting Techniques

In the event the well(s) are not able to flow to surface naturally a number of lifting techniques are available to the onshore oil and gas industry, including the aforementioned Nitrogen. Another lifting technique is a mechanical lift. The use of mechanical lifting techniques is common place within oil production wells and can take a number of forms.

The production fluids can be handled in two ways within the well depending on the characteristics of the well. If there is little, or no associated gas recovered from the reservoir then all of the fluids are pumped up the tubing string to surface. The fluids are then handled as described previously, by going through a separator and being separated into oil, water and gas. The gas is directed to the gas incineration unit and the oil and water are sent to the storage tanks.

If larger quantities of associated gas are expected from the reservoir then the gas will flow up the annulus and be directed straight from the wellhead to the gas incineration unit, whilst the rest of the fluids will be handled as previously described.

In both instances the gas will be separated from produced fluids by physical separation, again this does not produce any additional waste streams, and the management of each waste stream will remain the same as currently permitted.

7. ENVIRONMENTAL MANAGEMENT AND MONITORING

The Arreton Well Site will be managed to ensure that all operations will be undertaken in such a way as to minimise environmental impact. Management and monitoring regimes will be implemented at the wellsite by UKOG to which contractors and subcontractors much adhere to.

7.1 Odour

Forthcoming operations relating to well testing will be the subject of the Odour Management Plan (OMP) which will be in place for operations conducted at the Arreton Well Site. The OMP will be the subject of review by the Environment Agency as part of a permit variation process.

The OMP has identified a number of potential sources of odour together with the mitigation measures that will be used to ensure that odour is eliminated so far as reasonably practicable. The OMP also details monitoring techniques such as sniff testing, emissions monitoring and grab sampling.

7.2 Air Monitoring

Prior to the commencement of operations, baseline air quality samples will be collected at the Well Site. The main source of air emissions from the operations will be the incineration of natural gas during IFT and EWT operations.

The scheme of monitoring will be consistent with the parameters and methodologies previously approved by the Environment Agency.

The same parameters will then be sampled for, analysed and the findings issued to the Environment Agency in accordance with the requirements of the environmental permit.

8. EMERGENCY RESPONSE PROCEDURES

In the event of an incident occurring, the Well Site Supervisor is to comply with the Well Site Emergency Response Plan ensuring, if safe to do so, immediate action is undertaken to isolate, contain and prevent an incident.

In addition, UKOG will inform Emergency Services of the location of the well site and will be notified of circumstances in which they may be called out to attend. This will aid the emergency services developing an emergency response plan of their own specifically for the operations and well site.

8.1 Spillages

Spillages of crude oil during the transfer or over filling of vessels will result in associated vapour being dispersed to the local environment.

Spillages occurring during the transfer of crude oil are not to be hosed down or detergents used to remediate the spillage. Remediation of the spillage is to be undertaken and the contaminated stone is to be removed, segregated and disposed of to an Environment Agency licensed facility as hazardous waste.

Spillage response equipment is located onsite. During site inductions, personnel will be shown the location of spillage equipment, how to use the equipment correctly and how to store and use materials safely.

Spillage equipment is to be labelled and checked on a regular basis by the Well Site Supervisor and unserviceable items quarantined and replaced.

8.2 Well Shut In

The Borehole Sites and Operations Regulations 1995 requires that a site specific health and safety document is produced for well site operations and requires a plan for the prevention of fire and explosions including particular provisions for preventing uncontrolled escape of flammable gasses.

In the unlikely event of an emergency situation arising during the well testing operation, for example a failed component or exceedance in pressure leading to one of a number of pressure relief valves within the well test package being activated, the well will be shut in with any residual gas remaining within pipework incinerated.

Primary well control during a well testing is the choke manifold, which must be fully certified and pressure tested to ensure it is sufficient to withstand the anticipated well pressures.

Secondary well control, as an example, can be an active ESD, which consists of a hydraulically operated Surface Safety Valve (SSV) located between the wellhead and the choke. Depending on the nature of the emergency situation, the well will be shut in at the choke if there is any visual indicator of a potential emergency situation starting to occur. If the emergency situation is not so obvious, such as pressure build-up within the well test package, high pressure sensors located at the choke and possibly, at the three (3) phase separator, will send an electronic signal to the SSV, which will close, isolating the well from the well testing package.

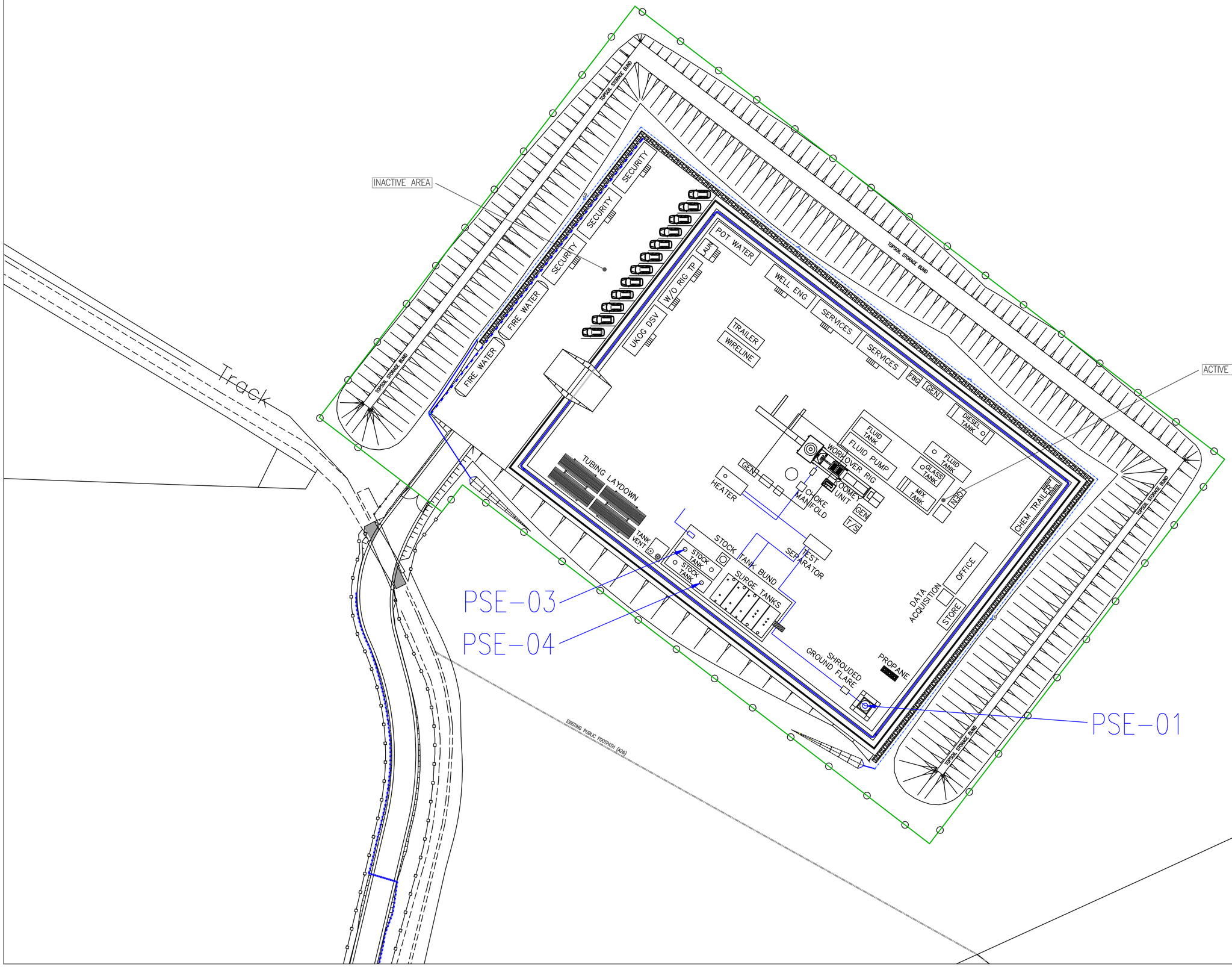
APPENDIX 1 – INDICATIVE SITE LAYOUT PLAN WITH EMISSION POINTS

*** Page Left Blank Intentionally ***

THE ORDNANCE SURVEY DATA ON THIS PLAN HAS BEEN REPRODUCED FROM ORDNANCE SURVEY ® BY PERMISSION OF ORDNANCE SURVEY ® ON BEHALF OF THE CONTROLLER OF HER MAJESTY'S STATIONERY OFFICE. © CROWN COPYRIGHT 2018. ALL RIGHTS RESERVED. LICENCE No. 100022432

KEY:

SITE BOUNDARY



NOTES:

PSE: POINT SOURCE EMISSIONS

REVISION HISTORY

REV	DATE	BY	DETAILS	APR
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
0	MAY20	JF	ORIGINAL FOR ISSUE	JF

ZETLAND GROUP
FROM CONCEPTION TO COMPLETION
ZETLAND GROUP LIMITED
THE INNOVATION CENTRE, KIRKLEATHAM BUSINESS PARK, REDCAR, TS10 5SH
T: +44(0)1642 777728 E: info@zetlandgroup.com W: www.zetlandgroup.com
Registered in England No. 05894408. Registered office: The Innovation Centre, Kirkleatham Business Park Redcar, TS10 5SH

THIS DOCUMENT IS THE PROPERTY OF ZETLAND GROUP LIMITED. IT CONTAINS PROPRIETARY AND CONFIDENTIAL INFORMATION WHICH MUST NOT BE DUPLICATED, USED OR DISCLOSED OTHER THAN AS EXPRESSLY AUTHORISED BY ZETLAND GROUP LIMITED OR ITS REPRESENTATIVE © 2020

SITE: ARRETON WELL SITE

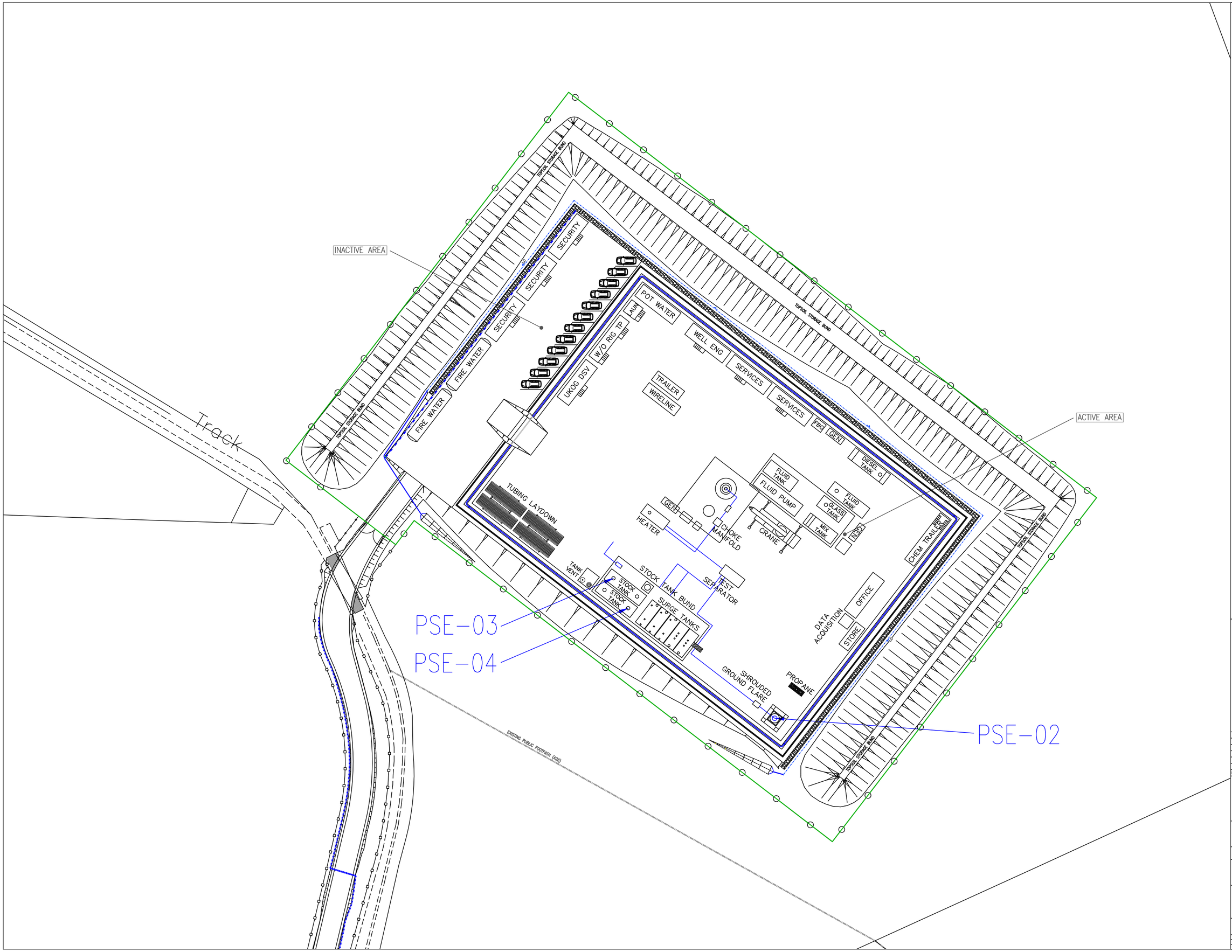
PROJECT: ARRETON WELL SITE HYDROCARBON EXPLORATION AND APPRAISAL

TITLE: PROPOSED INITIAL FLOW TESTING MODE LAYOUT PLAN

CLIENT: UK OIL & GAS PLC

Scale:	1:500
Size:	A2
Sheet:	1 of 1

DWG. No: UKOG-EPR-ATON-SP-OO4-04



THE ORDNANCE SURVEY DATA ON THIS PLAN HAS BEEN REPRODUCED FROM ORDNANCE SURVEY ® BY PERMISSION OF ORDNANCE SURVEY ® ON BEHALF OF THE CONTROLLER OF HER MAJESTY'S STATIONERY OFFICE. © CROWN COPYRIGHT 2018. ALL RIGHTS RESERVED. LICENCE No. 100022432

KEY:

SITE BOUNDARY

NOTES:

PSE: POINT SOURCE EMISSIONS

SHROUDED GROUND FLARE (PSE-01) MAY BE REPLACED WITH ENCLOSED GROUND FLARE (PSE-02) SHOULD THE INITIAL FLOW TEST CONFIRM THIS AS BEING POSSIBLE.

REVISION HISTORY

REV	DATE	BY	DETAILS	APR
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
0	MAY20	JF	ORIGINAL FOR ISSUE	JF

ZETLAND GROUP

FROM CONCEPTION TO COMPLETION

ZETLAND GROUP LIMITED
THE INNOVATION CENTRE, KIRKLEATHAM BUSINESS PARK, REDCAR, TS10 5SH
T: +44(0)1642 777726 E: info@zetlandgroup.com W: www.zetlandgroup.com

Registered in England No. 5586469. Registered office: The Innovation Centre, Kirkleatham Business Park, Redcar, TS10 5SH

THIS DOCUMENT IS THE PROPERTY OF ZETLAND GROUP LIMITED. IT CONTAINS PROPRIETARY AND CONFIDENTIAL INFORMATION WHICH MUST NOT BE DUPLICATED, USED OR DISCLOSED OTHER THAN AS EXPRESSLY AUTHORISED BY ZETLAND GROUP LIMITED OR ITS REPRESENTATIVE © 2020

SITE: ARRETON WELL SITE

PROJECT: ARRETON WELL SITE HYDROCARBON EXPLORATION AND APPRAISAL

TITLE: PROPOSED EXTENDED WELL TESTING MODE LAYOUT PLAN

CLIENT: UK OIL & GAS PLC

Scale:	1:500	DWG. No:
Size:	A2	UKOG-EPR-ATON-SP-OO4-05
Sheet:	1 of 1	

APPENDIX 2 – AIR QUALITY IMPACT ASSESSMENT

*** Page Left Blank Intentionally ***

UK OIL and GAS plc

Air quality assessment of an exploratory well site development

Arreton-3 Well Site (PEDL 331)

Carried out for:

UK Oil and Gas plc

8th Floor
The Broadgate Tower
20 Primrose Street
London
EC2A 2EW

Carried out by:

SOCOTEC UK Limited

Unit D
Bankside Trade Park
Cirencester
Gloucestershire
GL7 1YT

Date 7 February 2020

ISSUE HISTORY

Issue	Date	Approved	
191151,1	7 February 2020	N Ford	N Ford
First issue			

This Report has been prepared by SOCOTEC UK Limited with all reasonable skill and care, within the terms and conditions of the contract between SOCOTEC UK Limited and the Client ("Contract") and within the limitations of the resources devoted to it by agreement with the Client. Any reliance upon the Report is subject to the Contract terms and conditions.

This Report is confidential between the Client and SOCOTEC UK Limited. SOCOTEC UK Limited accepts no responsibility whatsoever to third parties to whom this document, or any part thereof, is made known. Any such party relies upon the Report at their own risk. The Contracts (Rights of Third Parties) Act 1999 does not apply to this Report nor the Contract and the provisions of the said Act are hereby excluded.

This Report shall not be used for engineering or contractual purposes unless signed above by the author, checker and the approver for and on behalf of SOCOTEC UK Limited and unless the Report status is 'Final'.

Unless specifically assigned or transferred within the terms and conditions of the Contract, SOCOTEC UK Limited asserts and retains all Copyright and other Intellectual Property Rights in and over the Report and its contents. The Report may not be copied or reproduced, in whole or in part, without the written authorisation from SOCOTEC UK Limited. SOCOTEC UK Limited shall not be liable for any use of the Report for any purpose other than that for which it was originally prepared.

Whilst every effort has been made to ensure the accuracy of the data supplied and any analysis interpretation derived from it, the possibility exists of variations in the ground and groundwater conditions around and between the exploratory positions. No liability can be accepted for any such variations in these conditions. Furthermore, any recommendations are specific to the development as detailed in this Report and no liability will be accepted should they be used for the design of alternative schemes without prior consultant with SOCOTEC UK Limited.

CONTENTS

		Page No.
	COVER	
	ISSUE HISTORY	1
	CONTENTS	2
	SUMMARY	4
1	INTRODUCTION	6
	1.1 Scope of study	6
	1.2 General approach	6
	1.3 Structure of report	7
2	POLICY CONTEXT AND ASSESSMENT CRITERIA	8
	2.1 Context of assessment	8
	2.2 Pollutants from site operations	8
	2.3 Environmental Standards	10
	2.3.1 Application of environmental standards	11
	2.4 Background air quality in Arreton	12
	2.5 Assessment criteria	14
	2.5.1 Criteria relevant to human health	14
	2.5.2 Criteria for deposition to ground	15
	2.5.3 Criteria relevant to protected conservation areas	15
	2.5.4 Significance of impact	16
3	MODELLING METHODOLOGY	18
	3.1 Assessment area	18
	3.2 Buildings	22
	3.3 Meteorology	24
	3.4 Surface characteristics	25
	3.4.1 Surface roughness	25
	3.4.2 Surface albedo	26
	3.4.3 Monin Obukhov length	27
	3.4.4 Priestley Taylor parameter	27
	3.4.5 Terrain	28

3.5 Pollutant releases and conditions 30
3.5.1 Stationary engines 30
3.5.2 Construction vehicles 32
3.5.3 Heavy duty vehicles 32
3.5.4 Flares 34
3.5.5 Fugitive releases and odour 36
3.5.6 Other releases 37
3.6 Modelling scenarios 37

4 MODELLING RESULTS 42

4.1 Impact of process releases 42
4.2 Impact of process releases at locations of human exposure 43
4.3 Impact of releases at sensitive nature conservation sites 46
4.4 Sensitivity analyses 52
4.4.1 Meteorological conditions 52
4.4.2 Model selection 53
4.4.3 Project scheduling 53
4.4.4 Flare selection 54
4.5 Fugitive releases 55
4.6 Modelling uncertainty 56
4.7 Photochemical ozone creation potential 57
4.8 Greenhouse gas releases and climate change 58
4.9 Construction dust 59
4.10 Operations traffic 60
4.11 Cumulative impacts 60

5 CONCLUSIONS 62

6 REFERENCES 64

Annex A Dispersion model contour plots 66
Annex B Model input data 69
Annex C Conversion of nitrogen monoxide to nitrogen dioxide 70
Annex D Meteorological data (St Catherines) 74
Annex E Construction dust risk assessment 79
Annex F Air quality impact of construction and operations traffic 84
Annex G Discrete receptors 86
Annex H Site equipment specification 81
Annex I Impact at sites of importance for nature conservation (SINC) 94

SUMMARY

UK Oil and Gas plc propose to develop a well site, known as the Arreton 3 well site, on land to the west of Arreton in off the Newport to Sandown highway (A3056) on the Isle of Wight. The aim of the project is to undertake drilling of an exploratory borehole and sidetrack borehole with subsequent testing for hydrocarbon minerals. The project is expected to engage around 86 working weeks within a project life of up to three calendar years after which the site will either be restored or retained to undertake further work.

As part of the planning and permitting process it is necessary to assess the dispersion of releases to atmosphere associated with the proposed operations to determine their impact on ambient concentrations of important pollutants around the local area. In particular, impact at locations of permanent human habitation and sensitive nature conservation sites in the context of attainment of applicable environmental standards requires assessment.

The main sources of pollutant releases during site operations will be from the use of diesel fuel in on-site stationary engines and construction and transport vehicles and from the disposal by flaring of produced natural gas. Releases of nitrogen oxides, carbon monoxide, volatile organic compounds, sulphur dioxide and particulate matter were considered. The assessment was undertaken using the UK ADMS 5.2 modelling system.

The drilling and appraisal phases of the project are the most energy intensive and result in the greatest pollutant releases. Depending on commencement date, the project will span up to three calendar years. Air quality standards are based on assessment over a calendar year. In order to capture worst case combinations of releases and meteorological conditions, long term air quality impact was assessed with a project schedule which accommodated the drilling and testing phases in one calendar year. Short term air quality impacts were based on year-round operation of the project phases which provided the greatest release rate for each pollutant. In practice it is expected that this worst case will be significantly mitigated by scheduling and breaks between project phases which will result in the execution of the drilling and testing over more than one calendar year.

Maximum pollutant process contributions from the site operations are localised and occur just within the well site boundary to the north east. Beyond this location, process contributions reduce significantly with distance. It is not considered that statutory air quality standards would be applicable around the area of maximum impact due to the infrequency of human exposure.

At neighbouring locations of residential occupation, where long term human exposure might be expected, it is considered unlikely that pollutant process contributions over the duration of the project would pose any significant threat to continued attainment of environmental standards.

Along the neighbouring footpaths and bridleways where short term environmental standards might be expected to apply, it is expected, in practice, that process pollutant contributions would be unlikely to compromise attainment of the applicable short-term environmental standards.

At local conservation sites sensitive to nitrogen and acid deposition maximum process contributions are considered to be unlikely to pose any threat to or have any substantial influence on the attainment of critical levels and critical loads in practice. The impact of process contributions of nitrogen oxides at the Arreton Down site of special scientific interest and at some nearby sites of importance for nature conservation are considered within the Ecological Impact Assessment that accompanies the planning application.

Necessary assumptions made to undertake the modelling are considered to have the effect of substantially overestimating the process contribution to ambient concentrations. It is considered that the predicted process impact reported herein is a conservative assessment and the conclusions reached therefore incorporate a reasonable margin of comfort in spite of the inevitable uncertainty of such modelling studies.

It is likely that the construction activities associated with the development of the well site will give rise to dust emissions. It is expected, based on Institute of Air Quality Management methodology, that with adequate mitigation measures in place the risk of dust impact from all project operations will be 'negligible'.

Increases in road traffic brought about by the construction activities, subsequent site operation and final site restoration are assessed to have a neutral impact on air quality based on Highway's Agency guidance.

Operations on site will give rise to releases of greenhouse gases. Based on an assessment of worst-case operation it is considered that Project lifetime greenhouse gas releases are largely insignificant in relation to the UK's current inventory and future budgets.

1 INTRODUCTION

UK Oil and Gas plc (UKOG) placed a contract with SOCOTEC UK Limited (SOCOTEC) to undertake an assessment of the impact on local air quality of a proposed exploratory well site development on land at Arreton on the Isle of Wight.

1.1 Scope of study

UKOG plc propose to construct a well site, known as the Arreton 3 well site, on land to the west of Arreton in off the Newport to Sandown highway (A3056) on the Isle of Wight. The area is within Petroleum Exploration and Development Licence (PEDL) 331. The aim is to drill one exploratory borehole and a sidetrack borehole which will be subsequently flow tested to determine viability. If unsuccessful the borehole will be decommissioned and the site restored. If successful, any subsequent developments would be subject to further planning applications. The temporary project is expected to be undertaken over a period of up to three calendar years with around 86 weeks of site work.

As part of the planning and permitting process UKOG have asked that the dispersion of releases to atmosphere associated with the proposed operations at the Arreton 3 well site be assessed to determine their impact on ambient concentrations of important pollutants around the local area.

The main sources of pollutant releases during site operations will be from the use of diesel fuel in on-site stationary engines, construction and transport vehicles and from the disposal of any produced natural gas by flaring. The main pollutants of concern are nitrogen oxides, carbon monoxide, volatile organic compounds, sulphur dioxide and particulate matter. The purpose of this study is to determine whether, under the proposed operating regime, releases to atmosphere are likely to be dispersed adequately in the context of applicable environmental standard attainment.

1.2 General approach

The approach taken comprised the following main stages:

- Determine a suitable modelling tool for the assessment.
- Collect appropriate representative operational data for the plant and vehicles intended for use for input to the model.
- Establish the proposed timeline for operations and their duration and frequency to determine the amount of discharges from each source and the likely timeline for discharge.
- Establish the location of the points of discharge for each source relative to proposed temporary buildings and structures on the well site.
- Establish the locations of any sensitive areas that might be impacted by releases from the site including residential properties, nature conservation areas, local footpaths and bridleways.
- Obtain information on local background concentrations of important pollutants.
- Obtain 5 years' recent meteorological data from a measurement station representative of the well site location.
- Model the dispersion of releases from the site operations to determine the process contribution to ambient concentrations of selected pollutants over the local area with particular attention to locations of human exposure and sensitive nature conservation sites.
- Assess the predicted process contributions and established background concentrations with reference to applicable environmental standards to determine compliance.
- Undertake a sensitivity analysis on the results for other important variable parameters and assess compliance with applicable environmental standards.

Further details of the approach taken and model input information are provided in the following sections.

1.3 Structure of the report

This report provides an assessment of the impact of releases from proposed exploratory drilling and subsequent flow testing operations on local air quality in the vicinity of the Arreton 3 well site. The approach to the assessment has been described above. The following sections provide a detailed commentary on the assessment and conclusions:

Section 2 Air quality standards and assessment criteria
Section 3 The model methodology employed and important input data
Section 4 The results of the assessment including sensitivity analyses
Section 5 Conclusions of the assessment

2 POLICY CONTEXT AND ASSESSMENT CRITERIA

UKOG propose to construct a well site, known as the Arreton 3 well site, on land to the west of Arreton in off the Newport to Sandown highway (A3056) on the Isle of Wight. The area is within Petroleum Exploration and Development Licence 331. The aim is to drill one exploratory borehole and a sidetrack borehole which will subsequently be flow tested to determine viability. If unsuccessful the borehole will be decommissioned and the site restored. If successful any subsequent developments would be subject to further planning applications. The project is expected to engage around 86 working weeks within a project life of up to three calendar years.

The Arreton 3 well site is near the village of Arreton and is in a rural area set around 400 m back from the Newport to Sandown highway (A3056). The nearest residential dwelling is approximately 664 m to the south west. The surrounding land is largely agricultural with the Arreton Down site of special scientific interest being the closest statutory site designated for ecology at around 1 km north east of the site. There are also some designated ancient woodlands within 800 m of the site. A local footpath and bridleway abut the well site running south east and south respectively before converging to north west.

2.1 Context of assessment

As part of the planning and permitting application it is necessary to demonstrate the likely impact of proposed operations on local ambient concentrations of important pollutants. It is in this context that the proposed operations are being examined to determine their additional contribution to the existing concentrations of important pollutants and therefore determine compliance with applicable air quality standards and environmental benchmarks.

Local Authorities are required to assess compliance with applicable air quality objectives. Where the objectives are unlikely to be met the Local Authority is required to declare an Air Quality Management Area (AQMA) and prepare proposals for remedial action to achieve the required objective. There are no declared AQMAs in the vicinity of Arreton 3 well site. A survey of planning and permitting applications indicates that there is one development in the area that might potentially have an influence on background concentrations of the pollutants of interest in this case.

The Environment Agency play an important role in relation to local air quality management by ensuring that processes under their regulatory control do not contribute any significant threat to the attainment of air quality standards. As part of the environmental permitting process it is necessary to demonstrate the impact of site operations on local air quality in the context of the published guidance provided by the Environment Agency[1].

2.2 Pollutants from site operations

The principal source of pollutant releases to atmosphere will be the operation of stationary and mobile plant and vehicles:

- Stationary diesel engines and generators providing power for site operations
- Non-road mobile plant brought to site for construction and site restoration operations
- The movement of heavy-duty vehicles (HDV) for transport operations throughout the project.

There will also be releases from the flaring of natural gas produced during flow testing.

All plant will be diesel fuelled and as such pollutant releases will be characteristic of the combustion of diesel fuel. The main pollutants from the combustion of diesel fuel are oxides of nitrogen, carbon monoxide and fine particulate matter.

Oxides of nitrogen are generally considered to comprise primarily of nitrogen monoxide and nitrogen dioxide. While oxides of nitrogen from road transport is a major contributor to ground level concentrations, emissions from

combustion processes could also be significant. Oxides of nitrogen are associated with lung damage and enhanced sensitivity to allergens. Emissions from combustion primarily consist of nitrogen monoxide, although reaction in the atmosphere results in conversion to nitrogen dioxide, which is the primary nitrogen oxide of interest with respect to ambient pollution. The emission of nitrogen oxides and their transformation products can cause a wide range of environmental effects including acidification and eutrophication

Combustion of diesel fuel will generally release some form of particulate matter. Particle size will determine the potential impact. Generally, the finer the particulate, the further it can travel into the human respiratory system. Particle size is defined by effective aerodynamic diameter. Material termed PM_{10} (i.e. all particles with an effective aerodynamic diameter up to 10µm) is seen as significant in this regard. Lower particle sizes (e.g. $PM_{2.5}$) are also considered in some air quality legislation and are the subject of monitoring.

Carbon monoxide is a product of incomplete combustion of the fuel and is therefore related to combustion efficiency. It reacts with other pollutants to form ground level ozone and has implications for neurological health. With incomplete combustion there is also the risk of elevated levels of volatile organic compounds which can give rise to odours and influence ground level ozone formation.

There will also be a release of sulphur dioxide which will be dependent on the sulphur content of the fuel.

In addition to the combustion of diesel fuel, there will be a need, during the flow testing phase of the project, to dispose of any natural gas produced by flaring. This will give rise to the same pollutants as combustion of diesel fuel, although it is not expected that there will be any significant releases of particulate matter from the flaring of natural gas.

Fugitive releases of natural gas, principally methane, are considered unlikely to be significant. Leakages from associated transport pipework on the site are likely to be minimal as the necessary surface pipework during the flow testing phase will be a temporary construction which will be pressure tested prior to use. Deterioration of the integrity of the pipework over the relatively short period of operation is considered unlikely to be significant, however fugitive releases in respect of their odour impact are considered for completeness.

This assessment considers the air quality impact of the following pollutants resulting from the proposed project operations:

Nitrogen oxides (NO_x, consisting of nitrogen monoxide (NO) and nitrogen dioxide (NO_2))
Sulphur dioxide (SO_2)
Carbon monoxide (CO)
Particulate matter (considered as both $PM_{2.5}$ and PM_{10})
Volatile organic compounds (VOCs – assessed as benzene)

In addition, the odour impact resulting from fugitive releases of sulphurous compounds in the produced natural gas is considered along with the air quality impact of methane and higher hydrocarbons (as benzene).

2.3 Environmental Standards

The UK's air quality strategy is based on meeting obligations within the European Union (EU) Ambient Air Quality Directive (2008/50/EC, 21 May 2008)[2] and the Fourth Daughter Directive (2004/107/EC, relating to metals and hydrocarbons)[3]. These directives specify legally binding limit values and target values. Limit values are set for individual pollutants and are made up of a concentration value, an averaging time over which it is to be measured, the number of exceedances allowed per year, if any, and a date by which it must be achieved. Some pollutants have more than one limit value covering different endpoints or averaging times. Target values are set out in the same way as limit values and are to be attained where possible by taking all necessary measures not entailing disproportionate costs.

The Air Quality (Standards) Regulations 2010[4] transpose into English law the requirements of Directives 2008/50/EC and 2004/107/EC on ambient air quality. Equivalent regulations have been made by the devolved administrations in Scotland, Wales and Northern Ireland. Schedules 2 and 3 of the Regulations specify limit and target values respectively.

Table 2.1 summarises the applicable limit values for the pollutants considered in this assessment as at 2019.

The limit values below are expressed as concentrations recorded over a specified time period which are considered to be acceptable in terms of current knowledge of the impact on health and the environment. Limit values are legally binding time averaged limits which must not be exceeded and which the UK is obliged to meet. In the case of target values these are values which are expected to be met by a specified date.

Table 2.1 Ambient Air Directive Limit Values and Target Values

Pollutant	Basis	Concentration
Carbon monoxide (CO)	running 8 hour mean across a 24 hour period[c]	10 mg/m^3
Nitrogen dioxide (NO_2)	1 hour mean (99.79 percentile – 18 exceedances per year)	200 µg/m^3
	annual mean	40 µg/m^3
Sulphur dioxide (SO_2)	*15 minute mean (99.90 percentile – 35 exceedances per year[a]*	*266 µg/m^3*
	1 hour mean (99.72 percentile – 24 exceedances per year)	350 µg/m^3
	24 hour mean (99.18 percentile – 3 exceedances per year)	125 µg/m^3
PM_{10}	24 hour mean (90.41 percentile- 35 exceedances per year)	50 µg/m^3
	annual mean	40 µg/m^3
$PM_{2.5}$	annual mean	25 µg/m^3
Benzene	annual mean	5 µg/m^3

a. Target value included in Environment Agency guidance[1].
b. Annual means refer to a calendar year.
c. Running 8 hour mean for each daily period commences at 1700 on the previous day and is updated every hour for the following 24 hours.

Critical levels are specified for sulphur dioxide and nitrogen oxides in relation to the protection of ecological conservation areas as shown in Table 2.2.

Table 2.2 Critical levels for the protection of ecological conservation areas

Pollutant	Basis	Concentration
Nitrogen oxides (as NO_2)	annual mean	30 µg/m^3
	daily mean	75 µg/m^3
Sulphur dioxide (SO_2)	annual mean[a]	10 µg/m^3

a. refers to the lower limit for sensitive lichen communities & bryophytes and ecosystems where lichens & bryophytes are an important part of the ecosystem's integrity. The upper limit where lichens are not present is 20 µg/m^3.

In addition, for the purposes of assessing the significance of pollutants in the ambient atmosphere the Environment Agency also publish Environmental Assessment Levels (EALs) for the protection of human health[1].

The EALs relevant to this study are summarised in Table 2.3.

Table 2.3 Environmental Assessment Levels

Pollutant	Basis	Concentration
Carbon monoxide	hourly mean	30000 µg/m^3
Benzene	hourly mean	195 µg/m^3
Nitrogen monoxide (NO)	hourly mean	4400 µg/m^3
	annual mean	310 µg/m^3
Methane (CH_4)[a]	hourly mean	21420 µg/m^3
	annual mean	7140 µg/m^3

a. The annual mean EAL for methane is based on an 8 hour time weighted average workplace exposure limit of 1000 ppm (NIOSH[5]) and is converted to long term and short term EALs based on the methodology specified in *H1, Annex F[6] and the Health and Safety Executive's EH40/2005[7].*

The EAL for methane is considered to be applicable in the assessment of the group of lower aliphatic hydrocarbon gases (C_1 to C_5). This is considered a precautionary approach as equivalent EALs for the remainder of the group (ethane, propane, butane and pentane) are considerably higher than methane.

2.3.1 Application of environmental standards

The Air Quality Standards Regulations 2010[4] specify legally binding concentrations of pollutants in the atmosphere which can broadly be taken to achieve a certain level of environmental quality. The Regulations define ambient air as;

"…outdoor air in the troposphere, excluding workplaces where members of the public do not have regular access."

Compliance with limit values for the protection of human health does not need to be assessed (Schedule 1, Part 1) at the following locations:

a) any location situated within areas where members of the public do not have access and there is no fixed habitation;
b) on factory premises or at industrial locations to which all relevant provisions concerning health and safety at work apply;
c) on the carriageway of roads and on the central reservation of roads except where there is normally pedestrian access to the central reservation.
It is therefore considered that compliance with environmental benchmarks should concentrate on areas where members of the general public are present over the entire duration of the concentration averaging period specific to the relevant standard. For the longer averaging periods the standards are considered to apply around the frontage of premises such as residential properties, schools and hospitals. The shorter-term limit value (1 hour or 1 day means) applies at these locations and other areas where exposure is likely to be of one hour or more on a regular basis.

In this context this assessment of compliance with environmental benchmarks in respect of protection of human health is considered at the nearest residential locations in the vicinity of the Arreton 3 well site and on the nearby public footpaths and bridleways. The assessment of compliance with critical loads and critical levels with respect to ecological impact is assessed at the conservation sites required for assessment within Environment Agency guidance[1] (see section 2.5.3).

2.4 Background air quality in Arreton

In considering the overall impact of a project, such as this herein, on local air quality and compliance with environmental benchmarks, it is necessary not only to consider the contribution from the proposed source but also the existing levels of pollutants of interest. Background air quality data for the area around Arreton are available from DEFRA's air quality archive (http://uk-air.defra.gov.uk/data/pcm-data). The archive provides estimated background concentrations of important pollutants for 1km^2 areas for the UK. The latest available background levels for the area within an approximate 2 km radius of the Arreton 3 well site (centre 452440 86370) were used for this assessment. Within this area there were 22 points at which background concentrations were available. Table 2.4 summarises the background pollutant concentrations obtained from the air quality archive for the assessment area. The values reported are the mean and maximum of the points for which data were available.

Table 2.4 Background pollutant concentrations from the DEFRA archive

Pollutant	Averaging basis	Concentration (µg/m^3)	
		Maximum	Mean
Nitrogen dioxide (2018)	annual mean	9.70	8.62
Total nitrogen oxides (2018)	annual mean (as NO_2)	12.79	11.23
Nitrogen monoxide (2018)[a]	annual mean	2.02	1.53
PM_{10} (2018)	annual mean	13.96	13.20
$PM_{2.5}$ (2018)	annual mean	8.70	8.42
Carbon monoxide (2010)	maximum 8 hour rolling mean	1451	1434
Sulphur dioxide (2018)	Annual mean	1.26	1.06
Benzene (2018)	annual mean	0.41	0.37

a. calculated based on the difference between total nitrogen oxides and nitrogen dioxide assuming total nitrogen oxides is the sum of nitrogen monoxide and nitrogen dioxide.

The Isle of Wight Council undertakes non-automatic air quality monitoring for nitrogen dioxide, although there are no measurement stations within 2 km of the Arreton 3 well site.

There are no AQMAs on the Isle of Wight. The nearest AQMA is around 17 km to the north east of the Arreton 3 well site in Portsmouth (Portsmouth AQMA No. 7). It is considered unlikely that releases from the Arreton 3 well site would have any influence on background pollutant concentration at this AQMA.

There are no monitoring stations within the area considered to be influenced by releases from proposed operations at the Arreton 3 well site. In the absence of locally measured background concentrations the maximum values, where available, from the DEFRA archive across the assessment area have been employed within this assessment. The use of the DEFRA maximum value for each pollutant is considered a precautionary approach which will most likely overestimate the existing background concentrations around the Arreton area.

The annual mean background concentration of methane employed in this assessment (1356 µg/m^3) is based on the Northern Hemisphere average[8] and is slightly higher than the background measurements reported by the Environment Agency for 2001-2003 (1278 µg/m^3)[9].

When considering the combination of estimated process contributions and background concentrations it should be noted that background concentrations are generally available as annual mean values and as such simple addition when considering short term air quality standards may not be appropriate. Guidance from the Environment Agency[1] suggests a simplified method for combining estimated process contributions and background concentrations. For comparison with long term standards the overall concentration is the sum of the process contribution (annual mean) and background concentration (annual mean). For comparison with short term standards the Environment Agency

suggest the sum of the process contribution (hourly or daily mean) and twice the background concentration (annual mean). This methodology has been employed in this assessment.

Table 2.5 summarises the pollutant background concentrations adopted for this assessment.

Table 2.5 Background concentrations adopted in the assessment

Pollutant	Averaging basis	Background concentration	
		µg/m^3	% of standard
Ambient Air Directive Limit Values and Target Values			
Carbon monoxide (CO)	8 hour mean	1451	15
Nitrogen dioxide (NO_2)	1 hour mean [a]	19.4	10
	annual mean	9.7	24
Sulphur dioxide (SO_2)	15 minute mean[b]	3.4	1
	1 hour mean[a]	2.5	<1
	24 hour mean[c]	1.5	1
PM_{10}	24 hour mean[d]	16.5	33
	annual mean	14.0	35
$PM_{2.5}$	annual mean	8.7	35
Benzene[e]	annual mean	0.41	8
Environmental assessment levels			
Carbon monoxide	hourly mean[f]	2075	7
Benzene[e]	hourly mean[a]	0.82	<1
Nitrogen monoxide (NO)	hourly mean[a]	4.0	<1
	annual mean	2.0	<1
Methane (CH_4)[g]	hourly mean[a]	2712	13
	annual mean	1356	19

a. One hour mean is determined from annual mean value using a conversion factor of 2.0[1].
b. 15 minute mean is determined from the hourly mean using a conversion factor of 1.34[1].
c. 24 hour mean is determined from the hourly mean using a conversion factor of 0.59[1].
d. 24 hour mean is determined from annual mean value using a conversion factor of 1.18 (a and c above).
e. Volatile organic compounds are assessed against the limit value for benzene in accordance with Environment Agency guidance[1].
f. One hour mean is determined from 8 hour mean using a conversion factor of 1.43[1].
g. Lower hydrocarbons (methane, ethane, propane, butane, pentane) are assessed against the limit for methane.

Background levels specific to the nature conservation sites considered are obtained from the Air Pollution Information System (APIS - www.apis.ac.uk) and are discussed later.

2.5 Assessment criteria

The Environment Agency[1] provides a methodology for assessing the impact and determining the acceptability of emissions to atmosphere on ambient air quality for human health and nature conservation areas and for deposition to ground. Two stages of assessment are recommended.

Screening assessment – based on standard dispersion factors the ambient impact of releases to atmosphere may be estimated. The estimates tend to be very conservative since no account is taken of plume rise, meteorological conditions or the locations of the sensitive receptors where impact is to be assessed. The estimates are compared with the assessment criteria discussed in sections 2.5.1 to 2.5.3. Where a release can be demonstrated to be 'insignificant' it may be screened out. Where this is not possible a further detailed assessment is required.

Detailed assessment – based on atmospheric dispersion modelling taking into account the factors which influence dispersion and ambient impact (e.g. meteorology, release conditions, locations of sensitive receptors, etc.). Process contributions and predicted environmental concentrations are compared with the same assessment

criteria. Where conditions for excluding the release from further consideration cannot be made a detailed cost benefit assessment will be necessary.

In this assessment all releases have been assessed using detailed modelling approach only.

The criteria considered in this assessment are described below.

2.5.1 Criteria relevant to human health

The contribution of the process (PC) to the ambient concentration of a given pollutant is considered insignificant, and requiring no further assessment, if both of the following conditions are met:

- the long-term PC is less than 1% of the long-term environmental standard
- the short-term PC is less than 10% of the short-term environmental standard

If these conditions are not met then the corresponding predicted environmental concentration (PEC, PC + background concentration) should be assessed. The process contribution is considered insignificant and requiring no further assessment, if both of the following conditions are met:

- the short-term PC is less than 20% of the short-term standard minus twice the long-term background concentration
- the long-term PEC is less than 70% of the long-term environmental standard

If these conditions are not met then the compliance of the process with Best Available Technique (BAT) will need to be assessed. No further action is necessary if it can be demonstrated that both of the following apply:

- proposed emissions comply with BAT associated emission levels (AELs) or the equivalent requirements where there is no BAT AEL
- the resulting PECs won't exceed environmental standards

Failure to meet these criteria requires that a cost-benefit analysis be undertaken for consideration by the Environment Agency.

2.5.2 Criteria for deposition to ground

Where any of the substances in Table 2.6 are released it is required that the impact they have when absorbed by soil and leaves (termed 'deposition') is assessed.

If the PC to ground for any of these substances is below 1% of the limit it is insignificant and requires no further assessment. Where the PC to ground is 1% of the limit or greater a further assessment will be necessary.

In this case none of the substances in Table 2.6 are considered to be released in a quantity sufficient to merit an assessment for deposition to ground.

Table 2.6 Limits for deposition to ground

Substance	Deposition limit (PC to ground) µg/m^2/day
Arsenic	0.02
Cadmium	0.009
Chromium	1.5
Copper	0.25
Fluoride	2.1
Lead	1.1
Mercury	0.004

Molybdenum	0.016
Nickel	0.11
Selenium	0.012
Zinc	0.48

2.5.3 Criteria relevant to protected conservation areas

Where there are protected conservation areas in the vicinity of the release it is necessary to consider the impact of following pollutants:

- nitrogen oxides (long and short-term bases)
- sulphur dioxide (long term basis)
- ammonia (long term basis)
- hydrogen fluoride (long and short-term bases)
- nutrient nitrogen and acid deposition

In this case releases of nitrogen oxides and sulphur dioxide are considered, together with their impact in relation to the deposition of nutrient nitrogen and acid.

An assessment is required where the release is within 10 km (15 km if the site is a large electric power station or refinery) of any of the following designated sites:

- special protection area (SPA)
- special area of conservation (SAC)
- Ramsar site (protected wetland of international importance)

or within 2 km of a:

- site of special scientific interest (SSSI)
- local nature site (ancient wood (AW), local wildlife site (LWS) and national or local nature reserve (NNR, LNR))

If the PC at a SPA, SAC, Ramsar or SSSI meets both of the following criteria, it is insignificant and no further assessment is required:

- the short-term PC is less than 10% of the short-term environmental standard for protected conservation areas
- the long-term PC is less than 1% of the long-term environmental standard for protected conservation areas

If these criteria are not met then the corresponding PEC should be assessed. The emission is considered insignificant if:

- the long-term PC is greater than 1% and the corresponding PEC is less than 70% of the long-term environmental standard,

If either of the following criteria are met a further more detailed consideration of ecological impact is required:

- the long-term PC is greater than 1% and the long-term PEC is greater than 70% of the long-term environmental standard
- the short-term PC is greater than 10% of the short-term environmental standard

For local nature sites releases are considered to be insignificant where both of the following criteria are met:

- the short-term PC is less than 100% of the short-term environmental standard
- the long-term PC is less than 100% of the long-term environmental standard

A failure to meet the above criteria requires a further more detailed consideration of ecological impact.

Environmental standards for conservation areas such as critical levels for ambient air and critical loads for nitrogen and acid deposition are considered to be specific to the habitat types associated with each conservation site. APIS provides acidity and nitrogen deposition critical loads for designated features within every SAC, SPA or A/SSSI in the UK.

2.5.4 Significance of impact

Environmental Protection UK (EP UK) and the Institute of Air Quality Management (IAQM) have published guidance on the impact of pollutant releases in the context of existing air quality assessment levels[10] (i.e. AAD limit and target values etc.). Their categorisation is shown in Table 2.7.

Table 2.7 Impact descriptor for individual receptors

Long term average concentration at receptor in assessment year	% change in concentration relative to Air Quality Assessment Level (AQAL)			
	1	2-5	6-10	>10
75% or less of AQAL	Negligible	Negligible	Slight	Moderate
76-94% of AQAL	Negligible	Slight	Moderate	Moderate
95-102% of AQAL	Slight	Moderate	Moderate	Substantial
103-109% of AQAL	Moderate	Moderate	Substantial	Substantial
110% or more of AQAL	Moderate	Substantial	Substantial	Substantial

In this case impact is considered as the change in the concentration of an air pollutant, as experienced by a receptor. This may have an effect on the health of a human receptor, depending on the severity of the impact and a range of other contributing factors. The descriptor in itself is not considered a measure of effect.

IAQM guidance indicates that for any point source some consideration must also be given to the impacts resulting from short term, peak concentrations of those pollutants that can affect health through inhalation. Background concentrations are considered less important in determining the severity of impact for short term concentrations. Short term concentrations in this context are those averaged over periods of an hour or less. These are exposures that would be regarded as acute and will occur when a plume from an elevated source affects airborne concentrations experienced by a receptor over an hour or less.

Where such peak short-term concentrations from an elevated source are in the range 10-20% of the relevant AQA_L, then their magnitude can be described as small, those in the range 20-50% medium and those above 50% as large. These are the maximum concentrations experienced in any year and the severity of this impact can be described as slight, moderate and substantial respectively, without the need to reference background or baseline concentrations. Table 2.8 summarises these descriptors.

Table 2.8 Impact descriptors for short term process contributions

Short term process contribution (% AQA_L)	Magnitude	Severity
11-20	Small	Slight
21-50	Medium	Moderate
>51	Large	Substantial

Background concentrations are not unimportant, but they will, on an annual average basis, be a much smaller quantity than the peak concentration caused by a substantial plume and it is the contribution that is used as a measure of the impact, not the overall concentration at a receptor.

In most cases, the assessment of impact severity for a proposed development will be governed by the long-term exposure experienced by receptors and it will not be a necessity to define the significance of effects by reference to short-term impacts. The severity of the impact will be substantial when there is a risk that the relevant AQAL for short-term concentrations is approached through the presence of the new source, taking into account the contribution of other prominent local sources.

3 MODELLING METHODOLOGY

The contributions to ambient concentrations of the selected pollutant releases from well site operations have been modelled using the Atmospheric Dispersion Modelling System (ADMS) version 5.2. The use of this modelling tool is accepted by the Environment Agency and UK Local Authorities for regulatory purposes.

ADMS and the United States Environmental Protection Agency's (US EPA) AERMOD modelling systems are the two most widely used air dispersion models for regulatory purposes worldwide. Both are based on broadly similar principles. In this case ADMS 5.2 has been employed for the assessment, although the results have been compared with those obtained from the same modelling using the AERMOD system in order to provide confidence in the assessment findings.

ADMS 5.2 requires a range of information in order to perform the modelling. The primary information required is discussed below.

All modelling files containing relevant input information (see Annex B) are provided to the Environment Agency to assist in their confirmatory assessment of the modelling undertaken herein as part of the environmental permitting process. This will include determination of permit conditions to ensure that the releases to atmosphere comply with relevant legislation and are consistent with the conditions modelled (see section 3.5). It would be expected that this would include a requirement for regular monitoring of releases to atmosphere to determine compliance with permit emission limit values where appropriate.

3.1 Assessment area

The area over which the assessment was undertaken is a 2 km x 2 km area with the well site (452440 86370) located approximately at the centre. Figure 3.1 illustrates the assessment area, location of the site, the surrounding area and nearest residential locations and public footpaths and bridleways.

Figure 3.2 illustrates the general proposed site layout and the immediate surrounding area.

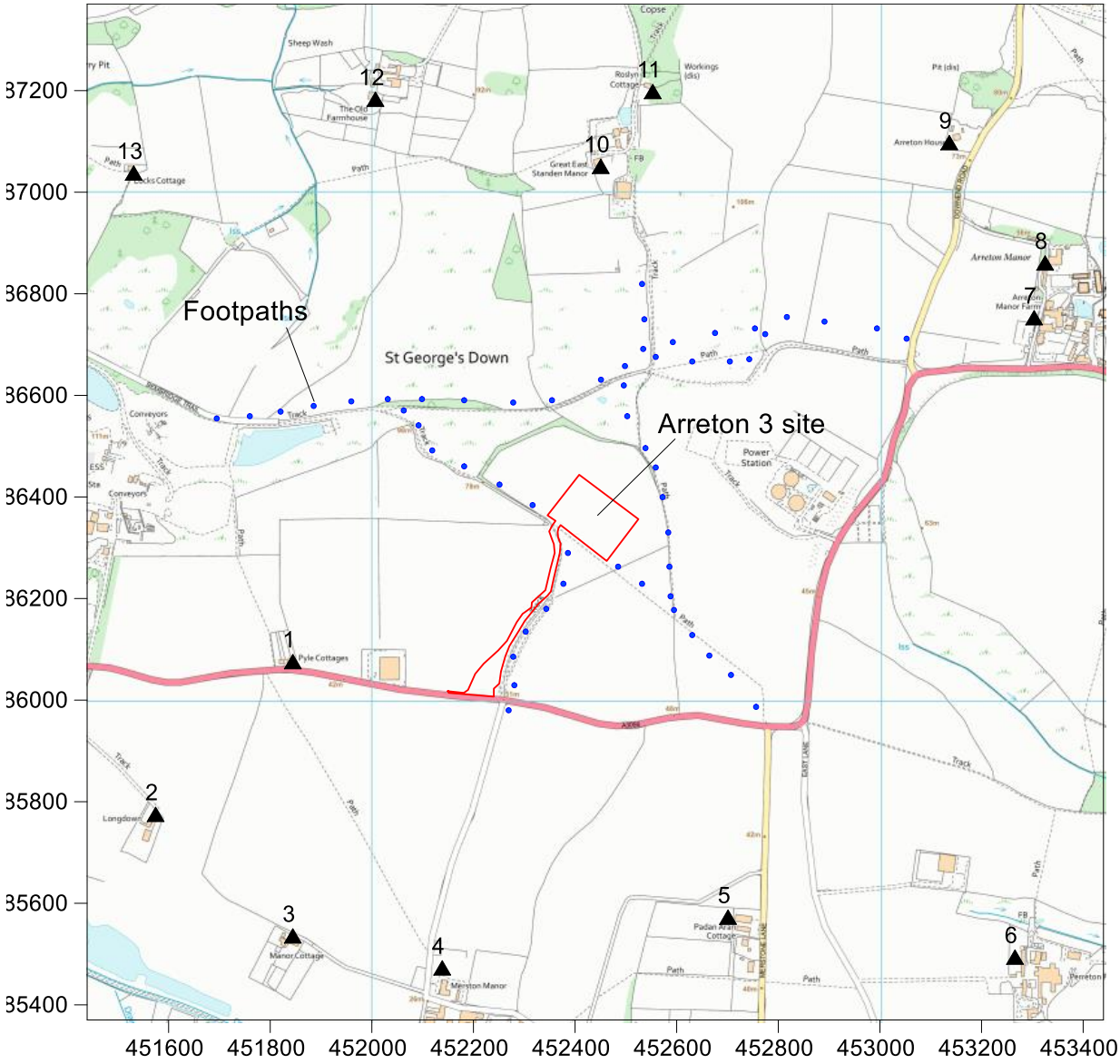
A general grid with receptors spaced at 20 m intervals (i.e. 10201 points for a 101 x 101 grid) was used to assess the process contribution to ground level concentrations over the assessment area illustrated in Figure 3.1. The grid was considered at an elevation of 1.5 m. This is intended to represent the typical height of human exposure.

In addition to the receptor grid, 13 receptors (1 to 13 in Figure 3.1) were positioned at residential locations in the vicinity of the well site. These receptors were placed at an elevation of 1.5 m and are described in Table 3.1. These are intended to correspond to the nearest location of long-term human exposure in the vicinity of the well site.

It is also expected that there will be frequent human exposure along the nearby public footpaths and bridleways. 55 receptors were located along the footpaths and bridleways which run close to the well site in order to monitor the likely impact of well site releases on air quality along the length of the routes as illustrated in Figure 3.1(blue dots). These receptors are described in Annex G.

There are a number of tracks in the area which are generally used for farm access and which are not considered to be locations of frequent human exposure where air quality standards for human health would be expected to apply, (as defined in section 2.3.1). These locations are not considered in this assessment.

Figure 3.1 Location of the Arreton 3 well site and assessment area



For the purposes of the assessment the receptors were considered in groups as described below:

1 to 13	Residential locations (see Table 3.1)
14 to 18	Local nature conservation sites (see Table 3.2)
19 to 73	Local footpaths and bridleways (see Table G.1)
74 to 78	Nature conservation sites with a European designation (see Table 3.2)

Annex G describes the location of these discrete receptors.

Figure 3.2 Arreton 3 well site layout (Phases 2A to 2F)

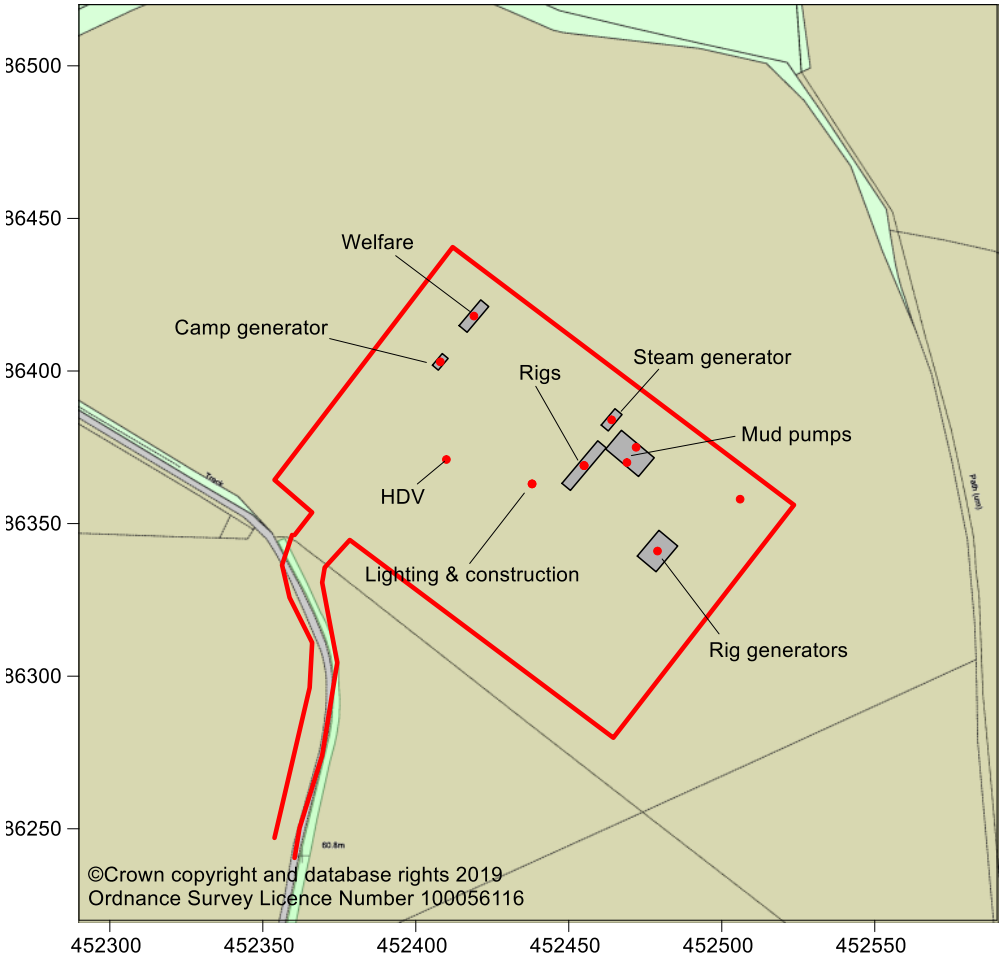


Table 3.1 Location of residential receptors

Receptor	Position[a]	Easting	Northing

(see Figure 3.1)			(m)	(m)
1	Pyle Cottages	664 m SW	451845	86076
2	Longdown	1050 m SW	451574	85775
3	Manor Cottage	1025 m SW	451845	85536
4	Merston Manor	946 m S	452139	85473
5	Padan Aran Cottage	839 m S	452701	85573
6	Perreton Farm	1204 m SE	453266	85494
7	Arreton Manor Farm	945 m NE	453304	86753
8	Arreton Manor	1012 m NE	453325	86861
9	Arreton House	1007 m NE	453137	87098
10	Great East Standen Manor	681 m N	452451	87051
11	Roslyn Cottage	836 m N	452553	87198
12	The Old Farmhouse	921 m NW	452007	87183
13	Locks Cottage	1128 m NW	451531	87038

a. Location of the receptor relative to the centre of the Arreton 3 well site.

It is also necessary to consider the impact of releases on any local statutory designated sites. Following a review of all sites in the local area, four ancient woodlands and a SSSI met the criteria for assessment along with six site with a European designation (see 2.5.3). Each location was described by a receptor located at the edge of the site closest to the well site as described in Table 3.2. The Solent and Dorset Coast proposed SPA and Solent Maritime SAC are overlapping sites and for the purposes of this assessment are described by a single discrete receptor (75). There are also a number of sites of important for nature conservation (SINC) which are considered separately in Annex I.

Table 3.2 Location of receptors at nature conservation sites

Receptor		Designation	Position[a]	Easting (m)	Northing (m)
14	Perreton Farm Wood	AW	1.1 km SE	453416	85859
15	Standen Copse	AW	0.8 km N	452578	87172
16	Wroxhall Bottom Copse	AW	1.2 km NW	451783	87401
17	Saltmoor Copse	AW	1.7 km NE	453434	87712
18	Arreton Down	SSSI	1.1 km NE	453240	87158
74	Briddlesford Copses	SAC	2.9 km NE	454180	88703
75	Solent and Dorset Coast	Proposed SPA	3.9 km NW	450154	89548
	Solent Maritime	SAC	3.9 km NW	450154	89539
76	Solent and Southampton Water	RAMSAR, SPA	6.0 km NE	454781	91931
77	South Wight Maritime	SAC	7.4 km SE	458912	82883
78	Isle of Wight Downs	SAC	8.5 km S	455603	78484

a. Location of the edge of the habitat closest to the Arreton 3 well site boundary.

3.2 Buildings

The presence of buildings close to a discharge flue can have a significant impact on the dispersion of releases. The most significant impact can be the downwash of a plume around a building causing increased concentrations in the immediate area around the building. Buildings can also disturb the wind flow causing a turbulent wake downwind which can also affect dispersion. It is normally considered that buildings within 5 times the height of release or within 5 times the height of the building should be considered in any modelling.

The significant structures within the well site will generally be mobile modules (e.g. generators, pumps etc.) and the arrangement will vary depending on the phase of the project. For the purposes of this assessment consideration is given to the general site arrangement during Phases 2A to 2F where it is expected that the greatest releases to atmosphere will occur due to the deployment of multiple generators. The expected placement of these modules is illustrated in Figure 3.2. While there will be a range of other temporary structures on the site, it is expected that these modules will have the most influence on dispersion due to their size and proximity to the more significant points of release to atmosphere.

ADMS 5.2 models buildings as either rectangular or circular structures. In this case the major modules considered were modelled as rectangular blocks. Based on the drawings provided by UKOG[11] the main parameters describing these modules were estimated as described in Table 3.3.

Table 3.3 Parameters describing major site structures

Structure (see Figure 3.2)	Structure centre grid reference		Height (m)	Angle (° from north)	Length (m)	Width (m)
	Easting	Northing				
Camp generator	452408	86403	3.5	40	5.0	2.5
Welfare unit	452419	86418	3.5	40	11.0	3.4
Rig engine	452455	86369	3.5	40	18.2	3.6
Mud pumps 1 & 2	452470	86373	3.5	40	8.0	14.0
Rig generator	452479	86341	3.5	40	11.0	8.0
Steam generator	452464	86384	3.5	40	7.0	3.0

It is assumed, for the purposes of the assessment, that these structures are present throughout the project duration and are the only structures influencing dispersion. In practice there will be periods when some or all of these structures are absent, although this will tend to be during less energy intensive phases of the project which will be unlikely to influence assessment outcomes.

A sensitivity analysis was undertaken to determine the effect of the selection of the structure that has most influence on dispersion.

Main structure (see Table 3.3 and Figure 3.2)	Change (%) in predicted PC of nitrogen dioxide over the residential receptors (1 to 13) compared with base case of the Camp Generator as main structure			
	Short term average		Long term average	
	Maximum	Mean	Maximum	Mean
Welfare unit	0	-0.4	-0.2	-0.4
Rig engine	0	-0.1	-0.2	-0.3
Mud pumps 1 & 2	0	0	-0.2	-0.3
Rig generator	0	-0.3	-0.2	-0.3
Steam generator	0	-0.1	-0.2	-0.3
No structure	0.7	1.0	1.0	1.4

The differences associated with the selection of the main structure are not considered to have any meaningful influence on the overall conclusions of this assessment. The sensitivity analysis indicated marginally greater predicted process contributions were achieved when the influence of buildings on dispersion was not considered. For this assessment structures are not considered. This is seen as a precautionary approach.

Releases to atmosphere will occur throughout the site depending on the placement of the major items of equipment and the movement of site vehicles such as construction equipment and heavy-duty vehicles (HDV) entering and leaving the site. For the purposes of this assessment a simplifying approach has been taken for minor emitters by treating these as a group represented as a single point source located at a position which is generally representative of that group. For the construction equipment and HDVs the release point is representative of their expected site movements, while the positioning of the source groups containing portable lighting towers and welfare unit is based on an assessment of their proposed locations for each phase of the project. The major emitters (see Table 3.4), which comprise the large stationary engines, steam generator and the flare are each treated as individual sources and are located as indicated in project phase site plans provided by UKOG[11].

Figure 3.2 illustrates the assumed position of each release point. Table 3.4 describes the release point locations for the grouped sources and the major emitters.

Table 3.4 Location of release points

Item	Equipment	Height of release (m)[b]	Easting (m)	Northing (m)
CON	All construction equipment used in Phases 1A and 4A.	4.0	452438	86363
LIGHT	Portable lighting used in all phases.	4.0	452438	86363
WEL	Welfare unit used in all phases.	4.0	452419	86418
HDV	Heavy duty vehicles entering and leaving the site during all phases.	4.0	452410	86371
CAMP	Camp generator (Phases 2B, 2Di.&ii, 2E, 2F, 3A)	4.0	452408	76403
WORIG	Workover rig (Phase 2Di.&ii, 2F, 3A)	4.0	452455	86369
COND	Conductor setting rig (Phase 1A)	4.0	452455	86369
RIGGEN[a]	Rig generator (Phases 2B & 2E)	4.0	452479	86341
RIGENG	Rig engine (Phases 2B & 2E)	4.0	452455	86369

Table 3.4 continued

Item	Equipment	Height of release (m)[b]	Easting (m)	Northing (m)
MUD 1	Mud pump generator 1 (Phases 2B & 2E)	4.0	452472	86375
MUD 2	Mud pump generator 2 (Phases 2B & 2E)	4.0	452469	86370
STEAM	Steam generator (Phase 2Di.&ii)	4.0	452464	86384
FLARE	Flare (Phase 2Di.&ii)	12.2	452506	86358

a. The rig has two generators, although one is for stand by purposes and is not synchronised to run simultaneously with the duty generator. Hence only one generator will operate at any one time.
b. Release heights estimated from site drawings provided by UKOG (234) Ltd[11].

3.3 Meteorology

For this modelling assessment hourly sequential meteorological data from the nearest suitable meteorological station to the area was obtained. The data, provided by the UK Met Office, was from the St Catherines station and covered the 5-year period 2014 to 2018. The St Catherines station is around 11 km south of the Arreton 3 well site at an elevation of 20 m, compared with the site elevation of around 66 m. The St Catherines station does not record cloud data and as such the UK Met Office recommended the use of cloud data from the Thorney Island station. There are two other stations in the area which were also considered as possible sources of meteorological data:

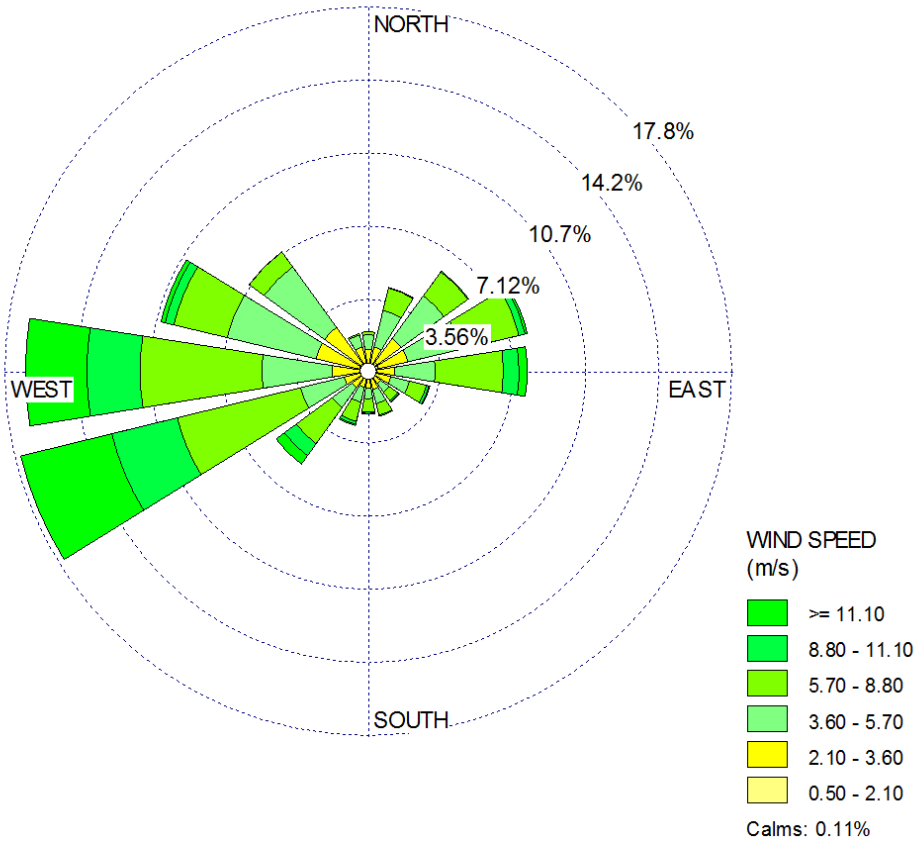
Station	Position	Elevation	Data coverage
Needles Old Battery	23 km W	80 m	Wind data only
Thorney Island	28 km NE	4 m	Complete

The UK Met Office also have stations at Ventnor and Shanklin on the Isle of Wight, although these do not record on an hourly basis.

Based on advice provided by the UK Met Office, the proximity of the station, elevation and data coverage, it was considered that data from the St Catherines, supplemented with cloud data from the Thorney Island station, provided measurements most representative of the conditions at Arreton.

The data included, among other parameters, hourly measurements of wind speed and direction. Figure 3.3 illustrates a composite wind rose for the St Catherines station. It may be seen that the wind has significant westerly component. Annex D provides a more detailed analysis of the meteorological data used.

Figure 3.3 Composite windrose for the St Catherines station (2014 to 2018)



3.4 Surface characteristics

The characteristics of the surrounding surfaces and the land use within the assessment area have an important influence in determining turbulent fluxes and hence the stability of the boundary layer and atmospheric dispersion. In ADMS it is necessary to consider the following parameters which describe land use and surface properties:

Surface roughness
Surface albedo
Minimum Monin Obukhov length
Priestley Taylor parameter

3.4.1 Surface roughness

The roughness length represents the aerodynamic effects of surface friction and is physically defined as the height at which the extrapolated surface layer wind profile tends to zero. This value is an important parameter used by meteorological pre-processors to interpret the vertical profile of wind speed and estimate friction velocities which are, in turn, used to define heat and momentum fluxes and, consequently, the degree of turbulent mixing.

The surface roughness length is related to the height of surface elements. Typically, the surface roughness length is approximately 10% of the height of the main surface features. Surface roughness is higher in built up areas than in rural locations.

A range of typical roughness values for common land use types are provided within ADMS:

Land use	Surface roughness (m)
Ice	0.00001
Snow	0.00005
Sea	0.0001
Short grass	0.005
Open grassland	0.02
Root crops	0.1
Agricultural areas	0.2-0.3
Parkland, open suburbia	0.5
Cities, woodland	1.0
Large urban areas	1.5

The Arreton well site is located in a rural location on reasonably flat agricultural land. The nearest residential location is around 600 m to the south west. A surface roughness of 0.3 m has been selected. A sensitivity analysis has been undertaken considering variations in surface roughness of between 0.1 and 1.0 m. This resulted in the following variations in predicted hourly and annual process contributions of nitrogen dioxide over the residential receptors (1 to 13 see Figure 3.1):

Surface roughness (m)	Change (%) in predicted PC of nitrogen dioxide over the residential receptors (1 to13) compared with base case of a surface roughness of 0.3 m			
	Short term average		Long term average	
	Maximum	Mean	Maximum	Mean
0.1	24.4	28.8	16.3	16.4
0.2	6.2	11.1	5.4	6.6
0.4	-6.6	-7.5	-3.4	-4.2
0.5	-3.9	-11.2	-6.3	-7.7
1.0	-27.9	-29.7	-20.2	-22.0

The assessment shows some sensitivity to surface roughness. It is considered that the selected surface roughness is reasonably representative of the area of influence and tends towards a more conservative estimate of the range likely to be most descriptive of the general assessment area. This selection does not introduce uncertainties which are significant in the context of the conclusions reached in section 4.

3.4.2 Surface albedo

The surface albedo is the ratio of reflected to incident shortwave solar radiation at the surface of the earth and lies in the range 0 to 1. This parameter is dependent upon surface characteristics and varies throughout the year. Surface albedo is higher (higher proportion of reflected radiation) when the ground is snow covered. Based on the recommendations of Oke (1987), ADMS provides default values of 0.6 for snow-covered ground and 0.23 for non-snow covered ground, respectively. In this case a value for surface albedo of 0.23 has been employed.

3.4.3 Monin Obukhov length

The Monin Obukhov length provides a measure of the stability of the atmosphere and allows for the effect of heat production in cities which may not be represented by the meteorological data. In urban areas heat generated from buildings and traffic warms the air above which has the effect of preventing the atmosphere from becoming very stable. Generally, the larger the area the greater the effect. In stable conditions the Monin Obukhov length will not fall below a minimum value with the value becoming larger depending on the size of the city. The minimum value of

the Monin Obukhov length generally lies between 1 and 200 m with 1 corresponding to a rural area. ADMS provides the following guidance on minimum Obukhov length:

Population size	Minimum Obukhov length (m)
Large conurbations (>1 million)	100
Cities and large towns	30
Mixed urban/industrial	30
Small towns	10
Rural area	1

In this case the area is considered to be typical of a rural area. A minimum Monin Obukhov length of 1.0 m has been employed. A sensitivity analysis has been undertaken considering minimum Monin Obukhov lengths in the range 1 to 30 m. This resulted in the following variations in predicted hourly and annual process contributions of nitrogen dioxide over the residential receptors (1 to 13, see Figure 3.1):

Minimum Monin Obukhov length (m)	Change (%) in predicted PC of nitrogen dioxide over the residential receptors (1 to 13) compared with base case of a minimum Monin Obukhov length of 1 m			
	Short term average		Long term average	
	Maximum	Mean	Maximum	Mean
5	0	1.0	0.8	0.8
10	0.9	2.2	2.4	2.1
20	0.9	2.3	4.2	4.0
30	2.0	11.3	6.3	5.8

The variations are largely insignificant over the length range considered to be descriptive of the assessment area and not likely to influence the conclusions reached in section 4.

AERMOD does require that the minimum Monin Obukhov length be specified.

3.4.4 Priestley Taylor parameter

The Priestley Taylor parameter represents the surface moisture available for evaporation. Areas where moisture availability is greater will experience a greater proportion of incoming solar radiation released back to atmosphere in the form of latent heat, leaving less available in the form of sensible heat and, thus, decreasing convective turbulence. The Priestley Taylor parameter lies between 0 and 3. Based on suggestions by Holstag and van Ulden, ADMS provides default values of:

Land type	Priestley Taylor parameter
Dry bare earth	0
Dry grassland	0.45
Moist grassland	1

In this case the area is considered to be representative of moist grassland and a value of 1.0 for the Priestley Taylor parameter has been employed. A sensitivity analysis has been undertaken considering Priestley Taylor parameters in the range 0 to 1.5. This resulted in the following variations in predicted hourly and annual process contributions of nitrogen dioxide averaged over the residential receptors (1 to 13, see Figure 3.1).

Priestley Taylor parameter	Change (%) in predicted PC of nitrogen dioxide over the residential receptors (1 to 13) compared with base case of a Priestley Taylor parameter of 1			
	Short term average		Long term average	
	Maximum	Mean	Maximum	Mean
1.5	0.9	3.1	2.6	5.2
0.5	-0.7	-2.7	-2.6	-3.0
0	-1.6	-3.0	-4.1	-4.7

The variations are largely insignificant and not likely to influence the conclusions reached in section 4. It is considered that the use of the model default value (for moist grass land) is likely to be most representative of the area.

It may be noted that AERMOD uses the Bowen ratio to describe available surface moisture rather than the Priestley Taylor parameter. The following default values are provided from Paine (1987).

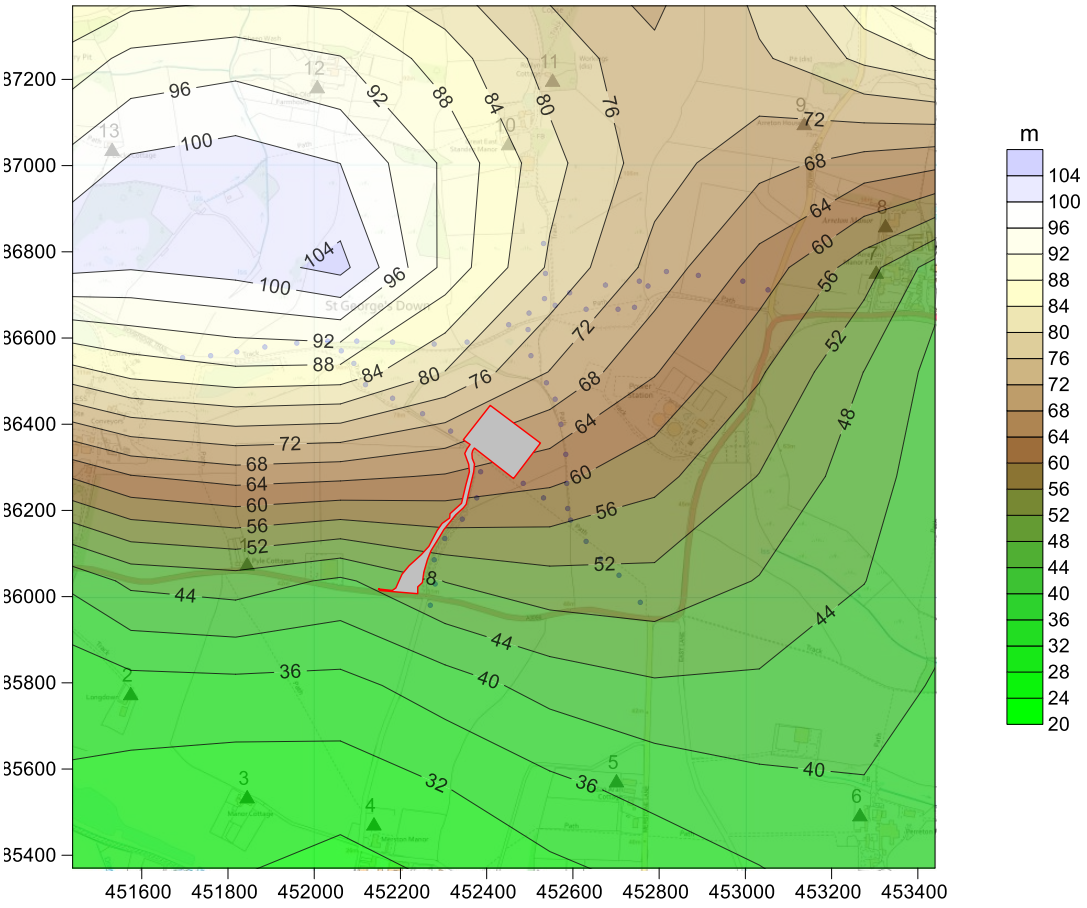
Land use	Bowen ratio (-variation with season)
Water	0.1
Deciduous forest	0.6-2.0
Coniferous forest	0.6-2.0
Swamp	0.2-2.0
Cultivated land	1.0-2.0
Grassland	1.0-2.0
Urban	2.0-4.0
Desert shrubland	5.0-10.0

For the modelling herein a value of 1.0 was employed for the Bowen ratio.

3.4.5 Terrain

Terrain data was obtained for the assessment area from the Ordnance Survey Land-form Panorama DTM data base. There is an increase in general elevation across the main assessment area. The ground rises from the south and east to the north west over the assessment area at an average gradient of around 5% as shown in Figure 3.4.

Figure 3.4 Ground elevation within assessment area



A sensitivity analysis was undertaken to determine the impact of consideration of terrain in the assessment in contrast to the assumption of a flat assessment area. The sensitivity of the predicted annual and hourly process contributions of nitrogen dioxide across the residential receptors (1 to 13, see Figure 3.1) to consideration of terrain was examined as below.

Terrain	Change (%) in predicted PC of nitrogen dioxide over the residential receptors (1 to 13) compared with base case of a flat assessment area			
	Short term average		Long term average	
	Maximum	Mean	Maximum	Mean
Elevated	-3.4	5.0	-3.2	3.7

General guidance suggests that consideration of terrain is not necessary at gradients of less than 5%. In this case it is not considered that the difference between a flat and elevated assessment area is likely to have any significant impact on the assessment outcomes, although for avoidance of doubt a flat assessment area has been considered in the overall air quality assessment as it provides generally higher predicted maximum process contributions. This is considered a precautionary approach.

3.5 Pollutant releases and conditions

Four general sources of pollutant releases are considered in this assessment:

Stationary engines
Construction vehicles used on site
HDV vehicle movements on site
Flaring of natural gas

UKOG[11] provided details of the flares, stationary engines, construction vehicles and HDV movements intended over the various phases of the project. A full listing of the equipment employed and references for the specifications used are provided in Annex H. These are summarised below.

3.5.1 Stationary engines

Table 3.5 summarises the diesel fuelled stationary engines specified for use by UKOG[11] during the project.

The engine specifications generally indicate compliance with either European Union or United States emission standards. The engines are assumed to operate at the emission standards, with the exception of those associated with the mud pumps which have no certification. Releases from these engines are based on the manufacturer's declared maximum emissions. The steam generator is assumed to operate at the emission factors for diesel combustion in industrial boilers as specified in US EPA AP42[12]. In addition, it is assumed that the engines and steam generator will use ultra-low sulphur diesel with a sulphur content of 10 mg/kg (10 ppm).

Table 3.5 Stationary engines and performance

Equipment		Diesel fuel consumption		Power output[b]	Emission standard
		l/h	kg/h[a]	kWh	
a	Lighting (4)	1.6	1.4	6.7	EU Stage 3A
b	Welfare unit	3.7	3.2	15.2	EU Stage 3A
i	Surface conductor rig	43.0	37.6	179	EU Stage 3A
j	Camp generator	81.0	71.0	350	EU Stage 3A
k	Rig engine[c]	85.0	74.0	354	US Tier 2
	Mud pump generators (2)[d]	306	267	1270	not certified
	Rig generator	192	167	797	US Tier 2
	All terrain fork lift	13.2	11.5	55	EU Stage 3B
l	Workover rig	85.0	74.0	354	US Tier 2
m	Steam generator	200	175	2077 (input)	AP42 1.3

a. Based on a fuel density of 0.874 kg/l (at 0°C).
b. Assumes a brake specific fuel consumption of 0.21 kg/kWh, where not specified.
c. The rig has two generators, although one is for stand by purposes and is not synchronised to run simultaneously with the duty generator. Hence only one generator will operate at any one time.
d. Mud pumps operate at no more than 80% load.

Based on the claimed emission standards and specified full load fuel usage and power output, pollutant release rates for each stationary engine have been determined as summarised in Table 3.6.

Table 3.6 Pollutant release rates for stationary engines

Equipment	Pollutant release rate per unit (g/s)					
	CO	VOCs[a]	NO_x[a]	PM	SO_2	CO_2

Lighting	0.010	0.001	0.013	0.0011	0.00001	1.2
Welfare unit	0.023	0.002	0.029	0.0025	0.00002	2.9
Surface conductor rig	0.174	0.015	0.184	0.0099	0.00021	33.4
Camp generator	0.340	0.029	0.360	0.0194	0.00039	63.0
Rig engine[c]	0.476	0.064	0.805	0.0272	0.00057	91.2
Mud pump generators[b]	0.493	0.061	3.38	0.0890	0.00119	189.9
Rig generator	0.775	0.105	1.312	0.0443	0.00093	148.9
Workover rig	0.344	0.046	0.582	0.0196	0.00041	66.0
Steam generator	0.033	0.002	0.133	0.0133	0.00097	155.4

a. Volatile organic compounds are expressed as benzene and nitrogen oxides are expressed as nitrogen dioxide.
b. A load of 100% is assumed for all engines, with the exception of the mud pumps which operate at no more than 80% load.
c. For simplicity the contributions of the all-terrain forklift and accommodation module of the drilling rig are included within the rig engine releases.

The exhaust gas conditions in Table 3.7 for each engine have been estimated and used in the assessment.

Table 3.7 Exhaust gas conditions for stationary engines

Equipment	Height of release (m)	Internal flue diameter (m)	Velocity[b] (m/s)	Temperature[a] (°C)
Lighting	4.0	0.2	1.6	150
Welfare unit	4.0	0.1	3.8	150
Surface conductor rig	4.0	0.2	21.4	550
Camp generator	4.0	0.2	40.4	550
Rig engine[c]	4.0	0.25	37.5	550
Mud pump generators	4.0	0.35	35.9	524
Rig generator	4.0	0.35	27.3	545
Workover rig	4.0	0.2	42.4	550
Steam generator	4.0	0.45	9.0	150

a. Based on engine specification with allowance for heat loss.
b. Based on combustion calculations assuming diesel lower heating value of 42.78 MJ/kg.
c. For simplicity the contributions of the all-terrain forklift and accommodation module of the drilling rig are included within the rig engine releases.

It is assumed that all stationary engines operate at 100% load continuously when operational (see Table 3.17), with the exception of the mud pump generators which are assumed to operate continuously at 80% load.

3.5.2 Construction vehicles

UKOG[11] specified the principal mobile plant that are intended to be employed for the construction and restoration phases of the project as shown in Table 3.8.

Table 3.8 Specification of main construction vehicles

Type	Gross power output (kW)	Fuel consumption (kg/h)[a]	Emission standard
c 20 t excavator	110	23.1	US Tier 3
d 12-14t excavator	74	15.5	US Tier 4
e 8 t mini excavator	40	8.4	EU Stage 3B
f 9t forward tipper[b]	70	14.7	EU Stage 3A
g Vibratory roller	100	21.0	EU Stage 3A
h Tracker dozer	78	16.4	EU Stage 3B

a. Assumes a brake specific fuel consumption of 0.21 kg/kWh.
b. Two tippers will be used for site construction and restoration.

It is assumed that all vehicles will operate at the specified emission standard at full load when operational. On this basis the pollutant emission rates for the construction vehicle fleet are estimated in Table 3.9.

Table 3.9 Pollutant release rates for construction vehicles

Type	Pollutant release rate per unit (g/s)					
	CO	VOCs[a]	NO_x[a]	PM	SO_2[c]	CO_2
20 t excavator	0.153	0.009	0.113	0.009	0.00013	20.5
12-14t excavator	0.103	0.004	0.008	0.0004	0.00009	13.8
8 t mini excavator	0.056	0.004	0.048	0.0003	0.00005	7.5
9t forward tipper[d]	0.389	0.027	0.338	0.031	0.00016	26.1
Vibratory roller	0.139	0.008	0.103	0.008	0.00012	18.7
Tracker dozer	0.108	0.004	0.072	0.001	0.00009	14.6

a. Volatile organic compounds are expressed as benzene and nitrogen oxides are expressed at nitrogen dioxide.
b. A load of 100% is assumed for all engines.
c. Assumes a diesel sulphur content of 10 mg/kg.
d. Emission rates are for two tippers.

It is assumed that releases from the construction vehicles can be considered as a single point release for the purposes of the assessment at a height of 4.0 m with a velocity of 19.9 m/s and exhaust temperature of 150°C.

3.5.3 Heavy duty vehicles

Heavy duty vehicles will enter the site via the access road and then generally off load, load and leave site. For the purposes of the assessment of releases from these vehicles while on site it is assumed that the vehicle enters site and then idles for a period of one hour before leaving. This is considered to be a conservative estimate of releases and it is noted that in practice vehicles will be switched off when not in use.

The emission factors for idling in Table 3.10 have been assumed based on an evaluation of four studies of heavy duty vehicle idling emissions[13, 14, 15, 16]. These are considered to be conservative estimates. A factor of 45 gNO_2/h for nitrogen oxides during HDV idling has been used as a guideline by the Greater London Authority[17].

Table 3.10 Emission factors for HDV idling

Parameter	Rahman[13]	DIESELNET[14]	Christopher Frey[15]	Khan[16]	Selected

Nitrogen oxides	g/h	56.9	70.9	89.5		70.9
Nitrous oxide	g/h	0.9				1.1[a]
Carbon monoxide	g/h	95.0	27.8	17.8		27.8
Carbon dioxide	g/h	9108		5931	4660	5296[b]
Particulate matter	g/h	2.6	2.5	1.3		2.6
Total hydrocarbons	g/h		13.6			13.6
Higher hydrocarbons	g/h	13.0		3.5		13.0
Sulphur dioxide	g/h	5.8		0.037	0.029	0.033[b]
Fuel consumption	l/h			2.12	1.67	1.90 [b]

a. based on ratio of N_2O to NO_x from Rahman.
b. Mean of values from Christopher Frey and Khan.

UKOG[11] have provided details of maximum daily HDV movements for the various phases of the project (see Table H.2). It is assumed that movements of HDVs occur between 0700 and 1900 on each working day and between 0900 and 1300 on Saturdays with no movements on Sundays. The average number of HDVs idling on each working day of a project phase is determined in Table 3.11.

Table 3.11 Frequency of HDV idling

Phase	HDV Working hours[a]	HDV movements (in/out /day)	Total HDVs arriving	HDVs idling /working hour	Fuel consumption l/working hour
1A	640	900	900	1.4	2.7
2A	192	270	270	1.4	2.7
2B	960	1350	1350	1.4	2.7
2C	192	270	270	1.4	2.7
2D(i)	640	900	900	1.4	2.7
2D(ii)	1024	480	1024	0.5	0.9
2E	960	1350	1350	1.4	2.7
2F	256	360	360	1.4	2.7
3A	192	180	180	0.9	1.8
3B	128	60	60	0.5	0.9
4A	320	300	300	0.9	1.8

a. HDVs are assumed to be restricted to an operational period of 0700 to 1900 (12 hours) during each normal 24 hour working day and between 0900 and 1330 on Saturdays with no movements on Sundays.

Based on the average frequency of HDV idling and the selected pollutant emission rates the release rates in Table 3.12 for HDV idling were estimated.

Table 3.12 Pollutant releases from HDV idling

Project phase	Pollutant release rate in each working hour (g/s)					
	CO	VOCs	NO_x	PM	SO_2	CO_2
1A	0.011	0.0053	0.028	0.0010	0.000013	2.1
2A	0.011	0.0053	0.028	0.0010	0.000013	2.1
2B	0.011	0.0053	0.028	0.0010	0.000013	2.1
2C	0.011	0.0053	0.028	0.0010	0.000013	2.1
2D(i)	0.011	0.0053	0.028	0.0010	0.000013	2.1
2D(ii)	0.004	0.0018	0.009	0.0003	0.000004	0.7
2E	0.011	0.0053	0.028	0.0010	0.000013	2.1
2F	0.011	0.0053	0.028	0.0010	0.000013	2.1
3A	0.007	0.0035	0.018	0.0007	0.000009	1.4

3B	0.004	0.0018	0.009	0.0003	0.000004	0.7
4A	0.007	0.0035	0.018	0.0007	0.000009	1.4

It is assumed that releases from the HDVs during idling can be considered as a single point release for the purposes of the assessment at a height of 4 m with a velocity of 7.8 m/s and exhaust temperature of 150°C. As a simplifying and precautionary approach, the assessment of air quality impact is based on a maximum two-way vehicle movement of 15 HDVs for each working day of the project. Release rates for the entire project are therefore considered to be equivalent to the maximum found for any phase (i.e. phases 1A to 2F).

3.5.4 Flares

For the appraisal phase of the project (Phase 2Di.&ii) the use of one flare is proposed, although the type will be dependent on the amount of produced natural gas that needs disposal. There will be a need to dispose of up to 10t of natural gas per day (equivalent to a mean disposal rate of around 0.5 MMscfd):

- If flows exceed 5t of natural gas per day UKOG propose to use a shrouded flare with a maximum disposal rate of 2.2 MMscfd (calibrated to accommodate a maximum permitted disposal rate of 0.5 MMscfd); or,

- If flows are below 5t of natural gas per day UKOG propose to use an enclosed flare with a maximum disposal rate of 0.25 MMscfd (see Table H.1).

The release conditions for the flares have been assessed in Table 3.14, based on the assumed natural gas composition in Table 3.13.

Table 3.13 Natural gas composition

Property		Value
Methane	% v/v	96.4
C_2	% v/v	0.4
C_3	% v/v	0.4
C_4	% v/v	0.4
C_5	% v/v	0.4
C_6+	% v/v	0.1
Nitrogen	% v/v	1.6
Carbon dioxide	% v/v	0.3
Total sulphur	mg/Nm^3	50
Lower heating value	MJ/kg	48.1
	MJ/Nm^3	36.3
Higher heating value	MJ/kg	53.4
	MJ/Nm^3	40.2

Table 3.14 Flare exhaust gas conditions

Flare		Shrouded flare	Enclosed flare
Disposal rate	MMscfd	0.5	0.25
	Nm^3/s	0.15	0.08
Heat release[a]	MW	6.18	3.09
Exhaust gas temperature[b]	^{o}C	1000	1000
Exhaust gas flow rate (actual)[c]	m^3/s	17.0	8.5
Flue diameter	m	2.0	2.1
Velocity	m/s	5.4	2.5
Flame length[d]	m	5.5	4.0
Carbon dioxide release[e]	g/s	313	157
Water vapour release[e]	g/s	250	125

a. Based on higher heating value based and a combustion efficiency of 99%.
b. Assumes a radiation loss of 20%.
c. Assumes an excess air level of 133%, equivalent to an oxygen content in the exhaust gas of 12.5% by volume, dry basis.
d. Based on API methodology (American Petroleum Institute, RP 521,1990).
e. Determined from gas composition and gas disposal rate.

Pollutant releases are estimated in Table 3.15 based on the emission factors for industrial flares published by the US EPA in their AP42 document[13].

Release rates determined based on the corresponding EMEP-EEA emission factors[18] are provided in brackets in the above table. It should be noted that the value for total hydrocarbons refers to the non-methane fraction. In this case a precautionary approach is adopted with the higher of the release rates in each case employed in the assessment (denoted in bold in Table 3.15). A sensitivity analysis (see section 4.4.4) indicated that the use of the larger shrouded flare gave rise to the greatest air quality impact at residential locations. The use of this flare is assumed during the project. This is a precautionary approach.

Table 3.15 Pollutant releases from flare operations

Property		Shrouded flare	Enclosed flare
Disposal rate	MMscfd	0.5	0.25
Emission factors (g/MJ heat input)[a]			
Total hydrocarbons		0.060	
Nitrogen oxides		0.029	
Carbon monoxide		0.133	
Release rates (g/s)			
Total hydrocarbons		0.372 (**0.010**)	0.186 (**0.005**)
Nitrogen oxides		**0.181** (0.179)	**0.090** (0.090)
Carbon monoxide		0.824 (**0.985**)	0.412 (**0.492**)
Sulphur dioxide[b]		**0.015**	**0.008**

a. Based on higher heating value.
b. Based on a total natural gas sulphur content of 50 mg/Nm^3.

3.5.5 Fugitive releases and odours

Site operations during the development and testing of a gas well prior to production will have the potential to result in leakages of produced gas. This largely results from leakages in pipework and connections and from the well itself. It is expected that standard loss prevention and maintenance procedures will minimise any leakages. It would therefore be expected that unintentional releases of produced gas to atmosphere will be insignificant. No cold venting of produced natural gas is intended and as such has not been considered in this assessment.

It is difficult to assess the likely level of leakage from activities associated with well exploration. Emissions factors for the release of gases from gas system operations, based on surveys of operations throughout the world, have been derived, primarily to provide an indication of the impact with respect to greenhouse gases. The Intergovernmental Panel on Climate Change (IPCC)[19] provide emission factors for fugitive releases for, among other gases, methane from activities associated with natural gas systems. In particular emission factors are provided for well exploration (including well drilling and testing) and gas production and gathering (including activities from the well head to the gas processing plant). Both activities are assumed to include some flaring and venting. Total annual fugitive releases are based on the number of wells drilled or number of active wells:

Activity	Methane release t/year	
Gas exploration	5.78	for each well drilled
Gas production	4.37 to 7.07[a]	for each active well

a. Range is for low and high emitting technologies and practices.

It is assumed that the annual fugitive release in this case for the drilling and testing of one well is 5.78 t methane. This is seen as a worse case precautionary approach. Table 3.16 summarises the fugitive releases from the Arreton 3 well site based on the gas composition in Table 3.13 and an even distribution of the fugitive release over the year.

Table 3.16 Fugitive natural gas releases

Well site		Arreton 3
Easting	m	452455
Northing	m	86369
Total annual methane release	t	5.78
	m^3	8096
Methane content of produced gas	% volume	96.4
Produced natural gas release	m^3	8399
	m^3/s	0.00027
	kg[a]	6334
	kg/s	0.00020
Methane release rate	g/s	0.1833
C_{6+} content of natural gas (see Table 3.13)	% by volume	0.1
C_{6+} content of natural gas (see Table 3.13)	% by mass	0.462 (as benzene)
C_{6+} release	g/s	0.0009
H2S content	mg/m^3	53
H_2S release	g/s	0.000014

a. Assumes a determined gas density of 0.7541 kg/Nm^3.

Odours are most likely to arise from the presence of sulphurous compounds contained in the produced natural gas. The most important sulphurous compound in terms of odour is hydrogen sulphide which has an odour threshold of 0.0005 ppm (0.76 $\mu g/m^3$)[20]. Other sulphur bearing compounds such as mercaptans have odour thresholds greater than hydrogen sulphide (e.g. ethyl mercaptan (0.001 ppm)). In the absence of understanding the synergistic odour effects of a mixture of sulphurous compounds, the assumption that all sulphur in the natural gas is present as hydrogen sulphide is considered a precautionary approach. The produced gas, while not yet analysed, is not expected to contain appreciable amounts of sulphur based on assessment of the gases in the area. In the main air quality assessment, a produced gas sulphur content of to 50 mgS/m^3 was assumed. This is the basis for the assumed fugitive release of hydrogen sulphide in Table 3.16. The above release rates and gas conditions have been used to assess the likely health and amenity impact of fugitive releases.

3.5.6 Other releases

The combustion of diesel fuel and natural gas will also give rise to other releases which are greenhouse gases or have implications for photochemical ozone creation. It is important that these are also considered. In addition to the pollutants above the inventories of nitrous oxide (N_2O) and methane (CH_4) have been considered.

For nitrous oxide emission factor of 2.1gN_2O/GJ and 0.5 gN_20/GJ (heat input) for diesel and natural gas combustion respectively[21] have been employed. It is assumed that, when considered as a greenhouse gas, all volatile organic compounds are present as methane.

3.6 Modelling scenarios

ADMS 5.2 has been employed to estimate process contributions to ambient pollutant concentrations based on the general conditions specified above. For the initial assessment the model has been run using meteorological data for each of five years (2014 to 2018).

The plant above have been considered to operate as specified over the period of the project. The project programme is summarised in Table 3.17 and indicates the duration for each phase of the operation. It should be noted that the well testing phases (2D(i) and 2D(ii)) are considered together, as phase 2D, for the purposes of the assessment. Plant usage and the worst case releases, with the exception of HDVs, are identical for both phases.

Table 3.18 provides more detail on expected equipment usage during each phase of the project on a day to day basis.

Table H.2 summarises the expected HDV movements during each phase of the project.

Table 3.17 Project programme

Phase of project		Equipment used	Duration weeks
1	Access and well site construction programme		
1A	Well site construction	Monday to Friday 07:00 – 19:00 Saturday 0900 to 1300	10
2	Drilling, appraisal and testing programme		
2A	Drilling – mobilisation and demobilisation	Monday to Friday 07:00 – 19:00 Saturday 0900 to 1300	3
2B	Drilling	24 hours/day, 7days/week	15
2C	Appraisal - mobilisation and demobilisation	Monday to Friday 07:00 – 19:00 Saturday 0900 to 1300	3
2D(i)	Appraisal – Initial well testing	24 hours/day, 7days/week	10
2D(ii)	Appraisal – Extended well testing	24 hours/day, 7days/week	16
2E	Sidetrack drilling	24 hours/day, 7days/week	15
2F	Maintenance workover	24 hours/day, 7days/week	4
3	Well plugging, abandonment and decommissioning programme		
3A	Plugging and abandonment	24 hours/day, 7days/week	3
3B	Removal of surface equipment	Monday to Friday 07:00 – 19:00 Saturday 0900 to 1300	2
4	Site restoration or retention programme		
4A	Site restoration	Monday to Friday 07:00 – 19:00 Saturday 0900 to 1300	5

For the purposes of this assessment it is assumed that the once commenced the programme will run continuously for a maximum period of up to 86 weeks. In practice there are likely to be breaks between and within phases which will expand the total duration of the project to a maximum of three calendar years. The assumed schedule therefore adopts a precautionary approach and will provide a worst case air quality impact. The modelling has been undertaken in accordance with this schedule and the specified working hours, although currently there is no start date.

It may be noted that long term air quality benchmarks are expressed as a mean over a calendar year while the project operations potentially span up to three consecutive calendar years. Different phases of the project will give rise to varying levels of pollutant releases. In order to ensure that the worst case combination of operational releases and meteorological conditions will be assessed over a calendar year, the pollutant releases for each phase of the project have been assessed based on the equipment usage schedule in Table 3.17 in order to determine worst case scheduling.

Table 3.19 identifies the phases which give rise to the greatest pollutant releases.

Table 3.18 Equipment usage

Phase of Development		Hours of Operation	Equipment	Hours
1	Access and well site construction			
1A	Access and well site construction	Lighting and welfare	a(4),b(1)	24 hours per day
		Construction vehicles	c,d,e,f (2),g,h	12 hours per working day and 4 hours on Saturdays
		HDV	-	12 hours per working day and 4 hours on Saturdays
		Surface conductor rig	i	12 hours per working day and 4 hours on Saturdays
2	Drilling, appraisal and testing programme			
2A	Drilling (mobilisation and demobilisation)	Lighting and welfare	a(4),b(1)	24 hours per day
		HDV	-	12 hours per working day and 4 hours on Saturdays
2B	Drilling	Lighting and welfare	a(4),b(1)	24 hours per day
		Drilling rig	k	24 hours per day
		Camp generator	j	24 hours per day
		HDV	-	12 hours per working day and 4 hours on Saturdays
2C	Appraisal (mobilisation and demobilisation)	Lighting and welfare	a(4),b(1)	24 hours per day
		HDV	-	12 hours per working day and 4 hours on Saturdays
2D	Appraisal comprising: i. Initial flow test; and ii. Extended well test	Lighting and welfare	a(4),b(1)	24 hours per day
		Workover rig	l	24 hours per day
		Camp generator	j	24 hours per day
		Flare	n	24 hours per day
		Steam generator	m	24 hours per day
		HDV	-	12 hours per working day and 4 hours on Saturdays
2E	Sidetrack drilling	Lighting and welfare	a(4),b(1)	24 hours per day
		HDV	-	12 hours per working day and 4 hours on Saturdays
		Drilling rig	k	24 hours per day
		Camp generator	j	24 hours per day

Table 3.18 continued

Phase of Development		Hours of Operation	Equipment	Hours
2F	Maintenance workover	Lighting and welfare	a(4),b(1)	24 hours per day
		HDV	-	12 hours per working day and 4 hours on Saturdays
		Workover rig	l	24 hours per day
		Camp generator	j	24 hours per day
3	Well plugging, abandonment and decommissioning programme			
3A	Plugging and abandonment	Lighting and welfare	a(4),b(1)	24 hours per day
		HDV	-	12 hours per working day and 4 hours on Saturdays
		Workover rig	l	24 hours per day
		Camp generator	j	24 hours per day
3B	Removal of surface equipment	Lighting and welfare	a(4),b(1)	24 hours per day
		HDV	-	12 hours per working day and 4 hours on Saturdays
4	Site restoration or retention programme			
4A	Site restoration	Lighting and welfare	a(4),b(1)	24 hours per day
		Construction vehicles	c,d,e,f (2),g,h	12 hours per working day and 4 hours on Saturdays
		HDV	-	12 hours per working day and 4 hours on Saturdays

Table 3.19 Pollutant releases over the project

Phase	Proportion of total project pollutant release (%)				
	Nitrogen dioxide	Volatile organic compounds	Carbon monoxide	Sulphur dioxide	Particulate matter
1A	1.6	3.3	4.3	0.8	3.4
2A	0.1	0.2	0.1	0.0	0.2
2B	42.4	36.3	28.5	10.9	38.7
2C	0.1	0.2	0.1	0.0	0.2
2Di.&ii	10.6	18.3	33.0	76.0	14.5
2E	42.4	36.3	28.5	10.9	38.7
2F	1.3	2.5	2.2	0.6	1.7
3A	0.9	1.8	1.6	0.4	1.3
3B	0.1	0.1	0.1	0.0	0.1
4A	0.5	1.1	1.5	0.2	1.2

It is evident that some phases are more important in terms of pollutant release than others. In particular the drilling phases (2B and 2E) and the appraisal phase (2Di.&ii) account for around 90% of pollutant releases. The worst case long term air quality impact would therefore arise when these phases occur within the same calendar year. The worst case long-term assessment was therefore based on a programme schedule where Phase 2B commenced at the beginning of the year:

Phase 2B weeks 1 to 15
Phase 2C weeks 16 to 18
Phase 2Di.& ii weeks 19 to 44

Phase 2E weeks 45 to 52

The equipment activity associated with the worst case calendar year scenario is summarised in Table 3.20.

Table 3.20 Equipment activity in the calendar year assessed

Plant	Phase			
	Days of operation during the 12 month period considered			
	2B	2C	2Di.&ii	2E
Lighting	1-365			
Welfare unit	1-365			
Heavy duty vehicles	1-365			
Workover rig	-	-	127-308	-
Camp generator	1-105		127-308	309-365
Rig engine	1-105	-	-	309-365
Mud pump generator 1	1-105	-	-	309-365
Mud pump generator 2	1-105	-	-	309-365
Rig generator	1-105	-	-	309-365
Steam generator	-	-	127-308	-
Flare	-	-	127-308	-

It is considered that this schedule will provide a worst case long term assessment for all pollutants.

For short term impacts it should be recognised that the project phases could occur at any time during the calendar year. In order to ensure that the worst combination of releases and meteorological conditions are considered for short-term impact, the assessment considers year-round operation for the phase which gives rise to the greatest process contribution for each pollutant:

Nitrogen oxides	Phase 2B	Carbon monoxide	Phase 2B
Volatile organic compounds	Phase 2B	Sulphur dioxide	Phase 2Di.&ii
Particulate matter	Phase 2B		

It is considered that this form of assessment will provide a worst case short-term assessment for all pollutants. For both long and short-term assessments the schedule considered is an unlikely worst case and in practice somewhat lower releases and corresponding process contributions would be expected.

In addition, sensitivity analyses have been undertaken to look at the impact on air quality of model selection. The US EPA's AERMOD modelling system is a widely used model for determining the dispersion of releases to air and their subsequent ambient impact and is accepted by the Environment Agency and UK Local Authorities for regulatory purposes. To determine the influence of the model selection, part of the assessment was repeated using the AERMOD model.

4 MODELLING RESULTS

ADMS 5.2 has been run for the operating scenarios described in Section 3.6. The results of the modelling are discussed below. In this section results are presented in tabular form, while in Annex A contour plots are provided which illustrate the estimated process contribution to ambient pollutant concentrations over the entire assessment area.

The initial part of this assessment is used to determine the air quality impact at the location of maximum concentration in order to identify those pollutants which are clearly insignificant in terms of air quality impact and those which may require further assessment. The second part of the assessment then considers in detail the impact of process contributions of selected pollutants at sensitive locations to determine their significance in the context of applicable air quality standards and critical levels and loads.

4.1 Impact of process releases

Figures A.1 and A.2 illustrate the dispersion of nitrogen dioxide on short term and long-term bases respectively. The dispersion patterns are reasonably typical of all pollutants considered. It may be seen that the locations of both the short term and long-term maxima occur within the Arreton 3 well site boundary towards the north east in the direction of the prevailing wind. Substantial process contributions are present at the location of maximum impact, although these decrease rapidly with distance. Process contributions drop to a third of the maximum within 150 m.

Table 4.1 details the estimated maximum process contributions (PC) and corresponding predicted environmental concentrations (PEC) in the context of the applicable environmental standards.

Table 4.1 Maximum process contributions and predicted environmental concentrations

Pollutant	Averaging basis	Year	Process contribution		Background	Predicted environmental concentration	
			µg/m^3	% std	µg/m^3	µg/m^3	% std
Carbon monoxide	8 hours	2015	490	4.9	1451	1941	19.4
Nitrogen dioxide	1 hour	2015	916	458	19.4	936	468
	annual	2015	304	760	9.7	314	785
Sulphur dioxide	15 mins	2017	1.8	0.7	3.38	5.1	1.9
	1 hour	2017	1.5	0.4	2.52	4.0	1.1
	24 hours	2014	1.1	0.9	1.49	2.6	2.1
PM_{10}	24 hours	2015	39.2	78.4	16.47	55.7	111
	annual	2015	11.1	27.7	13.96	25.0	62.6
$PM_{2.5}$	annual	2015	11.1	44.3	8.7	19.8	79.1
Benzene	annual	2015	11.9	238	0.41	12.3	246

Table 4.1 continued

Pollutant	Averaging basis	Year	Process contribution		Background	Predicted environmental concentration	
			µg/m^3	% std	µg/m^3	µg/m^3	% std
Carbon monoxide	1 hour	2018	543	1.8	2075	2618	8.7
Benzene	1 hour	2018	70.3	36.0	0.82	71.1	36.4
Nitrogen monoxide	1 hour	2015	1722	39.1	4.04	1726	39.2
	annual	2015	284	91.6	2.02	286	92.3

Maximum process contributions of carbon monoxide and sulphur dioxide are less than 10% of the applicable short-term environmental standards and are therefore considered to be insignificant.

Process contributions of nitrogen dioxide, PM_{10}, $PM_{2.5}$, volatile organic compounds (as benzene) and nitrogen monoxide at the location of maximum impact cannot be screened out based on Environment Agency assessment criteria and require further consideration.

At the location of maximum process contribution, the long term and short-term process contributions of nitrogen dioxide, the long-term process contribution of benzene and short-term process contribution of PM_{10} correspond to predicted environmental concentrations in excess of the applicable environmental standards. It should be considered that these concentrations are the maxima determined over the assessment area for the five years' meteorological conditions and with the worst case operational scheduling. Process contributions at other locations of interest and at other times and with alternative scheduling will be lower and often considerably lower. All maximum concentrations occur within the well site boundary with slightly lower concentrations extending on to open farmland. Air quality standards with respect to human health are not considered to be applicable within the site boundary and beyond in the areas most affected by site process contributions. It is not considered that frequent human exposure, over the periods of the standards is likely in these areas (see section 2.3.1) due to the absence of any residential locations.

The air quality impacts of these pollutants are considered in more detail in the following sections at sensitive locations where air quality standards would be expected to apply. These locations include the nearest residential properties and the neighbouring footpaths and bridleways. Nitrogen dioxide, nitrogen oxides and sulphur dioxide are also considered at nature conservation sites where critical levels and loads are applicable.

4.2 Impact of process releases at locations of human exposure

In order to determine the impact of well site releases at locations of frequent human exposure discrete receptors were located at the residential locations in the vicinity of the Arreton 3 well site (Table 3.1 and Figure 3.1) and along nearby footpaths and in particular that (footpath No. 26 and bridleway No. 29) running close to the southern boundary of the well (see Figure 3.1 and Table G.1). These are considered to be the only locations in the vicinity of the well site to which the public normally have access and where human exposure for some or all of the air quality standard averaging periods is likely. Tables 4.2 and 4.3 summarise the maximum process contributions and predicted environmental concentrations at the residential and footpath/bridleway groups of receptors respectively.

At the residential locations (Table 4.2) process contributions of the following substances are equivalent to less than 1% and/or 10% of the applicable long term and short-term environmental standards respectively:

Carbon monoxide
Sulphur dioxide
PM_{10}
$PM_{2.5}$

In addition, process contributions of the following substances are considered insignificant as their long term predicted environmental concentration is less than 70% of the long-term standard and their short-term process contribution is less than 20% of the short-term environmental standard less the background concentration:

Volatile organic compounds (assessed as benzene)
Nitrogen monoxide

Long term predicted environmental concentrations of nitrogen dioxide at the residential locations, where long term exposure might be expected, are less than 70% of the long-term ambient air directive limit. The corresponding short-term process contribution exceeds the Environment Agency's screening criteria, although the predicted environmental concentration for both long term and short-term impacts is just a third of the applicable ambient air directive limit. Bearing in mind the precautionary assumptions made in the assessment of short term impacts it is considered unlikely that process contributions of nitrogen dioxide over the duration of the project would pose any significant threat to attainment of short-term ambient air directive limits at the nearest residential locations.

Table 4.2 Maximum process contributions and predicted environmental concentrations at residential locations

Pollutant	Averaging basis	Process contribution		Background	Predicted environmental concentration	
		µg/m^3	% std	µg/m^3	µg/m^3	% std
Carbon monoxide	8 hours	35.8	0.4	1451	1487	14.9
Nitrogen dioxide	1 hour	55.4	27.7	19.4	74.8	37.4
	annual	3.8	9.4	9.7	13.5	33.7
Sulphur dioxide	15 mins	0.1	0.04	3.38	3.5	1.3
	1 hour	0.1	0.03	2.52	2.6	0.7
	24 hours	0.1	0.05	1.49	1.5	1.2
PM_{10}	24 hours	0.5	1.1	16.47	17.0	34.0
	annual	0.1	0.4	13.96	14.1	35.3
$PM_{2.5}$	annual	0.1	0.6	8.7	8.8	35.4
Benzene	annual	0.2	3.7	0.41	0.6	11.9
Carbon monoxide	1 hour	56.7	0.2	2075	2132	7.1
Benzene	1 hour	7.0	3.6	0.82	7.8	4.0
Nitrogen monoxide	1 hour	138	3.1	4.04	142	3.2
	annual	3.5	1.1	2.02	5.5	1.8

Table G.2 summarises the maximum process contribution of nitrogen dioxide at each residential location.

At the neighbouring footpaths and bridleways, it would be expected that only short-term environmental standards would apply and as such Table 4.3 is confined to consideration of short-term process contributions only. The process contributions of the following substances are equivalent to less than 10% of the applicable short-term environmental standard and are therefore considered insignificant:

Carbon monoxide
Sulphur dioxide

In addition, process contributions of the following substances are considered insignificant as their short-term process contribution is less than 20% of the short-term environmental standard less the background concentration:

Volatile organic compounds (assessed as benzene)
Nitrogen monoxide

Maximum daily average concentrations of PM_{10} exceed screening criteria, although the corresponding predicted environmental concentration is less than 60% of the ambient air directive limit and as such is not considered to pose any substantial threat to continued compliance with the standard.

Table 4.3 Maximum short-term process contributions and predicted environmental concentrations at nearby footpaths and bridleways

Pollutant	Averaging basis	Process contribution		Background	Predicted environmental concentration	
		µg/m³	% std	µg/m³	µg/m³	% std
Carbon monoxide	8 hours	217.2	2.2	1451	1668	16.7
Nitrogen dioxide	1 hour	348.2	174	19.4	368	184
Sulphur dioxide	15 mins	1.0	0.4	3.38	4.4	1.7
	1 hour	1.0	0.3	2.52	3.5	1.0
	24 hours	0.8	0.6	1.49	2.3	1.8
PM_{10}	24 hours	12.4	24.9	16.47	28.9	57.8
Carbon monoxide	1 hour	288.7	1.0	2075	2364	7.9
Benzene	1 hour	37.4	19.2	0.82	38.2	19.6
Nitrogen monoxide	1 hour	834.2	19.0	4.04	838	19.1

The short-term process contribution and corresponding predicted environmental concentration for nitrogen dioxide exceeds the ambient air directive limit. Bearing In mind the conservative approach to the assessment, in particular the worst case assessment scenario, process contributions are likely in practice to be lower than those predicted. Furthermore, if short term nitrogen monoxide to nitrogen dioxide conversion rates are considered, the Janssen analysis (see Appendix C) suggests rates significantly less than those assumed in the assessment. As shown in Table G.2, at the conversion rates suggested by the Janssen relationship maximum process contributions and predicted environmental concentrations equivalent to around 54% and 64% respectively of the ambient air directive limit would be expected at the most affected footpath/bridleways section. It is therefore considered that, in practice, even under worst case conditions, process contributions of nitrogen dioxide on the neighbouring footpath/bridleways would be unlikely to compromise attainment of the short-term ambient air directive limit.

It should also be noted that the maximum impact for process contributions of all substances is restricted to relatively short sections of the footpaths and bridleways closest to the well site (see Figure A.1) and that operation at conditions resulting in the maximum impact is only likely over a relatively short period.

It is concluded that process pollutant contributions at the nearest locations of frequent human exposure, where air quality standards might be expected to apply, are largely insignificant with respect to air quality and unlikely to pose any significant threat to continued attainment of air quality standards.

Based on Environmental Protection UK (EP UK) and the Institute of Air Quality Management (IAQM) classification (section 2.5.4) the maximum impact significance of releases of nitrogen dioxide at residential locations is considered to be ‘slight’. For PM_{10}, $PM_{2.5}$, volatile organic compounds (as benzene) and nitrogen monoxide the impact significance is classed as ‘negligible’ in all cases. Table 4.4 summarises the assessment of significance.

Table 4.4 Assessment of impact significance at residential locations based on IAQM classification

Pollutant	Maximum process contribution	Maximum predicted environmental concentration	IAQM classification (see Table 2.7)
	% environmental standard[a]		
Nitrogen dioxide	9.4	34	Slight
PM_{10}	0.4	35	Negligible
$PM_{2.5}$	0.6	35	Negligible
Benzene	3.7	12	Negligible
Nitrogen monoxide	1.1	2	Negligible

a. Process contributions and predicted environmental concentrations are expressed as a percentage of the applicable long-term environmental standard (see Tables 4.2).

4.3 Impact of process releases at sensitive nature conservation sites

A number of statutory designated sites requiring assessment, based on Environment Agency criteria (see section 2.5.3), were identified in the vicinity of the Arreton 3 well site. The main pollutants of interest at the nature conservation sites are nitrogen oxides, nitrogen dioxide and sulphur dioxide. For the purposes of the assessment of process contributions at these sites, a discrete receptor was placed on the site boundary closest to the Arreton 3 well site as described in Table 3.2.

The critical loads and levels adopted for these sites for use in this assessment have been obtained from the UK Air Pollution Information System (APIS) and are summarised in Table 4.5

In the selection of critical loads, the minimum for the most sensitive habitat within each site has been selected. Where the nitrogen critical load is provided as a range the minimum in that range has been adopted for the assessment. This represents a worse case precautionary approach to the assessment and will most likely result in an overestimate of impact. A general broad leaved woodland habitat was assumed for all ancient woodland sites.

The background concentrations at each site, as obtained from APIS, are summarised in Table 4.6. These represent the maximum background concentration across the entire site and as such there will be parts of these sites which experience somewhat lower background concentrations. This represents a precautionary approach.

For the purposes of this assessment the four ancient woodlands identified a being within 2 km of the Arreton 3 well site (see Table 3.2) are considered as a group as are the Solent and Dorset Coast pSPA and Solent Marine SAC (receptor 75) which are overlapping designations. The assessment uses the maximum process contributions over the sites and the minimum critical levels and loads to present a worst case.

Table 4.5 Site relevant critical loads and levels

Site		25-28	29
		Ancient woodlands	Arreton Down SSSI
Critical levels for nitrogen oxides and sulphur dioxide (see Table 2.2)			
Annual mean NO_x	$\mu gNO_2/m^3$	30	
Daily mean NO_x	$\mu gNO_2/m^3$	75	
Annual mean SO_2	$\mu gSO_2/m^3$	10	
Critical load for nitrogen deposition			
Most sensitive habitat		Broadleaved deciduous woodland	Sub-Atlantic semi dry calcerous grassland
N deposition CL	kgN/ha/y	10-20	15-25
Critical loads for acid deposition			
Most sensitive habitat		Broadleaved/coniferous unmanaged woodland	Calcerous grassland
Minimum CLminN	keq	0.142	0.856
Minimum CLmaxS	keq	1.242	4.000
Minimum CLmaxN	keq	1.384	4.856

Table 4.5 continued

Site		74	75	76	77	78
		Briddlesford Copses SAC	Solent Marine SAC	Solent & Southampton Water SPA	South Wight[b] Maritime SAC	Isle of Wight Downs SAC
Critical levels for nitrogen oxides and sulphur dioxide (see Table 2.2)						
Annual mean NO_x	$\mu gNO_2/m^3$	30				
Daily mean NO_x	$\mu gNO_2/m^3$	75				
Annual mean SO_2	$\mu gSO_2/m^3$	10				
Critical load for nitrogen deposition						
Most sensitive habitat		Broadleaved deciduous woodland	Coastal stable dune grasslands	Suppra littoral sediment	Not sensitive	Dwarf shrub heath
N deposition CL	kgN/ha/y	10-20	8-15	8-10	-	10-20
Critical loads for acid deposition						
Most sensitive habitat		Unmanaged broadleaved/ coniferous woodland	Acid grassland	Suppra littoral sediment	Not sensitive	Dwarf shrub heath
Minimum CLminN	keq	0.357	0.223	0.223	-	0.892
Minimum CLmaxS	keq	2.522	0.260	0.260	-	0.490
Minimum CLmaxN	keq	2.879	0.626	0.626	-	1.382

a. Critical levels and critical loads are the minimum specified for most sensitive habitat within the site. For all ancient woodlands a broadleaved woodland habitat is considered.
b. The South Wight Maritime SAC is not sensitive to nitrogen or acid deposition.

Table 4.6 Site relevant background concentrations

Site		25-28	29
		Ancient woodlands	Arreton Down SSSI
Nitrogen oxides annual mean	$\mu gNO_2/m^3$	12.05	12.79
Sulphur dioxide annual mean	$\mu gSO_2/m^3$	0.989	0.95
Nitrogen deposition	kgN/ha/y	24.22	15.5
Nitrogen acid deposition	keq/ha y	1.73	1.1
Sulphur acid deposition	keq/ha y	0.35	0.3

Table 4.6 continued

Site		74	75	76	77	78
		Briddlesford Copses SAC	Solent Marine SAC	Solent & Southampton Water SPA	South Wight Maritime SAC	Isle of Wight Downs SAC
Nitrogen oxides annual mean	$\mu gNO_2/m^3$	16.05	63.42	63.42	15.06	11.83
Sulphur dioxide annual mean	$\mu gSO_2/m^3$	1.45	5.36	5.36	1.50	1.50
Nitrogen deposition	kgN/ha/y	24.2	19.0	19.0	10.2	11.6
Nitrogen acid deposition	keq/ha y	1.7	1.4	1.4	0.7	0.8
Sulphur acid deposition	keq/ha y	0.4	0.5	0.5	0.2	0.2

a. Background concentrations are the maximum across the entire site.

The maximum process contributions to concentrations of nitrogen oxides and sulphur dioxide at the conservation sites are summarised in Table 4.7.

Table 4.7 Maximum process contributions of nitrogen oxides and sulphur dioxide at the conservation sites

Site		25-28	29
		Ancient woodlands	Arreton Down SSSI
Nitrogen oxides[a]			
Maximum annual mean PC	$\mu gNO_2/m^3$	4.48	1.50
	% CL	15.0	5.0
Background concentration	$\mu gNO_2/m^3$	12.05	12.79
Maximum annual mean PEC	$\mu gNO_2/m^3$	16.53	14.29
	% CL	55	48
Maximum daily mean PC	$\mu gNO_2/m^3$	47.6	23.7
	% CL	63	32
Back ground concentration	$\mu gNO_2/m^3$	24.1	25.6
Maximum daily mean PEC	$\mu gNO_2/m^3$	71.7	49.3
	% CL	96	66
Sulphur dioxide			
Maximum annual mean PC	$\mu gSO_2/m^3$	0.004	0.002
	% CL	0.04	0.02
Background concentration	$\mu gSO_2/m^3$	0.98	0.95
Maximum annual mean PEC	$\mu gSO_2/m^3$	0.98	0.95
	% CL	10	10

Table 4.7 continued

Site		74 Briddlesford Copses SAC	75 Solent Marine SAC	76 Solent & Southampton Water SPA	77 South Wight Maritime SAC	78 Isle of Wight Downs SAC
Nitrogen oxides[a]						
Maximum annual mean PC	$\mu gNO_2/m^3$	0.26	0.11	0.08	0.26	0.06
	% CL	0.9	0.4	0.3	0.9	0.2
Background concentration	$\mu gNO_2/m^3$	16.05	63.42	63.42	15.06	11.83
Maximum annual mean PEC	$\mu gNO_2/m^3$	16.31	63.53	63.50	15.32	11.89
	% CL	54	212	212	51	40
Maximum daily mean PC	$\mu gNO_2/m^3$	5.8	4.0	3.2	5.4	2.0
	% CL	7.8	5.4	4.3	7.2	2.6
Back ground concentration	$\mu gNO_2/m^3$	32.10	126.8	126.8	30.12	23.66
Maximum daily mean PEC	$\mu gNO_2/m^3$	37.90	130.8	130.0	35.52	25.66
	% CL	51	175	173	47	34
Sulphur dioxide						
Maximum annual mean PC	$\mu gSO_2/m^3$	0.00027	0.00010	0.000007	0.00024	0.00007
	% CL	<0.01	<0.01	<0.01	<0.01	<0.01
Background concentration	$\mu gSO_2/m^3$	1.45	5.36	5.36	1.50	1.50
Maximum annual mean PEC	$\mu gSO_2/m^3$	1.45	5.36	5.36	1.50	1.50
	% CL	15	54	54	15	15

a. Total nitrogen oxides are expressed as NO_2.

The maximum process contributions of sulphur dioxide are equivalent to less than 1% of the applicable critical level in all cases and as such may be considered insignificant.

At all sites, with the exception of the Arreton Down SSSI, the long term and short-term process contributions of nitrogen oxides are less than 100% of the critical levels and as such are considered insignificant.

At the Arreton Down SSSI, the short-term process contribution of nitrogen oxides exceeds 10% of the critical level and as such further consideration in terms of ecological impact is required (see section 2.5.3).

The process contributions considered for the short-term assessment present a worst case. Taking into account the very conservative assumptions made within the assessment with regard to releases of nitrogen oxides it is considered that in practice process contributions at the nearest nature conservation sites would be substantially less than predicted herein.

The determination of nitrogen deposition at the selected nature conservation sites is summarised in Table 4.8. The determination was undertaken in accordance with the guidance in AQTAG 06[22] and considered dry deposition only. Guidance indicates that wet deposition over relatively short distances is unlikely to be significant.

Table 4.8 Nitrogen deposition at the conservation sites

Site		25-28	29
		Ancient woodlands	Arreton Down SSSI
Maximum process N deposition	$\mu gNO_2/m^2/s$[a]	0.0094	0.0016
	kgN/ha/y	0.903	0.151
	% CL[b]	9.0	1.0
Background concentration	kN/ha y	24.22	15.50
Maximum annual mean PEC	kN/ha y	25.12	15.65
	% CL[b]	251	104

Table 4.8 continued

Site		74	75	76	78
		Briddlesford Copses SAC	Solent Marine SAC	Solent & Southampton Water SPA	Isle of Wight Downs SAC
Maximum process N deposition	$\mu gNO_2/m^2/s$[a]	0.00054	0.00023	0.00016	0.00012
	kgN/ha/y	0.052	0.022	0.015	0.012
	% CL[b]	0.5	0.3	0.2	0.1
Background concentration	kN/ha y	24.2	19.0	19.0	11.6
Maximum annual mean PEC	kN/ha y	24.3	19.0	19.0	11.6
	% CL[b]	243	238	238	116

a. Determination of deposition is based on the deposition velocity for forest terrain for ancient woodlands and grassland terrain for the Arreton Down SSSI[22].
b. The critical load selected is the minimum of the range specified for the most sensitive habitat over the entire site.

Process contributions to nutrient nitrogen deposition are below 100% of the applicable critical load at the ancient woodlands and below 1% of the applicable critical loads at all other sites and as such are considered insignificant. While there is exceedance of the critical loads at all of these sites, this is due to an existing large background deposition and it is not considered that the process contributions have any significant influence on critical load compliance.

The South Wight Maritime SAC is not sensitive to nitrogen deposition.

The determination of the process contribution to acid deposition at these sites is summarised in Table 4.9.

The process contributions to acid deposition are below 100% of the applicable critical load at the ancient woodlands and below 1% of the applicable critical loads at all other sites and as such are considered insignificant. While there is exceedance of the critical loads at most of these sites, this is due to an existing large background deposition and it is not considered that the process contributions have any significant influence on critical load compliance.

Table 4.9 Acid deposition at conservation sites

Site		25-28 Ancient woodlands	29 Arreton Down SSSI
Nitrogen acid deposition	$\mu gNO_2/m^2/s$[a]	0.0094	0.0016
	kgN/ha/y	0.903	0.151
	keq/ha y	0.0645	0.0108
Sulphur acid deposition	$\mu gSO_2/m^2/s$[a]	0.0038	0.0017
	kgS/ha/y	0.000091	0.000020
	keq/ha y	0.00090	0.00020
Total process acid deposition	keq/ha/y	0.0654	0.0110
	% CL[b,c]	4.7	0.2
Total background acid deposition	keq/ha/y	2.08	1.40
Maximum annual mean PEC	keq/ha y	2.15	1.41
	% CL[b,c]	155	29

Table 4.9 continued

Site		74 Briddlesford Copses SAC	75 Solent Marine SAC	76 Solent & Southampton Water SPA	78 Isle of Wight Downs SAC
Nitrogen acid deposition	$\mu gNO_2/m^2/s$[a]	0.00054	0.00023	0.00016	0.00012
	kgN/ha/y	0.052	0.022	0.015	0.012
	keq/ha y	0.0037	0.0016	0.0011	0.0009
Sulphur acid deposition	$\mu gSO_2/m^2/s$[a]	0.000007	0.000003	0.000002	0.000002
	kgS/ha/y	0.00102	0.00039	0.00026	0.00026
	keq/ha y	0.000064	0.000025	0.000016	0.000016
Total process acid deposition	keq/ha/y	0.0038	0.0016	0.0011	0.0009
	% CL[b,c]	0.1	0.3	0.2	<0.1
Total background acid deposition	keq/ha/y	2.1	1.9	1.9	1.0
Maximum annual mean PEC	keq/ha y	2.1	1.9	1.9	1.0
	% CL[b,c]	73	304	304	41

a. Determination of deposition is based on the deposition velocity for forest terrain for all sites with the exception of the Arreton Down SSSI which is based on grassland terrain[22].
b. Calculations of process contribution and predicted environmental concentrations were used the APIS critical load tool.
c. The critical loads selected are the minimum specified for all habitats over the entire site, where applicable.

At the sites sensitive to nitrogen and acid deposition maximum process contributions are considered to be largely insignificant. While the maximum process contributions at the Arreton Down SSSI exceed screening criteria for nitrogen oxides, this is considered unlikely to pose any threat to or have any substantial influence on the attainment of critical levels in practice, although a further ecological opinion is required. A similar additional ecological assessment for the impact of nitrogen oxides at nearby SINCs will also be required (see Annex I).

4.4 Sensitivity analyses

In the assessment of the impact of process contributions the worst case results have been reported. For the assessment process contributions were modelled for each of 5 years' meteorological data using the ADMS modelling system. A sensitivity analysis was undertaken to determine the influence of meteorological conditions and model selection on the findings of the assessment and hence provide some measure of their robustness.

4.4.1 Meteorological conditions

Table 4.10 summarises the influence of meteorological conditions on maximum process contributions for the discrete receptor groups describing the neighbouring residential locations, local footpath, local bridleway and ecological conservation sites (see Annex G). The assessment is based on the project schedule described in section 3.6 which represents the worst case with respect to air quality impact.

Table 4.10 Influence of meteorological conditions on maximum process contribution

Pollutant	Averaging basis	Maximum process contribution (ratio of maximum to minimum year)		
		Residential	Footpath/ Bridleway	Conservation sites
Carbon monoxide	8 hour	1.5	1.2	1.3
Nitrogen dioxide	1 hour	1.4	1.2	1.4
	annual	2.0	1.9	2.2
Sulphur dioxide	15 min	1.2	1.1	1.1
	1 hour	1.1	1.1	1.1
	24 hour	1.5	12.4	1.5
PM_{10}	24 hour	2.0	2.1	2.5
	annual	1.8	1.9	2.1
$PM_{2.5}$	annual	1.8	1.9	2.1
Benzene	annual	1.8	1.9	2.1
Carbon monoxide	1 hour	1.3	1.2	1.2
Benzene	1 hour	1.3	1.2	1.2
Nitrogen oxide	1 hour	1.3	1.2	1.2
	annual	1.9	1.9	2.2

Annual variations in meteorological conditions on average show up to a twofold difference between maximum and minimum process contributions. This assessment is based on the maximum process contribution for all the years considered at each location and as such will be an over estimation for most years.

4.4.2 Model selection

The main assessment has been undertaken using the ADMS modelling system. The US EPA's AERMOD model is also widely used for regulatory purposes worldwide. To determine how the model used may have influenced the findings of the assessment, the AERMOD model was employed to predict process contributions to ambient concentrations of nitrogen dioxide over the important averaging bases at 2014 meteorological conditions. Table 4.11 illustrates the comparison between the ADMS and AERMOD model predictions averaged over receptor groups describing the neighbouring residential locations, local footpath, local bridleway and ecological conservation sites (see Annex G).

Table 4.11 Maximum process contributions (variation with model)

Pollutant	Averaging basis	Maximum process contribution (ratio of ADMS to AERMOD – 2014)		
		Residential	Footpath/ Bridleway	Conservation sites
Nitrogen dioxide	annual	1.4	2.1	3.7
	1 hour	1.1	1.0	1.1
	1 hour maximum	1.1	1.0	1.3
	24 hours	1.3	1.3	1.7

In general, the AERMOD and ADMS models provide predicted ambient process contributions which are in good agreement for all averaging bases at the human receptors considered. There are slight differences between the receptor groups although, bearing in mind the margin available in the assessment of air quality standard compliance and the maximum impact relative to critical loads at the ecological receptors, it is not considered that the differences exhibited due to model selection will have any substantial impact on the conclusions of this assessment. Overall the ADMS model provides somewhat higher predicted process contributions compared with AERMOD.

4.4.3 Project scheduling

The project is characterised by four main elements of operation (see Table 3.17), with the drilling appraisal and testing phases being of a much greater duration than all others. The drilling phases (2B and 2E), where several large diesel-fired generators are employed, are the most energy intensive and give rise to around 85% of all nitrogen oxides emitted during the project. These phases are each scheduled to be of 15 weeks duration, separated by a period of 29 weeks while well testing is undertaken. This does not account for any breaks between or within phases. Other phases of operations, while featuring the use of plant which emit nitrogen oxides, are not as energy intensive and release rates and subsequent air quality impact are substantially lower (see Table 3.10).

While it is necessary to consider pollutant releases during all phases of the operations within the assessment, of crucial importance is how the phases are scheduled within the calendar year being assessed and the duration of any non-operational breaks between or within phases. The assessment has considered a worst case scenario where Phase 2B and 2E are largely accommodated within a calendar year. This requires Phase 2B to commence at the beginning of the year and for there to be no non-operational breaks within the year. Any other start date or any non-operational time will result in part of the drilling phase shifting into the following calendar year resulting in a lower annual mean air quality impact than that assessed. In practice in might be expected that the drilling and testing phases would span two or maybe three calendar years resulting in a substantially lower air quality impact than that determined for the worst case.

Assuming that the project is conducted continuously in accordance with the proposed schedule the most beneficial scheduling in terms of air quality impact would be to have the two drilling phases undertaken in separate years with the appraisal phase straddling the two years. This equates to a project start of around the

end of February. With this scheduling it might be expected that calendar year releases of all pollutants would be around half of those considered in the assessment of the worst case, providing a proportionate reduction in annual mean process contributions. Scheduling has less impact on short term process contributions, although some reduction compared with the assessed worst case would be expected.

Project scheduling can have a substantial impact on the maximum process contributions at a given location, with a variation in long term process contributions of up to a factor of 2. In the assessment the greatest process contribution at each location for the schedule providing the worst case air quality impact has been reported. This is likely to be a substantial overestimate in practice.

4.4.4 Flare selection

As discussed in section 3.5, the type of flare used in the well testing phase of the project (phase 2Di.&ii) will be dependent on produced gas volumes. UKOG have indicated that either a shrouded ground flare with a disposal capacity of up to 2.2 MMscfd or a smaller enclosed flare with a capacity of 0.25 MMscfd will be employed with a maximum daily disposal of 10 tonnes.

This assessment has been undertaken assuming the use of the higher capacity shrouded flare operating continuously at a disposal rate of 0.5 MMscfd (equivalent to 10 tonnes/day). To determine the likely impact on the assessment outcome of using the smaller flare a further assessment was made at worst case conditions (see section 3.6). Table 4.12 summarises the differences in pollutant process contributions with flare selection for the operational arrangements providing the greatest process contribution at the residential locations.

It may be seen that the use of the larger flare, as assumed in the main assessment, provides the greater air quality impact at the residential locations. The conclusions of the main assessment therefore hold regardless of the flare type selected for use in the well testing plashes.

Table 4.12 Maximum process contributions at residential locations for the flaring options

Pollutant	Averaging basis	Maximum process contribution				Difference
		Enclose flare (0.25 MMscfd)		Shrouded flare (0.5 MMscfd)		
		µg/m^3	% standard	µg/m^3	% standard	%
Carbon monoxide	8 hours	35.8	0.4	35.8	0.4	0
Nitrogen dioxide	1 hour	55.4	27.7	55.4	27.7	0
	annual	2.8	6.9	3.8	9.4	-27
Sulphur dioxide	15 mins	0.1	<0.1	0.1	<0.1	-20
	1 hour	0.1	<0.1	0.1	<0.1	-22
	24 hours	0.0	<0.1	0.1	<0.1	-29
PM_{10}	24 hours	0.3	0.7	0.5	1.1	-37
	annual	0.1	0.3	0.1	0.4	-27

Table 4.12 continued

Pollutant	Averaging basis	Maximum process contribution				Difference
		Enclose flare (0.25 MMscfd)		Shrouded flare (0.5 MMscfd)		
		µg/m^3	% standard	µg/m^3	% standard	%
$PM_{2.5}$	annual	0.1	0.4	0.1	0.6	-27

Benzene	annual	0.1	2.7	0.2	3.7	-28
Carbon monoxide	1 hour	56.7	0.2	56.7	0.2	0
Benzene	1 hour	7.0	3.6	7.0	3.6	0
Nitrogen monoxide	1 hour	138	3.1	138	3.1	0
	annual	2.6	0.8	3.5	1.1	-27

4.5 Fugitive releases

Fugitive releases of natural gas may have implications for both human health and amenity with respect to odours. Fugitive releases were assessed separately to the other releases from the well sites. The fugitive emission is assumed to be a continuous constant release.

Table 4.13 summarises the air quality impact at local residential locations in terms of human health for methane and volatile organic compounds (as benzene) releases and in terms of risk to amenity for the odours resulting from hydrogen sulphide releases.

Table 4.13 Maximum process contributions resulting from fugitive releases

Averaging basis		Annual mean	Hourly mean
Maximum process contribution of benzene	µg/m^3	0.004	0.65
	% standard	0.1	0.3
Maximum process contribution of methane	µg/m^3	0.8	131
	% standard	<0.1	0.6
Averaging basis		98th percentile of hourly means	
Maximum process contribution of hydrogen sulphide	µg/m^3	0.0005	
	ou$_E$/m^{3a}	0.001	
	% benchmark^b	0.02	

a.The concentration of hydrogen sulphide is expressed as an odour concentration based on an odour threshold of 0.76 ug/m^3.
b. The Environment Agency odour benchmark adopted for the assessment is 3.0 ou$_E$/m^3 (98th percentile of hourly means) consistent with a 'moderately offensive odour'.

Maximum short-term process contributions of methane and benzene are less than 10% of the environmental standard and the corresponding long term predicted environmental concentration is less than 1% of the long-term environmental standard. Process contributions are therefore considered insignificant and unlikely to have any substantial influence on environmental standard attainment at the nearest residential locations.

It should be noted that there are other process contributions of benzene associated with the normal site operations as summarised in Tables 4.1 to 4.3. The addition of the process contribution from fugitive release to the maximum process contribution from these activities does not alter the overall conclusions of this assessment or the finding that all process contributions of benzene at sensitive locations are insignificant with respect to air quality.

The maximum process contribution at residential locations to odour from releases of hydrogen sulphide is estimated to be equivalent to 0.02% of the Environment Agency's benchmark for moderately offensive odours. It is therefore considered that fugitive releases from operations at the well site pose a negligible risk to loss of amenity due to odour.

4.6 Modelling uncertainty

The use of models to predict the dispersion of releases has associated uncertainties. The main uncertainties in this assessment result from:

- The operational load in practice is likely to be lower on occasions than that modelled in this assessment. The project is modelled based on full load operation of most engines, the steam generator and flare on a continuous 24 hour per day basis for the entire duration of the project phase, except where specifically limited by working hours or know maximum usage. This provides, what is considered to be, a significant over estimate of process releases in practice, particularly for the high energy intensive phases such as drilling (phases 2B and 2E) and testing (phase 2Di.&ii). In these phases it is expected that the duration, frequency and intensity of equipment operation will be substantially lower than that considered in the assessment. As such the process contributions and subsequent ambient impact for all pollutants are likely to be an overestimate of those in practice.

- The release rates upon which the assessment is based are consistent with the operation of engines and flare and construction vehicles at the regulation or benchmark limits. In addition, heavy duty vehicle idling emissions are considered to be conservative estimates. In practice it is likely that pollutant release rates will be somewhat lower, and in some cases substantially lower, than the levels assumed in this assessment. This will result in an overestimate of ambient impact.

- Conversion rates for nitrogen monoxide to nitrogen dioxide of 35% and 70% have been employed as recommended by the Environment Agency[1] for short and long-term air quality impacts respectively. These are generally considered to be quite conservative estimates. Conversion rates over the relatively short distances considered in this assessment are likely to be substantially lower than those assumed with estimates based on the Janssen equation[23], indicating a likely overestimate of the significance of process releases (see Annex C and Tables G.1 and G.2) of nitrogen dioxide and associated nitrogen and acid deposition at the nature conservation sites.

- In the assessment of particulate matter releases the environmental standards used are those for $PM_{2.5}$ and PM_{10}. A precautionary approach is adopted and it is assumed that when comparing the release with the corresponding standards, all particulate matter is present as PM_{10} or $PM_{2.5}$ as appropriate.

- Volatile organic compounds are assessed as benzene as required within guidance for situations where the composition of the release is not known. In practice it is expected that a large proportion of the volatile organic compounds release will be methane or other lower hydrocarbons. Experience[21] suggests the composition of the release closely mirrors the composition of the fuel. Methane and lower hydrocarbons have significantly higher environmental benchmarks compared with benzene (see Table 2.3) and as such the air quality impact on human health in practice will be substantially less than reported in this assessment.

- The meteorological conditions upon which the assessment was based vary from year to year and influence ambient impact. A sensitivity analysis has shown the differences expected due to changes in meteorological conditions for a five year period. This assessment is based on the year providing the maximum impact for each location and pollutant and as such is likely to be an overestimate for most meteorological years.

- Due to the phased nature of the project and the differences in pollutant releases for each phase, the ambient impact relative to standards, which are based on a calendar year, will be dependent on the commencement date of the project and any breaks between of within phases. The assessment has shown significant differences depending on the assumed starting date for the project. This assessment is based on an unlikely worst case project schedule which provides the maximum impact for each location and each pollutant and as such is likely to be an overestimate for most cases in practice, particularly for process contributions determined on a long term (annual) basis.

- The model used can influence predictions of ambient impact. In this case a sensitivity analysis of the two most widely used models for regulatory purposes indicated that the conclusions of the assessment were not dependent on the selection of model. The ADMS and AERMOD shown generally good agreement and it is not considered that model selection has any significant impact on assessment conclusions. Overall the ADMS model provided somewhat higher predicted process contributions than the AERMOD model.

- The necessary assumptions made regarding surface characteristics (section 3.4) can have either a negative or positive impact on modelling outcomes. A sensitivity analysis indicates that variations due to the assumed

surface characteristics are unlikely to be significant in terms of the conclusions of the assessment as the potential for any impact is mitigated by the selection of descriptive parameters considered representative of the assessment area.

There are inherent uncertainties associated with the use of air dispersion models to predict the ambient impact of releases. With this in mind the assessment herein has been undertaken using conservative assumptions which tend towards an over estimation of the ambient impact. It is considered that the assessment has taken a precautionary approach and the conclusions reached therefore incorporate a reasonable margin of comfort in spite of the inevitable uncertainty of such modelling studies.

4.7 Photochemical ozone creation potential

Some of the pollutants released have the potential to react to form ozone. Ground level ozone is a highly reactive pollutant with a potential to damage human health and vegetation. It is produced by the action of sunlight on volatile organic compounds and oxides of nitrogen. Environment Agency guidance[6], provides a standardised methodology for determination of the photochemical ozone creation potential (POCP) of a release. In the case of the proposed operations it is considered that releases of volatile organic compounds, nitrogen dioxide, sulphur dioxide and carbon monoxide have implications for ozone formation. The total release of each of these over the duration of the project is assessed in Table 4.14 on the basis of operating conditions in section 3.5.

Table 4.14 Calculation of POCP related releases

Pollutant		Release over project (t)				POCP	
		NO_2	CO	SO_2	Benzene		
POCP factor		2.8	2.7	4.8	21.8	t	% of total
1A	Well site construction	3.24	3.65	<0.01	0.54	31	2.3
2A	Drilling – mobilisation and demobilisation	0.17	0.12	<0.01	0.03	1	0.1
2B	Drilling	84.63	24.00	0.04	7.28	461	34.7
2C	Appraisal - mobilisation and demobilisation	0.17	0.12	<0.01	0.03	1	0.1
2Di.&ii	Appraisal – Initial and extended well testing	21.19	27.84	0.27	8.69	325	24.5
2E	Sidetrack drilling	84.63	24.00	0.04	7.28	461	34.7
2F	Maintenance workover	2.50	1.82	<0.01	0.41	21	1.6
3A	Plugging and abandonment	1.88	1.36	<0.01	0.30	16	1.2
3B	Removal of surface equipment	0.11	0.08	<0.01	0.02	1	0.1
4A	Site restoration	1.06	1.30	<0.01	0.18	10	0.8
	TOTAL	199.58	84.29	0.36	24.77	1328	100

The assumptions made in relation to releases are considered to represent the worst case for the proposed operations. The determination indicates a POCP for the project of 1328 (tonnes).

The initial and extended flow testing operations (Phase 2Di.&ii), where produced natural gas is being flared, and the exploratory borehole and sidetrack borehole drilling phases (Phases 2B and 2E) are the greatest contributors to POCP. These phases account for around 93% of the total project POCP.

4.8 Greenhouse gas releases and climate change

Some of the pollutants released are greenhouse gases and it is required that the impact on climate change be determined. In this case the assessment confines itself to the consideration of direct emissions to air from the project plant. There is no assessment of any indirect emission (i.e. heat or power imported to site for use in operations). Environment Agency guidance[24], provides a standardised methodology for determination of the impact on climate change of a release on the basis of the equivalent mass release of carbon dioxide. The global warming potential factors for methane and nitrous oxide use the values specified in the Intergovernmental Panel on Climate Change's 5th Assessment Report. For the purposes of this assessment methane is assumed to comprise both methane and non-methane volatile organic compounds.

In the case of the proposed plant it is considered that releases of carbon dioxide, methane and nitrous oxide have implications for climate change warming. The annual release of each of these is assessed in Table 4.15 on the basis of operating conditions in section 3.5 and represents the total release for the project duration.

Table 4.15 Calculation of greenhouse gas releases

Species		Release over project (t)			Impact	
		CO_2	N_2O	CH_4	(t CO_2 equivalent)	% of total
Global warming potential – IPPC AR5 (relative to CO_2, 100 years)		1	265	28		
1A	Well site construction	487	0.0137	0.54	506	2.1
2A	Drilling – mobilisation and demobilisation	16	0.0004	0.03	17	0.1
2B	Drilling	6274	0.1761	7.28	6524	27.0
2C	Appraisal - mobilisation and demobilisation	16	0.0004	0.03	17	0.1
2Di.&ii	Appraisal – Initial and extended well testing	9531	0.1731	8.69	9820	40.6
2E	Sidetrack drilling	6274	0.1761	7.28	6524	27.0
2F	Maintenance workover	333	0.0093	0.41	347	1.4
3A	Plugging and abandonment	250	0.0070	0.30	260	1.1
3B	Removal of surface equipment	10	0.0003	0.02	11	0.0
4A	Site restoration	143	0.0040	0.18	149	0.6
TOTAL		23333	0.56	24.8	24176	100

The initial and extended flow testing operations (Phase 2Di.&ii) and the exploratory borehole and sidetrack borehole drilling phases (Phases 2B and 2E) give rise to the greatest release of greenhouse gases within the project. These phases account for around 95% of the total greenhouse gas release over the project lifetime.

The Project lifetime release of greenhouse gases is determined to be equivalent to 24176 tCO_{2e}. This is considered a worst case assessment and is based on simplifying assumptions which tend towards an over estimation of plant operational duration and load and hence greenhouse gas emissions.

Assuming worst case scheduling, where 82% of the greenhouse gas release occurs in one calendar year, the maximum annual release (19824 tCO_{2e}) is equivalent to around 0.02% of the total annual greenhouse gas release from the Energy Supply industries in 2018 or around 0.004% of the mean annual UK total release within the third carbon budget for 2018-2022. It is considered that Project lifetime greenhouse gas releases are largely insignificant in relation to the UK's current inventory and future budgets.

4.9 Construction dust

It is likely that the construction activities associated with the proposed site will give rise to dust emissions, albeit temporary in nature and largely restricted the areas close to the construction site.

The potential for fugitive dust is most likely to arise from the movement of vehicles over the earth, the stripping of soil, excavations and the subsequent storage of excavated materials and transfer of materials to and from lorries. This may be exacerbated by spillages during transportation and handling and also by periods of dry weather and high wind speeds. This is considered in Annex E in accordance with the methodology described in the IAQM's guidance[25] on the assessment of dust from demolition and construction.

It is expected that with adequate mitigation measures in place the risk of dust impact from all operations will be 'negligible'.

4.10 Operations traffic

The development of the site, the subsequent operation and final site restoration will have the effect of increasing traffic flow in the area, which in turn will result in additional releases of certain pollutants to air. It is necessary to

understand the likely ambient impact of this increase in traffic flow. This is assessed in Annex F using methodology provided by the Highways Agency[26] and the IAQM[11].

Increases in road traffic brought about by the construction activities, subsequent site operations and final site restoration are assessed to have a neutral impact on air quality based on Highway's Agency guidance. The additional contributions to ambient pollutant concentrations from associated road traffic have no influence on the findings of the main air quality assessment for plant releases to air.

4.11 Cumulative impacts

This assessment has quantified the likely air quality impact of the development at the Arreton 3 well site in relation to releases to atmosphere and determined significance and compliance with environmental benchmarks based on the process contribution from the proposed site and the existing background pollutant concentrations. As discussed in section 2.4, the assessment has tended towards a precautionary approach using maximum values of background concentrations for the general area and nature conservation sites which provides some margin of comfort. Future background concentrations will also be enhanced by other developments in the area of influence which contribute process pollutant contributions. It is therefore important to understand whether there are any significant current or planned developments in the area of influence. Details of current and planned developments may be obtained from the local planning register and the Environment Agency's permitting database.

For the purposes of this assessment a circular area of radius 10 km with centre the proposed Arreton 3 well site was considered. A search of the Isle of Wight Council's planning register for planned and current developments from 2016 onwards was undertaken and screened for contribution of affected pollutants and distance from the well site. All developments beyond the 10 km search area were omitted as it considered unlikely that releases would have any significant impact around the selected area. The remaining developments falling within the search area were assessed for their likely additional contribution to 2016 pollutant background concentrations around the Arreton 3 well site. Only one development was considered to be potentially significant:

Wight Farm Energy (1900018/FUL) – Combined heat and power (CHP) unit serving an anaerobic digestion plant. The Environmental Statement (RPS, Environmental Statement Addendum OXF9173, January 2017) was employed to determine the important operating parameters for the CHP unit as shown in Table 4.16.

Table 4.16 Declared releases from the Wight Energy CHP development

Property		Value
Easting	m	452729
Northing	m	86482
Stack height	m	10
Stack diameter	m	0.125
Exhaust gas velocity	m/s	15
Exhaust gas temperature	^{o}C	120
Nitrogen dioxide discharge rate	g/s	0.178
Carbon monoxide discharge rate	g/s	0.356

The assessment was repeated and the CHP unit included assuming continuous operation at the conditions in Table 4.16.

Table 4.17 compares the maximum predicted process contributions of nitrogen dioxide at the residential receptors with and without consideration of the Wight Energy CHP development.

Table 4.17 Effect of Cumulative Impacts

Condition	Maximum process contribution of nitrogen dioxide at residential receptors	
	Short term	Long term

	µg/m^3	%standard	µg/m^3	%standard
Without CHP	55.4	27.7	3.8	9.4
With CHP	56.0	28.0	3.9	9.6
Difference	1.1	1.1	2.1	2.1

It may be noted that for both long and short-term impacts there is a slight increase in nitrogen dioxide process contributions when releases from the nearby CHP development are considered. The increases are relatively small at around 1.5-2% and have no impact on the outcome or conclusions of the main assessment.

5 CONCLUSIONS

UK Oil and Gas plc propose to develop a well site, known as the Arreton 3 well site, on land to the west of Arreton in off the Newport to Sandown highway (A3056) on the Isle of Wight. The aim of the project is to undertake drilling of an exploratory borehole and sidetrack borehole with subsequent testing for hydrocarbon minerals. The project is expected to engage around 86 working weeks within a project life of up to three calendar years after which the site will either be restored or retained to undertake further work.

As part of the planning and permitting process it is necessary to assess the dispersion of releases to atmosphere associated with the proposed operations to determine their impact on ambient concentrations of important pollutants around the local area. In particular, impact at locations of permanent human habitation and sensitive nature conservation sites in the context of attainment of applicable environmental standards requires assessment.

The main sources of pollutant releases during site operations will be from the use of diesel fuel in on-site stationary engines and construction and transport vehicles and from the disposal by flaring of produced natural gas. Releases of nitrogen oxides, carbon monoxide, volatile organic compounds, sulphur dioxide and particulate matter were considered. The assessment was undertaken using the UK ADMS 5.2 modelling system.

The drilling and appraisal phases of the project are the most energy intensive and result in the greatest pollutant releases. Depending on commencement date, the project will span up to three calendar years. Air quality standards are based on assessment over a calendar year. In order to capture worst case combinations of releases and meteorological conditions, long term air quality impact was assessed with a project schedule which accommodated the drilling and testing phases in one calendar year. Short term air quality impacts were based on year-round operation of the project phases which provided the greatest release rate for each pollutant. In practice it is expected that this worst case will be significantly mitigated by scheduling and breaks between project phases which will result in the execution of the drilling and testing over more than one calendar year.

Maximum pollutant process contributions from the site operations are localised and occur just within the well site boundary to the north east. Beyond this location, process contributions reduce significantly with distance. It is not considered that statutory air quality standards would be applicable around the area of maximum impact due to the infrequency of human exposure.

At neighbouring locations of residential occupation, where long term human exposure might be expected, it is considered unlikely that pollutant process contributions over the duration of the project would pose any significant threat to continued attainment of environmental standards.

Along the neighbouring footpaths and bridleways where short term environmental standards might be expected to apply, it is expected, in practice, that process pollutant contributions would be unlikely to compromise attainment of the applicable short-term environmental standards.

At local conservation sites sensitive to nitrogen and acid deposition maximum process contributions are considered to be unlikely to pose any threat to or have any substantial influence on the attainment of critical levels and critical loads in practice. The impact of process contributions of nitrogen oxides at the Arreton Down site of special scientific interest and at some nearby sites of importance for nature conservation are considered within the Ecological Impact Assessment that accompanies the planning application.

Necessary assumptions made to undertake the modelling are considered to have the effect of substantially overestimating the process contribution to ambient concentrations. It is considered that the predicted process impact reported herein is a conservative assessment and the conclusions reached therefore incorporate a reasonable margin of comfort in spite of the inevitable uncertainty of such modelling studies.

It is likely that the construction activities associated with the development of the well site will give rise to dust emissions. It is expected, based on Institute of Air Quality Management methodology, that with adequate mitigation measures in place the risk of dust impact from all project operations will be 'negligible'.

Increases in road traffic brought about by the construction activities, subsequent site operation and final site restoration are assessed to have a neutral impact on air quality based on Highway's Agency guidance.

Operations on site will give rise to releases of greenhouse gases. Based on an assessment of worst case operation it is considered that Project lifetime greenhouse gas releases are largely insignificant in relation to the UK's current inventory and future budgets.

6 REFERENCES

1. Environment Agency and Department for Environment Food and Rural Affairs, Risk assessment for specific activities, environmental permits, Environmental Management guidance: Air emissions risk assessment for your environmental permit, 2 August 2016 (www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit#environmental-standards-for-air).

2. Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

3. Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air.

4. SI 2010:1001, Environmental Protection, The Air Quality Standards Regulations 2010.

5. Institute for Occupational Safety and Health, International Chemical Safety Card 0291, 22 July 2015.

6. Environment Agency, "Horizontal guidance note H1 – Annex (f) Air Emissions", version 2.2, December 2011 (withdrawn 1 February 2016).

7. Health and Safety Executive, EH40/2005 Workplace exposure limits, March 2013.

8. British Geological Survey, Air quality and greenhouse gas monitoring in the Vale of Pickering, 2018 (http://www.bgs.ac.uk).

9. Environment Agency, UK Air Pollutants – Key Factors and monitoring data, Report SC 030174, April 2006.

10. EP UK & IAQM, Land use planning development and control: planning for air quality, January 2017.

11. Private communication, email N Moore (Zetland Group) to N Ford (SOCOTEC), dated 20 November 2019.

12. 'Compilation of Air Pollutant Emission Factors', Volume 1, 5th Edition, January 1995, United States Environmental Protection Agency.

13. Rahman SM, Impact of idling on fuel consumption and exhaust emissions and available idle-reduction technologies for diesel vehicles – A review, Energy Conversion and Management 74 (2013) 171–182.

14. DIESELNET, Technology guide 2017.04

15. H Christopher Frey, Real world energy use and emission rates for idling long haul trucks and selected idle reduction technologies, Journal of the Air and Waste Management Association. Vol 59, July 2009.

16. Khan S et al, Idle emissions from medium heavy duty diesel and gasoline trucks, Journal of the Air and Waste Management Association. Vol 59, March 2009.

17. Freedom of information request to Greater London Authority, May 2016.

18. EMEP/EEA, Emissions inventory guidebook 2013, September 2014.

19. Intergovernmental Panel on Climate Change, 2019 refinement to the 2006 guidelines for National greenhouse gas inventories, Volume 2, Chapter 4.

20. Scottish Environmental Protection Agency, Odour guidance 2010, 201

21. National Environmental Research Institute, Emissions from Decentralised CHP plants 2007, Project 5 report – Emission factors and emission inventory for decentralised CHP production, NERI Technical report 786, 2010.

22. AQTAG 06, Technical Guidance on Detailed Modelling Approach for an Appropriate Assessment for Emissions to Air, Environment Agency Air Quality Monitoring and Assessment Unit, March 2014.

23. Janssen LHJM, Van Wakeren JHA, Van Duuren H and Elshout A J, 1988, A classification of NO oxidation rates in power plant plumes based on atmospheric conditions, Atmospheric Environment, 22, 43-53.

24. Environment Agency and Department of Environment, Risk assessment for specific activities, environmental permits, Environmental Management guidance: Assess the impact of air emissions on global warming, 1 February 2016 (www.gov.uk/guidance/assess-the-impact-of-air-emissions-on-global-warming).

25. Institute of Air Quality Management, Guidance on the assessment of dust from demolition and construction, February 2014.

26. Highways Agency, Design Manual for Roads and Bridges, HA207/07, May 2007.

Annex A Dispersion modelling contour plots

The results of the modelling of the impact of pollutant releases from the project operations on local ambient ground level concentrations are presented in tabular form in Section 4. In Annex A typical examples of the long-term and short-term dispersion pattern for nitrogen dioxide, the most significant pollutant, are presented. Contour plots illustrating the process contribution to ground level concentrations of nitrogen dioxide are provided. The results relate to modelling of site operation and meteorological conditions which provide the maximum process contributions. All results are presented as the maximum contribution of the process (excluding existing background concentrations), expressed as a percentage of the applicable ambient air directive limit.

The plots are considered over an area of 2 km x 2km, which includes the immediate area around the Arreton 3 well site and the nearest residential neighbours.

For long term and short-term averaging periods, the contour plots are limited to minimum values of 1% and 10% of the ambient air directive limits respectively. Values below 1% and 10% of the long term and short-term ambient air directive limits respectively, are generally considered to be insignificant in terms of air quality impact.

The following figures are presented:

Figure 1 Predicted maximum process contributions of nitrogen dioxide (AAD limit 99.8 percentile of 1 hour means – 2015)

Figure 2 Predicted maximum process contributions of nitrogen dioxide (AAD limit annual mean - 2015)

Figure A.1 Predicted maximum process contributions of nitrogen dioxide (AAD limit 99.8 percentile of 1 hour means – 2015)

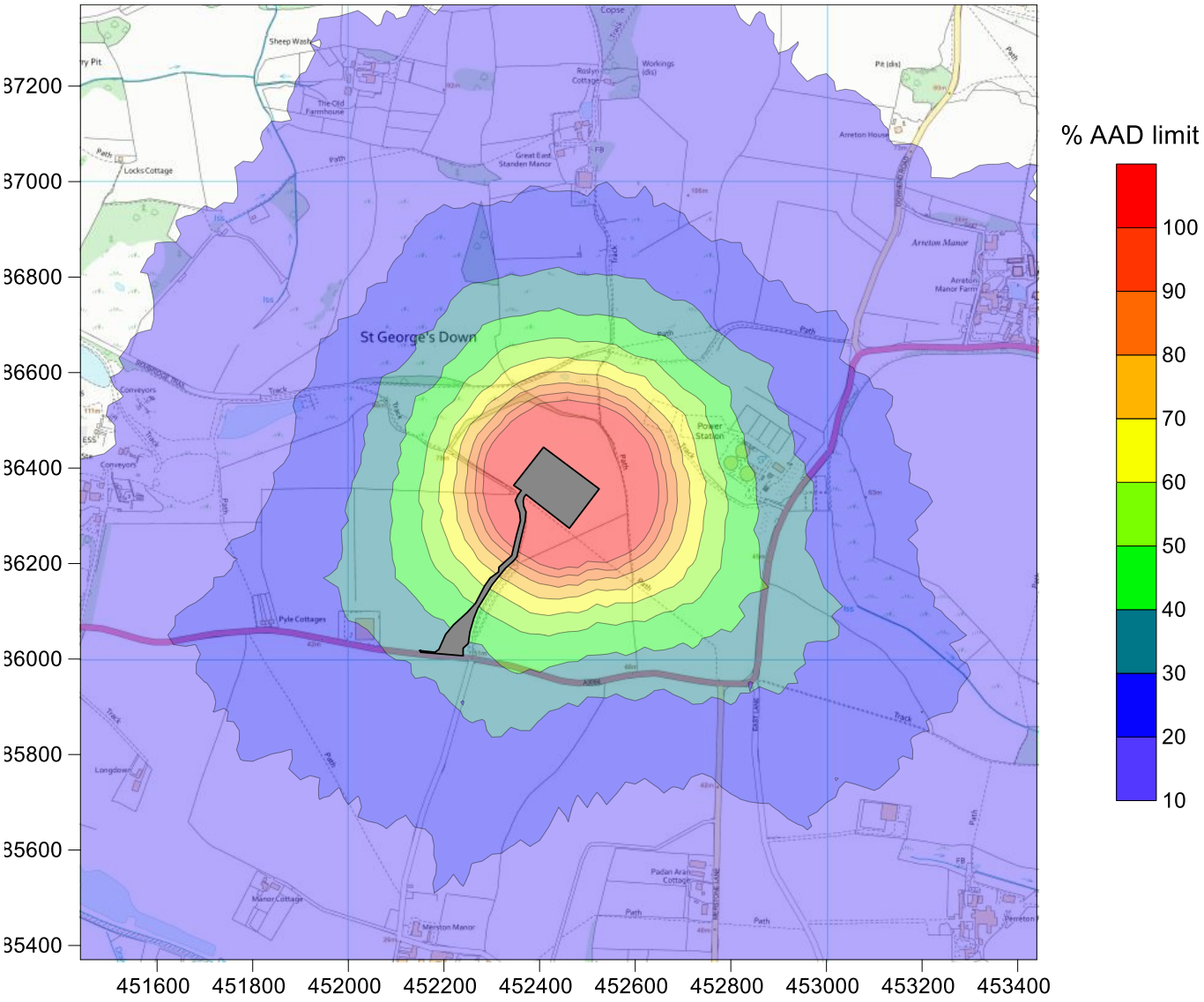
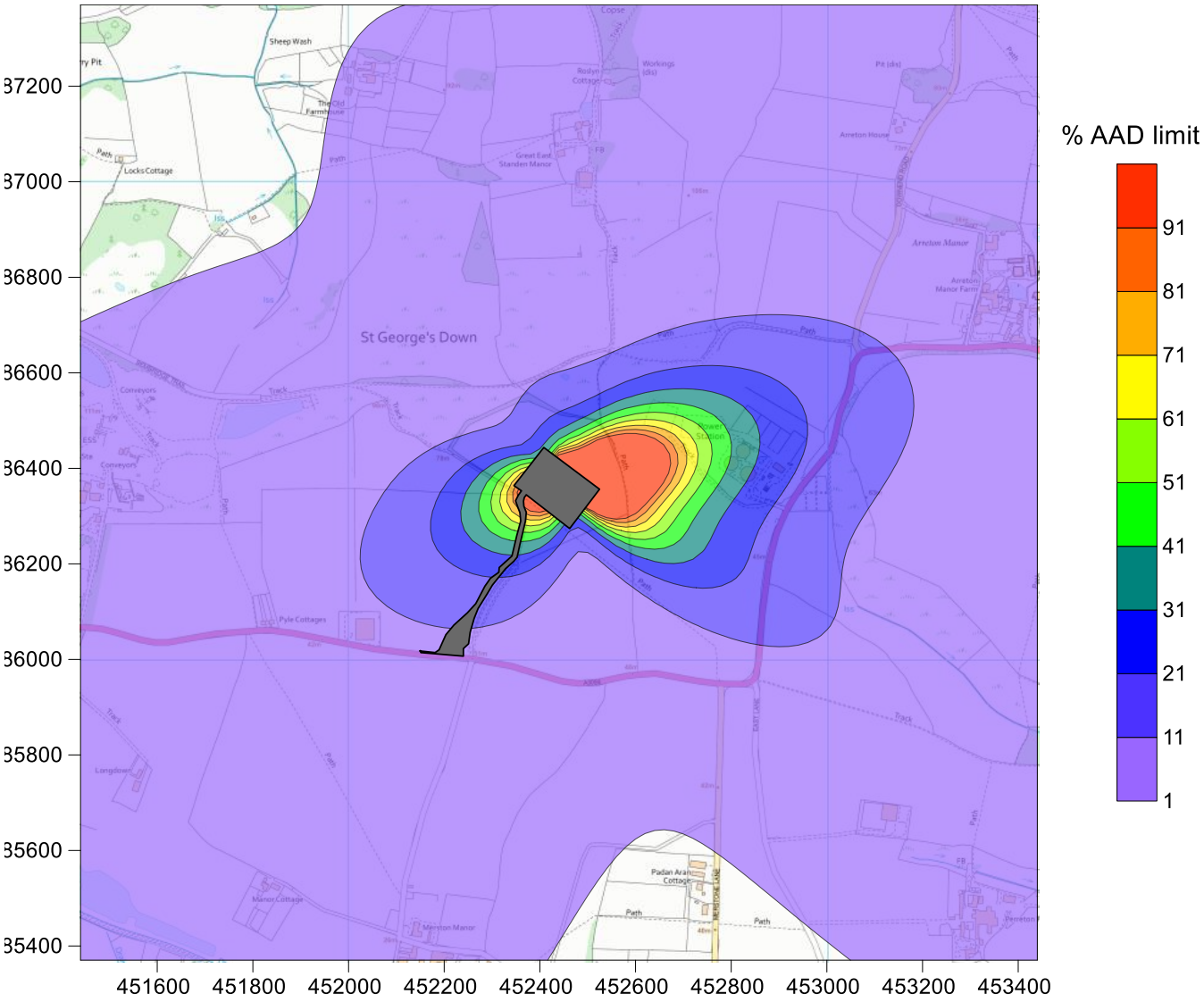


Figure A.2 Predicted process contributions of nitrogen dioxide (AAD limit annual mean - 2015)



ANNEX B Model input data

B.1 Assessment area and surface characteristics

Table B.1 summarises the assessment area considered in the modelling and the values of the parameters describing its surface characteristics. These are described in more detail in sections 3.1 to 3.4.

Table B.1 Assessment area and surface characteristics

Parameter	Value
Assessment area	2000 m x 2000m area with centre 452440 86370
Cartesian receptor grid	101 x 101 receptor grid (total 10201) with receptors spaced at 20m intervals
Discrete receptors	73 receptors - see Table G.1 for description
Meteorological data	Hourly sequential data supplied by the UK Meteorological Office from the St Catherines station (supplemented with cloud data from the Thorney Island station) for the 5 year period 2014 to 2018
Topography	Flat terrain
Surface roughness	0.3m
Minimum Monin Obukhov length	1m
Surface albedo	0.23
Priestley Taylor parameter	1.0

The release characteristics of the main sources considered in this assessment are detailed in Tables 3.3 to 3.16.

B.2 Model input files

The input data used in the current assessment have been provided under separate cover. Electronic files containing the input data used in the modelling of the maximum process contributions over the entire assessment area of all pollutants considered have been provided as detailed below:

Carbon monoxide (CO)	8 hour mean	ARR ST 2B 2015.APL
Nitrogen dioxide (NO_2)	1 hour mean	ARR ST 2B 2015.APL
	annual mean	ARR LT 2015.APL
Sulphur dioxide (SO_2)	15 minute mean	ARR ST 2D 2017.APL
	1 hour mean	ARR ST 2D 2017.APL
	24 hour mean	ARR ST 2B 2014.APL
PM_{10}	24 hour mean	ARR ST 2B 2015.APL
	annual mean	ARR LT 2015.APL
$PM_{2.5}$	annual mean	ARR LT 2015.APL
Benzene	annual mean	ARR LT 2015.APL
Carbon monoxide	hourly mean	ARR ST 2B 2018.APL
Benzene	hourly mean	ARR ST 2B 2018.APL
Nitrogen monoxide (NO)	hourly mean	ARR ST 2B 2015.APL
	annual mean	ARR LT 2015.APL

ANNEX C Conversion of nitrogen monoxide to nitrogen dioxide

The majority of oxides of nitrogen released will be in the form of nitrogen monoxide. While conversion to nitrogen dioxide will occur in the atmosphere it is unlikely that all of the nitrogen oxides in the flue emission will be in the form of nitrogen dioxide at ground level. It may be noted that for this type of assessment the Environment Agency[1]

recommend that conversion rates of 35% and 70% be considered for short and long-term air quality impacts respectively. These are considered quite conservative estimates. These conversion rates have been used in this assessment and represent a precautionary approach which will, it is considered, significantly over estimate the process contribution to ground level concentrations of nitrogen dioxide at most locations and as such provide a reasonable margin of headroom which should go some way to offsetting the inevitable uncertainties associated with this type of assessment and the necessary modelling assumptions.

There are methodologies available which enable a more representative estimation of conversion rates at specific locations, largely based on distance from the point of release. Based on a study of Dutch power station plumes, Janssen et al[23] determined an approximate relationship between the conversion of NO to NO_2 and the distance from the point of release as below:

$$\frac{NO_2}{NO_x} = A\left(1 - e^{(-\alpha x)}\right)$$

where A is the ozone parameter describing the oxidation of NO to NO_2 in the presence of ozone and the photolysis of NO_2 by sunlight to reform NO.
α is the wind parameter which expresses conversion rates in respect of downwind distance based on wind speed at plume height and ozone concentration.
x is the downwind distance (km)

The values of A and α depend on ozone concentration, incoming solar radiation and wind speed. Janssen developed empirical values for these based on seasonal measurements of conditions in the Netherlands. It is assumed that a similar relationship is applicable in the UK.

Janssen proposed the following seasonal values for A and α:

Winter (December to February)

Background ozone concentration (ppb)	Wind speed at plume height (m/s)					
	0-5		5-15		>15	
	A	α	A	α	A	α
0-10	0.49	0.05	0.49	0.05	0.49	0.05
10-20	0.74	0.07	0.74	0.07	0.74	0.07
20-30	0.83	0.07	0.83	0.07	0.83	0.10
30-40	0.87	0.07	0.87	0.07	0.87	0.15

Spring/Autumn (March to May and September to November)

Background ozone concentration (ppb)	Wind speed at plume height (m/s)					
	0-5		5-15		>15	
	A	α	A	α	A	α
10-20	0.635	0.10	0.635	0.10	0.635	0.10
20-30	0.74	0.10	0.74	0.10	0.74	0.15
30-40	0.80	0.10	0.80	0.10	0.80	0.25
40-60	0.85	0.10	0.85	0.15	0.85	0.30

Summer (June to August)

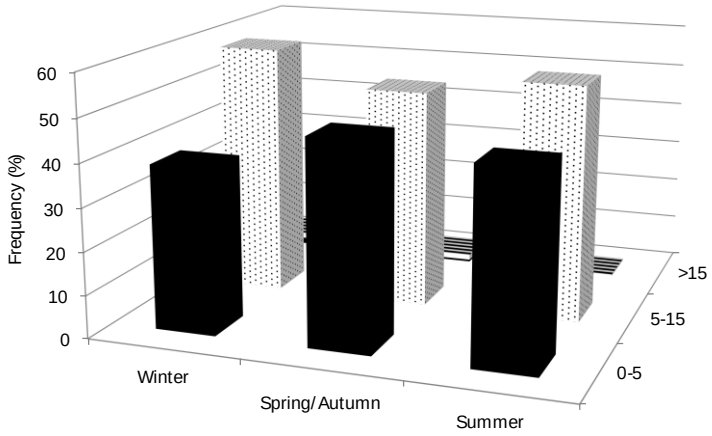
Background ozone concentration (ppb)	Wind speed at plume height (m/s)					
	0-5		5-15		>15	
	A	α	A	α	A	α
20-30	0.67	0.10	0.67	0.10	0.67	0.10
30-40	0.74	0.10	0.74	0.15	0.74	0.25
40-60	0.81	0.15	0.81	0.25	0.81	0.35
60-120	0.88	0.20	0.88	0.35	0.88	0.45
120-200	0.93	0.40	0.93	0.65	0.93	0.80

Janssen indicates that '*the method presented therefore proved to be highly suitable to predict NO_2/NO_x ratios in power plant plumes under widely varying atmospheric conditions*'.

An assessment of the meteorological data for the St Catherines station over the period employed in this assessment (2014 to 2018) indicated the following seasonal distribution of wind speed.

Season	Frequency in wind speed category (%)			Mean wind speed (m/s)
	0-5 m/s	5-15 m/s	>15 m/s	
Winter	38.3	58.6	3.1	6.9
Spring/Autumn	47.4	50.8	1.8	5.8
Summer	44.7	54.9	0.4	5.8

Seasonal wind speed

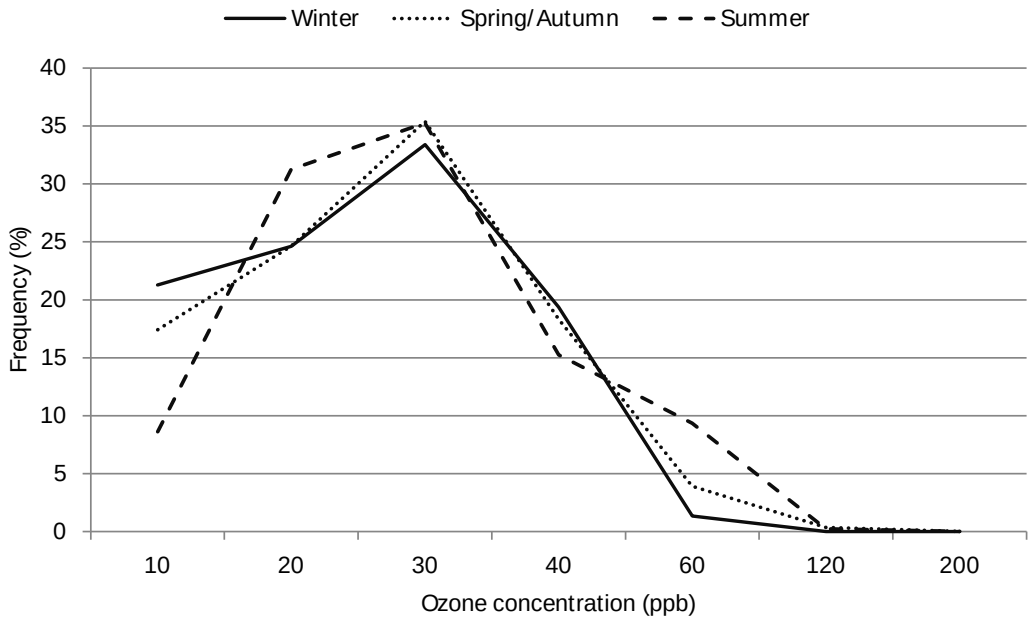


The wind speed is largely below the 15 m/s category for all seasons, with an overall average of 5.9 m/s.

The nearest automatic station monitoring station which includes measurement of ozone is Portsmouth (UKA00421) which is located around 22 km north east of Arreton (465695 103666). An analysis of hourly average data for 2018 indicated the following seasonal concentrations:

Season	Frequency in ozone concentration category (%)							Mean
	0-10	10-20	20-30	30-40	40-60	60-120	120-200	
	ppb							
Winter	21.3	24.6	33.4	19.4	1.3	<0.1	<0.1	20.2
Spring/Autumn	17.4	24.6	35.4	18.3	3.9	0.3	<0.1	21.7
Summer	8.6	31.3	35.3	15.3	9.4	0.2	<0.1	23.9

Seasonal ozone concentration



Based the values of wind speed and ozone concentration and Janssen's empirical relationship, it is considered that the following seasonal values for the parameters A and α are appropriate:

Season	Wind speed (m/s)	Ozone concentration (ppb)	A	α
Winter	5-15	20-30	0.83	0.07
Spring/Autumn	5-15	20-30	0.74	0.10
Summer	5-15	20-30	0.67	0.10

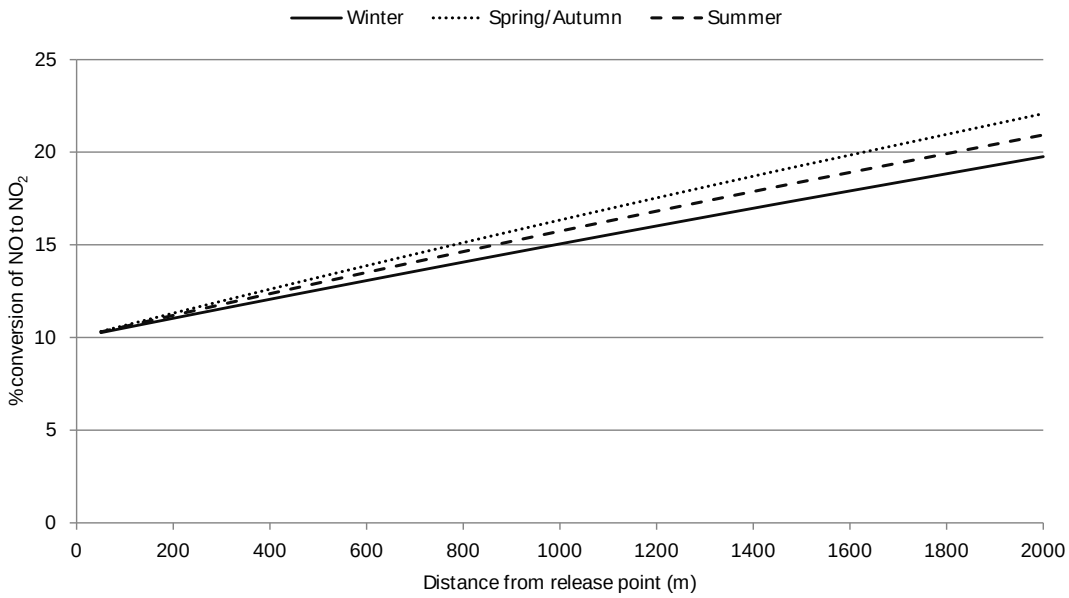
It is likely that a small amount of the nitrogen oxides emitted will be in the form of nitrogen dioxide. For the purposes of this assessment it is assumed that 10% of nitrogen oxides comprise nitrogen dioxide and as such Janssen's relationship for this situation is described by:

$$\frac{NO_2}{NO_x} = y + (1-y)A\left(1-e^{(-\alpha x)}\right)$$

where y is the fraction of nitrogen oxides present as nitrogen dioxide at the point of release.

Based on Janssen's relationship the following seasonal conversion rates are estimated with distance from the source.

Estimated seasonal NO to NO_2 conversion rates



The conversion rates expected for locations within 1 km of the source are less, and in some cases significantly less, than those assumed within the assessment.

ANNEX D Meteorological data

For this modelling assessment hourly sequential meteorological data provided by the UK Met Office from the St Catherines station was employed, supplemented with cloud data from the Thorney Island station, and covered the 5 year period 2014 to 2018. Further details of the data employed are provided in this section.

D.1 Windroses

In section 3.3 a cumulative wind rose for the period 2014 to 2018 is presented. The windroses for each individual year of data used are illustrated below.

Figure D.1 St Catherines 2014

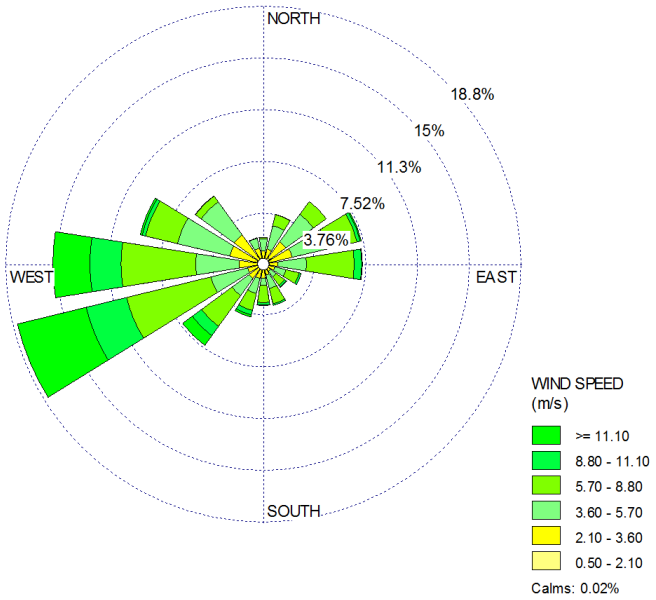


Figure D.2 St Catherines 2015

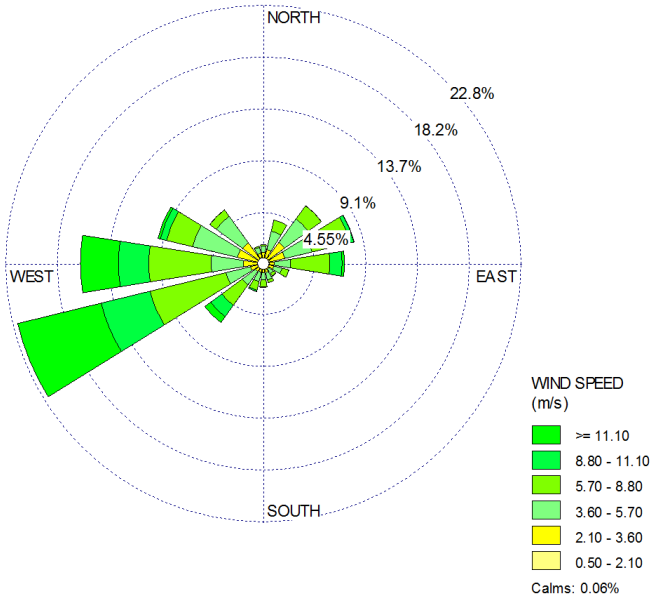


Figure D.3 St Catherines 2016

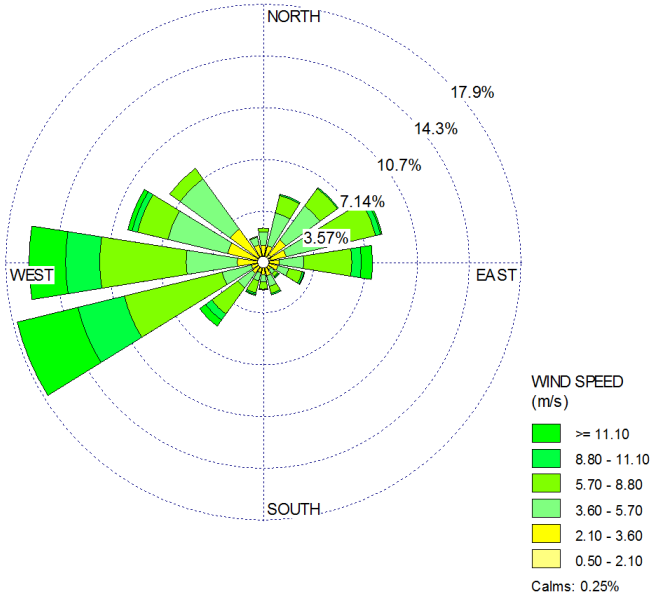


Figure D.4 St Catherines 2017

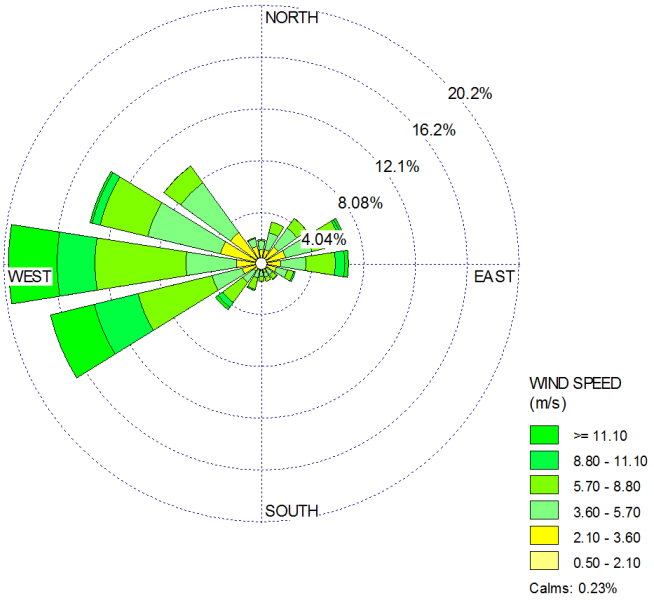
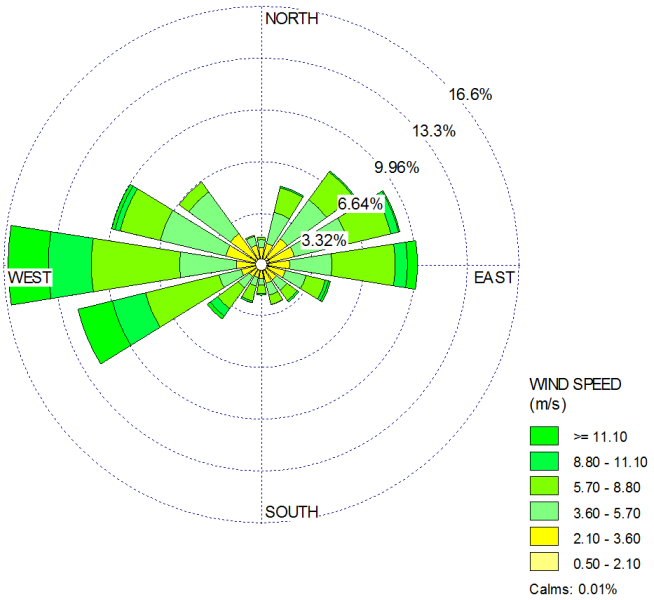


Figure D.5 St Catherines 2018



D.2 Data analysis and characteristics

Analyses of the wind direction, wind speed and precipitation are summarised in Tables D.1 and D.2 for the period 2014 to 2018.

Table D.1 Wind speed and direction (2014 to 2018) for St Catherines

Wind direction blowing from	Wind speed (m/s)						
	0.3-2.1	2.1-3.6	3.6-5.7	5.7- 8.8	8.8-11.1	> 11.1	Total
	Frequency (% of time)						
N	0.8	1.7	2.1	0.8	<0.1	<0.1	5.4
NE	0.9	2.6	4.1	2.5	0.1	<0.1	10.1
E	0.9	2.1	3.8	6.0	1.1	0.4	14.3
SE	0.6	0.9	0.8	0.7	0.1	<0.1	3.1
SE	0.7	1.2	1.5	1.5	0.2	0.1	5.1
SW	0.5	1.2	2.6	4.3	1.7	1.6	12.0
W	0.9	3.2	7.1	12.7	5.9	7.9	37.9
NW	0.9	3.6	5.8	1.7	<0.1	<0.1	11.9
Calm							0.1

a. Missing data is ignored from the determination of percentage frequency.

Table D.2 Rainfall and wind direction (2014 to 2018) for St Catherines

Wind direction Blowing from	Rain fall (mm/h)						
	Dry	0.1-0.3	0.3-0.6	0.6-0.9	0.9-1.2	1.2-1.5	>1.5
	Frequency (% of time)						
N	5.2	0.1	<0.1	<0.1	<0.1	<0.1	0.1
NE	9.6	0.2	0.1	<0.1	0.1	<0.1	0.1
E	13.5	0.3	0.2	0.1	0.1	<0.1	0.1
SE	2.6	0.1	0.2	<0.1	<0.1	<0.1	0.1
SE	3.8	0.3	0.3	0.1	0.2	0.1	0.4
SW	9.5	0.9	0.7	0.2	0.3	0.1	0.3
W	34.7	1.4	0.8	0.2	0.3	0.1	0.3
NW	11.3	0.3	0.2	<0.1	0.1	<0.1	0.1
Calm	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total	90.3	3.7	2.5	0.6	1.0	0.3	1.6

a. Missing data is ignored from the determination of percentage frequency.

The main data characteristics are summarised in Table D.3.

Table D.3 Dataset characteristics (2014 to 2018) for St Catherines

No. days data	1827		
No. hours data	43848		
No. calm hours (<0.3 m/s)	54	0.12	%
No. dry hours (<0.1 mm/h)	39610	90.39	%
Mean wind speed (m/s)	6.1		
No. missing records	26	0.06	%
Available records	43822	99.94	%

ANNEX E Construction dust risk assessment

E.1 Introduction

It is likely that the construction activities associated with the proposed well site development will give rise to dust emissions, albeit temporary in nature and largely restricted the areas close to the well site.

The potential for fugitive dust is most likely to arise from the movement of vehicles over the earth, the stripping of soil, excavations and the subsequent storage of excavated materials and transfer of materials to and from lorries. This may be exacerbated by spillages during transportation and handling and also by periods of dry weather and high wind speeds.

The potential for dust impact has been assessed based on the guidance provided by the Institute of Air Quality Management (IAQM)[25]. Four activities considered to have the most significant potential for fugitive release of dust are identified; demolition, earthworks, construction, and track-out. In this case there are no demolition activities associated with the proposed development.

Construction of the site including an access track and a temporary tarmac junction where the access track meets the Newport to Sandown highway (A3056) will be in Phase 1A of the project and will last around 10 weeks. The subsequent restoration of the site will be undertaken in Phase 4A of the project and is scheduled for a duration of 5 weeks and will include the break up and removal of the well site and restoration of the land with landscaping. The access track and junction may remain with the agreement of the Council and landowner. No major construction activities likely to cause related dust releases are scheduled in Phases 2 and 3 of the project which are of 71 weeks duration.

E.2 Screening assessment

IAQM guidance indicates that an assessment will normally be required where there is:

• a 'human receptor' within 350 m of the boundary of the site or within 50 m of the route(s) used by construction vehicles on the public highway, up to 500 m from the site entrance(s).

• an 'ecological receptor' within 50 m of the boundary of the site or 50 m of the route(s) used by construction vehicles on the public highway, up to 500 m from the site entrance(s).

In this case there are no ecological receptors within 50 m of the well site boundary. The nearest site with an ecological designation is Standen Copse which is around 800 m to the north of the well site. Site traffic will leave the site via the access track and new junction on to the A3056 and then largely head north. At no time, within a distance of 500 m from the site entrance, does this main access route come within 50 m of an ecological receptor. Ecological receptors are therefore not considered within this assessment.

The nearest human receptors are around 570 m from the well site entrance at Pyle Cottages located to the south west. There are also a number of public footpaths and bridleways in the area with the closest being adjacent to the southern well site boundary. While the activities likely to give rise to the greatest releases of dust will be arise from the construction of the well site, there will be some affects due to activities associated with construction of the access track. A temporary junction which will be constructed to join the access track to A3056 which will be around 320m m from Pyle Cottages. It is therefore necessary to consider human receptors in the assessment.

E.3 Risk of dust impact

E3.1 Potential dust emission magnitude

The potential dust emission magnitude for the earthwork, construction and track-out activities, before any mitigation, are assessed in Tables E.1 to E.4. The assessment generally adopts a conservative approach.

Table E.1 Dust emission magnitude for earthworks activities

Criteria	Effect	Classification
Site area	The well site area is around 14,500 m^2, with a further estimated 7,000 m^2 of access track and junction.	Large
Soil type	Moderately dusty soil	Medium
Earth moving vehicles operating	Maximum of 10 or fewer vehicles operating at any one time (see Table H.2)	Medium
Material moved	Expected that around 10,000 tonnes of materials will be moved during the construction of the well site and access track.	Small
Presence of bunds	Bunds of around 4 m height are expected around the well site boundary.	Medium
Operating times	The construction and restoration phases of the project will last for around 10 and 5 weeks respectively, although the scheduling is as yet unknown.	Small
Overall rating	Conservative estimate of effects.	Medium

The dust emission magnitude for the earthworks associated with the project is considered to be 'Medium'.

Table E.2 Dust emission magnitude for construction activities

Criteria	Effect	Classification
Building volume	Total building volume is less than 25000 m^3.	Small
Dust potential of construction materials	Largely concrete for pad.	Small
Concrete batching	Small scale concrete batching is possible	Medium
Sand blasting	No sand blasting is expected.	Small
Overall rating	Conservative estimate of effects.	Medium

Construction activities, which will involve the construction of a drilling cellar, will be confined to the well site. These activities will be conducted over a relatively short duration of around 7 days. While the dust magnitude is classified as 'Medium' this is considered a precautionary assessment.

Table E.3 Dust emission magnitude for track out

Criteria	Effect	Classification
Number of HDV vehicle movements	Less than 50 HDV outward movements expected in any one day (see Table H.2).	Medium
Surface material	Moderately dusty.	Medium
Length of unpaved road	The access track, which will be prepared with a crushed and compacted stone base, is around 400 m in length	Small
Overall rating	Conservative estimate of effects.	Medium

The access track from the well site is around 400 m in length and will be constructed of crushed and compacted stone. The access track will join the A3056 at a temporary tarmac junction. There is a further 320 m of paved road

before the route passes within 50 m of the nearest residential location (Pyle Cottages). While the dust magnitude is conservatively estimated as 'Medium' it is considered that significant impact at the nearest residential locations will be unlikely.

Table E.4 Summary of dust emission magnitude

Activity	Dust emission magnitude
Earthworks	Medium
Construction	Medium
Track-out	Medium

E3.2 Sensitivity of the area

IAQM guidance recommends the assessment of the sensitivity of the area takes into account:

- the specific sensitivities of receptors in the area
- the proximity and number of those receptors
- in the case of PM_{10}, the local background concentration
- site specific factors, such as whether there are natural shelters, such as trees, to reduce the risk of wind-blown dust.

It is considered that in terms of both dust soiling and the human health effects of PM_{10} there are a small number of 'high' sensitivity receptors present at around 320 m from the nearest locations of earthworks (A3056 temporary junction) associated with the project. Construction activities are confined to the well site, which is around 570 m from the nearest residential locations and 10 m from the nearest public footpath and bridleway.

IAQM guidance for trackout sensitivity indicates that receptor distances should be measured from the side of the roads used by construction traffic. Without site specific mitigation, trackout may occur from roads up to 500 m from large sites, 200 m from medium sites and 50 m from small sites, as measured from the site exit. The impact declines with distance from the site, and it is only necessary to consider trackout impacts up to 50m from the edge of the road.

A conservative approach is taken herein and the site exit is assumed to be at the end of the access track meeting A3056. Pyle Cottages is around 320 m from the access track junction which will be the main construction traffic route from the well site.

There are no significant areas of woodland close to the site which might provide a natural barrier to wind blown dust emissions for residential properties in any direction.

The sensitivity of the area for the site activities is estimated in Table E.5.

Table E.5 Assessment of sensitivity of area

Potential impact	Condition	Earthworks	Construction	Trackout
Dust soiling	Receptor sensitivity	High	High	High
	Number of receptors	1-10	1-10	1-10
	Distance from site (m)	320	570	320
	Sensitivity of area	Low	Low	Low
Human health (residential)	Receptor sensitivity	High	High	High
	Number of receptors	1-10	1-10	1-10
	Distance from site (m)	320	570	320
	PM_{10} background concentration ($\mu g/m^3$)	<24	<24	<24
	Sensitivity of area	Low	Low	Low
Human health	Receptor sensitivity	Low	Low	Low

(footpath/ bridleway)	Number of receptors	1-10	1-10	1-10
	Distance from site (m)	10	10	10
	PM_{10} background concentration ($\mu g/m^3$)	<24	<24	<24
	Sensitivity of area	Low	Low	Low

E3.3 Risk of impact

The risk of impact for human health and dust soiling is estimated by considering the magnitude of the effect (Table E.4) and the sensitivity of the receiving area (Table E.5) as summarised in Table E.6.

Table E.6 Assessment of risk of impact

Potential impact	Earthworks	Construction	Trackout
Dust soiling	Low	Low	Low
Human health	Low	Low	Low
Ecology	Negligible		

E.4 Conclusions and mitigation measures

The impact on human health is considered 'low' based on the distance between the site, and the nearest high sensitivity residential locations, the small number of receptors at that distance and the generally low background concentration of PM_{10}.

The risk of dust soiling is considered to be 'low' based on the location of residential properties relative to the site and access track boundary and the small number of receptors.

The assessment indicates that due to the distance between the site and the nearest nature conservation areas the risk of impact on ecological receptors is 'negligible'.

This assessment is made without any mitigation measures being considered.

Mitigation measures, adhering to industry best practice, specific to the control of dust during construction have been incorporated into the design of the development. The following measures will further reduce the dust impact risk determined in this assessment:

- A construction environmental management plan (CEMP), incorporating best practices, will be employed during the construction phase.
- Material deliveries and stock piles on site will be sheeted to prevent windblown dust releases.
- Loads entering and leaving the site will be sheeted, where appropriate, to prevent windblown dust releases.
- In dry periods a bowser will be available to dampen any dry and dusty road surfaces to minimise entrainment of dust.
- Vehicle wheel washing facilities will be available to minimise the transfer of site dust on to the road network.

It is expected that with these mitigation measures in place and bearing in mind the conservative approach to the assessment before mitigation, the risk of dust impact from all operations will reduce to 'negligible' for all activities and for all impacts.

ANNEX F Air quality impact of construction and operations traffic

F.1 Introduction

The development of the site, the subsequent operation and final site restoration will have the effect of increasing traffic flow in the area, which in turn will result in additional releases of certain pollutants to air. It is necessary to assess the likely ambient impact of this increase in traffic flow.

Assessment methodology based on the Design Manual for Roads and Bridges (DMRB) published by the Highways Agency[26] has been used to determine significance and impact of additional off-site traffic movements during the main phases of the project. The impact of on-site vehicle movements is considered within the main air quality assessment.

F.2 Expected traffic flows

The main route to the site will be along the A3056 (Newport to Sandown highway) and the well site access track. Table F.1 summarises the expected maximum heavy duty vehicle (HDV) movements for the duration of the project.

Table F.1 HDV movements over project

Phase of project		Duration (working days)	Maximum HDV[a] movements	
			Two way movements/day	Total movements (inbound and outbound)
1A	Well site construction	60	15	900
2A	Drilling – mobilisation and demobilisation	18	15	270
2B	Drilling	90	15	1350
2C	Appraisal - mobilisation and demobilisation	18	15	270
2D(i)	Well testing	60	15	900
2D(ii)	Extended Well Testing	96	5	480
2E	Sidetrack drilling	90	15	1350
2F	Maintenance workover	24	15	360
3A	Plugging and abandonment	18	10	180
3B	Removal of surface equipment	12	5	60
4A	Site restoration	30	10	300

a. HDV – a heavy duty vehicle of gross weight greater than 3.5 t.

The highest number of two-way HDV movements over a period of 365 consecutive days is 4020 (within the 52 week period of phases 1A to 2Di.&ii) equivalent to an annual average daily traffic (AADT) count of 22.0.

In addition to HDV movements it is expected that there will be no more than 100 movements of passenger cars and light goods vehicles (less than 3.5 t gross weight) during each day of the project.

F.3 Assessment criteria

The DRMB provides guidance on the screening out of changes with the objective of determining whether a proposed development is likely to have a significant impact in terms of air quality. It is first necessary to identify any affected roads in the vicinity using the criteria in Table F.2.

Table F.2 Screening assessment for affected roads

Criterion	Assessment
Road alignment will change by 5 m or more	Not applicable
Daily traffic flows will change by 1,000 AADT or more	No – see Table F.1
Heavy duty vehicle flows will change by 200 AADT or more	No – see Table F.1
Daily average speed will change by 10 km/h or more	Unlikely
Peak hour speed will change by 20 km/h or more	Unlikely

In this case none of the main routes to and from the Arreton 3 well site is classed as an affected road. The DMRB specifies that if none of the roads in the relevant network meet any of the traffic/alignment criteria then the impact of the scheme can be considered to be neutral in terms of local air quality and no further work is needed.

The IAQM[11] also provide guidance on the need for an air quality assessment based on indicative criteria related to the change in traffic flow brought about by a development as summarised in Table F.3.

Table F.3 IAQM indicative criteria for traffic change significance

The development will	Indicative criteria to proceed to an air quality assessment
Cause a significant change in Light Duty Vehicle (LDV) traffic flows on local roads with relevant receptors. (LDV = cars and small vans of <3.5 t gross weight)	A change of LDV flows of: - more than 100 AADT within or adjacent to an AQMA - more than 500 AADT elsewhere
Cause a significant change in Heavy Duty Vehicle (HDV) flows on local roads with relevant receptors. (HDV = goods vehicles + buses >3.5t gross vehicle weight)	A change of HDV flows of - more than 25 AADT within or adjacent to an AQMA - more than 100 AADT elsewhere

There are no air quality management areas adjacent to any of the main routes into or out of the well site. Expected increases in average vehicle movements over the duration of the project fall well below the IAQM criteria for an air quality assessment with AADT for HDVs of 22.

On this basis it is determined that an air quality assessment for the change in traffic brought about by the proposed development is not required.

F.4 Conclusions

Increases in road traffic brought about by the construction activities, subsequent site operation and final site restoration are assessed to have a neutral impact on air quality based on Highway's Agency guidance. The additional contributions to ambient pollutant concentrations from associated road traffic have no influence on the findings of the main air quality assessment for plant releases to air.

ANNEX G Discrete receptors

Discrete receptors were used to monitor the process contribution to ambient pollutant concentrations at a range of locations including the local footpaths and bridleways as illustrated in Figure 3.1. Details of their location are provided in Table G.1, together with the predicted nitrogen monoxide to nitrogen dioxide conversion rate (see Annex C). All receptors were at an elevation of 1.5 m with the exception of those at the nature conservation sites which are at an elevation of 0 m.

The receptors fall into the following groups:

1 to 13 Residential locations (see Figure 3.1 & Table 3.1)
14 to 18 Local nature conservation sites (see Table 3.2)
19 to 73 Local footpaths and bridleways (see Figure 3.1)
74 to 78 Nature conservation sites with a European designation (see Table 3.2)

Table G.1 Receptor locations

Receptor		Position[a]	Easting	Northing	NO to NO_2 conversion rate (%)
1	Pyle Cottages	664 m SW	451845	86076	14.3
2	Longdown	1050 m SW	451574	85775	16.6
3	Manor Cottage	1025 m SW	451845	85536	16.5
4	Merston Manor	946 m S	452139	85473	16.0
5	Padan Aran Cottage	839 m S	452701	85573	15.4
6	Perreton Farm	1204 m SE	453266	85494	17.6
7	Arreton Manor Farm	945 m NE	453304	86753	16.0
8	Arreton Manor	1012 m NE	453325	86861	16.4
9	Arreton House	1007 m NE	453137	87098	16.4
10	Great East Standen Manor	681 m N	452451	87051	14.4
11	Roslyn Cottage	836 m N	452553	87198	15.3
12	The Old Farmhouse	921 m NW	452007	87183	15.9
13	Locks Cottage	1128 m NW	451531	87038	17.1
14	Perreton Farm Wood	1102 m SE	453416	85859	16.9
15	Standen Copse	814 m N	452578	87172	15.2
16	Wroxhall Bottom Copse	1223 m NW	451783	87401	17.7
17	Saltmoor Copse	1670 m NE	453434	87712	20.2
18	Arreton Down SSSI	1123 m NE	453240	87158	17.1
19	Footpath/bridleway	768 m W	451695	86554	14.9
20		706 m W	451760	86559	14.5
21		650 m W	451820	86568	14.2
22		593 m W	451885	86579	13.8
23		528 m NW	451960	86588	13.4
24		465 m NW	452031	86593	13.0
25		408 m NW	452099	86593	12.7
26		340 m NW	452182	86590	12.2

Table G.1 continued

Receptor	Position[a]	Easting	Northing	NO to NO_2 conversion rate (%)
27	270 m NW	452278	86586	11.8
28	236 m N	452355	86590	11.6
29	261 m N	452451	86631	11.7
30	294 m N	452498	86658	11.9
31	335 m N	452534	86691	12.2
32	392 m N	452536	86750	12.6
33	459 m N	452532	86819	13.0
34	328 m N	452559	86676	12.1
35	353 m NE	452631	86667	12.3
36	398 m NE	452705	86667	12.6
37	427 m NE	452743	86671	12.8
38	484 m NE	452774	86721	13.1
39	538 m NE	452817	86754	13.5
40	587 m NE	452891	86745	13.8
41	662 m NE	452994	86732	14.3
42	701 m NE	453052	86712	14.5
43	368 m NE	452592	86705	12.4
44	424 m NE	452675	86723	12.8
45 Footpath/Bridleway	479 m NE	452754	86732	13.1
46	256 m N	452496	86620	11.7
47	199 m N	452503	86559	11.3
48	160 m NE	452539	86496	11.1
49	148 m NE	452559	86458	11.0
50	135 m E	452572	86400	10.9
51	149 m E	452583	86330	11.0
52	181 m SE	452586	86263	11.2
53	222 m SE	452588	86204	11.5
54	247 m SE	452595	86177	11.6
55	308 m SE	452631	86128	12.0
56	361 m SE	452664	86088	12.4
57	417 m SE	452707	86050	12.7
58	497 m SE	452756	85987	13.2
59	427 m NW	452063	86570	12.8
60	388 m NW	452092	86541	12.5
61	343 m W	452119	86492	12.2
62	274 m W	452182	86460	11.8
63	196 m W	452251	86424	11.3

Table G.1 continued

Receptor		Position[a]	Easting	Northing	NO to NO_2 conversion rate (%)
64	Footpath/Bridleway	124 m W	452316	86384	10.8
65		116 m SE	452485	86263	10.8
66		168 m SE	452532	86229	11.1
67		97 m SW	452386	86290	10.6
68		154 m SW	452377	86229	11.0
69		213 m SW	452343	86180	11.4
70		272 m SW	452303	86135	11.8
71		327 m SW	452278	86085	12.1
72		376 m SW	452280	86029	12.5
73		426 m SW	452269	85980	12.8
74	Briddlesford Copses SAC	2910 m NE	454180	88703	26.8
75	Solent and Dorset Coast pSPA	3915 m NW	450154	89548	31.6
	Solent Maritime SAC	3907 m NW	450154	89539	31.5
76	Solent and Southampton Water SPA	6034 m NE	454781	91931	40.2
77	South Wight Maritime SAC	7352 m SE	458912	82883	44.7
78	Isle of Wight Downs SAC	8497 m S	455603	78484	48.1

a. Position of receptor relative to the centre of the Arreton 3 well site.

Table G.2 details the results of the assessment for the discrete residential receptors. The maximum process contributions for nitrogen dioxide are provided for each discrete receptor expressed as a proportion of the applicable air quality standard.

The standard assessment is based on Environment Agency nitrogen monoxide to nitrogen dioxide conversion factors of 35% and 70% for short and long-term impacts respectively. Conversion factors specific to each receptor based on distance from the source have been determined using the Janssen relationship (see Annex C) and Table G.1. In Table G.2 these are applied to the predicted process contributions to provide what is considered a more realistic determination of the nitrogen dioxide process contribution in practice. Short term and long-term process contributions are based on the Janssen conversion and twice the Janssen conversion respectively.

Table G.2 Maximum process contributions at residential locations

Receptor (see Figure 3.1 and Table G.1)		Maximum nitrogen dioxide process contribution (% air quality standard)			
		EA conversion		Janssen conversion	
		annual	1 hour	annual	1 hour
1	Pyle Cottages	9.4	27.7	3.9	11.3
2	Longdown	4.1	16.1	2.0	7.7
3	Manor Cottage	2.8	16.5	1.3	7.8
4	Merston Manor	2.3	19.4	1.0	8.9
5	Padan Aran Cottage	1.4	19.8	0.6	8.7
6	Perreton Farm	3.7	15.7	1.9	7.9
7	Arreton Manor Farm	6.9	15.4	3.2	7.1
8	Arreton Manor	5.4	14.8	2.5	7.0
9	Arreton House	3.1	22.5	1.4	10.5
10	Great East Standen Manor	2.9	22.7	1.2	9.3
11	Roslyn Cottage	2.3	20.7	1.0	9.1
12	The Old Farmhouse	1.7	14.7	0.8	6.7
13	Locks Cottage	1.5	10.7	0.7	5.2
14	Perreton Farm Wood	7.8	16.9	3.8	8.2
15	Standen Copse	2.5	20.7	1.1	9.0
16	Wroxhall Bottom Copse	1.1	9.9	0.6	5.0
17	Saltmoor Copse	1.1	13.2	0.6	7.6
18	Arreton Down SSSI	2.6	19.8	1.3	9.7
19	Footpath/Bridleway	3.9	15.0	1.6	6.4
20		4.3	17.5	1.8	7.3
21		4.7	18.9	1.9	7.7
22		5.2	22.6	2.1	8.9
23		6.0	25.8	2.3	9.9
24		7.0	29.6	2.6	11.0
25		8.1	35.0	2.9	12.7
26		9.8	42.6	3.4	14.9
27		12.2	55.9	4.1	18.8
28		15.5	67.6	5.1	22.3
29		14.7	63.8	4.9	21.3
30		13.7	56.9	4.7	19.4
31		12.1	48.8	4.2	17.0
32		9.0	40.3	3.2	14.5
33		6.6	33.9	2.5	12.6
34		13.6	53.8	4.7	18.7
35		14.9	51.9	5.2	18.3
36		14.8	44.2	5.3	15.9
37		14.3	41.0	5.2	15.0
38		11.0	39.3	4.1	14.8

Table G.2 continued

Receptor (see Figure 3.1 and Table G.1)	Maximum nitrogen dioxide process contribution (% air quality standard)			
	EA conversion		Janssen conversion	
	annual	1 hour	annual	1 hour
39	9.4	36.9	3.6	14.2
40	9.8	31.3	3.9	12.3
41	10.1	23.3	4.1	9.5
42	10.4	20.7	4.3	8.6
43	11.9	47.5	4.2	16.9
44	11.1	43.1	4.0	15.7
45	10.5	41.2	3.9	15.4
46	17.4	66.6	5.8	22.2
47	28.7	90.7	9.3	29.3
48	61.7	128.5	19.5	40.6
49	114.3	145.5	35.8	45.6
50	245.8	174.1	76.5	54.2
51	192.8	158.2	60.5	49.7
52	101.7	123.7	32.5	39.6
53	39.4	93.3	12.9	30.6
54	27.6	80.4	9.2	26.7
55	19.7	62.9	6.8	21.6
56 Footpath/Bridleway	16.0	52.5	5.7	18.6
57	14.4	44.3	5.2	16.1
58	10.9	38.4	4.1	14.5
59	8.1	32.7	3.0	12.0
60	9.8	36.8	3.5	13.2
61	13.1	42.9	4.6	15.0
62	19.7	55.5	6.6	18.7
63	36.2	80.4	11.7	26.0
64	88.5	128.4	27.4	39.7
65	25.3	162.4	7.8	50.0
66	28.7	121.4	9.1	38.5
67	103.0	169.3	31.3	51.5
68	43.9	111.2	13.8	35.0
69	28.7	79.0	9.3	25.7
70	20.9	60.9	7.1	20.5
71	15.4	49.6	5.3	17.2
72	11.3	41.4	4.0	14.7
73	9.0	37.0	3.3	13.5

ANNEX H Site equipment specification

Details of the equipment specified for use in the project are provided in Table H.1

Table H.1 Site equipment specification

Equipment		Type	Description	Reference
a	Lighting	Site light 908	Perkins 403D-11G engine, 8.8 kVA standby power, EU stage 3A	Bruno Generators, Site light 908P specification
b	Welfare unit	Liberty Guard	15 kVA generator. Assume 3.7 l/h fuel consumption and EU Stage 3A compliant	MHM UK, MG15000 SSK-MV specification
c	20 t excavator	Caterpillar 320DL	Caterpillar C6.4 ACERT engine, 110 kW, fuel consumption 26.4 l/h, claimed US EPA Tier 3 compliant.	Caterpillar 320DL hydraulic excavator, AEHQ5856-02 (4-08), 2008.
d	12-14t excavator	Caterpillar 313 FL	Caterpillar 4.4 engine, 74 kW, fuel consumption 17.8 l/h, claimed US EPA Tier 4	Caterpillar 313 FL
e	8 t mini excavator	Caterpillar 307 E2	Caterpillar C2.4 engine, 40 kW, fuel consumption 9.6 l/h, claimed US EPA Tier 4 and EU Stage 3B compliant	Caterpillar 307 E2 mini hydraulic excavator, AEHQ7466 (05-2015), 2015.
f	9t forward tipper	Alldrive 9 front tip	2 off Perkins 1100 D engine, 70 kW, EU stage 3A compliant	Twaites, Alldrive 9 specification, February 2009.
g	Vibratory roller	Hamm HD90	Deutz TCD 2012 LO4 2V engine, 100 kW, claimed EU Stage 3A complaint	Hamm HD 90 articulated roller, HD 90 / HD 90K 10.10 20434 33 E4
h	Tracker dozer	D5K2 tracked type dozer	Cat C4.4 ACERT engine, 77.6 kW, EU stage 3B compliant	Cat, D5K2 tracked type dozer specification, AEHQ6687 (03-2012)
i	Surface conductor rig	Junttan PM 20LC	Cummins QSB6.7 engine, 179 kW, EU stage 3A compliant	Junttan, PM20LC Pile Driving Rig Data sheet, M120LC003, 2 March 2009
j	Camp generator	Perkins 2206A-E143TAG3	Gross power 350 kW, fuel consumption 81 l/h, assume EU Stage 3A compliant	Perkins, PM1880A/12/14. 2206A-E13TAG3 engine specification

Table H.1 continued

Equipment		Type	Description	Reference
K	Drilling rig	Rig engine	Detroit 12V71 engine, 354 kW, assumed US EPA Tier 2.	Central Power Systems and Services, PF 12V71T Specification and application data, DS10075.
		Mud pumps	2 off Caterpillar 3512 A engines, 1271 kW, fuel consumption 305.4 l/h. Not certified, emission from engine specification. Operating at 80% of full load (1017 kW).	Caterpillar Diesel generator set, STANDBY 1100 ekW 1375 kVA 60 Hz 1800 rpm 480 Volts, engine emission data, 2523756, 29 July 2011.
		Rig power system	2 off Caterpillar 3412 engines, fuel consumption 191.7 l/h, US EPA Tier 2 compliant.	Caterpillar Diesel generator set, STANDBY 720 ekW 900 kVA 50 Hz 1500 rpm 400 Volts, engine emission data, 1492445, 23 September 2011.
		Accommodation	100 kVa generator, assume US EPA Tier 2.	Greaves Power, Diesel Generator Set Specifications Sheet- 100 kVA,
		Rough terrain forklift	JCB 940 RTFL, 55kW, fuel consumption 13.2 l/h, assume EU stage 3B.	JCB, Rough terrain fork lift, 9999/5829, 07/14 Issue 1
l	Workover rig	Moor 475	Detroit Series 60 engine, 354 kW, fuel consumption 85 l/h, US Tier 2 compliant	Detroit Diesel Corp, Detroit engine series 50 and 60 for petroleum applications, 6SA587 304, 2003
m	Steam generator	RBC 1850	RBC 1850 oil burner, fuel consumption 200 l/h at AP42, 1.3 emission rates	Fulton, Technical information, Sheet 109, Issue 6.
n1	Flare	PW Well Testing	1 off shrouded ground flare, 2.2 MMscfd disposal capacity	Appendix 4 in private email from N Moore (Zetland) to N Ford (SOCOTEC), AQIA modelling parameters, 20.11.19
n2		PW enclosed flare (EWT 9.5)	1 off enclosed flare, 0.25 MMscfd disposal capacity	

The projected HDV movements over the duration of the project are summarised in Table H.2.

Table H.2 HDV movements during project phases

Phase	Duration weeks	Working days[a]	Working hours	HDV movements (in and out)	HDV visits to site	Vehicles idling /h	Vehicle movements (in and out) /day
1A	10	60	640	900	900	1.4	15
2A	3	18	192	270	270	1.4	15
2B	15	90	960	1350	1350	1.4	15
2C	3	18	192	270	270	1.4	15
2D(i)	10	60	640	900	900	1.4	15
2D(ii)	16	96	1024	480	480	0.5	5
2E	15	90	960	1350	1350	1.4	15
2F	4	24	256	360	360	1.4	15
3A	3	18	192	180	180	0.9	10
3B	2	12	128	60	60	0.5	5
4A	5	30	320	300	300	0.9	10

a. HDVs are assumed to be restricted to an operational period of 0700 to 1900 (12 hours) during each normal 24 hour working day, 0900 to 1300 on a Saturday (4 hours) and no operation on a Sunday.

The highest number of two-way HDV movements over a period of 365 consecutive days is 4020 (within the 52 week period of phases 1A to 2Di.&ii) equivalent to an annual average daily traffic (AADT) count of 22.0.

ANNEX I Impact at local sites of importance for nature conservation (SINC)

Section 4.3 considers the impact of the proposed well site development on sites with a statutory designation for ecology. There are also a number of sites of importance for nature conservation (SINC) in the vicinity of the proposed well site. In this annex the impact of the proposed well site development at these sites considered.

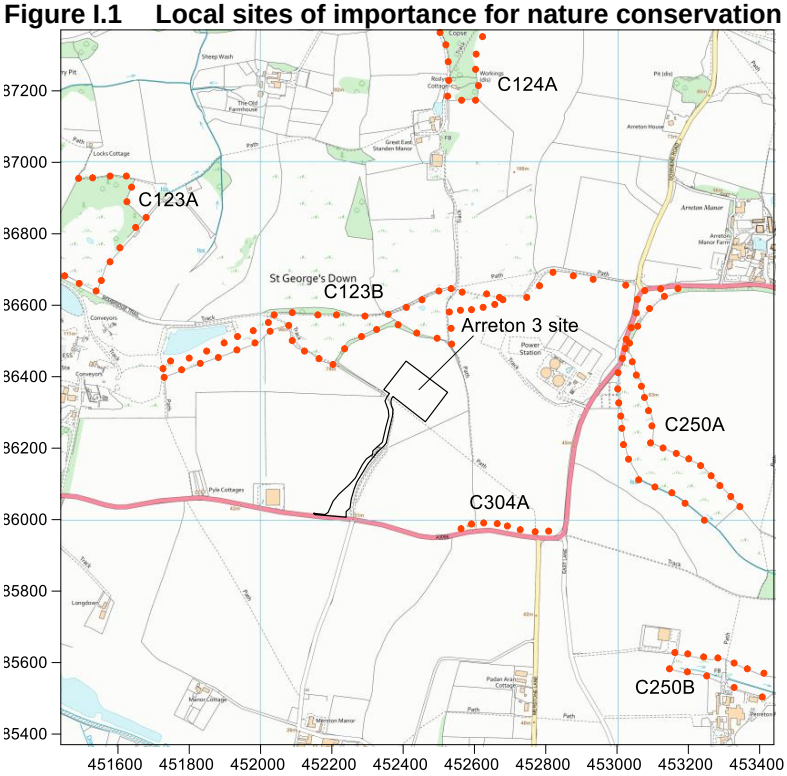
For the purposes of this assessment all SINCs within 1 km of the proposed well site are considered. As demonstrated within the assessment and illustrated in Figures A.1 and A.2, pollutant process contributions are greatest in the vicinity of the well site. While there are other SINCs beyond 1 km from the well site, these will experience a much lower air quality impact from site operations than those within 1 km.

A search of the local SINCs indicated five sites within 1 km of the well site. Standen Copse SINC (C124A in Figure I.1) is already considered in section 4.3 under its designation as an ancient woodland. The remaining sites, some of which comprise more than one area, are summarised in Table I.1 and are located as shown in Figure I.1.

Table I.1 Local sites of importance for nature conservation

SINC number	Name	Description
C123A	St Georges Down	Woodland, grassland/wetland
C123B	St Georges Down	
C250A	Perreton Down and Marsh	Grassland/heathland
C250B	Perreton Down and Marsh	
C304A	Merstone Verges	Grassland

Figure I.1 Local sites of importance for nature conservation



For the purposes of this assessment discrete receptors (orange dots in Figure I.1) were located around the perimeter of each SINC. The process contributions at these locations were then determined as in the main assessment (see section 3.6) in order to determine the maximum process contributions to nitrogen oxides, sulphur dioxide, nitrogen and acid deposition at each site.

The critical loads and levels adopted for these sites were obtained from APIS and are summarised in Table I.2. A general neutral grassland habitat was assumed for all sites.

The background concentrations at each site, as obtained from APIS, are summarised in Table I.3.

Table I.2 Site relevant critical loads and levels

Site		St Georges Down	Perreton Down & Marsh	Merstone Verges
Critical levels for nitrogen oxides and sulphur dioxide (see Table 2.2)				
Annual mean NO_x	$\mu gNO_2/m^3$	30		
Daily mean NO_x	$\mu gNO_2/m^3$	75		
Annual mean SO_2	$\mu gSO_2/m^3$	10		
Critical load for nitrogen deposition				
Most sensitive habitat		Neutral grassland		
N deposition CL	kgN/ha/y	10-20	10-20	10-20
Critical loads for acid deposition				
Most sensitive habitat		Neutral grassland		
Minimum CLminN	keq	0.856	0.856	0.856
Minimum CLmaxS	keq	4.0	4.0	4.0
Minimum CLmaxN	keq	4.856	4.856	4.856

a.. For all SINCs a neutral grassland habitat is considered.

Table I.3 Site relevant background concentrations

		St Georges Down	Perreton Down & Marsh	Merstone Verges
Nitrogen oxides annual mean	$\mu gNO_2/m^3$	13.31	13.28	12.99
Sulphur dioxide annual mean	$\mu gSO_2/m^3$	0.98	0.98	0.98
Nitrogen deposition	kgN/ha/y	15.54	15.54	15.54
Nitrogen acid deposition	keq/ha y	1.11	1.11	1.11
Sulphur acid deposition	keq/ha y	0.31	0.31	0.31

The maximum process contributions to concentrations of nitrogen oxides and sulphur dioxide at the SINCs are summarised in Table I.4.

Table I.4 Maximum process contributions of nitrogen oxides and sulphur dioxide at the SINCs

Site		St Georges Down	Perreton Down & Marsh	Merstone Verges
Nitrogen oxides[a]				
Maximum annual mean PC	$\mu gNO_2/m^3$	37.5	9.8	4.8
	% CL	125	33	16
Background concentration	$\mu gNO_2/m^3$	13.31	13.28	12.99
Maximum annual mean PEC	$\mu gNO_2/m^3$	50.8	23.1	17.8
	% CL	169	77	59
Maximum daily mean PC	$\mu gNO_2/m^3$	574	96	87
	% CL	766	127	116
Back ground concentration	$\mu gNO_2/m^3$	26.6	26.6	26.0
Maximum daily mean PEC	$\mu gNO_2/m^3$	601	123	113
	% CL	801	163	150
Sulphur dioxide				
Maximum annual mean PC	$\mu gSO_2/m^3$	0.024	0.017	0.004
	% CL	0.24	0.17	0.04
Background concentration	$\mu gSO_2/m^3$	0.98	0.98	0.98
Maximum annual mean PEC	$\mu gSO_2/m^3$	1.00	1.00	0.98
	% CL	10.0	10.0	9.8

a. Total nitrogen oxides are expressed as NO_2.

The maximum process contributions of sulphur dioxide are equivalent to less than 100% of the applicable critical load in all cases and as such may be considered insignificant.

At all of the SINCs short-term process contributions of nitrogen oxides are greater than 100% of the critical level. In addition, at the St Georges Down SINC the long term process contribution of nitrogen oxides also exceeds 100% of critical level. Further consideration in terms of ecological impact is required for nitrogen oxides at these sites.

The determination of nitrogen deposition at the SINCs is summarised in Table I.5. The determination was undertaken in accordance with the guidance in AQTAG 06[22] and considered dry deposition only. Guidance indicates that wet deposition over relatively short distances is unlikely to be significant.

Table I.5 Nitrogen deposition at the SINCs

Site		St Georges Down	Perreton Down & Marsh	Merstone Verges
Maximum process N deposition	$\mu gNO_2/m^2/s$[a]	0.039	0.010	0.005
	kgN/ha/y	3.78	0.99	0.48
	% CL	37.8	9.9	4.8
Background concentration	kN/ha y	15.54	15.54	15.54
Maximum annual mean PEC	kN/ha y	19.32	16.53	16.02
	% CL	193	165	160

a. Determination of deposition is based on the deposition velocity for grassland terrain[22].

.

Process contributions to nutrient nitrogen deposition are below 100% of the applicable critical loads at all sites and as such are considered insignificant. While there is exceedance of the critical loads at all of these sites, this is due to an existing large background deposition and it is not considered that the process contributions have any significant influence on critical load compliance.

The determination of the process contribution to acid deposition at these sites is summarised in Table I.6.

Table I.6 Acid deposition at conservation sites

Site		St Georges Down	Perreton Down & Marsh	Merstone Verges
Nitrogen acid deposition	$\mu gNO_2/m^2/s$[a]	0.039	0.010	0.005
	kgN/ha/y	3.78	0.99	0.48
	keq/ha y	0.27	0.07	0.03
Sulphur acid deposition	$\mu gSO_2/m^2/s$[a]	0.00028	0.00020	0.00005
	kgS/ha/y	0.0445	0.0316	0.0078
	keq/ha y	0.0028	0.0020	0.0005
Total process acid deposition	keq/ha/y	0.273	0.072	0.035
	% CL[b]	5.6	1.5	0.7
Total background acid deposition	keq/ha/y	1.42	1.42	1.42
Maximum annual mean PEC	keq/ha y	1.69	1.49	1.46
	% CL[b]	35	31	30

a. Determination of deposition is based on the deposition velocity for grassland [22].
b. Calculations of process contribution and predicted environmental concentrations were used the APIS critical load tool.

The process contributions to acid deposition are below 100% of the applicable critical loads at all SINCs and as such are considered insignificant.

At the sites sensitive to nitrogen and acid deposition maximum process contributions are considered to be largely insignificant. While the maximum process contributions for nitrogen oxides exceed screening criteria at all sites, this is considered unlikely to pose any threat to or have any substantial influence on the attainment of critical levels in practice, although a further ecological opinion is required.

.

END OF REPORT

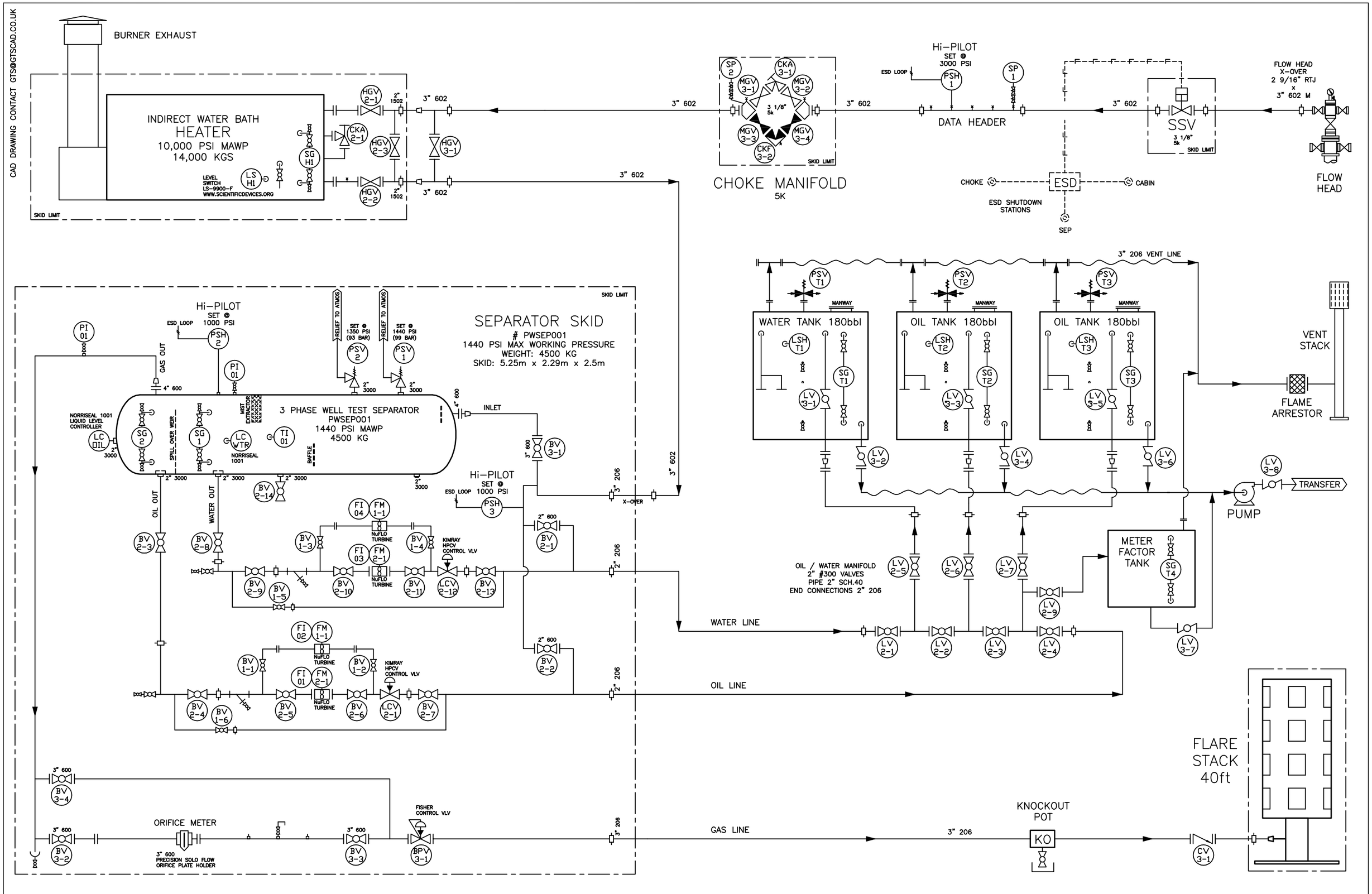
END OF REPORT

Contact:

Dr Nick Ford
SOCOTEC UK Ltd
Unit D
Bankside Trade Park
Cirencester
Gloucestershire
GL7 1YT
T: 07768 257628
E: nick.ford@socotec.com

APPENDIX 3 – PW SHROUDED FLARE DESIGN AND EMISSIONS REPORT

*** Page Left Blank Intentionally ***



NOTES

- BALL VALVE SCREWED
- BALL VALVE FLANGED
- TURBINE FLOW METER
- LEVEL CONTROL VALVE
- PRESSURE CONTROL VALVE
- ORIFICE METER
- Y STRAINER
- RELIEF VALVE
- ADJUSTABLE CHOKE
- CHECK VALVE
- HYDRAULIC GATE VALVE
- POSITIVE (FIXED) CHOKE
- WECO HAMMER TYPE UNION
- PRESSURE & VACUUM SAFETY VALVE
- PI PRESSURE INDICATOR
- TI TEMP INDICATOR
- FI FLOW INDICATOR
- FM FLOW METER
- SP SAMPLE POINT
- SG SIGHT GLASS
- LS LEVEL SWITCH
- LC LEVEL CONTROLLER
- PSH PRESSURE SWITCH HIGH
- DOUBLE BLOCK INST NEEDLE VALVES

1" PIPE SIZE
2" PIPE SIZE
3" PIPE SIZE
4" PIPE SIZE

REV	DATE	DESCRIPTION	DRN	CHK	APP
2	01-15	UPDATED & FOR APPROVAL	GTS	WB	–
1	01-15	UPDATED & FOR APPROVAL	GTS	WB	–
0	10-14	ISSUED FOR APPROVAL	GTS	WB	–

PW Well Test Ltd.

Hawton Lane
New Balderton
Newark
Lincolnshire NG24 3BU

SITE

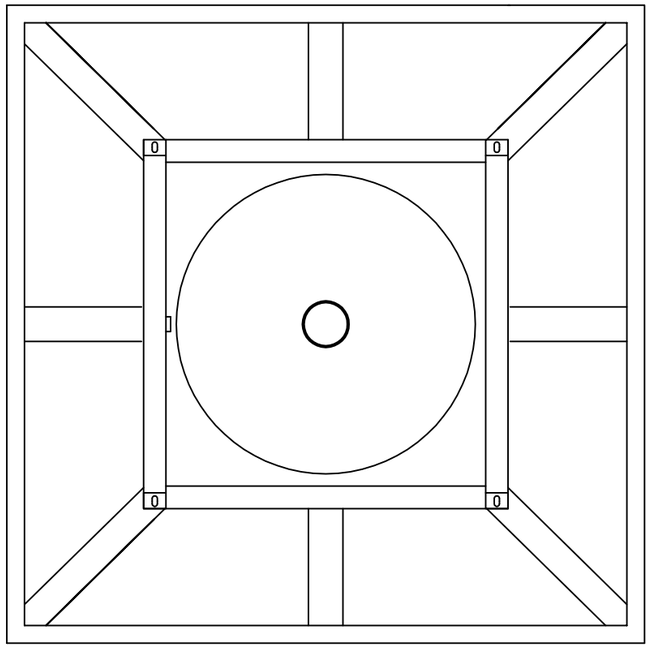
WELL TESTING PACKAGE
PIPING & INSTRUMENTATION DIAGRAM
10th January 2015

SITE Ref:

DRAWING No. PW-WT-PID-02

REV 2

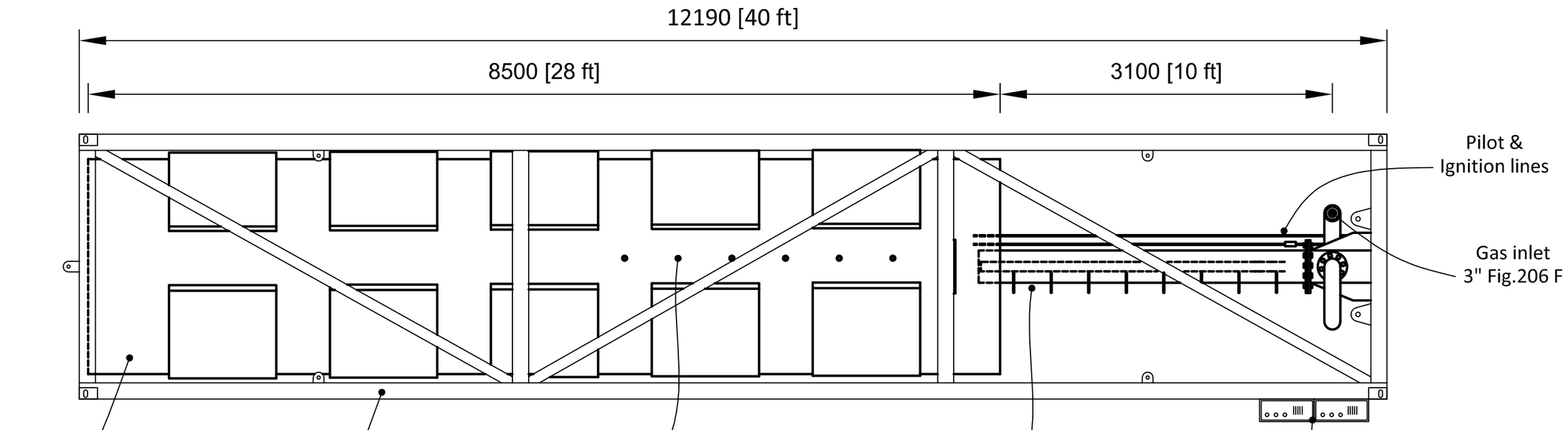
CAD DRAWING CONTACT GTS@GTSCAD.CO.UK



Flare Stack Skid on Base Plate - Plan View

The Flare Stack is used to burn gas during land operations.
Allows gas to be burned at a safe distance from the work area, protecting workers and the environment.

Skid frame 40ft x 8ft x 8ft
Equipped with a gas pilot and electronic ignition system.
Gas inlet connection is 3" Fig.206 female union
Gas capacity 2.5 MMscf/day
Burner, 14" diameter x 10ft long
Pilot line 1/2" diameter
Air Assist line 1/2" diameter
Thermocouple and data logging
Shroud, 6.5ft (2m) diameter x 28ft (8.5m) long



Flare Stack Skid - Side View
(shown in horizontal transit position)

NOTES

REV	DATE	DESCRIPTION	DRN	CHK	APP
-	-	–	-	-	-
-	-	–	-	-	-
0	01-16	FOR INFO	GTS	WB	-

pw well test

Title: FLARE STACK 2.5MMscf/d

GA DRAWING
18th March 2016

Ref:

DRAWING No. PW–FLARE–GA–01

REV 2

Flare outlet configuration : 1 off 3.068" ID pipe exit							
Flow rate (MMscf/d)	Tip Inlet (Psia)	Tip Exit (Psia)	Differential pressure (Psia)	Flare Temperature (°F)	Exit Velocity (ft/sec)	Flame Length (1) (ft)	Noise at 20ft from stack (2) (dB)
1.0	14.87	14.7	0.17	681.3	226.0	16.68 (5.08m)	93.72
1.5	15.09	14.7	0.39	783.5	339.0	20.24 (6.17m)	95.48
2.0	15.39	14.7	0.6971	854.1	452.0	23.22 (7.08)	96.73
2.5	15.8	14.7	1.1	905.7	564.9	25.84 (7.87m)	97.70

(1) Flare length calculation

The flare length calculation:
ft^3/hr x LHV = Q (BTU/Hr)

L = 0.003936*Q^0.4776

LHV = Lower heat value = HHV * 0.9

HHV = 39.05 MJ/m^3 = 1048.1 BTU/ft^3

Gas S.G. = 0.618

(2) API/Brzustowski heat radiation and noise method

Once the flame shape is known, these models may be simply represented by the equation:

$$K = \frac{F.Q}{4\pi D^2}$$

K, Thermal radiation at the specified distance from the mid point of the flame.

F, Flame emissivity.

Q, total heat release from the flame.

D, Distance from the receptor to the mid point of the flame.

Mark Ball

Well Test Support Engineer

ISO/IEC 17025 Accredited Legal Entity, UKAS Accredited Testing Laboratory No. 4279
Exova (UK) Ltd trading as Exova Catalyst & Exova Catalyst Ireland
Unit C5, Emery Court, The Embankment Business Park, Stockport, SK4 3GL

Exova Catalyst, Unit 4A Adwick Park, Manvers, Rotherham, S63 5AB
E: [redacted]
Your Exova Catalyst Contact: [redacted]

Stack Emissions Testing Report Commissioned by

[redacted]

Installation Name & Address

[redacted]

[redacted]

Stack Reference
Clean Up Flare

Dates of the Monitoring Campaign
4th - 6th April 2018

Job Reference Number
CRO-1621

Report Written by
[redacted] Team Leader MCERTS Level 2 MM 04 501 TE1 TE2 TE3 TE4

Report Approved by
[redacted] Deputy Regional Manager MCERTS Level 2 MM 05 641 TE1 TE2 TE3 TE4

Report Date
8th June 2018

Version
Version 1

Signature of Report Approver
[redacted]

CONTENTS

TITLE PAGE

CONTENTS

Summary of Sampling Deviations 2

EXECUTIVE SUMMARY

Monitoring Objectives 3

Monitoring Results 4

Monitoring Dates & Times 5

Process Details 6

Monitoring & Analytical Methods 7

Sampling Location 8

Plant Photos / Sample Points 9

APPENDIX 1 - Monitoring Personnel & List of Equipment

APPENDIX 2 - Raw Data, Sampling Equations & Charts

Opinions and interpretations expressed herein are outside the scope of Exova Catalyst's ISO 17025 accreditation.

This test report shall not be reproduced, except in full, without the written approval of Exova Catalyst.

Executive Summary

MONITORING OBJECTIVES

[redacted], [redacted]

Clean Up Flare

4th - 6th April 2018

Overall Aim of the Monitoring Campaign

Exova Catalyst were commissioned by [redacted] to carry out stack emissions testing on the Clean Up Flare at [redacted].

The aim of the monitoring campaign was to perform testing of an investigative nature under trial operation.

Special Requirements

There were no special requirements.

Target Parameters

Total VOCs (as Carbon), Oxides of Nitrogen (as NO_2), Sulphur Dioxide, Carbon Monoxide, Methane

Executive Summary

MONITORING RESULTS

[redacted], [redacted]

Clean Up Flare

4th - 6th April 2018

where MU = Measurement Uncertainty associated with the Result

		Concentration			
Parameter	**Units**	**Result**		**MU +/-**	**Limit**
Total VOCs (as Carbon) [1]	mg/m³	112		5.6	-
Oxides of Nitrogen (as NO_2) [1]	mg/m³	183		11.7	-
Sulphur Dioxide [1]	mg/m³	15.8		9.7	-
Carbon Monoxide [1]	mg/m³	522		26.4	-
Methane [1]	mg/m³	52.8		14.3	-
Ethane [1]	mg/m³	2.4		5.3	-
Propane [1]	mg/m³	48.3		7.4	-
Benzene [1]	mg/m³	22.3		7.1	-
Toluene [1]	mg/m³	61.1		32.0	-
m-Xylene [1]	mg/m³	22.1		40.0	-
0-Xylene [1]	mg/m³	30.7		95.6	-
p-Xylene [1]	mg/m³	22.0		95.9	-
Ethylbenzene [1]	mg/m³	8.8		38.4	-
Carbon Dioxide	% v/v	**Dry**	1.8	0.17	
Oxygen	% v/v	**Dry**	17.6	0.47	
Water Vapour	% v/v	4.2		0.18	
Stack Gas Temperature Range (04/04/2018)	°C	480 - 720			
Stack Gas Temperature Range (05/04/2018)	°C	654 - 933			
Stack Gas Temperature Range (06/04/2018)	°C	483 - 610			

[1] Reference Conditions (REF) are: 273K, 101.3kPa, dry gas, 3% oxygen.

COMBUSTION DESTRUCTION EFFICIENCIES

Parameter	Run Number	Raw Gas Concentration (ppm)	Clean Up Flare Gas Concentration (ppm)	Destruction Efficiency (%)
Methane	Run 1	967800	16.5	99.9983
	Run 2		23.3	99.9976
	Run 3		3.0	99.9997
Ethane	Run 1	6118	0.22	99.9964
	Run 2		0.26	99.9958
	Run 3		0.28	99.9954
Propane	Run 1	4035	5.2	99.8709
	Run 2		1.2	99.9708
	Run 3		3.0	99.9260
Benzene	Run 1	6.9	0.51	92.6447
	Run 2		1.82	73.6604
	Run 3		0.90	87.0137
Toluene	Run 1	7.1	2.2	68.7150
	Run 2		1.4	80.3545
	Run 3		2.2	68.9118

NOTE: Raw Gas Concentration values have been taken from EffecTech Certificate No: 18/0297/01 - issued 11th April 2018 - attached to the back of this report

Executive Summary

(Page 3 of 7)

MONITORING DATE(S) & TIMES

[redacted], [redacted]

Clean Up Flare

4th - 6th April 2018

Parameter		Units	Concentration		Sampling Date(s)	Sampling Times	Duration mins
Total VOCs (as Carbon)	R1	mg/m³	230		04/04/2018	18:00 - 18:50	50
Total VOCs (as Carbon)	R2	mg/m³	69.1		05/04/2018	08:42 - 15:07	265
Total VOCs (as Carbon)	R3	mg/m³	36.4		06/04/2018	08:35 - 10:56	142
Oxygen	R1	% v/v	18.4		04/04/2018	18:00 - 18:50	50
Oxygen	R2	% v/v	15.1		05/04/2018	08:41 - 17:34	413
Oxygen	R3	% v/v	19.5		06/04/2018	08:35 - 10:57	142
Oxides of Nitrogen (as NO_2)	R1	mg/m³	193		04/04/2018	18:00 - 18:50	50
Oxides of Nitrogen (as NO_2)	R2	mg/m³	197		05/04/2018	08:41 - 17:37	416
Oxides of Nitrogen (as NO_2)	R3	mg/m³	159		06/04/2018	08:35 - 11:00	145
Sulphur Dioxide	R1	mg/m³	0.77		04/04/2018	18:00 - 18:50	50
Sulphur Dioxide	R2	mg/m³	5.9		05/04/2018	08:41 - 17:37	416
Sulphur Dioxide	R3	mg/m³	40.7		06/04/2018	08:35 - 11:00	145
Carbon Monoxide	R1	mg/m³	673		04/04/2018	18:00 - 18:50	50
Carbon Monoxide	R2	mg/m³	684		05/04/2018	08:41 - 17:37	416
Carbon Monoxide	R3	mg/m³	210		06/04/2018	08:35 - 11:00	145
Methane	R1	mg/m³	82.9		04/04/2018	18:00 - 18:50	50
Methane	R2	mg/m³	51.9		05/04/2018	08:41 - 17:37	416
Methane	R3	mg/m³	23.6		06/04/2018	08:35 - 11:00	145
Ethane	R1	mg/m³	2.1		04/04/2018	18:00 - 18:50	50
Ethane	R2	mg/m³	1.1		05/04/2018	08:41 - 17:37	416
Ethane	R3	mg/m³	4.2		06/04/2018	08:35 - 11:00	145
Propane	R1	mg/m³	72.3		04/04/2018	18:00 - 18:50	50
Propane	R2	mg/m³	7.2		05/04/2018	08:41 - 17:37	416
Propane	R3	mg/m³	65.4		06/04/2018	08:35 - 11:00	145
Benzene	R1	mg/m³	12.5		04/04/2018	18:00 - 18:50	50
Benzene	R2	mg/m³	19.7		05/04/2018	08:41 - 17:37	416
Benzene	R3	mg/m³	34.8		06/04/2018	08:35 - 11:00	145
Toluene	R1	mg/m³	64.4		04/04/2018	18:00 - 18:50	50
Toluene	R2	mg/m³	17.9		05/04/2018	08:41 - 17:37	416
Toluene	R3	mg/m³	101		06/04/2018	08:35 - 11:00	145
m-Xylene	R1	mg/m³	12.0		04/04/2018	18:00 - 18:50	50
m-Xylene	R2	mg/m³	7.0		05/04/2018	08:41 - 17:37	416
m-Xylene	R3	mg/m³	47.3		06/04/2018	08:35 - 11:00	145
0-Xylene	R1	mg/m³	19.8		04/04/2018	18:00 - 18:50	50
0-Xylene	R2	mg/m³	11.5		05/04/2018	08:41 - 17:37	416
0-Xylene	R3	mg/m³	60.9		06/04/2018	08:35 - 11:00	145
p-Xylene	R1	mg/m³	16.6		04/04/2018	18:00 - 18:50	50
p-Xylene	R2	mg/m³	19.1		05/04/2018	08:41 - 17:37	416
p-Xylene	R3	mg/m³	30.2		06/04/2018	08:35 - 11:00	145
Ethylbenzene	R1	mg/m³	7.0		04/04/2018	18:00 - 18:50	50
Ethylbenzene	R2	mg/m³	4.4		05/04/2018	08:41 - 17:37	416
Ethylbenzene	R3	mg/m³	14.9		06/04/2018	08:35 - 11:00	145
Water Vapour	R1	% v/v	3.5		04/04/2018	18:00 - 18:50	50
Water Vapour	R2	% v/v	7.0		05/04/2018	08:41 - 17:37	416
Water Vapour	R3	% v/v	2.1		06/04/2018	08:35 - 11:00	145
Carbon Dioxide	R1	% v/v	1.5		04/04/2018	18:00 - 18:50	50
Carbon Dioxide	R2	% v/v	3.0		05/04/2018	08:41 - 17:37	416
Carbon Dioxide	R3	% v/v	0.78		06/04/2018	08:35 - 11:00	145

All results are expressed at the respective reference conditions.

PROCESS DETAILS

[redacted], [redacted]

Clean Up Flare

4th - 6th April 2018

Standard Operating Conditions

Parameter	Value
Process Status	Normal Clean Up
Capacity (of 100%) and Tonnes / Hour	Variable
Continuous or Batch Process	Batch
Feedstock (if applicable)	-
Abatement System	-
Abatement System Running Status	-
Fuel	Gas
Plume Appearance	None visable

MONITORING & ANALYTICAL METHODS

[redacted], [redacted]
Clean Up Flare
4th - 6th April 2018

	Monitoring				Analysis					
Parameter	**Standard**	**Technical Procedure**	**ISO 17025 Testing**	**Testing Lab**	**Analytical Procedure**	**Analytical Technique**	**ISO 17025 Analysis**	**Analysis Lab**	**MCERTS Testing**	**LOD (Average)**
Water Vapour	EN 14790	CAT-TP-05	Yes	CAT	CAT-TP-05	Gravimetric	Yes	CAT	Yes	0.10 % v/v
Total VOCs (as Carbon)	EN 12619:2013	CAT-TP-20	Yes	CAT	Flame Ionisation Detection by Sick 3006 FID				Yes	0.32 mg/m³
Oxygen	EN 14789	CAT-TP-21	Yes	CAT	Dry Zirconia Cell by Horiba PG-250				Yes	0.1 %
Oxides of Nitrogen (as NO_2)	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	0.33 mg/m³
Sulphur Dioxide	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	0.03 mg/m³
Carbon Monoxide	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	0.02 mg/m³
Methane **FS**	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	0.01 mg/m³
Ethane **FS**	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	0.24 mg/m³
Propane **FS**	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	0.24 mg/m³
Benzene **FS**	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	1.74 mg/m³
Toluene **FS**	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	2.67 mg/m³
m-Xylene **FS**	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	1.71 mg/m³
0-Xylene **FS**	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	3.08 mg/m³
p-Xylene **FS**	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	2.32 mg/m³
Ethylbenzene **FS**	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	1.14 mg/m³
Water Vapour	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	0.03 %
Carbon Dioxide	TGN M22	CAT-TP-22(b)	Yes	CAT	FTIR by ProtIR 204M				Yes	0.01 %

ANALYSIS LABORATORIES

(with short name reference as appears in the table above)

Exova Catalyst (CAT)	ISO 17025 Accreditation Number: 4279

SUMMARY OF SAMPLING DEVIATIONS

Parameter	Run	Deviation
All Parameters	All	There are no deviations associated with the sampling employed.

SUITABILITY OF SAMPLING LOCATION

Duct Characteristics

Parameter	Units	Value
Type	-	Circular
Depth	m	2.50
Width	m	-
Area	m²	4.91
Port Depth	cm	9
Orientation of Duct	-	Vertical
Number of Ports	-	1
Sample Port Size	-	5" Flange

Location of Sampling Platform

General Platform Information	Value
Permanent / Temporary Platform	Permanent
Inside / Outside	Outside

Platform Details

EA Technical Guidance Note M1 / EN 15259 Platform Requirements	Value
Sufficient working area to manipulate probe and operate the measuring instruments	Yes
Platform has 2 levels of handrails (approx. 0.5m & 1.0m high)	Yes
Platform has vertical base boards (approx. 0.25m high)	Yes
Platform has chains / self closing gates at top of ladders	Yes
There are no obstructions present which hamper insertion of sampling equipment	Yes
Safe Access Available	Yes
Easy Access Available	Yes

Sampling Location / Platform Improvement Recommendations

The sampling location meets all the requirements specified in EA Guidance Note M1 and EN 15259, and therefore there are no improvement recommendations.

EN 15259 Homogeneity Test Requirements

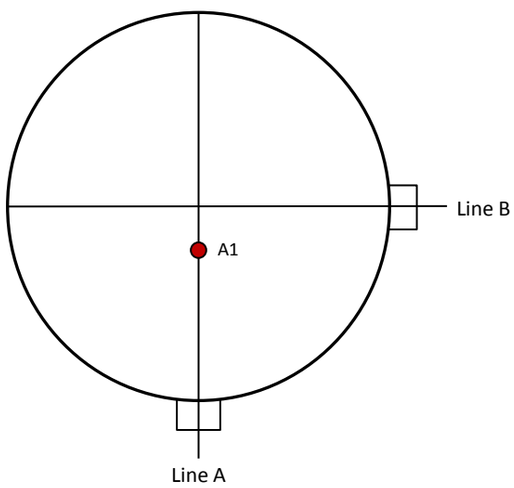
There is no requirement to perform a EN 15259 Homogeneity Test on this Stack.

PLANT PHOTOS

Photo 1

Photo 2

SAMPLE POINTS



where
- ○ = isokinetic point sampled at
- ● = isokinetic point not sampled at
- ● = combustion gases sample point
- ● = non-isokinetic sample point

APPENDIX CONTENTS

APPENDIX 1 - Stack Emissions Monitoring Personnel, List of Equipment & Methods and Technical Procedures Used

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

STACK EMISSIONS MONITORING PERSONNEL

Position	Name	MCERTS Accreditation	MCERTS Number	Technical Endorsements
Team Leader	[redacted]	MCERTS Level 2	MM 04 501	TE1 TE2 TE3 TE4
Trainee	[redacted]	MCERTS Trainee	MM 18 1486	None

LIST OF EQUIPMENT

Extractive Sampling	
Equipment Type	**Equipment I.D.**
Control Box DGM (1)	-
Control Box DGM (2)	-
Box Thermocouples (1)	-
Box Thermocouples (2)	-
Umbilical (1)	-
Umbilical (2)	-
Oven Box (1)	-
Oven Box (2)	-
Heated Probe (1)	-
Heated Probe (2)	-
Heated Probe (3)	-
S-Pitot (1)	-
S-Pitot (2)	-
L-Pitot	-
Site Balance	CAT 17.19
500g / 1Kg Check Weights	CAT 17.19
Last Impinger Arm	CAT 5.60
Callipers	CAT 23.12
Tubes Kit Thermocouple	-

Instrumental Analysers	
Equipment Type	**Equipment I.D.**
Horiba PG-250	CAT 9.12
Horiba PG-250	-
Servomex 4900	-
Eco Physics CLD 822Mh	-
ABB AO2020-URAS26	-
Testo 350 XL	-
JCT JCC P1 Cooler	-
ProtIR 204M	CAT 19.10
Gasmet Sampling System	-
Bernath 3006 FID	CAT 8.8
M&C PSS	-
Mass Flow Controller (1)	CAT 6.47
Mass Flow Controller (2)	CAT 6.46
Mass View (1)	-
Mass View (2)	-
Easylogger EN-EL-12 Bit	-
Hioki 5043 (V)	CAT 11.68
Bioaerosols Temperature Logger	-
Electronic Refrigerator	-

Miscellaneous Items	
Equipment Type	**Equipment I.D.**
Digital Manometer (1)	CAT 3.54
Digital Manometer (2)	-
Digital Temperature Meter	CAT 3.54
Stopwatch	CAT 14.68
Barometer	CAT 13.12
Stack Thermocouple (1)	CAT 4.990
Stack Thermocouple (2)	-
Stack Thermocouple (3)	-
1m Heated Line (1)	-
1m Heated Line (2)	-
1m Heated Line (3)	-
5m Heated Line (1)	-
15m Heated Line (1)	-
20m Heated Line (1)	-
20m Heated Line (2)	-
Dual Channel Heater Controller	-
Single Channel Heater Controller	-
Laboratory Balance	
Tape Measure	CAT 16.24

METHODS & TECHNICAL PROCEDURES USED

Parameter	Standard	Technical Procedure
Water Vapour	EN 14790	CAT-TP-05
Total VOCs (as Carbon)	EN 12619:2013	CAT-TP-20
Oxygen	EN 14789	CAT-TP-21
Oxides of Nitrogen (as NO_2)	TGN M22	CAT-TP-22(b)
Sulphur Dioxide	TGN M22	CAT-TP-22(b)
Carbon Monoxide	TGN M22	CAT-TP-22(b)
Methane	TGN M22	CAT-TP-22(b)
Ethane	TGN M22	CAT-TP-22(b)
Propane	TGN M22	CAT-TP-22(b)
Benzene	TGN M22	CAT-TP-22(b)
Toluene	TGN M22	CAT-TP-22(b)
m-Xylene	TGN M22	CAT-TP-22(b)
0-Xylene	TGN M22	CAT-TP-22(b)
p-Xylene	TGN M22	CAT-TP-22(b)
Ethylbenzene	TGN M22	CAT-TP-22(b)
Water Vapour	TGN M22	CAT-TP-22(b)
Carbon Dioxide	TGN M22	CAT-TP-22(b)

TOTAL VOCs (as CARBON): RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m³	230	69.1	36.4	112
Uncertainty	±mg/m³	8.6	2.8	5.3	5.6
Mass Emission	g/hr				
Uncertainty	±g/hr				

General Sampling Information

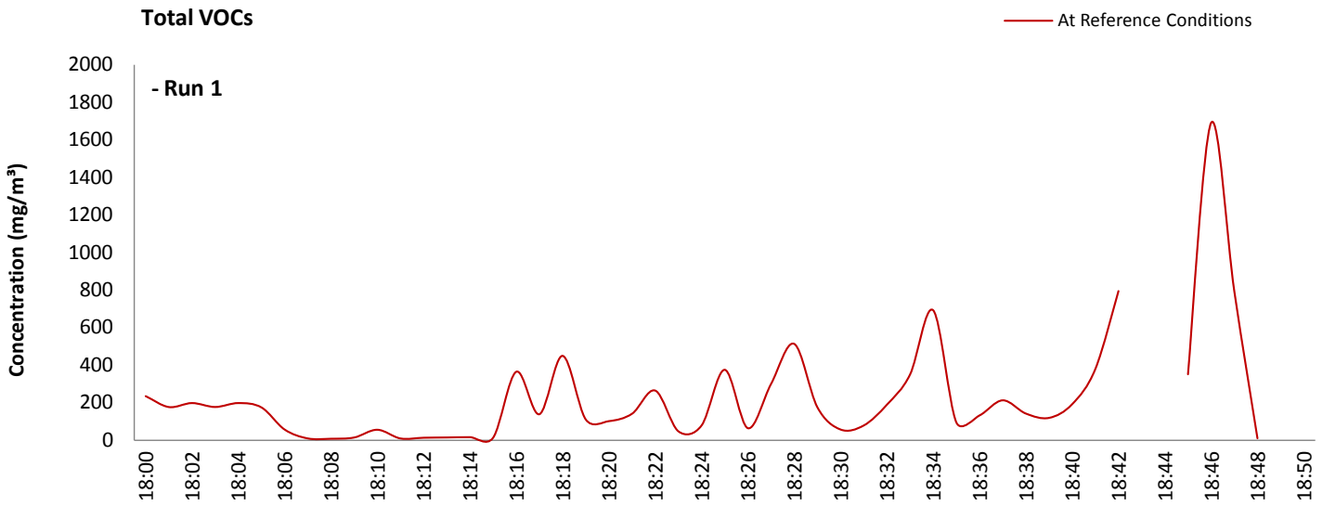
Parameter	Value	
Standard	EN 12619:2013	
Technical Procedure	CAT-TP-20	
Probe Material	Titanium	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Span Gas Type	Propane In Synthetic Air (5 Grade)	
Span Gas Reference Number	Cyl 1.0285a	
Span Gas Expiry Date	28/06/2022	
Span Gas Start Pressure (bar)	160	
Gas Cylinder Concentration (ppm)	8000	
Span Gas Set Point (ppm)	8000.00	
Span Gas Uncertainty (%)	N/A	
Zero Gas Type	Synthetic Air (5 Grade)	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

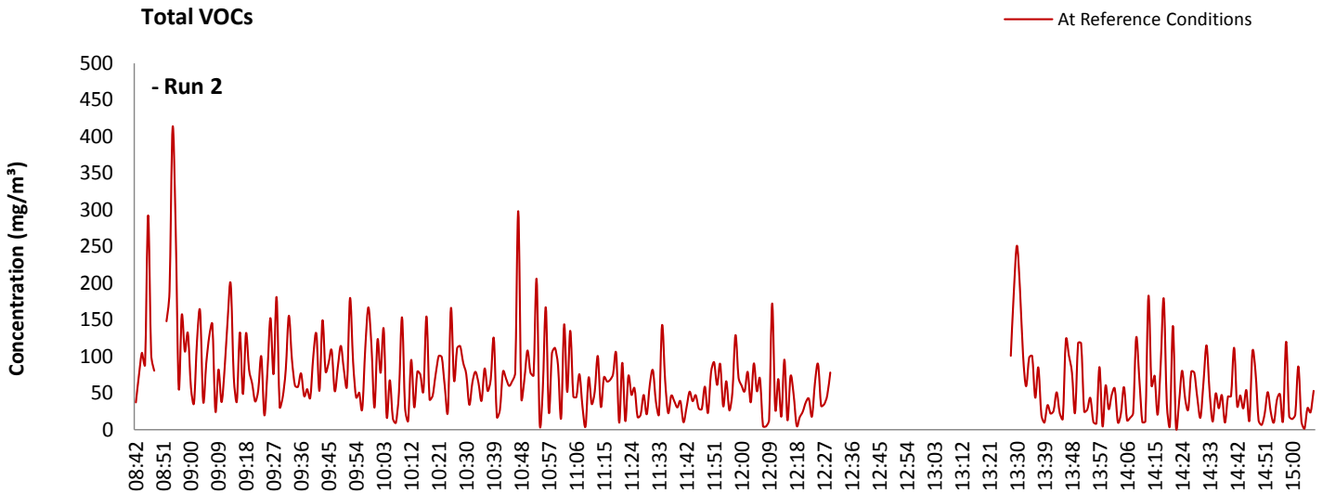
Reference Conditions

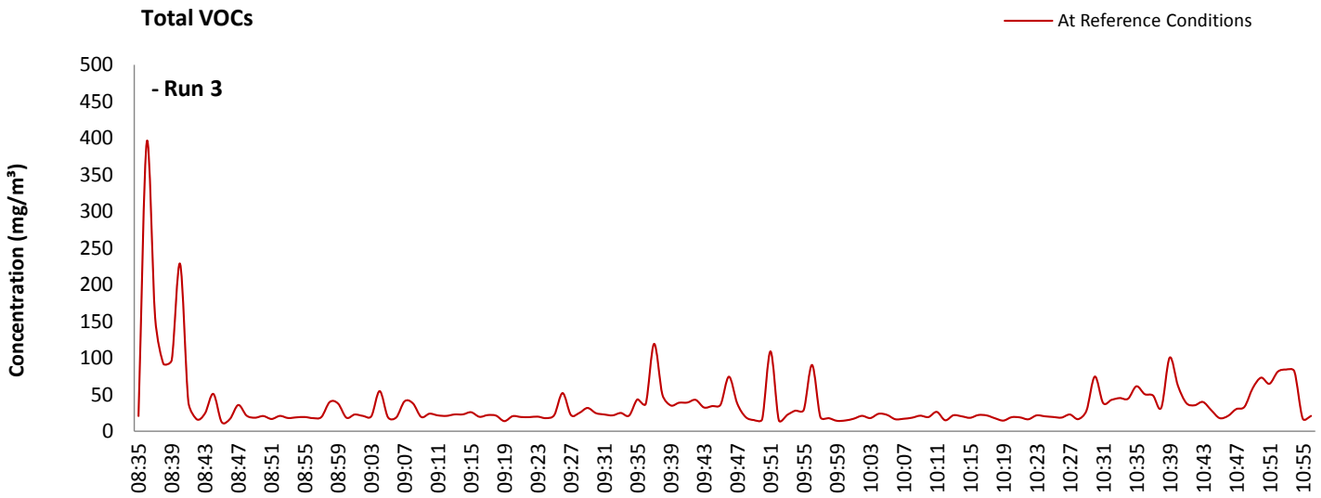
Reference Conditions are: 273K, 101.3kPa, dry gas, 3% oxygen.

TOTAL VOCs (as CARBON): DATA TREND

Graphical Trend of Data







TOTAL VOCs (as CARBON): SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1	Run 2	Run 3
Sampling Times	-	18:00 - 18:50	08:42 - 15:07	08:35 - 10:56
Sampling Dates	-	04/04/2018	05/04/2018	06/04/2018
Instrument Range	ppm	1000	1000	1000
Span Gas Value	ppm	8000	8000	8000

Quality Assurance

	Zero Drift	Units	Run 1	Run 2	Run 3
CAL 1	Zero Down Sampling Line (Pre)	ppm	0.00	0.00	0.00
	Zero Down Sampling Line (Post)	ppm	0.00	0.00	0.00
	Zero Drift	ppm	0.00	0.00	0.00
	Allowable Zero Drift	± ppm	400.00	400.00	400.00
	Zero Drift Acceptable	-	Yes	Yes	Yes

	Span Drift	Units	Run 1	Run 2	Run 3
CAL 1	Span Down Sampling Line (Pre)	ppm	7990.00	8020.00	7992.00
	Span Down Sampling Line (Post)	ppm	8020.00	7992.00	8000.00
	Span Drift	ppm	30.00	-28.00	8.00
	Allowable Span Drift	± ppm	400.00	400.00	400.00
	Span Drift Acceptable	-	Yes	Yes	Yes

Test Conditions	Units	Run 1	Run 2	Run 3
Run Ambient Temperature Range	°C	09 - 10	10 - 11	10 - 11

Method Deviations

Nature of Deviation (x = deviation applies to the associated run)	Run Number 1	2	3
There are no deviations associated with the sampling employed.	x	x	x

TOTAL VOCs (as CARBON): MEASUREMENT UNCERTAINTY CALCULATIONS

Performance characteristics	RUN 1	RUN 2	RUN 3	Units
Limit value	-	-	-	mg/m³ (REF)
TGN M2 Allowable MU	15.0	15.0	15.0	%
Measured concentration	32.71	23.83	3.03	mg/m³ (STP, dry)
Range Used	1000.0	1000.0	1000.0	ppm
Range Used [A]	1606.1	1606.1	1606.1	mg/m³
Cal gas conc.	8000.0	8000.0	8000.0	ppm
Conversion	1.61	1.61	1.61	ppm to mg/m³
MCERTS Range [B]	15.0	15.0	15.0	mg/m³
Lower of [A] or [B]	15.0	15.0	15.0	mg/m³
Cal gas conc.	12849.1	12849.1	12849.1	mg/m³

Performance characteristics	RUN 1	RUN 2	RUN 3	Units
Response time	45	45	45	seconds
Number of readings in measurement	50	265	142	-
Repeatability at zero	2.00	2.00	2.00	% full scale
Repeatability at span level	0.00	0.00	0.00	% full scale
Deviation from linearity	0.20	0.20	0.20	% of value
Zero drift	0.00	0.00	0.00	% full scale
Span drift	0.38	-0.35	0.10	% full scale
Volume or pressure flow dependence	1.60	1.60	1.60	% of full scale
Atmospheric pressure dependence	0.30	0.30	0.30	% of value/kPa
Ambient temperature dependence	1.40	1.40	1.40	% full scale/10K
Combined interference	0.45	0.45	0.45	% range
Dependence on voltage	0.50	0.50	0.50	% full scale/10V
Losses in the line (leak)	0.13	0.00	0.10	% of value
Uncertainty of calibration gas	2.00	2.00	2.00	% of value

Performance characteristic	RUN 1	RUN 2	RUN 3	Units
Standard deviation of repeatability at zero	use rep at span	use rep at span	use rep at span	mg/m³
Standard deviation of repeatability at span level	0.00	0.00	0.00	mg/m³
Lack of fit	0.02	0.02	0.02	mg/m³
Drift	0.07	-0.05	0.00	mg/m³
Volume or pressure flow dependence	0.00	0.00	0.00	mg/m³
Atmospheric pressure dependence	0.01	0.01	0.01	mg/m³
Ambient temperature dependence	0.20	0.20	0.20	mg/m³
Combined interference (from MCERTS Certificate)	0.04	0.04	0.04	mg/m³
Dependence on voltage	0.06	0.06	0.06	mg/m³
Losses in the line (leak)	0.02	0.00	0.00	mg/m³
Uncertainty of calibration gas	0.38	0.28	0.03	mg/m³

			RUN 1	RUN 2	RUN 3	Units
Measurement uncertainty		**Result**	32.71	23.83	3.03	mg/m³
Combined uncertainty			0.44	0.35	0.22	mg/m³
Expanded uncertainty	k =	1.96	0.87	0.69	0.43	mg/m³
Uncertainty corrected to std conds. (O_2)			6.11	2.01	5.20	mg/m³ (REF)

	RUN 1	RUN 2	RUN 3	Units
Expanded uncertainty (no O_2) - at 95% Confidence	2.65	2.92	14.30	% of Value
Expanded uncertainty (no O_2) - at 95% Confidence	N/A	N/A	N/A	% at ELV
Overall Allowable uncertainty (no O_2) - at 95% Confidence	N/A	N/A	N/A	% at ELV
Result of Compliance with Uncertainty Requirement in M2	N/A	N/A	N/A	-

	RUN 1	RUN 2	RUN 3	Units
Expanded uncertainty (with O_2) - at 95% Confidence	3.73	4.03	14.54	% of Value
Expanded uncertainty (with O_2) - at 95% Confidence	N/A	N/A	N/A	% at ELV
Overall Allowable uncertainty (with O_2) - at 95% Confidence	N/A	N/A	N/A	% at ELV
Result of Compliance with Uncertainty Requirement in M2	**N/A**	**N/A**	**N/A**	-

Requirement for SRM is that Uncertainty should be <15% of the value at the ELV, on a dry gas basis, or if O_2 correction is applied less than 15% + the uncertainty associated with the O_2 correction (using sqrt of sum squares to add uncertainty components). Ref EA TGN M2.

OXYGEN: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

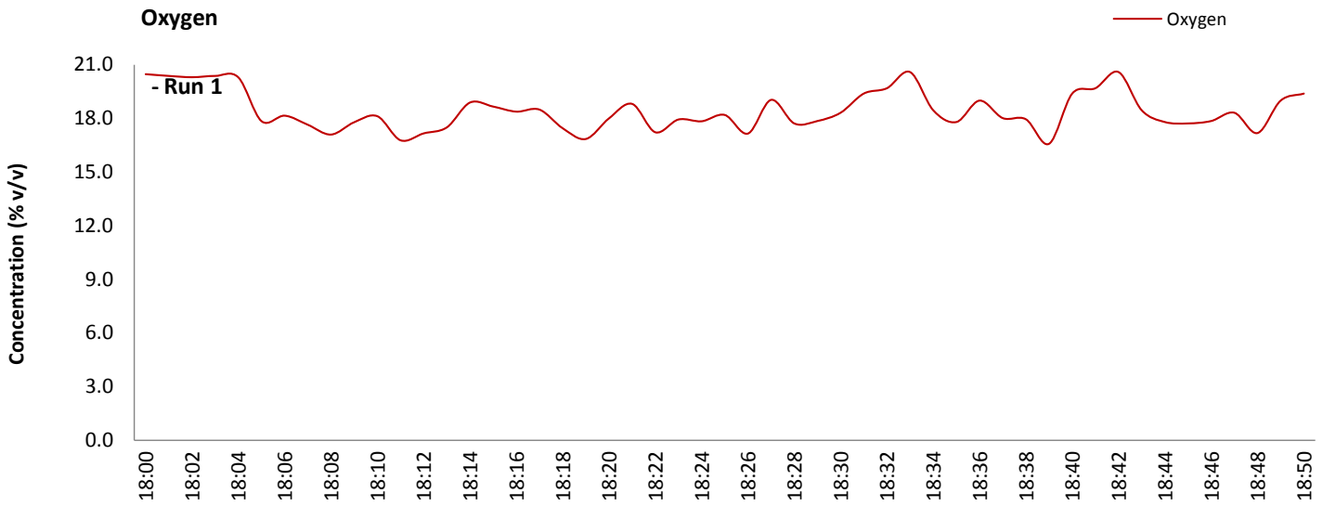
Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	% v/v	18.4	15.1	19.5	17.7
Uncertainty	±% v/v	0.48	0.42	0.51	0.47

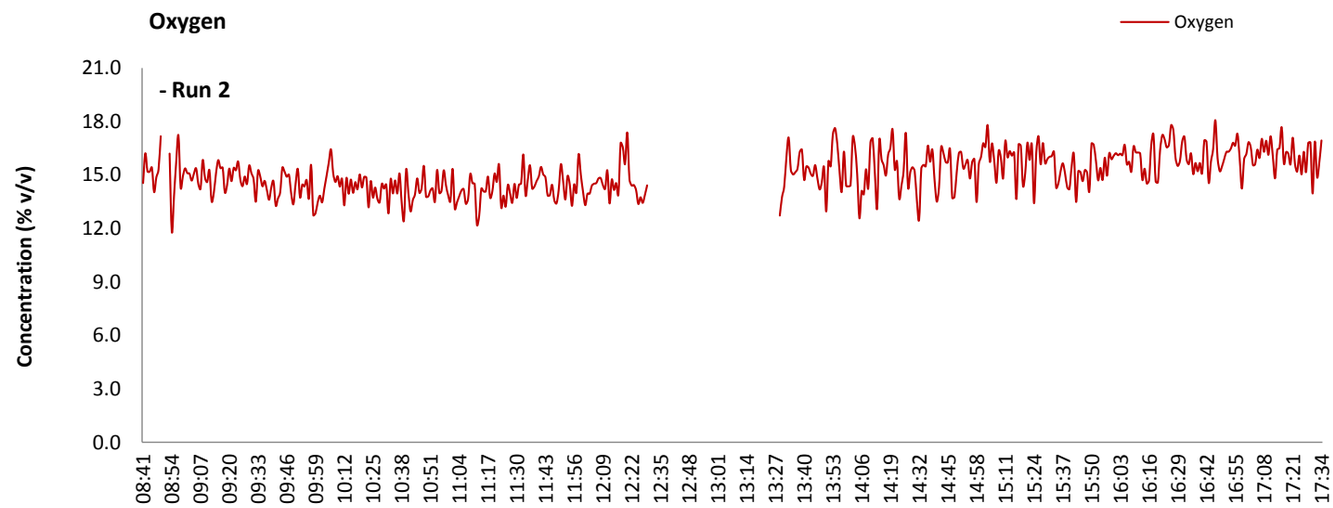
General Sampling Information

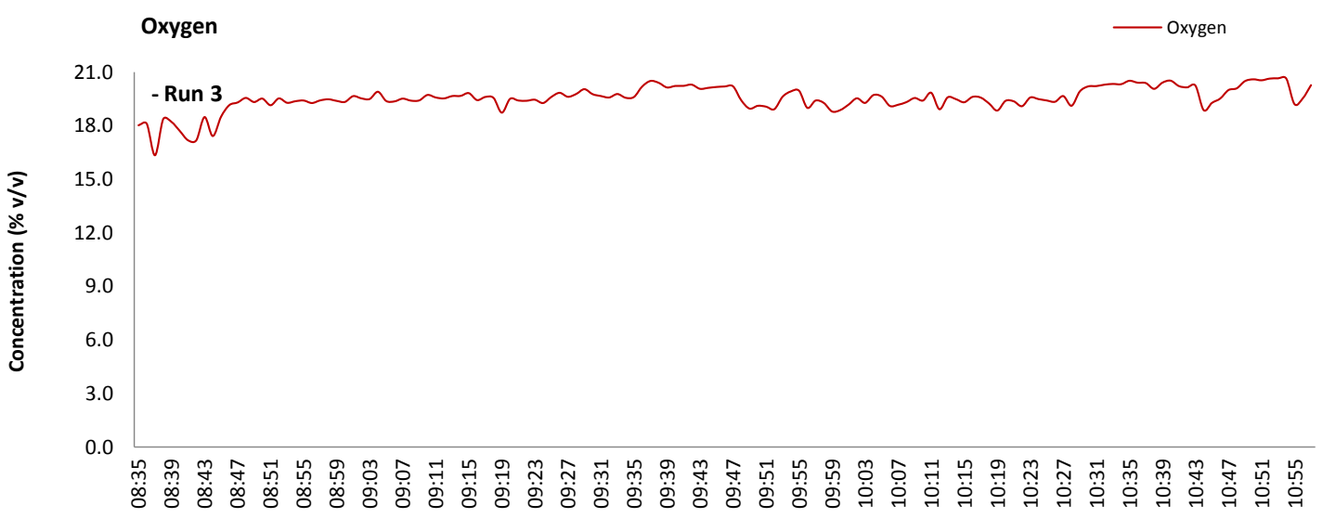
Parameter	Value	
Standard	EN 14789	
Technical Procedure	CAT-TP-21	
Probe Material	Titanium	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Span Gas Type	Synthetic Air (5 Grade)	
Span Gas Reference Number	Cyl 11.0309	
Span Gas Expiry Date	23/11/2022	
Span Gas Start Pressure (bar)	80	
Gas Cylinder Concentration (% v/v)	21.09	
Span Gas Uncertainty (%)	2	
Zero Gas Type	Nitrogen (5 Grade)	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

OXYGEN: DATA TREND

Graphical Trend of Data







OXYGEN: SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1	Run 2	Run 3
Sampling Times	-	18:00 - 18:50	08:41 - 17:34	08:35 - 10:57
Sampling Dates	-	04/04/2018	05/04/2018	06/04/2018
Instrument Range	% v/v	25	25	25
Span Gas Value	% v/v	21.09	21.09	25.00

Quality Assurance

Conditioning Unit Temperature	Units	Run 1	Run 2	Run 3
Average Temperature	°C	2.6	2.8	2.8
Allowable Temperature	< °C	4.0	4.0	4.0
Temperature Acceptable	-	Yes	Yes	Yes

	Zero Drift	Units	Run 1	Run 2	Run 3
CAL 1	Zero Down Sampling Line (Pre)	% v/v	0.00	0.00	0.00
CAL 1	Zero Down Sampling Line (Post)	% v/v	0.00	0.00	0.04
CAL 1	Zero Drift	% v/v	0.00	0.00	0.04
	Allowable Zero Drift	± % v/v	1.05	1.05	1.25
	Zero Drift Acceptable	-	Yes	Yes	Yes

	Span Drift	Units	Run 1	Run 2	Run 3
CAL 1	Span Down Sampling Line (Pre)	% v/v	21.09	21.10	21.09
CAL 1	Span Down Sampling Line (Post)	% v/v	21.10	21.10	21.12
CAL 1	Span Drift	% v/v	0.01	0.00	0.03
	Allowable Span Drift	± % v/v	1.05	1.05	1.25
	Span Drift Acceptable	-	Yes	Yes	Yes

Test Conditions	Units	Run 1	Run 2	Run 3
Run Ambient Temperature Range	°C	9 - 10	10 - 11	10 - 11

Method Deviations

Nature of Deviation (x = deviation applies to the associated run)	Run Number 1	2	3
There are no deviations associated with the sampling employed.	x	x	x

OXYGEN: MEASUREMENT UNCERTAINTY CALCULATIONS

Performance characteristics	RUN 1	RUN 2	RUN 3	Units
Limit value	N/A	N/A	N/A	%vol
TGN M2 Allowable MU	6.0	6.0	6.0	%
Measured concentration	18.42	15.08	19.51	%vol
Range Used	25.0	25.0	25.0	%vol
Cal gas conc.	21.1	21.1	21.1	%vol

Performance characteristics	RUN 1	RUN 2	RUN 3	Units
Response time	60	60	60	seconds
Number of readings in measurement	50	413	142	-
Repeatability at zero	0.04	0.04	0.04	% full scale
Repeatability at span level	0.04	0.04	0.04	% full scale
Deviation from linearity	0.30	0.30	0.30	% of value
Zero drift	0.00	0.00	0.19	% full scale
Span drift	0.05	0.00	0.14	% full scale
Volume or pressure flow dependence	0.20	0.20	0.20	% of full scale
Atmospheric pressure dependence	0.30	0.30	0.30	% of value/kPa
Ambient temperature dependence	-0.07	-0.07	-0.07	% full scale/10K
Combined interference	0.56	0.56	0.56	% range
Dependence on voltage	0.02	0.02	0.02	% full scale/10V
Losses in the line (leak)	0.00	0.00	0.00	% of value
Uncertainty of calibration gas	2.00	2.00	2.00	% of value

Performance characteristic	RUN 1	RUN 2	RUN 3	Units
Standard deviation of repeatability at zero	use rep at span	use rep at span	use rep at span	%vol
Standard deviation of repeatability at span level	0.01	0.00	0.00	%vol
Lack of fit	0.04	0.04	0.04	%vol
Drift	0.01	0.00	0.04	%vol
Volume or pressure flow dependence	0.00	0.00	0.00	%vol
Atmospheric pressure dependence	0.02	0.02	0.02	%vol
Ambient temperature dependence	-0.01	-0.01	-0.01	%vol
Combined interference (from MCERTS Certificate)	0.08	0.08	0.08	%vol
Dependence on voltage	0.00	0.00	0.00	%vol
Losses in the line (leak)	0.00	0.00	0.00	%vol
Uncertainty of calibration gas	0.21	0.17	0.23	%vol

			RUN 1	RUN 2	RUN 3	Units
Measurement uncertainty		**Result**	18.42	15.08	19.51	%vol
Combined uncertainty			0.25	0.21	0.26	%vol
Expanded uncertainty	k =	1.96	0.48	0.42	0.51	%vol

	RUN 1	RUN 2	RUN 3	Units
Expanded uncertainty (no O_2) - at 95% Confidence	2.62	2.78	2.62	% of Value
Result of Compliance with Uncertainty Requirement in M2	**COMPLIANT**	**COMPLIANT**	**COMPLIANT**	-

Requirement for SRM is that Uncertainty should be 0.5%vol absolute or 6% relative whichever is the lower, on a dry gas basis. Ref EA TGN M2.

OXIDES OF NITROGEN (AS NO_2): RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m³	193	197	159	183
Uncertainty	±mg/m³	12.8	11.9	10.2	11.7
Mass Emission	g/hr				
Uncertainty	±g/hr				

General Sampling Information

Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	1548 - 1677, 1872 - 2013, 2811 - 3160	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	NO	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	409.6	
Check Gas Uncertainty (%)	2	
Zero Gas Type	Nitrogen (5 Grade)	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

References Used in Analytical Algorithm Application

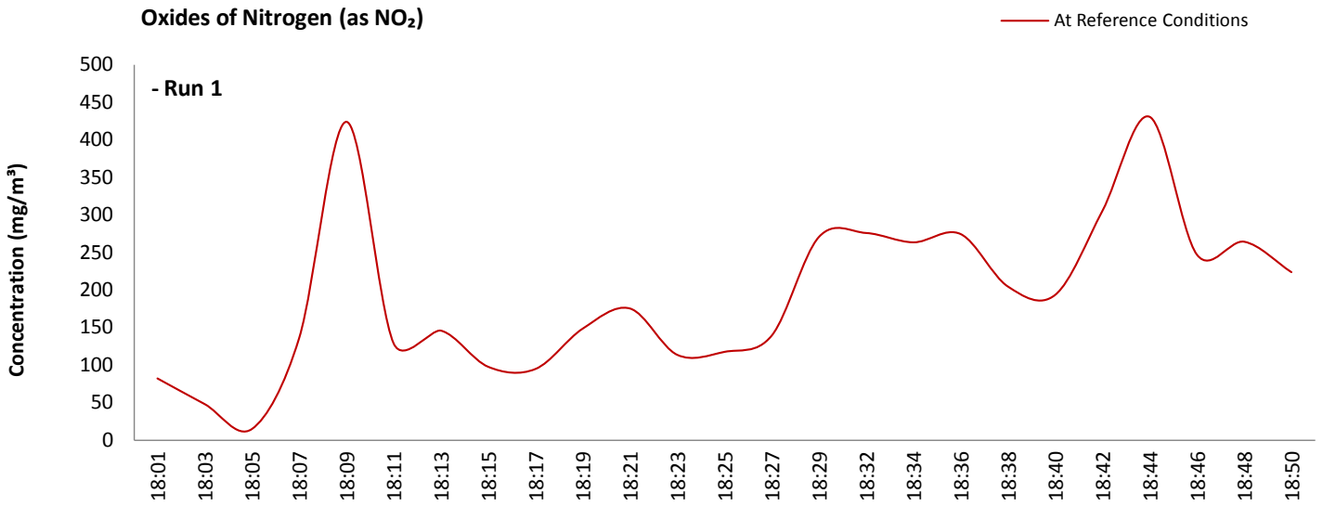
Type of Reference	Concentration of References
Transportable	10 - 1001.5ppm

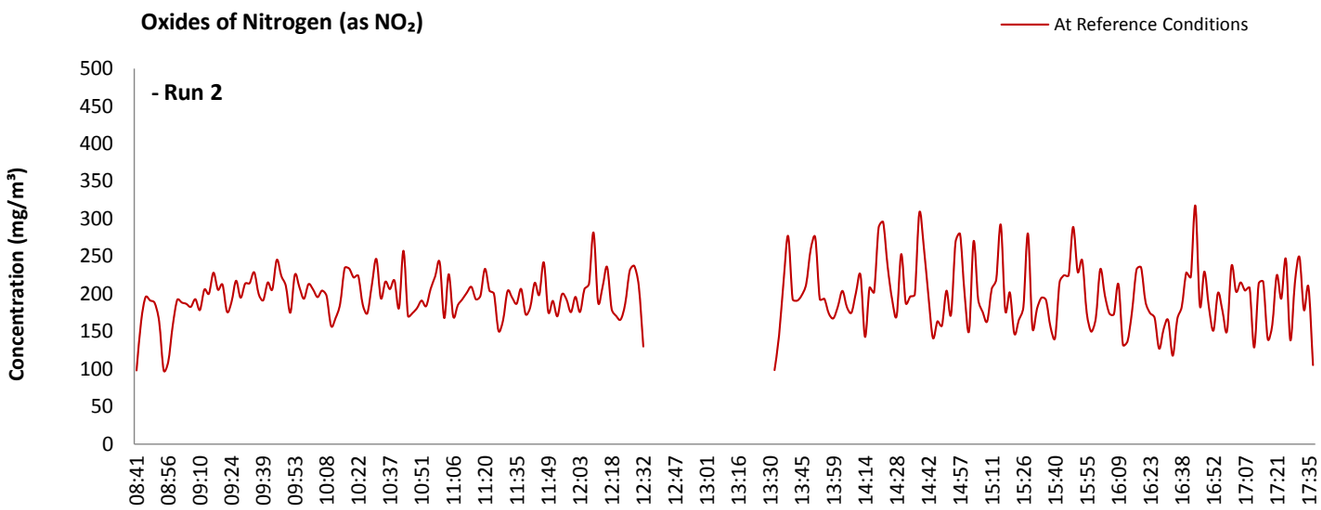
Reference Conditions

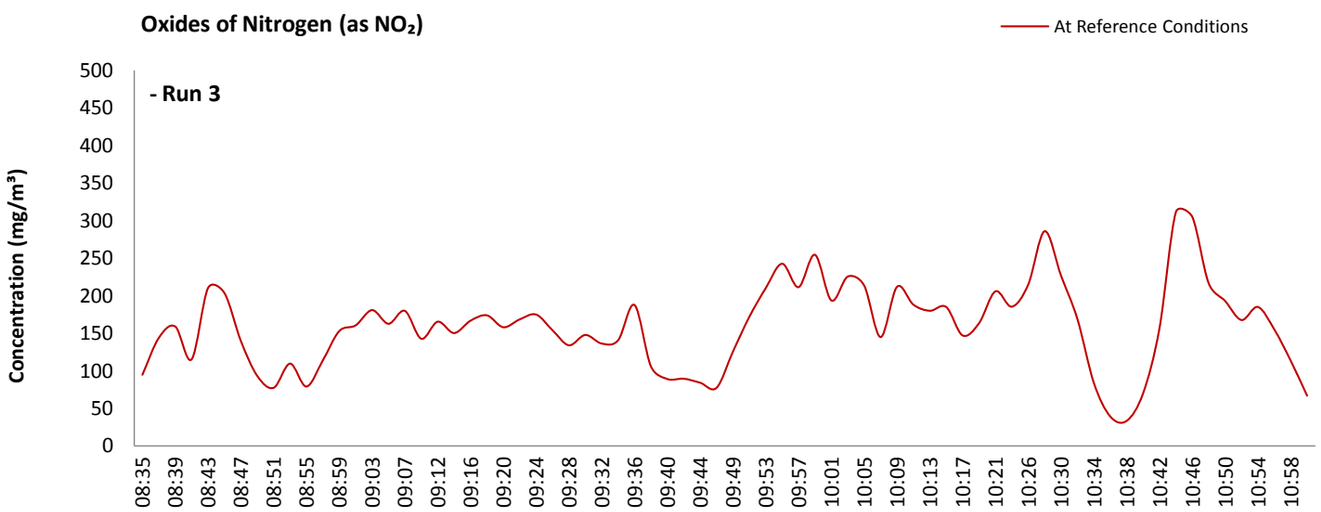
Reference Conditions are: 273K, 101.3kPa, dry gas, 3% oxygen.

OXIDES OF NITROGEN (AS NO_2): DATA TREND

Graphical Trend of Data







OXIDES OF NITROGEN (AS NO_2): MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (ppm)	13.33
Oxides of Nitrogen (as NO_2)				Range (ppm)	20
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	1.67	rectangular	√3	0.13	0.13
Zero Drift	0.50	rectangular	√3	0.20	0.06
Span Drift	2.00	rectangular	√3	0.20	0.23
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	0.03	rectangular	√3	0.02	0.00
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.04	0.00
Interferents	2.80	rectangular	√3	0.20	0.32
Standard Deviation of Repeatability at Zero	0.18	normal	1	0.20	0.04
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.13	0.13
Combined Uncertainty	-	normal	-	-	0.44
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.89
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	6.65

RUN 2				Measured (ppm)	30.83
Oxides of Nitrogen (as NO_2)				Range (ppm)	41
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	1.67	rectangular	√3	0.31	0.30
Zero Drift	0.50	rectangular	√3	0.41	0.12
Span Drift	2.00	rectangular	√3	0.41	0.47
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	0.03	rectangular	√3	0.04	0.00
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.08	0.00
Interferents	2.80	rectangular	√3	0.41	0.66
Standard Deviation of Repeatability at Zero	0.18	normal	1	0.41	0.07
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.31	0.31
Combined Uncertainty	-	normal	-	-	0.93
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	1.86
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	6.04

RUN 3				Measured (ppm)	6.97
Oxides of Nitrogen (as NO_2)				Range (ppm)	10
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	1.67	rectangular	√3	0.07	0.07
Zero Drift	0.50	rectangular	√3	0.10	0.03
Span Drift	2.00	rectangular	√3	0.10	0.12
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	0.03	rectangular	√3	0.01	0.00
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.02	0.00
Interferents	2.80	rectangular	√3	0.10	0.16
Standard Deviation of Repeatability at Zero	0.18	normal	1	0.10	0.02
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.07	0.07
Combined Uncertainty	-	normal	-	-	0.22
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.45
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	6.42

SULPHUR DIOXIDE: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m³	0.77	5.9	40.7	15.8
Uncertainty	±mg/m³	9.7	4.3	15.3	9.7
Mass Emission	g/hr				
Uncertainty	±g/hr				

General Sampling Information

Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	1019 - 1233, 1295 - 1415, 2810 - 2936, 3388 - 3405	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	SO_2	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	100.6	
Check Gas Uncertainty (%)	2	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

References Used in Analytical Algorithm Application

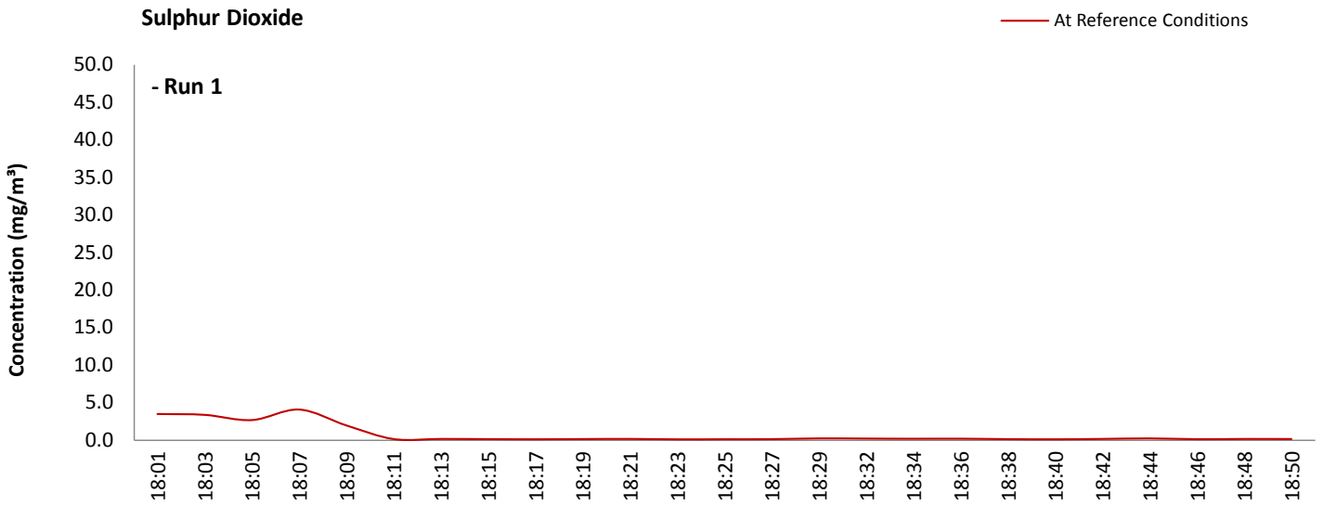
Type of Reference	Concentration of References
Transportable	10 - 9989ppm

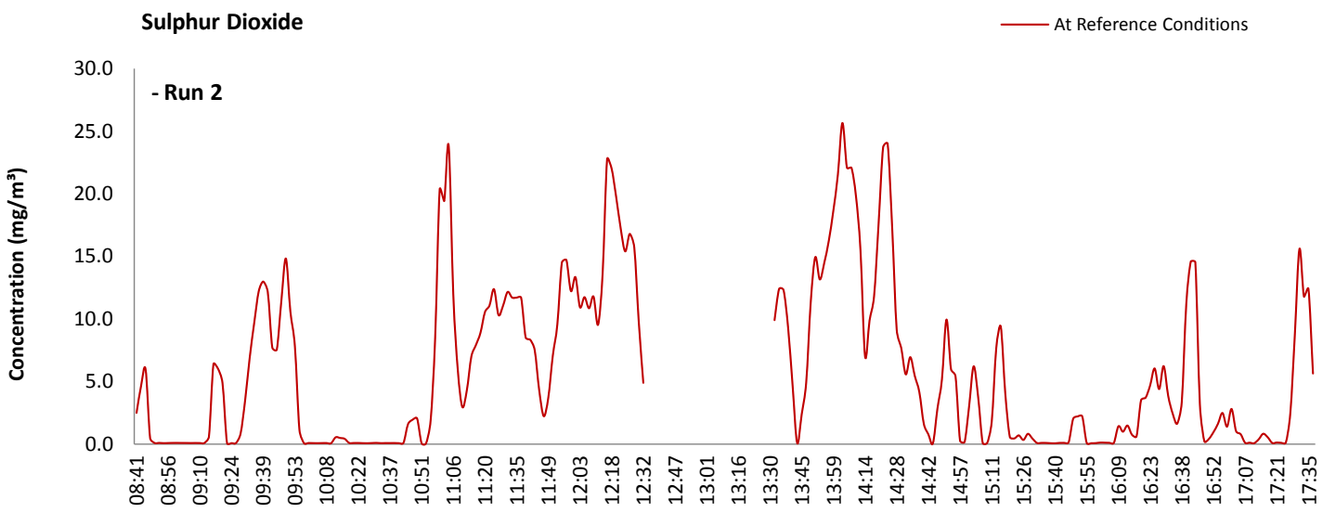
Reference Conditions

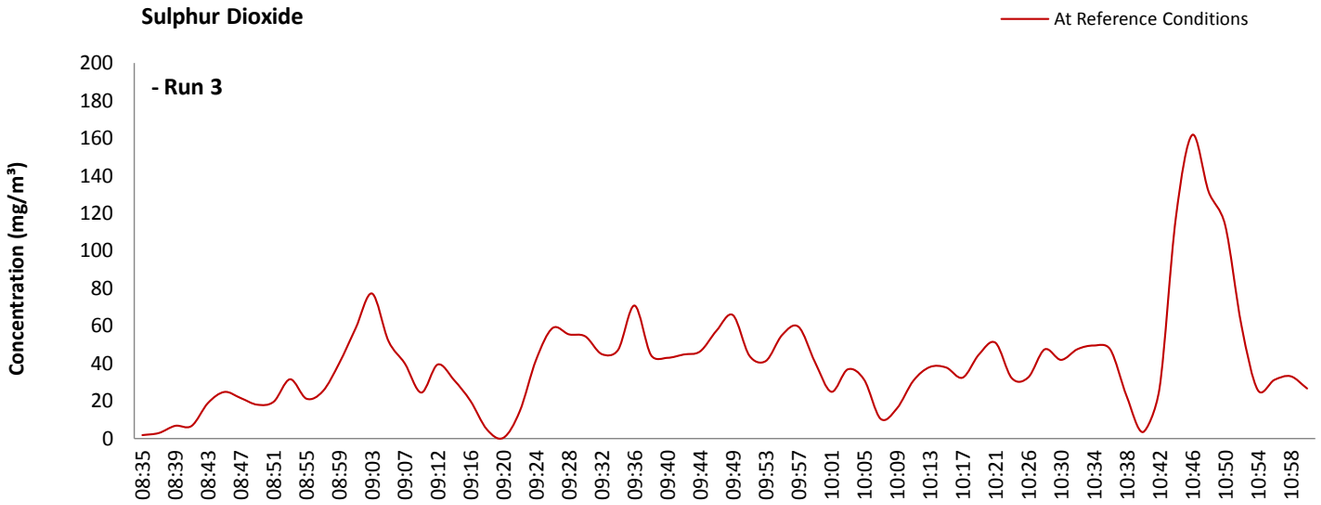
Reference Conditions are: 273K, 101.3kPa, dry gas, 3% oxygen.

SULPHUR DIOXIDE: DATA TREND

Graphical Trend of Data







SULPHUR DIOXIDE: MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (ppm)	0.04
Sulphur Dioxide				Range (ppm)	10
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	0.80	rectangular	√3	0.0004	0.0002
Zero Drift	0.50	rectangular	√3	0.1000	0.0289
Span Drift	2.00	rectangular	√3	0.1000	0.1155
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.0000
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.0000
Sensitivity to Ambient Temperature	0.06	rectangular	√3	0.0100	0.0003
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.0200	0.0000
Interferents	3.60	rectangular	√3	0.1000	0.2078
Standard Deviation of Repeatability at Zero	0.10	normal	1	0.1000	0.0100
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.0000
Uncertainty of Certified Reference Material	2.00	normal	2	0.0004	0.0004
Combined Uncertainty	-	normal	-	-	0.24
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.48
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	1252.71

RUN 2				Measured (ppm)	0.66
Sulphur Dioxide				Range (ppm)	10
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	0.80	rectangular	√3	0.007	0.003
Zero Drift	0.50	rectangular	√3	0.100	0.029
Span Drift	2.00	rectangular	√3	0.100	0.115
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Ambient Temperature	0.06	rectangular	√3	0.010	0.000
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.020	0.000
Interferents	3.60	rectangular	√3	0.100	0.208
Standard Deviation of Repeatability at Zero	0.10	normal	1	0.100	0.010
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.000
Uncertainty of Certified Reference Material	2.00	normal	2	0.007	0.007
Combined Uncertainty	-	normal	-	-	0.24
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.48
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	72.81

RUN 3				Measured (ppm)	1.28
Sulphur Dioxide				Range (ppm)	10
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	0.80	rectangular	√3	0.013	0.006
Zero Drift	0.50	rectangular	√3	0.100	0.029
Span Drift	2.00	rectangular	√3	0.100	0.115
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Ambient Temperature	0.06	rectangular	√3	0.010	0.000
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.020	0.000
Interferents	3.60	rectangular	√3	0.100	0.208
Standard Deviation of Repeatability at Zero	0.10	normal	1	0.100	0.010
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.000
Uncertainty of Certified Reference Material	2.00	normal	2	0.013	0.013
Combined Uncertainty	-	normal	-	-	0.24
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.48
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	37.55

CARBON MONOXIDE: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m³	673	684	210	522
Uncertainty	±mg/m³	32.2	35.3	11.8	26.4
Mass Emission	g/hr				
Uncertainty	±g/hr				

General Sampling Information

Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	2021 - 2201	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	CO	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	94.8	
Check Gas Uncertainty (%)	2	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

References Used in Analytical Algorithm Application

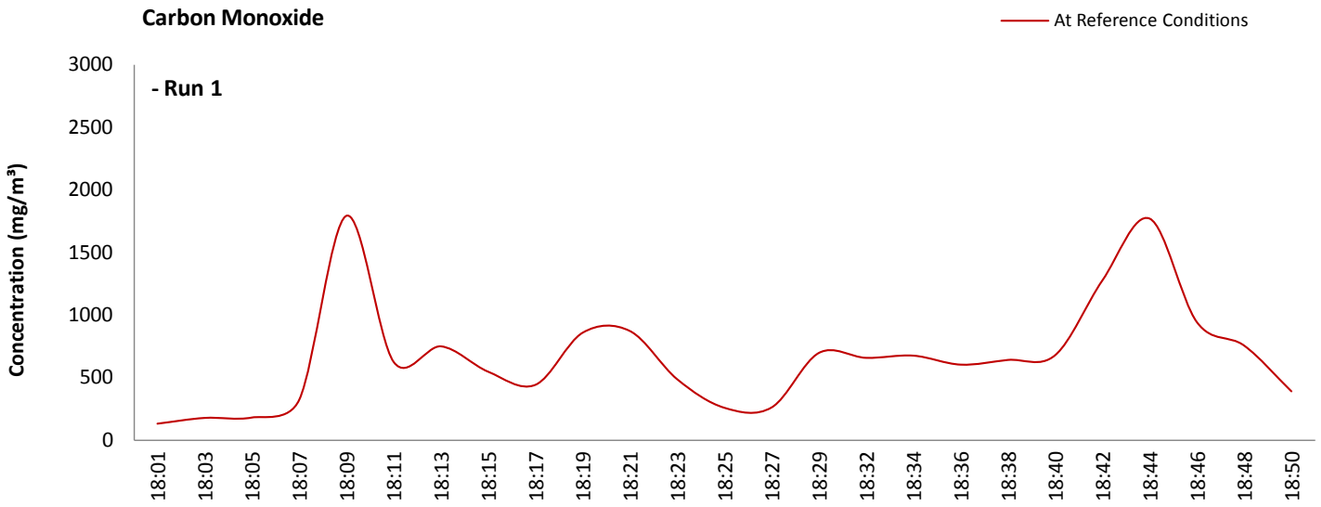
Type of Reference	Concentration of References
Transportable	10 - 745ppm

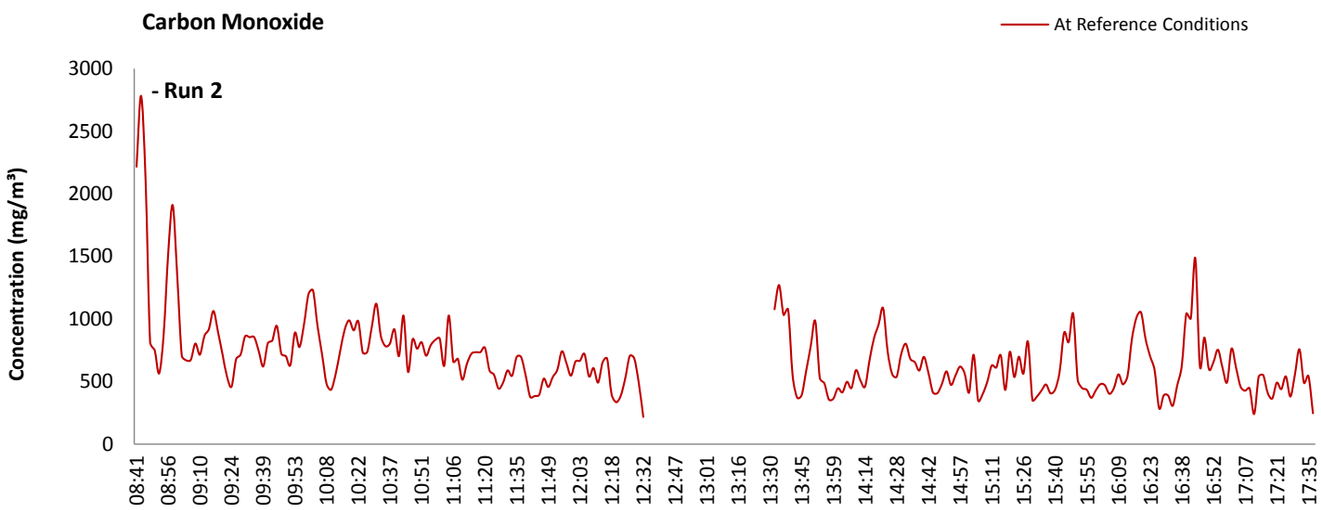
Reference Conditions

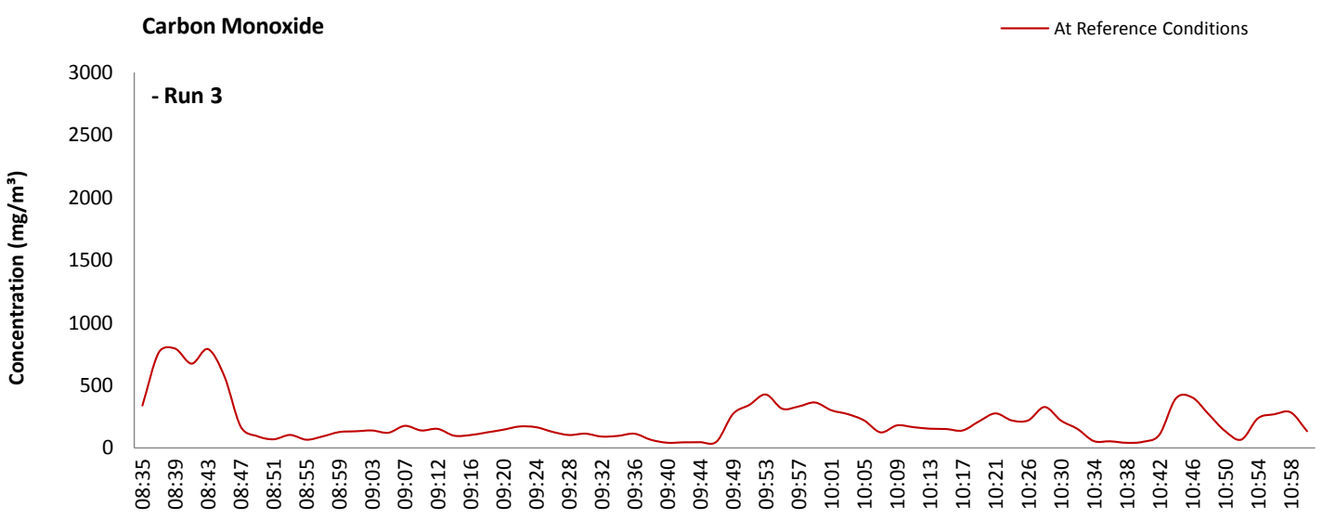
Reference Conditions are: 273K, 101.3kPa, dry gas, 3% oxygen.

CARBON MONOXIDE: DATA TREND

Graphical Trend of Data







CARBON MONOXIDE: MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (ppm)	76.38
Carbon Monoxide				Range (ppm)	78.0
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	1.22	rectangular	√3	0.76	0.54
Zero Drift	0.50	rectangular	√3	0.78	0.23
Span Drift	2.00	rectangular	√3	0.78	0.90
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	0.02	rectangular	√3	0.08	0.00
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.16	0.00
Interferents	2.80	rectangular	√3	0.78	1.26
Standard Deviation of Repeatability at Zero	0.16	normal	1	0.78	0.12
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.76	0.76
Combined Uncertainty	-	normal	-	-	1.83
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	3.66
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	4.79

RUN 2				Measured (ppm)	175.76
Carbon Monoxide				Range (ppm)	198
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	1.22	rectangular	√3	1.8	1.24
Zero Drift	0.50	rectangular	√3	2.0	0.57
Span Drift	2.00	rectangular	√3	2.0	2.29
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	0.02	rectangular	√3	0.2	0.00
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.4	0.00
Interferents	2.80	rectangular	√3	2.0	3.20
Standard Deviation of Repeatability at Zero	0.16	normal	1	2.0	0.32
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	1.8	1.76
Combined Uncertainty	-	normal	-	-	4.53
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	9.06
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	5.15

RUN 3				Measured (ppm)	15.07
Carbon Monoxide				Range (ppm)	19
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	1.22	rectangular	√3	0.151	0.11
Zero Drift	0.50	rectangular	√3	0.190	0.05
Span Drift	2.00	rectangular	√3	0.190	0.22
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	0.02	rectangular	√3	0.019	0.00
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.038	0.00
Interferents	2.80	rectangular	√3	0.190	0.31
Standard Deviation of Repeatability at Zero	0.16	normal	1	0.190	0.03
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.151	0.15
Combined Uncertainty	-	normal	-	-	0.42
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.85
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	5.64

METHANE: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m³	82.9	51.9	23.6	52.8
Uncertainty	±mg/m³	14.2	6.4	22.1	14.3
Mass Emission	g/hr				
Uncertainty	±g/hr				

General Sampling Information

Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	2991 - 3033	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	C_3H_8	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	87.74	
Check Gas Uncertainty (%)	2	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

References Used in Analytical Algorithm Application

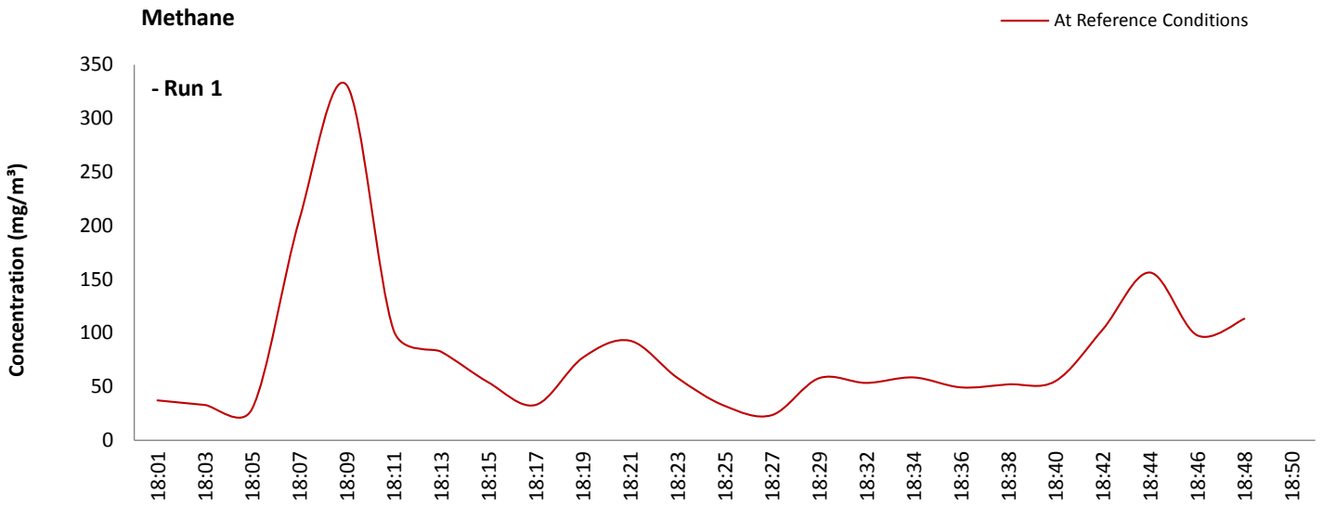
Type of Reference	Concentration of References
Transportable	49.5 - 1054

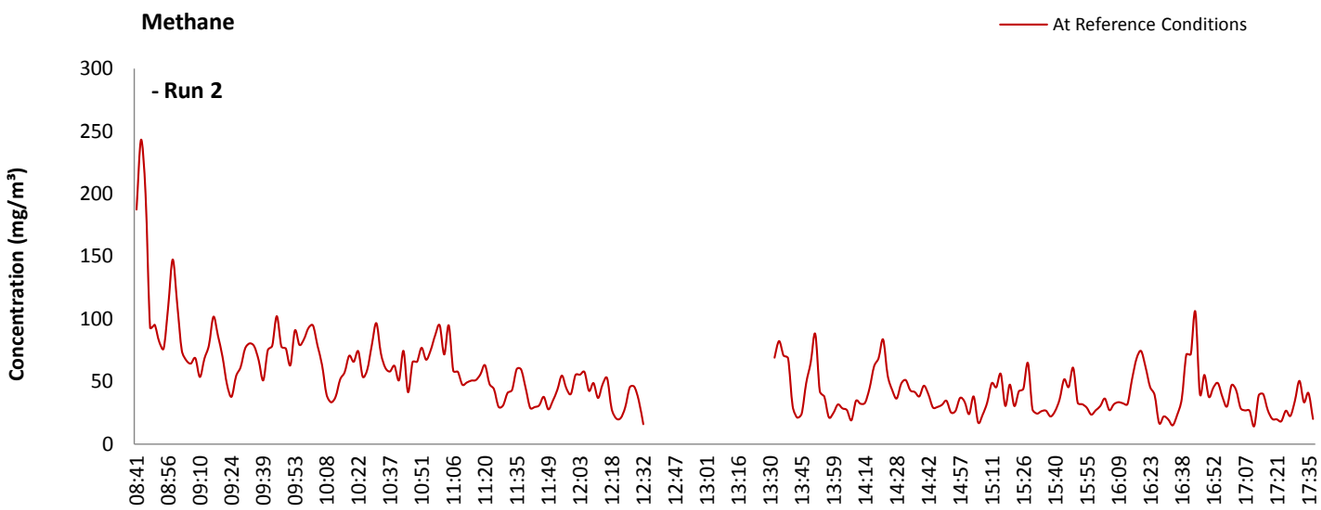
Reference Conditions

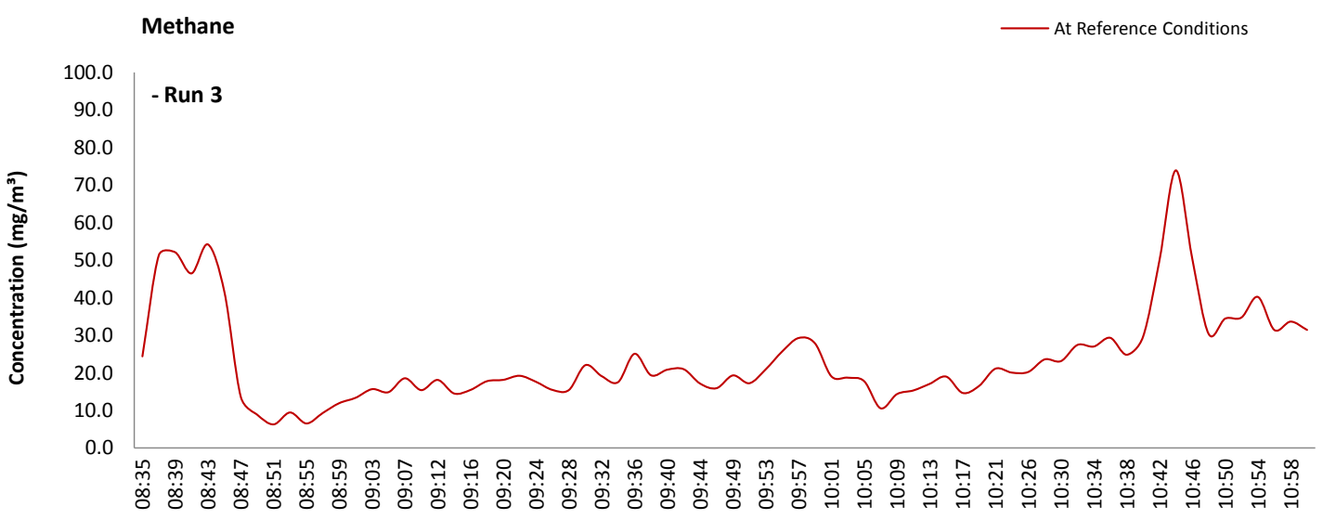
Reference Conditions are: 273K, 101.3kPa, dry gas, 3% oxygen.

METHANE: DATA TREND

Graphical Trend of Data







METHANE: MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (ppm)	16.46
Methane				Range (ppm)	49.9
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.16	0.19
Zero Drift	0.50	rectangular	√3	0.50	0.14
Span Drift	2.00	rectangular	√3	0.50	0.58
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.05	0.09
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.10	0.00
Interferents	4.00	rectangular	√3	0.50	1.15
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.50	0.50
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.16	0.16
Combined Uncertainty	-	normal	-	-	1.41
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	2.83
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	17.19

RUN 2				Measured (ppm)	23.34
Methane				Range (ppm)	49.9
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.23	0.27
Zero Drift	0.50	rectangular	√3	0.50	0.14
Span Drift	2.00	rectangular	√3	0.50	0.58
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.05	0.09
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.10	0.00
Interferents	4.00	rectangular	√3	0.50	1.15
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.50	0.50
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.23	0.23
Combined Uncertainty	-	normal	-	-	1.44
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	2.87
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	12.31

RUN 3				Measured (ppm)	2.97
Methane				Range (ppm)	49.9
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.03	0.03
Zero Drift	0.50	rectangular	√3	0.50	0.14
Span Drift	2.00	rectangular	√3	0.50	0.58
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.05	0.09
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.10	0.00
Interferents	4.00	rectangular	√3	0.50	1.15
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.50	0.50
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.03	0.03
Combined Uncertainty	-	normal	-	-	1.39
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	2.79
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	93.73

ETHANE: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m³	2.1	1.1	4.2	2.4
Uncertainty	±mg/m³	5.3	2.3	8.3	5.3
Mass Emission	g/hr				
Uncertainty	±g/hr				

General Sampling Information

Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	2974 - 3181	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	C_3H_8	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	87.74	
Check Gas Uncertainty (%)	2	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

References Used in Analytical Algorithm Application

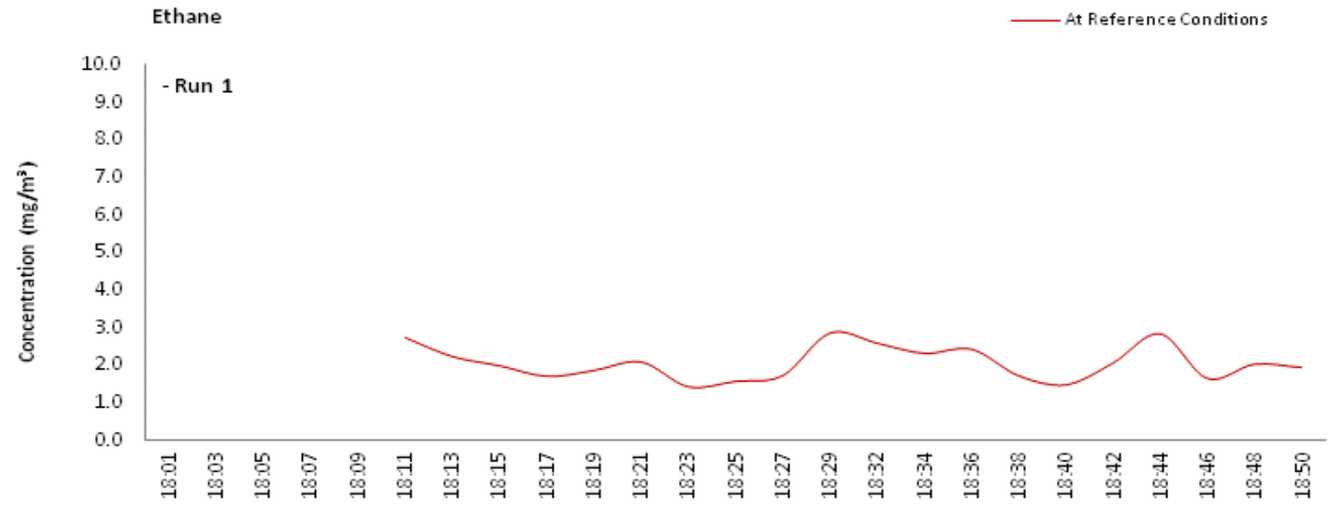
Type of Reference	Concentration of References
Transportable	10 - 100ppm

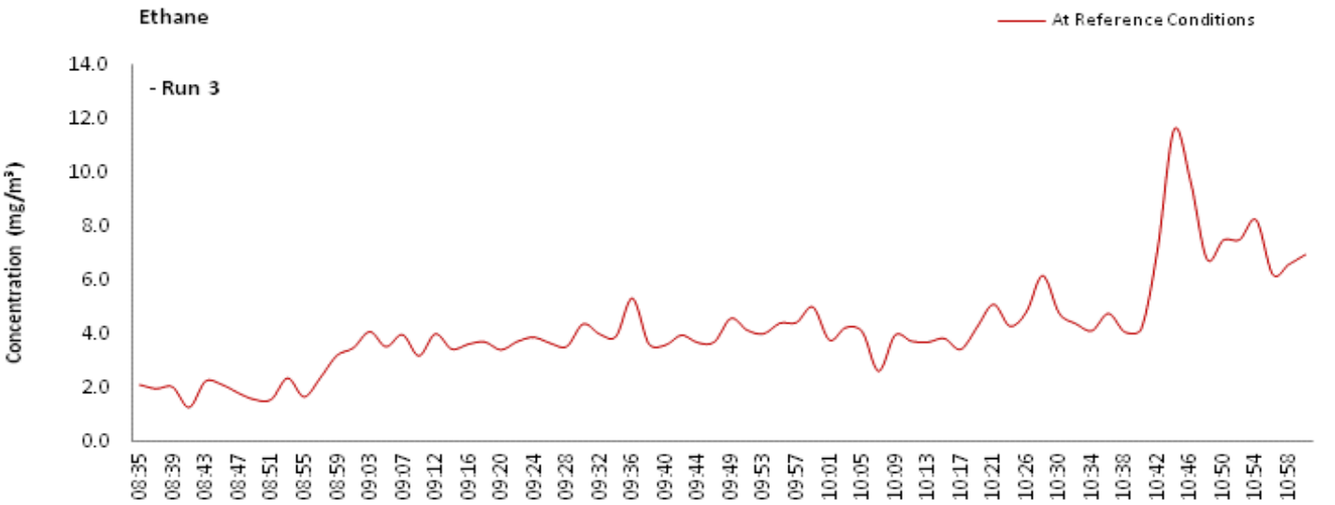
Reference Conditions

Reference Conditions are: 273K, 101.3kPa, dry gas, 3% oxygen.

ETHANE: DATA TREND

Graphical Trend of Data





ETHANE: MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (ppm)	0.22
Ethane				Range (ppm)	10
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.002	0.003
Zero Drift	0.50	rectangular	√3	0.100	0.029
Span Drift	2.00	rectangular	√3	0.100	0.115
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.010	0.017
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.020	0.000
Interferents	4.00	rectangular	√3	0.100	0.231
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.100	0.100
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.000
Uncertainty of Certified Reference Material	2.00	normal	2	0.002	0.002
Combined Uncertainty	-	normal	-	-	0.28
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.56
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	256.70

RUN 2				Measured (ppm)	0.26
Ethane				Range (ppm)	10
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.003	0.003
Zero Drift	0.50	rectangular	√3	0.100	0.029
Span Drift	2.00	rectangular	√3	0.100	0.115
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.010	0.017
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.020	0.000
Interferents	4.00	rectangular	√3	0.100	0.231
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.100	0.100
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.000
Uncertainty of Certified Reference Material	2.00	normal	2	0.003	0.003
Combined Uncertainty	-	normal	-	-	0.28
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.56
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	217.63

RUN 3				Measured (ppm)	0.28
Ethane				Range (ppm)	10
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.003	0.003
Zero Drift	0.50	rectangular	√3	0.100	0.029
Span Drift	2.00	rectangular	√3	0.100	0.115
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.010	0.017
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.020	0.000
Interferents	4.00	rectangular	√3	0.100	0.231
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.100	0.100
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.000
Uncertainty of Certified Reference Material	2.00	normal	2	0.003	0.003
Combined Uncertainty	-	normal	-	-	0.28
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.56
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	198.62

PROPANE: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m³	72.3	7.2	65.4	48.3
Uncertainty	±mg/m³	7.4	3.2	11.5	7.4
Mass Emission	g/hr				
Uncertainty	±g/hr				

General Sampling Information

Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	2810 - 3038	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	C_3H_8	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	87.74	
Check Gas Uncertainty (%)	2	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

References Used in Analytical Algorithm Application

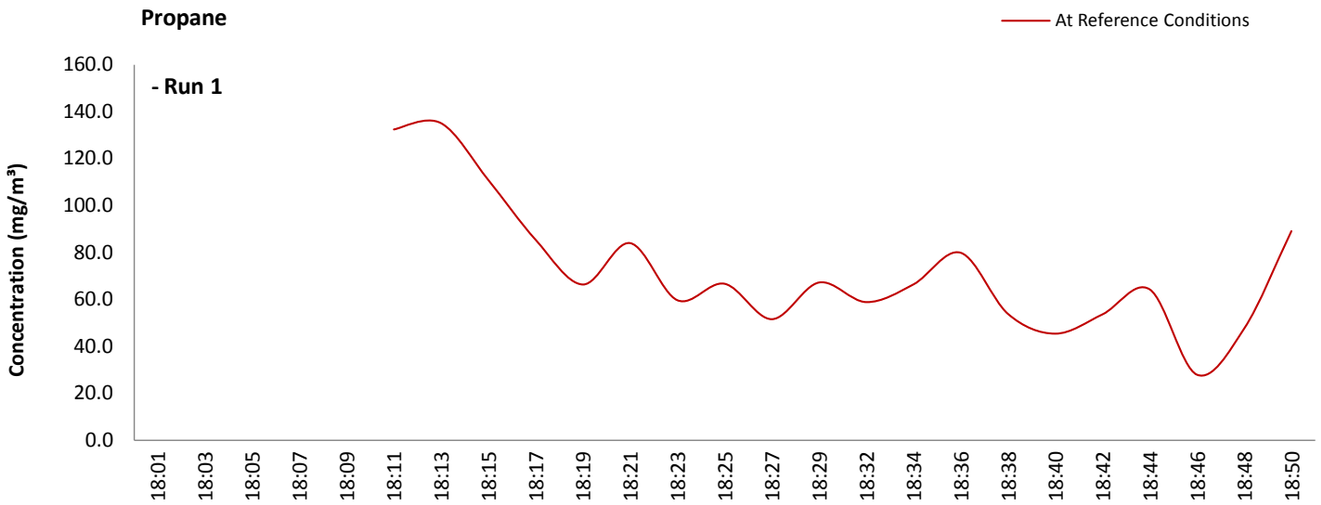
Type of Reference	Concentration of References
Transportable	10 - 100ppm

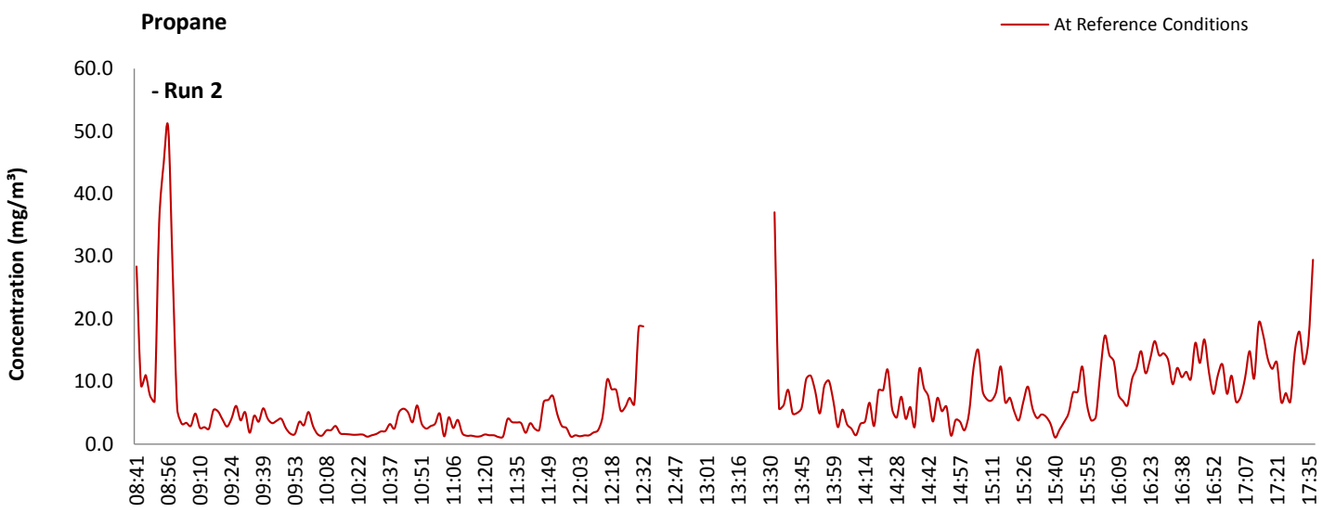
Reference Conditions

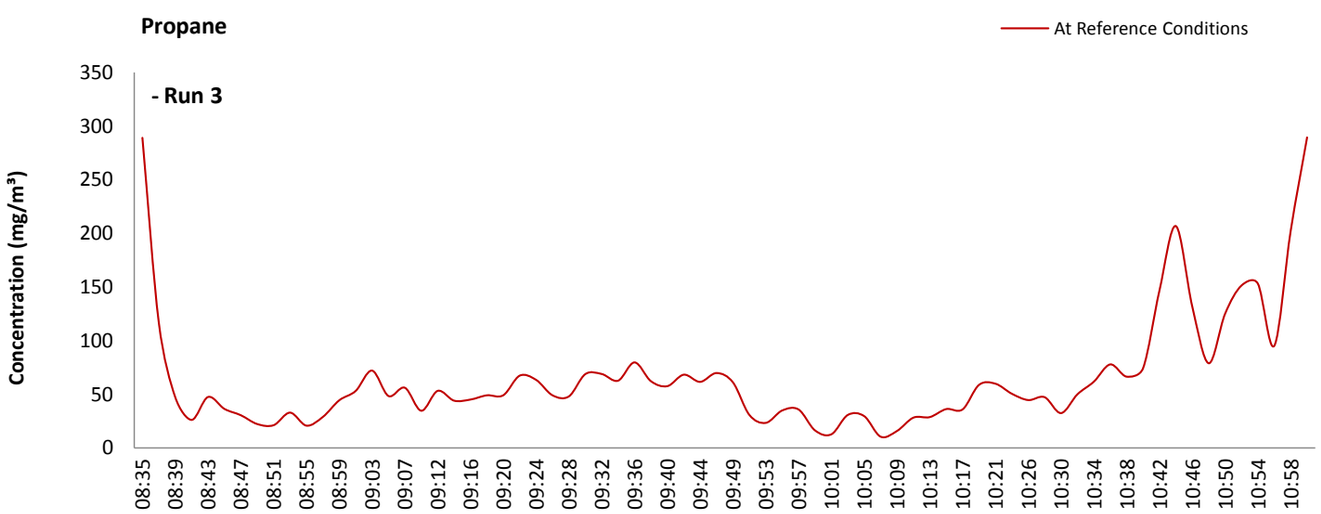
Reference Conditions are: 273K, 101.3kPa, dry gas, 3% oxygen.

PROPANE: DATA TREND

Graphical Trend of Data







PROPANE: MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (ppm)	5.21
Propane				Range (ppm)	10
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	0.35	rectangular	√3	0.05	0.01
Zero Drift	0.50	rectangular	√3	0.10	0.03
Span Drift	2.00	rectangular	√3	0.10	0.12
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.01	0.02
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.02	0.00
Interferents	4.00	rectangular	√3	0.10	0.23
Standard Deviation of Repeatability at Zero	0.10	normal	1	0.10	0.01
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.05	0.05
Combined Uncertainty	-	normal	-	-	0.27
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.53
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	10.21

RUN 2				Measured (ppm)	1.18
Propane				Range (ppm)	10
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	0.35	rectangular	√3	0.012	0.002
Zero Drift	0.50	rectangular	√3	0.100	0.029
Span Drift	2.00	rectangular	√3	0.100	0.115
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.010	0.017
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.020	0.000
Interferents	4.00	rectangular	√3	0.100	0.231
Standard Deviation of Repeatability at Zero	0.10	normal	1	0.100	0.010
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.000
Uncertainty of Certified Reference Material	2.00	normal	2	0.012	0.012
Combined Uncertainty	-	normal	-	-	0.26
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.52
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	44.33

RUN 3				Measured (ppm)	2.99
Propane				Range (ppm)	10
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	0.35	rectangular	√3	0.03	0.01
Zero Drift	0.50	rectangular	√3	0.10	0.03
Span Drift	2.00	rectangular	√3	0.10	0.12
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.01	0.02
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.02	0.00
Interferents	4.00	rectangular	√3	0.10	0.23
Standard Deviation of Repeatability at Zero	0.10	normal	1	0.10	0.01
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.03	0.03
Combined Uncertainty	-	normal	-	-	0.26
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.52
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	17.56

BENZENE: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m³	12.5	19.7	34.8	22.3
Uncertainty	±mg/m³	7.0	3.1	11.1	7.1
Mass Emission	g/hr				
Uncertainty	±g/hr				

General Sampling Information

Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	3015 - 3120 / 1010 - 1065	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	C_3H_8	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	87.74	
Check Gas Uncertainty (%)	2	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

References Used in Analytical Algorithm Application

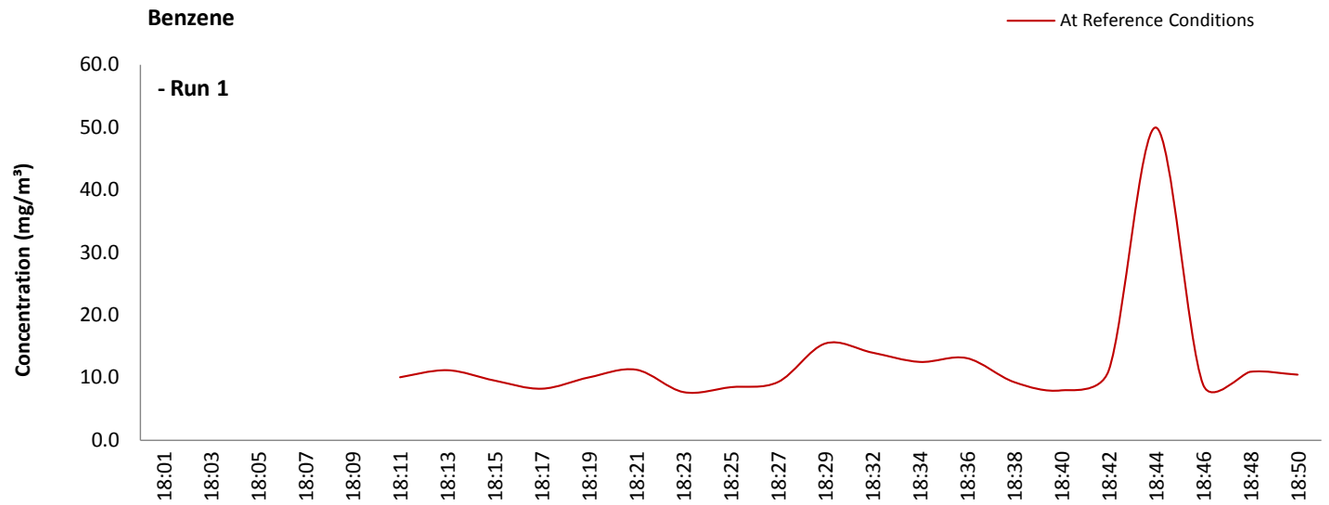
Type of Reference	Concentration of References
Transportable	5.1 - 201.9ppm

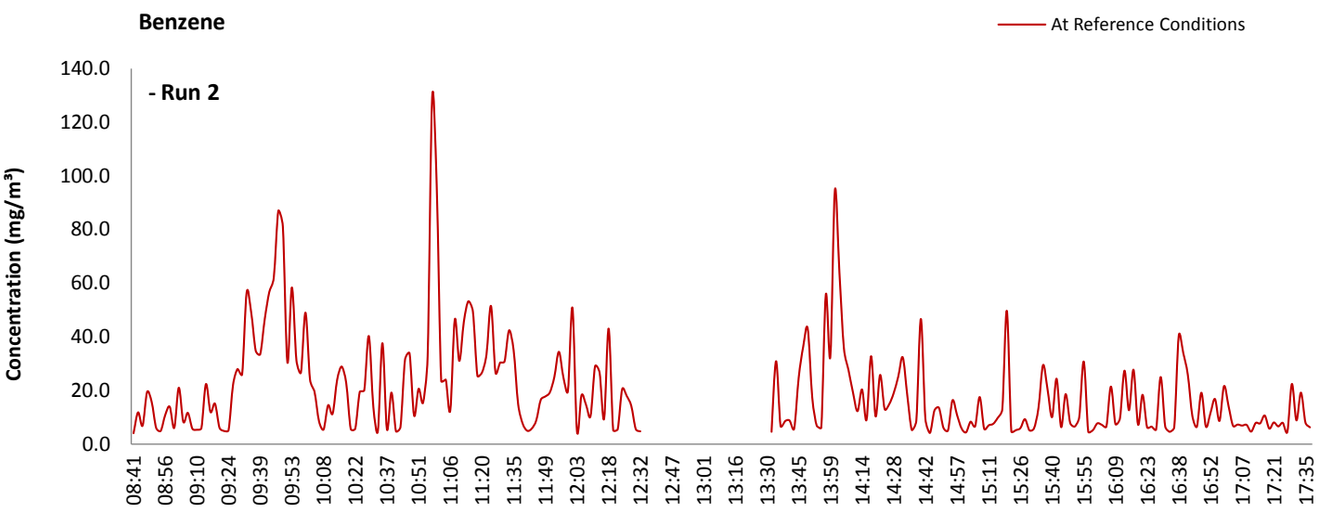
Reference Conditions

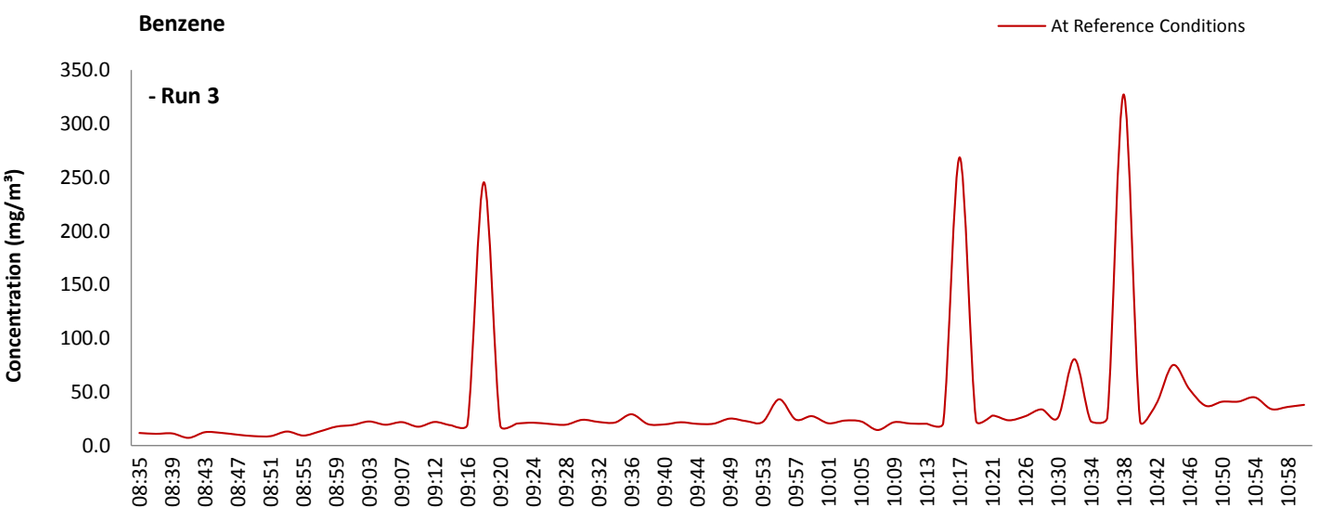
Reference Conditions are: 273K, 101.3kPa, dry gas, 3% oxygen.

BENZENE: DATA TREND

Graphical Trend of Data







BENZENE: MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (ppm)	0.51
Benzene				Range (ppm)	5.1
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.005	0.01
Zero Drift	0.50	rectangular	√3	0.051	0.01
Span Drift	2.00	rectangular	√3	0.051	0.06
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.005	0.01
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.010	0.00
Interferents	4.00	rectangular	√3	0.051	0.12
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.051	0.05
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.005	0.01
Combined Uncertainty	-	normal	-	-	0.14
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.28
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	56.14

RUN 2				Measured (ppm)	1.82
Benzene				Range (ppm)	5.1
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.018	0.02
Zero Drift	0.50	rectangular	√3	0.051	0.01
Span Drift	2.00	rectangular	√3	0.051	0.06
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.005	0.01
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.010	0.00
Interferents	4.00	rectangular	√3	0.051	0.12
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.051	0.05
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.018	0.02
Combined Uncertainty	-	normal	-	-	0.14
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.29
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	15.95

RUN 3				Measured (ppm)	0.90
Benzene				Range (ppm)	5.1
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.009	0.01
Zero Drift	0.50	rectangular	√3	0.051	0.01
Span Drift	2.00	rectangular	√3	0.051	0.06
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.005	0.01
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.010	0.00
Interferents	4.00	rectangular	√3	0.051	0.12
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.051	0.05
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.009	0.01
Combined Uncertainty	-	normal	-	-	0.14
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	0.29
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	31.90

TOLUENE: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m³	64.4	17.9	101	61.1
Uncertainty	±mg/m³	31.8	14.0	50.1	32.0
Mass Emission	g/hr				
Uncertainty	±g/hr				

General Sampling Information

Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	2850 - 3090 / 1010 - 1095	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	C_3H_8	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	87.74	
Check Gas Uncertainty (%)	2	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

References Used in Analytical Algorithm Application

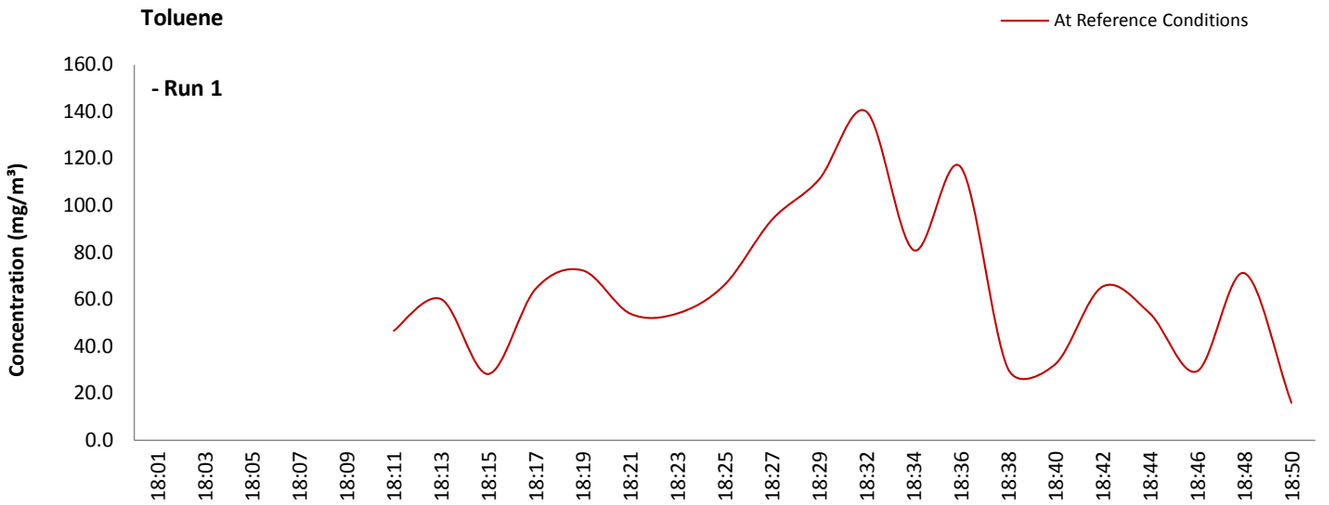
Type of Reference	Concentration of References
Transportable	19.6 - 198.1ppm

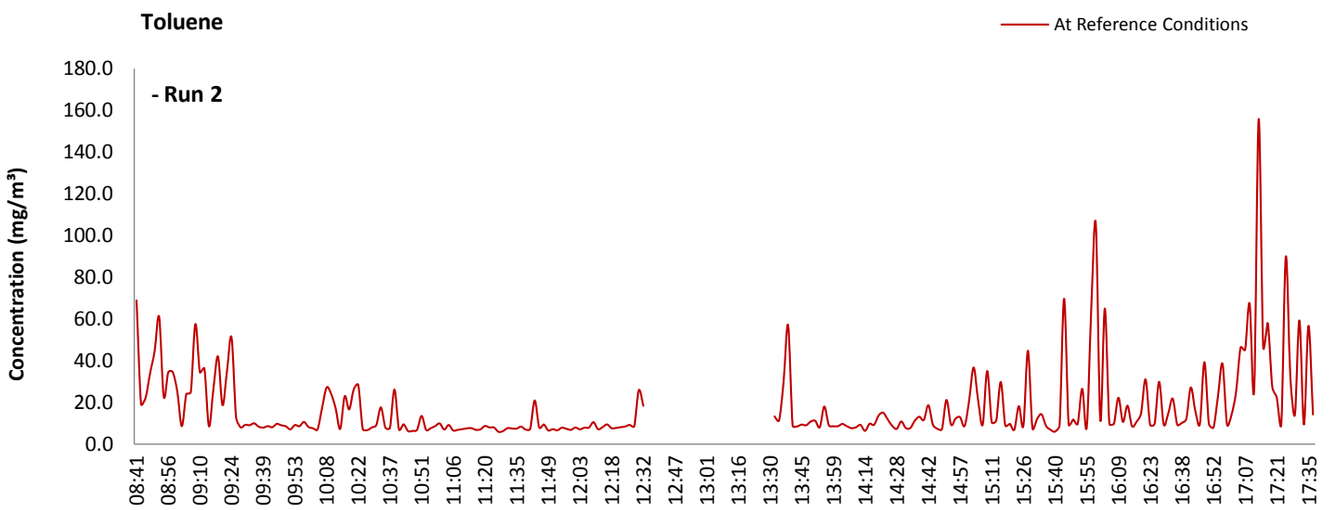
Reference Conditions

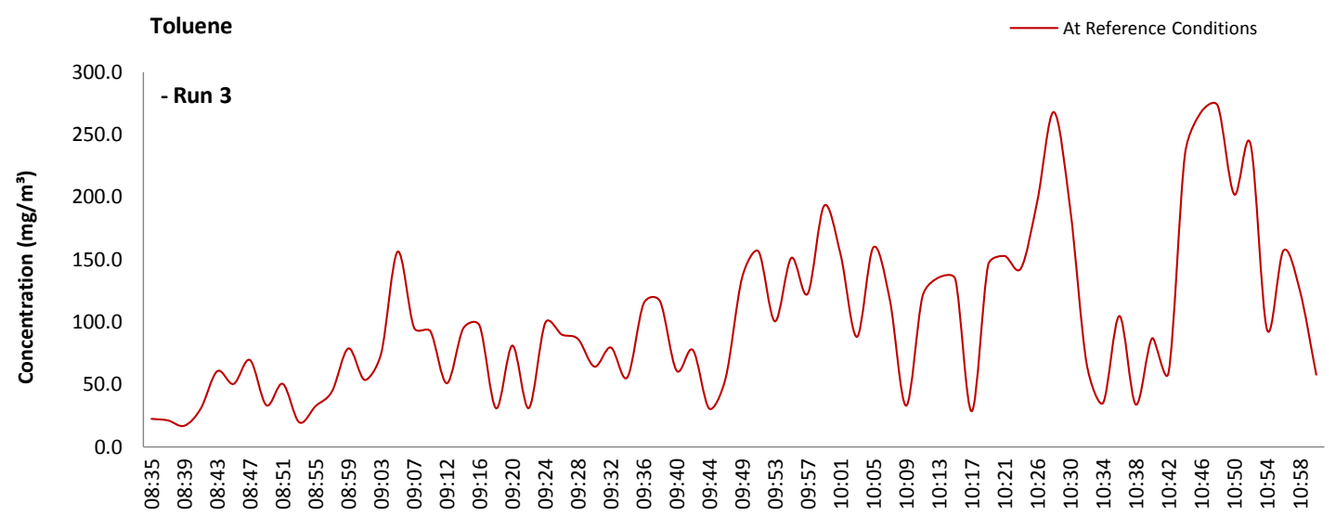
Reference Conditions are: 273K, 101.3kPa, dry gas, 3% oxygen.

TOLUENE: DATA TREND

Graphical Trend of Data







TOLUENE: MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (ppm)	2.22
Toluene				Range (ppm)	19.6
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.02	0.03
Zero Drift	0.50	rectangular	√3	0.20	0.06
Span Drift	2.00	rectangular	√3	0.20	0.23
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.02	0.03
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.04	0.00
Interferents	4.00	rectangular	√3	0.20	0.45
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.20	0.20
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.02	0.02
Combined Uncertainty	-	normal	-	-	0.55
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	1.10
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	49.32

RUN 2				Measured (ppm)	1.39
Toluene				Range (ppm)	19.6
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.01	0.02
Zero Drift	0.50	rectangular	√3	0.20	0.06
Span Drift	2.00	rectangular	√3	0.20	0.23
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.02	0.03
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.04	0.00
Interferents	4.00	rectangular	√3	0.20	0.45
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.20	0.20
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.01	0.01
Combined Uncertainty	-	normal	-	-	0.55
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	1.09
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	78.45

RUN 3				Measured (ppm)	2.21
Toluene				Range (ppm)	19.6
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.02	0.03
Zero Drift	0.50	rectangular	√3	0.20	0.06
Span Drift	2.00	rectangular	√3	0.20	0.23
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.02	0.03
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.04	0.00
Interferents	4.00	rectangular	√3	0.20	0.45
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.20	0.20
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.02	0.02
Combined Uncertainty	-	normal	-	-	0.55
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	1.10
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	49.63

M-XYLENE: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m³	12.0	7.0	47.3	22.1
Uncertainty	±mg/m³	39.7	17.5	62.7	40.0
Mass Emission	g/hr				
Uncertainty	±g/hr				

General Sampling Information

Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	2850 - 3050 / 1599 - 1630	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	C_3H_8	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	87.74	
Check Gas Uncertainty (%)	2	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

References Used in Analytical Algorithm Application

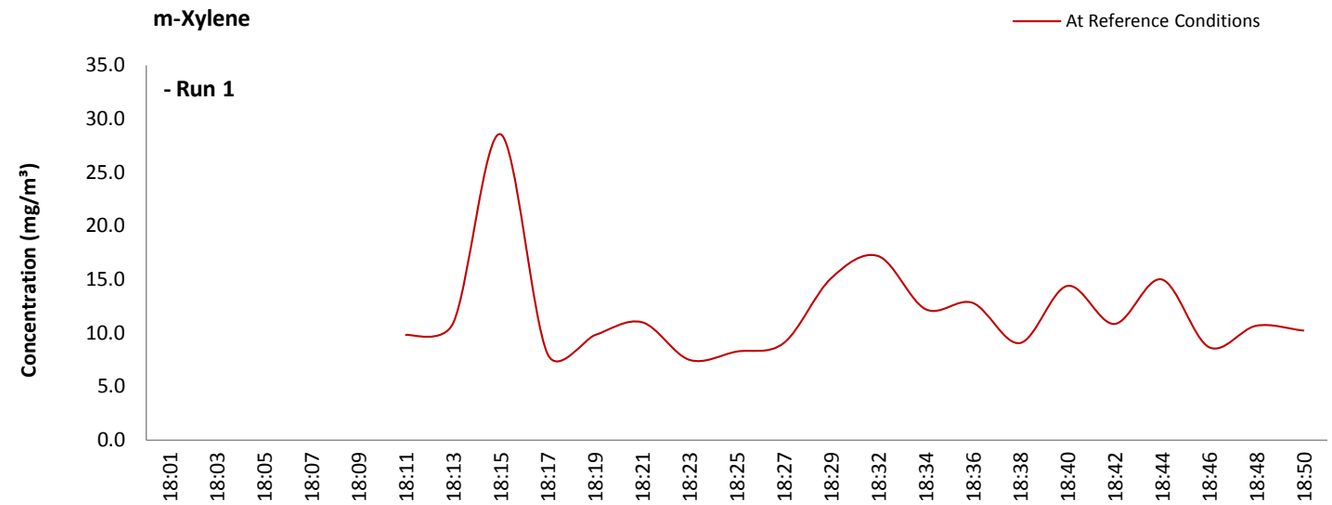
Type of Reference	Concentration of References
Transportable	21.3 - 205.3ppm

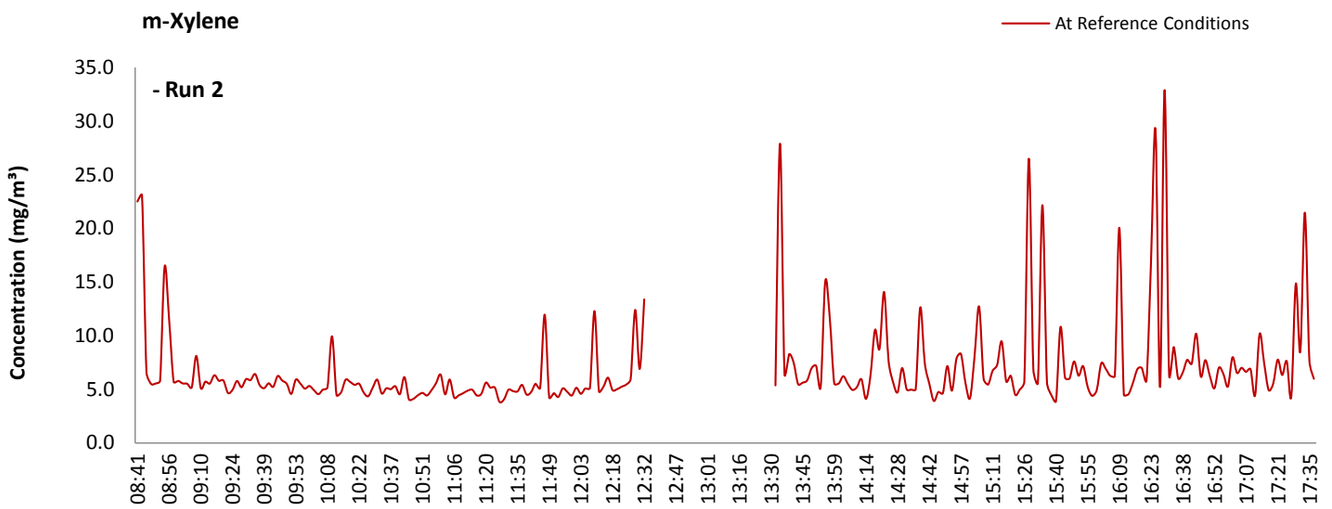
Reference Conditions

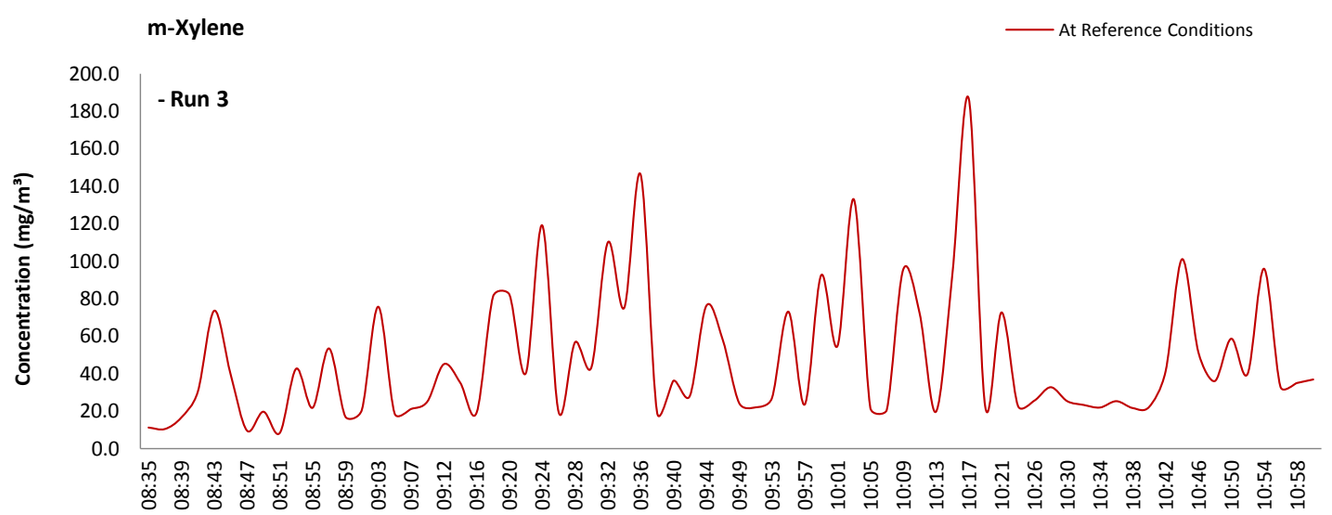
Reference Conditions are: 273K, 101.3kPa, dry gas, 3% oxygen.

M-XYLENE: DATA TREND

Graphical Trend of Data







M-XYLENE: MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (ppm)	0.36
m-Xylene				Range (ppm)	21.3
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.004	0.004
Zero Drift	0.50	rectangular	√3	0.213	0.061
Span Drift	2.00	rectangular	√3	0.213	0.246
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.021	0.037
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.043	0.000
Interferents	4.00	rectangular	√3	0.213	0.492
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.213	0.213
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.000
Uncertainty of Certified Reference Material	2.00	normal	2	0.004	0.004
Combined Uncertainty	-	normal	-	-	0.59
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	1.19
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	331.37

RUN 2				Measured (ppm)	0.47
m-Xylene				Range (ppm)	21.3
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.005	0.01
Zero Drift	0.50	rectangular	√3	0.213	0.06
Span Drift	2.00	rectangular	√3	0.213	0.25
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.021	0.04
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.043	0.00
Interferents	4.00	rectangular	√3	0.213	0.49
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.213	0.21
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.005	0.00
Combined Uncertainty	-	normal	-	-	0.59
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	1.19
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	252.11

RUN 3				Measured (ppm)	0.90
m-Xylene				Range (ppm)	21.3
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.009	0.01
Zero Drift	0.50	rectangular	√3	0.213	0.06
Span Drift	2.00	rectangular	√3	0.213	0.25
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.021	0.04
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.043	0.00
Interferents	4.00	rectangular	√3	0.213	0.49
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.213	0.21
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.009	0.01
Combined Uncertainty	-	normal	-	-	0.59
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	1.19
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	132.62

O-XYLENE: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m³	19.8	11.5	60.9	30.7
Uncertainty	±mg/m³	95.0	42.0	150	95.6
Mass Emission	g/hr				
Uncertainty	±g/hr				

General Sampling Information

Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	2850 - 3050 / 1460 - 1500	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	C_3H_8	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	87.74	
Check Gas Uncertainty (%)	2	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

References Used in Analytical Algorithm Application

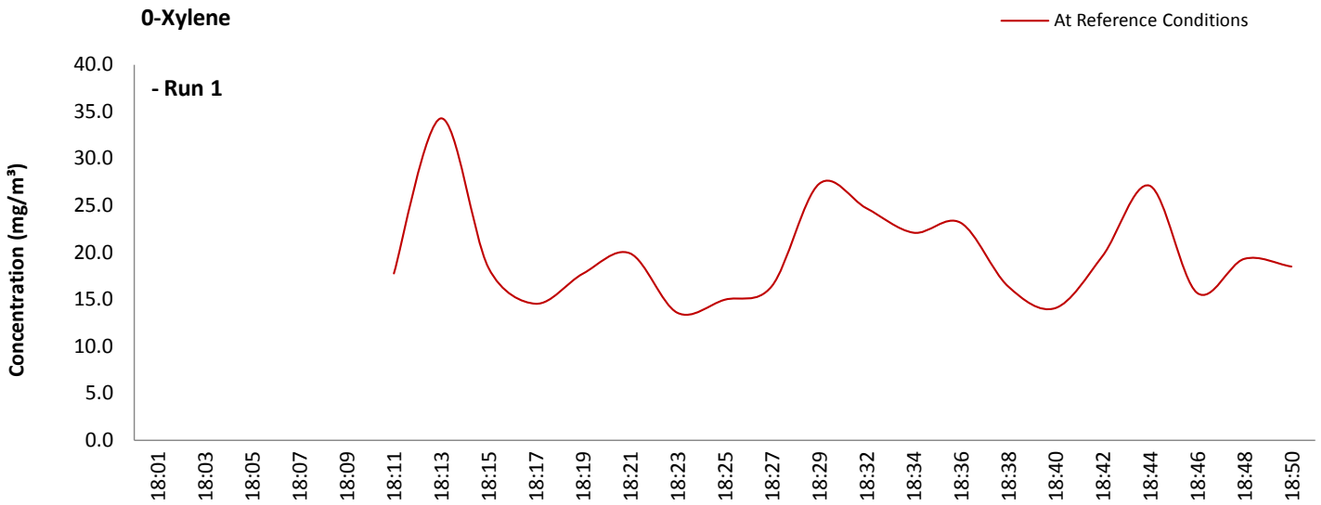
Type of Reference	Concentration of References
Transportable	50.96 - 204.27ppm

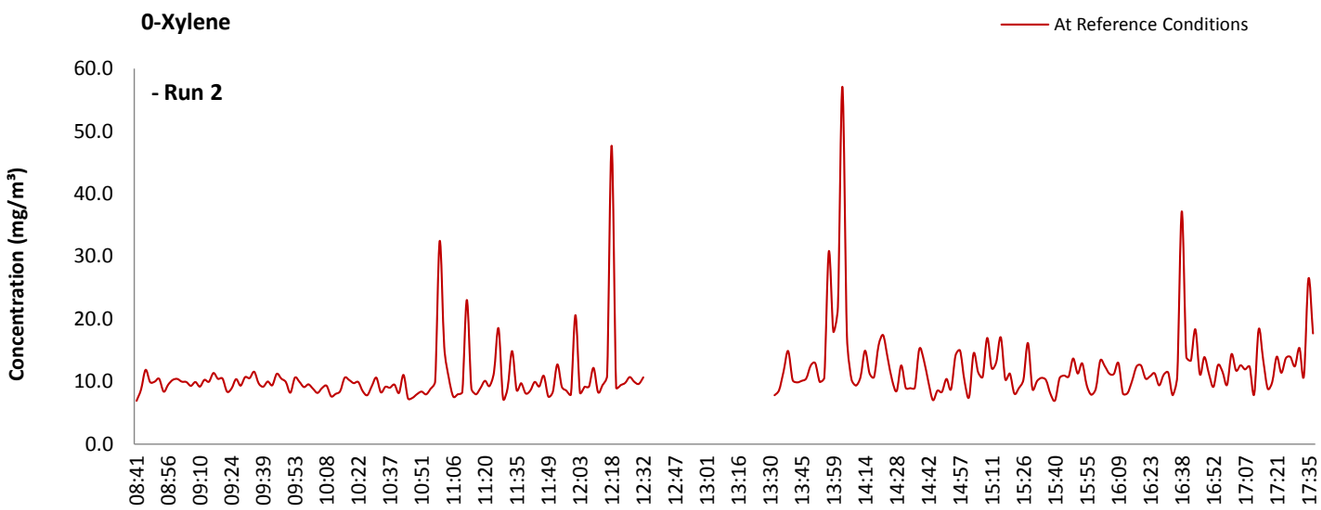
Reference Conditions

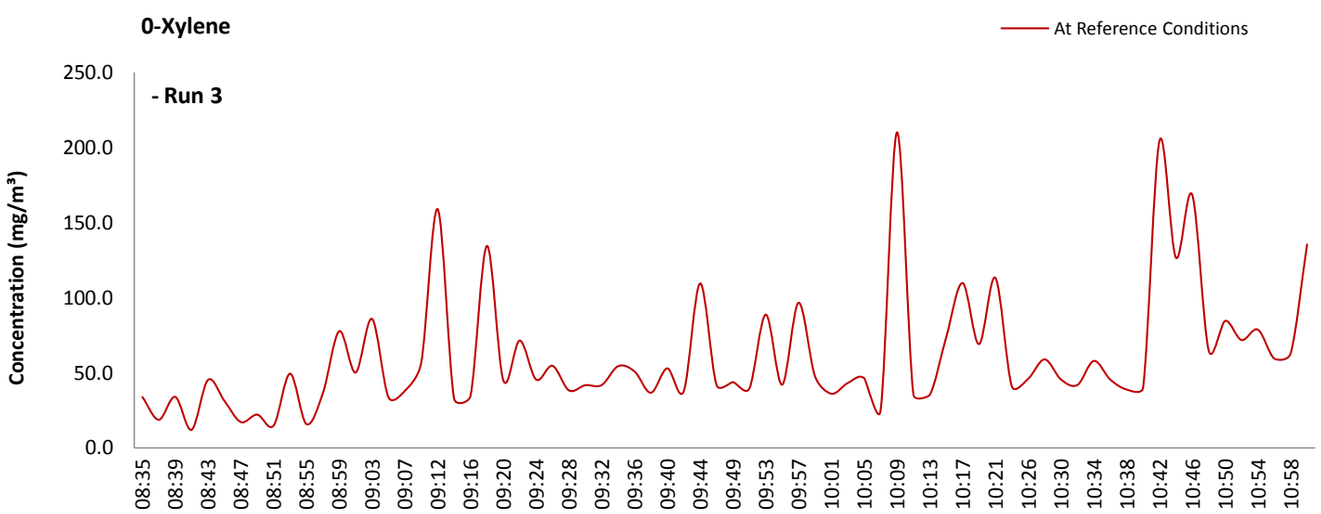
Reference Conditions are: 273K, 101.3kPa, dry gas, 3% oxygen.

O-XYLENE: DATA TREND

Graphical Trend of Data







O-XYLENE: MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (ppm)	0.59
0-Xylene				Range (ppm)	50.96
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.006	0.01
Zero Drift	0.50	rectangular	√3	0.510	0.15
Span Drift	2.00	rectangular	√3	0.510	0.59
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.051	0.09
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.102	0.00
Interferents	4.00	rectangular	√3	0.510	1.18
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.510	0.51
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.006	0.01
Combined Uncertainty	-	normal	-	-	1.42
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	2.84
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	480.07

RUN 2				Measured (ppm)	0.78
0-Xylene				Range (ppm)	50.96
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.008	0.01
Zero Drift	0.50	rectangular	√3	0.510	0.15
Span Drift	2.00	rectangular	√3	0.510	0.59
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.051	0.09
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.102	0.00
Interferents	4.00	rectangular	√3	0.510	1.18
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.510	0.51
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.008	0.01
Combined Uncertainty	-	normal	-	-	1.42
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	2.84
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	365.53

RUN 3				Measured (ppm)	1.15
0-Xylene				Range (ppm)	50.96
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.01	0.01
Zero Drift	0.50	rectangular	√3	0.51	0.15
Span Drift	2.00	rectangular	√3	0.51	0.59
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.05	0.09
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.10	0.00
Interferents	4.00	rectangular	√3	0.51	1.18
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.51	0.51
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.01	0.01
Combined Uncertainty	-	normal	-	-	1.42
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	2.84
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	246.27

P-XYLENE: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m³	16.6	19.1	30.2	22.0
Uncertainty	±mg/m³	95.3	42.1	150	95.9
Mass Emission	g/hr				
Uncertainty	±g/hr				

General Sampling Information

Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	2850 - 3050 / 1510 - 1529	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	C_3H_8	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	87.74	
Check Gas Uncertainty (%)	2	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

References Used in Analytical Algorithm Application

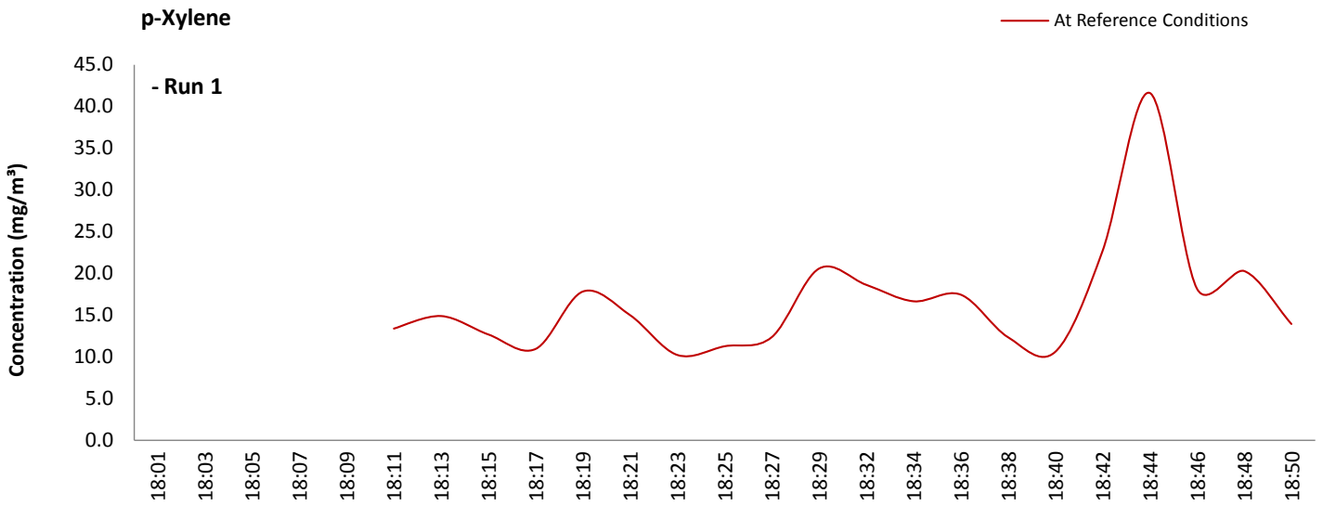
Type of Reference	Concentration of References
Transportable	51.12 - 203.73ppm

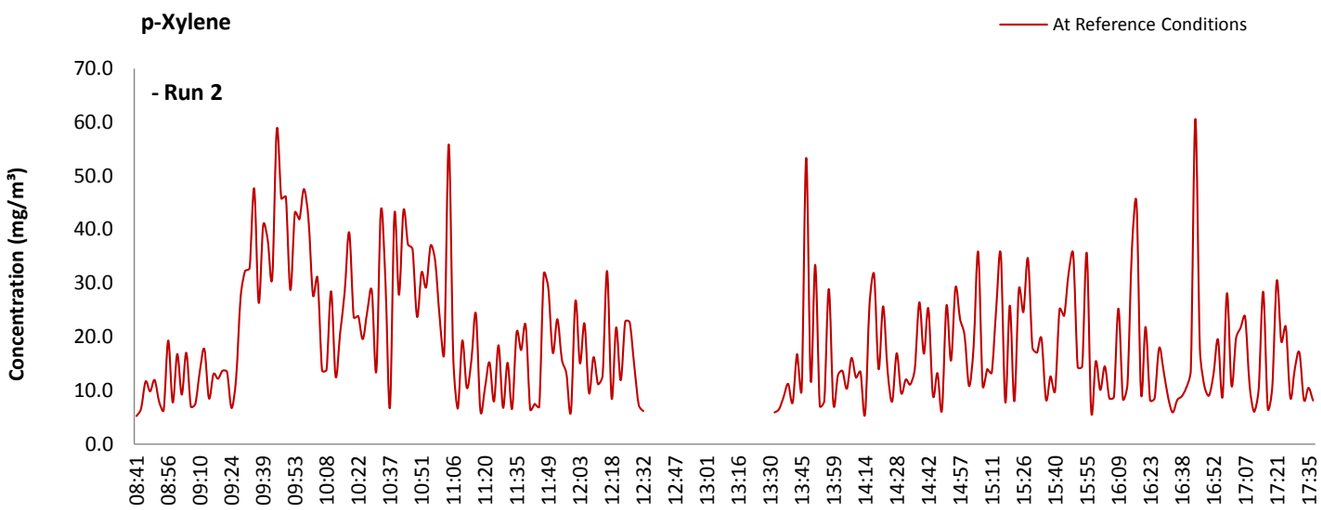
Reference Conditions

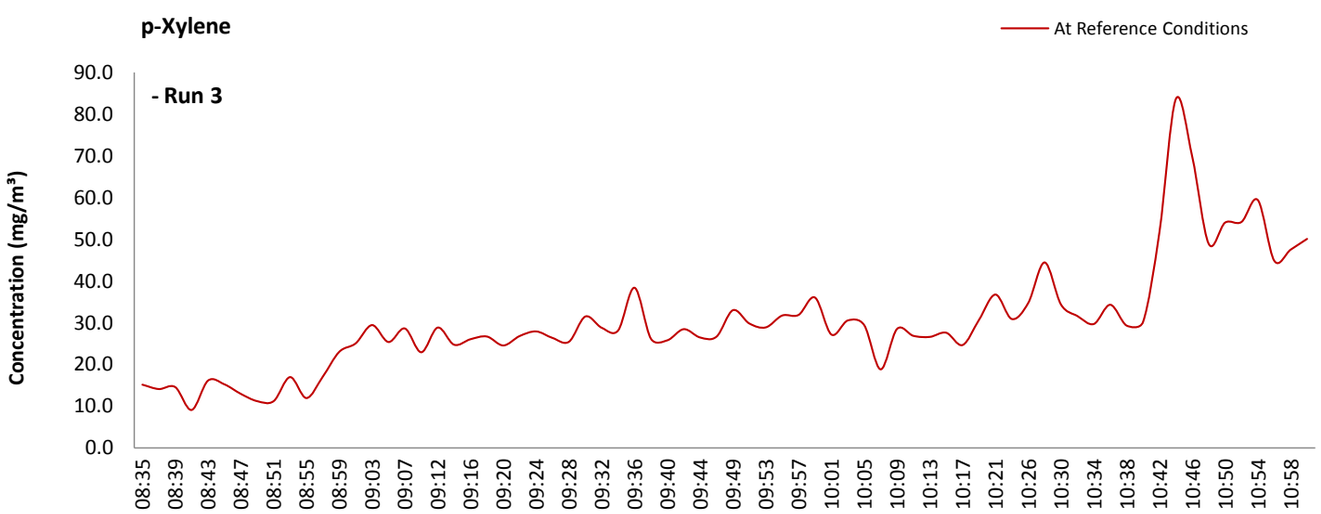
Reference Conditions are: 273K, 101.3kPa, dry gas, 3% oxygen.

P-XYLENE: DATA TREND

Graphical Trend of Data







P-XYLENE: MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (ppm)	0.50
p-Xylene				Range (ppm)	51.12
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.005	0.01
Zero Drift	0.50	rectangular	√3	0.511	0.15
Span Drift	2.00	rectangular	√3	0.511	0.59
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.051	0.09
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.102	0.00
Interferents	4.00	rectangular	√3	0.511	1.18
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.511	0.51
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.005	0.00
Combined Uncertainty	-	normal	-	-	1.43
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	2.85
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	574.35

RUN 2				Measured (ppm)	1.29
p-Xylene				Range (ppm)	51.12
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.01	0.01
Zero Drift	0.50	rectangular	√3	0.51	0.15
Span Drift	2.00	rectangular	√3	0.51	0.59
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.05	0.09
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.10	0.00
Interferents	4.00	rectangular	√3	0.51	1.18
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.51	0.51
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.01	0.01
Combined Uncertainty	-	normal	-	-	1.43
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	2.85
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	220.46

RUN 3				Measured (ppm)	0.57
p-Xylene				Range (ppm)	51.12
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.006	0.01
Zero Drift	0.50	rectangular	√3	0.511	0.15
Span Drift	2.00	rectangular	√3	0.511	0.59
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.051	0.09
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.102	0.00
Interferents	4.00	rectangular	√3	0.511	1.18
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.511	0.51
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.006	0.01
Combined Uncertainty	-	normal	-	-	1.43
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	2.85
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	497.25

EYTHLBENZENE: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m³	7.0	4.4	14.9	8.8
Uncertainty	±mg/m³	38.1	16.9	60.2	38.4
Mass Emission	g/hr				
Uncertainty	±g/hr				

General Sampling Information

Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	2860 - 3050 / 1595 - 1620	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	C_3H_8	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	87.74	
Check Gas Uncertainty (%)	2	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

References Used in Analytical Algorithm Application

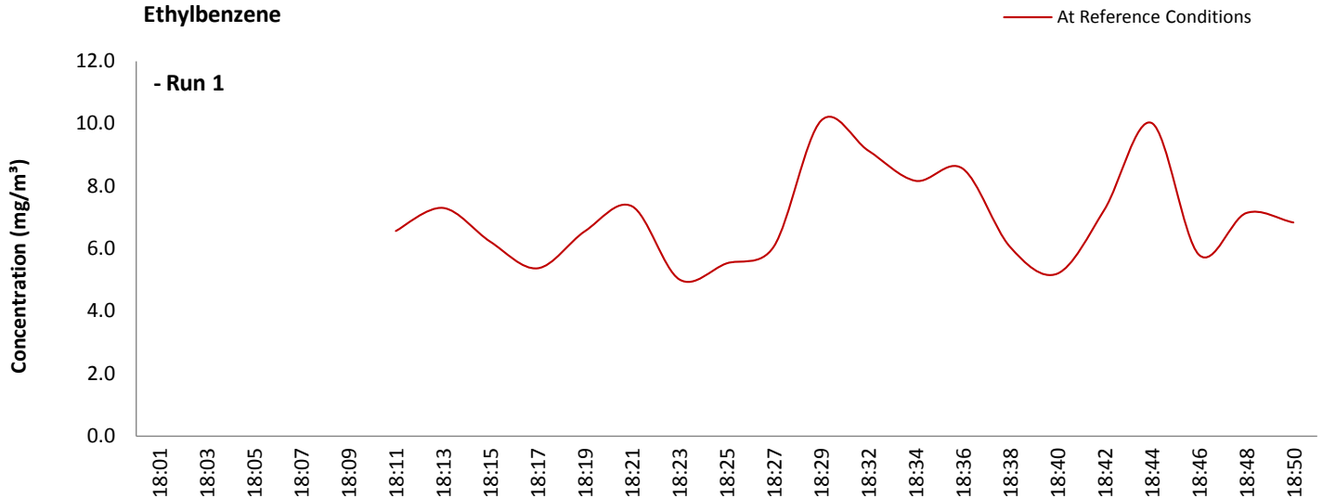
Type of Reference	Concentration of References
Transportable	20.46 - 203.84ppm

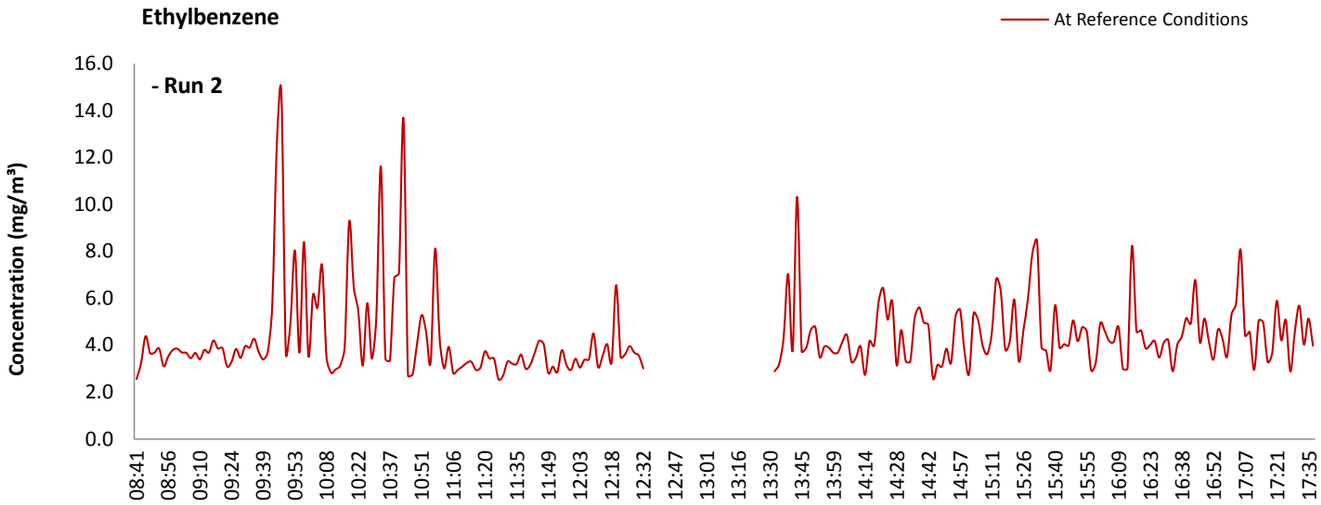
Reference Conditions

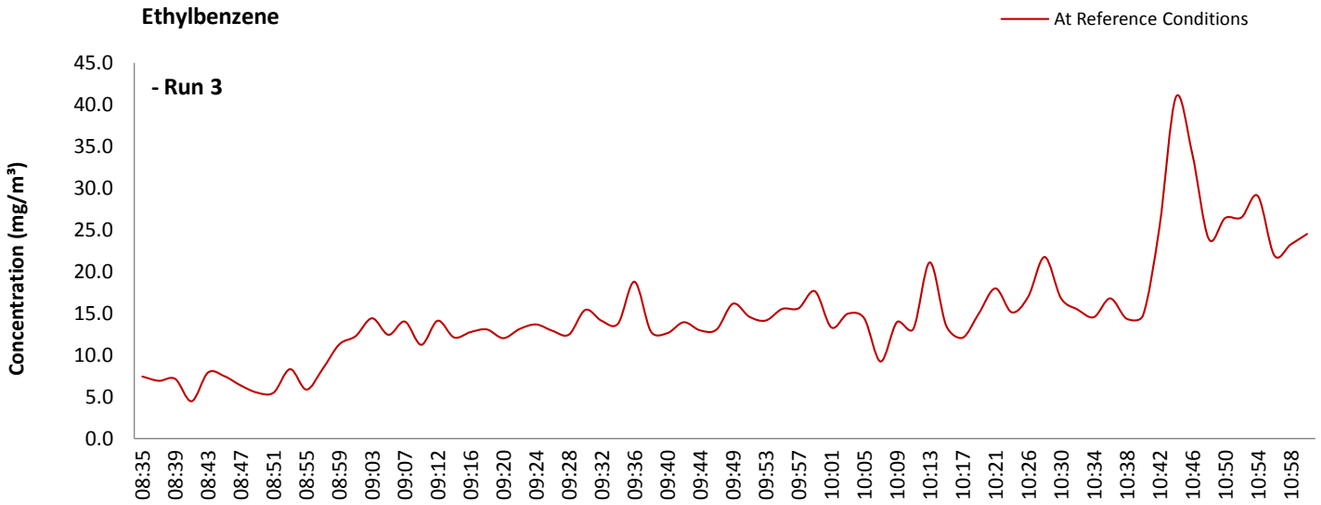
Reference Conditions are: 273K, 101.3kPa, dry gas, 3% oxygen.

ETHYLBENZENE: DATA TREND

Graphical Trend of Data







ETHYLBENZENE: MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (ppm)	0.21
Ethylbenzene				Range (ppm)	20.46
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.002	0.002
Zero Drift	0.50	rectangular	√3	0.205	0.059
Span Drift	2.00	rectangular	√3	0.205	0.236
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.020	0.035
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.041	0.000
Interferents	4.00	rectangular	√3	0.205	0.473
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.205	0.205
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.000
Uncertainty of Certified Reference Material	2.00	normal	2	0.002	0.002
Combined Uncertainty	-	normal	-	-	0.57
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	1.14
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	544.14

RUN 2				Measured (ppm)	0.30
Ethylbenzene				Range (ppm)	20.46
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.003	0.003
Zero Drift	0.50	rectangular	√3	0.205	0.059
Span Drift	2.00	rectangular	√3	0.205	0.236
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.020	0.035
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.041	0.000
Interferents	4.00	rectangular	√3	0.205	0.473
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.205	0.205
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.000
Uncertainty of Certified Reference Material	2.00	normal	2	0.003	0.003
Combined Uncertainty	-	normal	-	-	0.57
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	1.14
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	384.07

RUN 3				Measured (ppm)	0.28
Ethylbenzene				Range (ppm)	20.46
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | ppm**
Lack of Fit	2.00	rectangular	√3	0.003	0.003
Zero Drift	0.50	rectangular	√3	0.205	0.059
Span Drift	2.00	rectangular	√3	0.205	0.236
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.000
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.020	0.035
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.041	0.000
Interferents	4.00	rectangular	√3	0.205	0.473
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.205	0.205
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.000
Uncertainty of Certified Reference Material	2.00	normal	2	0.003	0.003
Combined Uncertainty	-	normal	-	-	0.57
Expanded Uncertainty (ppm)	-	t-distribution (k=2)	-	-	1.14
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	403.27

WATER VAPOUR: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	% v/v	3.5	7.0	2.1	4.2
Uncertainty	% v/v	0.13	0.33	0.08	0.18

General Sampling Information

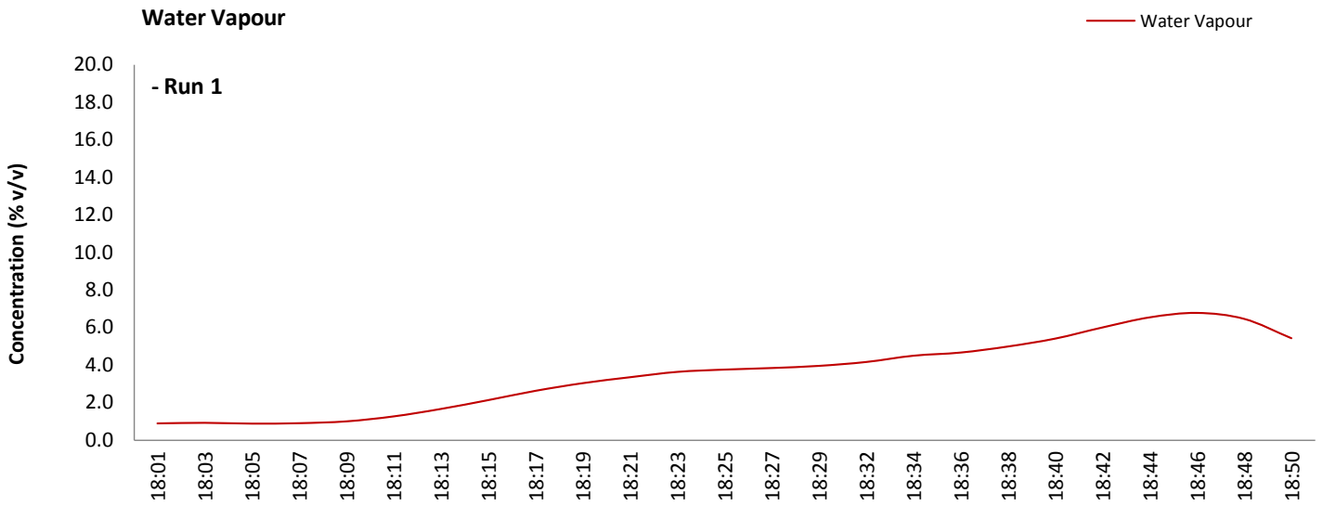
Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	3319 - 3405	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	C_3H_8	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	87.74	
Check Gas Uncertainty (%)	2	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

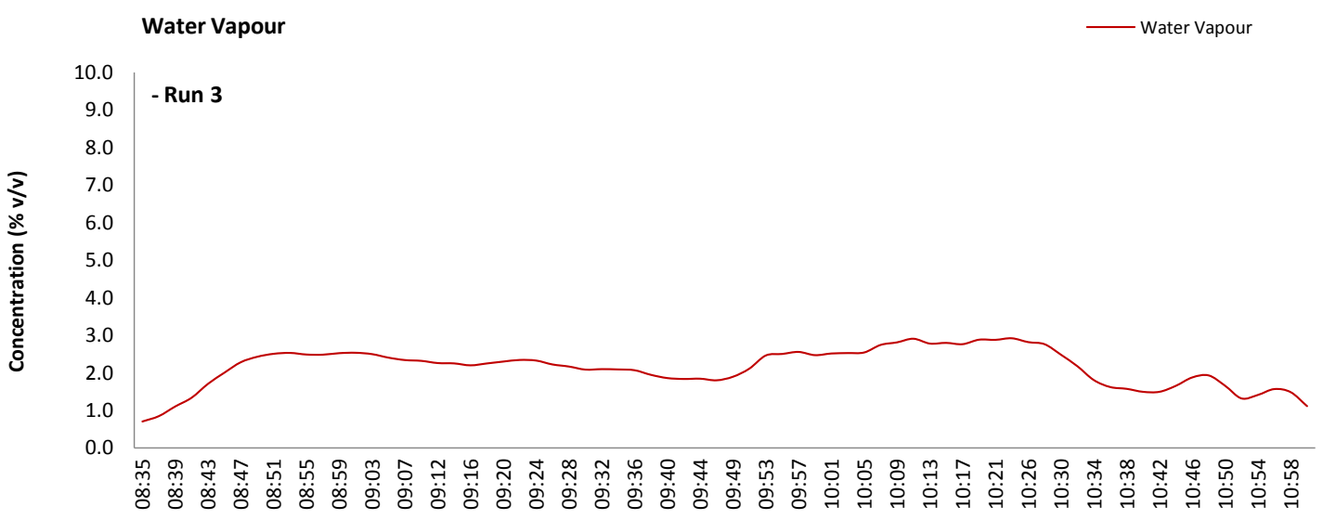
References Used in Analytical Algorithm Application

Type of Reference	Concentration of References
Transportable	0.80 - 39.6%

WATER VAPOUR: DATA TREND

Graphical Trend of Data





WATER VAPOUR: MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (% v/v)	3.55
Water Vapour				Range (%v/v)	3.8
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | % v/v**
Lack of Fit	1.37	rectangular	√3	0.04	0.03
Zero Drift	0.50	rectangular	√3	0.04	0.01
Span Drift	2.00	rectangular	√3	0.04	0.04
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	0.03	rectangular	√3	0.00	0.00
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.01	0.00
Interferents	0.50	rectangular	√3	0.04	0.01
Standard Deviation of Repeatability at Zero	0.05	normal	1	0.04	0.00
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.04	0.04
Combined Uncertainty	-	normal	-	-	0.06
Expanded Uncertainty (% v/v)	-	t-distribution (k=2)	-	-	0.13
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	3.66

RUN 2				Measured (% v/v)	7.01
Water Vapour				Range (%v/v)	11.2
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | % v/v**
Lack of Fit	1.37	rectangular	√3	0.07	0.06
Zero Drift	0.50	rectangular	√3	0.11	0.03
Span Drift	2.00	rectangular	√3	0.11	0.13
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	0.03	rectangular	√3	0.01	0.00
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.02	0.00
Interferents	0.50	rectangular	√3	0.11	0.03
Standard Deviation of Repeatability at Zero	0.05	normal	1	0.11	0.01
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.07	0.07
Combined Uncertainty	-	normal	-	-	0.16
Expanded Uncertainty (% v/v)	-	t-distribution (k=2)	-	-	0.33
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	4.68

RUN 3				Measured (% v/v)	2.14
Water Vapour				Range (%v/v)	2.6
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | % v/v**
Lack of Fit	1.37	rectangular	√3	0.02	0.02
Zero Drift	0.50	rectangular	√3	0.03	0.01
Span Drift	2.00	rectangular	√3	0.03	0.03
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	0.03	rectangular	√3	0.00	0.00
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.01	0.00
Interferents	0.50	rectangular	√3	0.03	0.01
Standard Deviation of Repeatability at Zero	0.05	normal	1	0.03	0.00
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.02	0.02
Combined Uncertainty	-	normal	-	-	0.04
Expanded Uncertainty (% v/v)	-	t-distribution (k=2)	-	-	0.08
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	3.93

CARBON DIOXIDE: RESULTS SUMMARY

[redacted], [redacted]

Clean Up Flare

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	% v/v	1.5	3.0	0.78	1.8
Uncertainty	% v/v	0.10	0.34	0.08	0.17

General Sampling Information

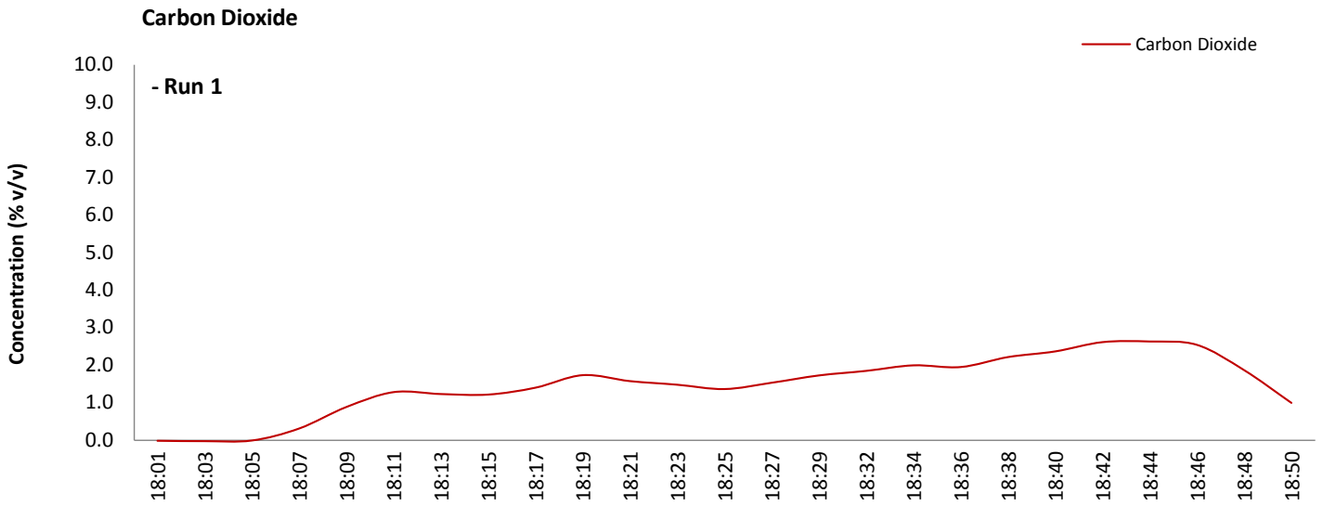
Parameter	Value	
Standard	TGN M22	
Technical Procedure	CAT-TP-22(b)	
Analysis Areas (Wave Number Limits)	903 - 997, 2044 - 2092	
Sampling System Path Length (m)	6.4	
Sample Cell Temperature (°C)	180	
Sample Cell Pressure (mbar)	937.8	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Check Gas Type	SO_2	
Check Gas Reference Number	Cyl 12.0106	
Check Gas Expiry Date	09/08/2019	
Check Gas Start Pressure (bar)	40	
Gas Cylinder Concentration (ppm)	100.6	
Check Gas Uncertainty (%)	2	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

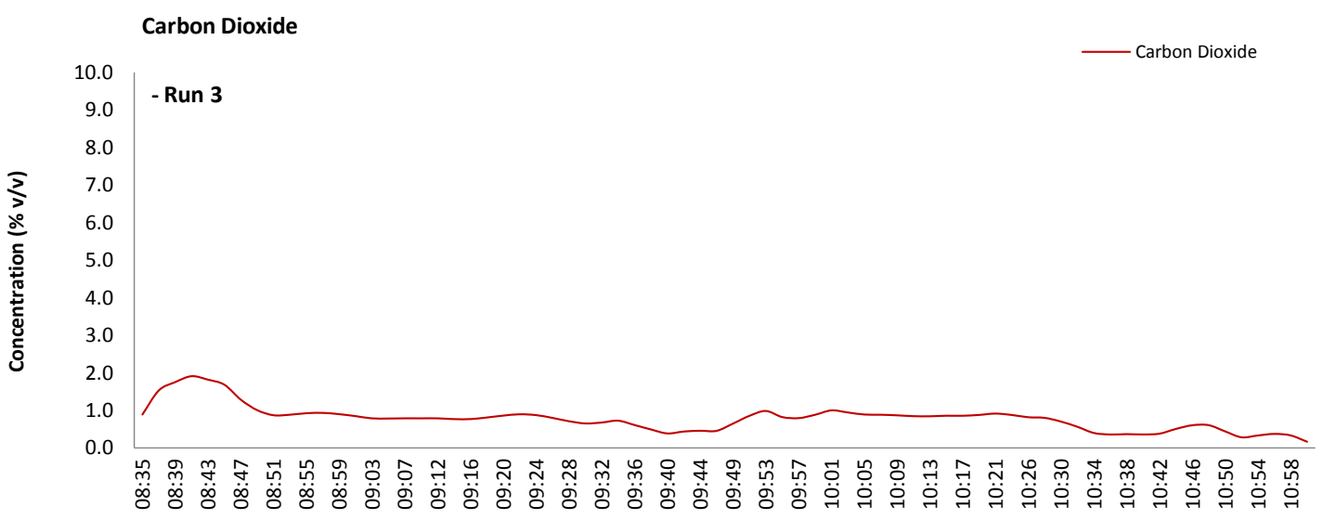
References Used in Analytical Algorithm Application

Type of Reference	Concentration of References
Transportable	1.3 - 19.6%

CARBON DIOXIDE: DATA TREND

Graphical Trend of Data





CARBON DIOXIDE: MEASUREMENT UNCERTAINTY CALCULATIONS

RUN 1				Measured (% v/v)	1.46
Carbon Dioxide				Range (%v/v)	1.7
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | % v/v**
Lack of Fit	2.00	rectangular	√3	0.01	0.02
Zero Drift	0.50	rectangular	√3	0.02	0.00
Span Drift	2.00	rectangular	√3	0.02	0.02
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.00	0.00
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.00	0.00
Interferents	4.00	rectangular	√3	0.02	0.04
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.02	0.02
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.01	0.01
Combined Uncertainty	-	normal	-	-	0.05
Expanded Uncertainty (% v/v)	-	t-distribution (k=2)	-	-	0.10
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	7.16

RUN 2				Measured (% v/v)	3.03
Carbon Dioxide				Range (%v/v)	5.9
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | % v/v**
Lack of Fit	2.00	rectangular	√3	0.03	0.04
Zero Drift	0.50	rectangular	√3	0.06	0.02
Span Drift	2.00	rectangular	√3	0.06	0.07
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.01	0.01
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.01	0.00
Interferents	4.00	rectangular	√3	0.06	0.14
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.06	0.06
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.03	0.03
Combined Uncertainty	-	normal	-	-	0.17
Expanded Uncertainty (% v/v)	-	t-distribution (k=2)	-	-	0.34
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	11.28

RUN 3				Measured (% v/v)	0.78
Carbon Dioxide				Range (%v/v)	1.3
Source of Uncertainty	**Value (±%)**	**Probability Distribution**	**Divisor**	**Conversion Factor**	**ui | % v/v**
Lack of Fit	2.00	rectangular	√3	0.008	0.01
Zero Drift	0.50	rectangular	√3	0.013	0.00
Span Drift	2.00	rectangular	√3	0.013	0.02
Sensitivity to Atmospheric Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Sample Gas Pressure	N/A	rectangular	√3	N/A	0.00
Sensitivity to Ambient Temperature	3.00	rectangular	√3	0.001	0.00
Sensitivity to Electrical Voltage	0.00	rectangular	√3	0.003	0.00
Interferents	4.00	rectangular	√3	0.013	0.03
Standard Deviation of Repeatability at Zero	1.00	normal	1	0.013	0.01
Standard Deviation of Repeatability at Span	N/A	normal	1	N/A	0.00
Uncertainty of Certified Reference Material	2.00	normal	2	0.008	0.01
Combined Uncertainty	-	normal	-	-	0.04
Expanded Uncertainty (% v/v)	-	t-distribution (k=2)	-	-	0.08
Expanded Uncertainty (%age of Reading)	-	t-distribution (k=2)	-	-	9.76

M22 FTIR SAMPLING DETAILS & QUALITY ASSURANCE

(PAGE 1 OF 2)

Sampling Details

Parameter	Units	Run 1	Run 2	Run 3
Sampling Times	-	18:00 - 18:50	08:41 - 17:37	08:35 - 11:00
Sampling Date	-	04/04/2018	05/04/2018	06/04/2018

Quality Assurance

	Background / Zero Calibration Check	Units	Value
CAL 1	ADC Saturation	%	53.5500
	Acceptable Background?	-	Yes
	Allowable ADC Saturation	%	> 20

Test Conditions	Units	Run 1	Run 2	Run 3
Run Ambient Temperature Range	°C	9 - 10°C	10 - 11°C	10 - 11°C

Method Deviations

Nature of Deviation (x = deviation applies to the associated run)	Run Number 1	2	3
There are no deviations associated with the sampling employed.	x	x	x

Interference Check

Target Parameter	DAY 1	DAY 2	DAY 3
Oxides of Nitrogen (as NO_2)	P	P	P
Sulphur Dioxide	P	P	P
Carbon Monoxide	P	P	P
Methane	P	P	P
Ethane	P	P	P
Propane	P	P	P
Benzene	P	P	P
Toluene	P	P	P
M-Xylene	P	P	P
O-Xylene	P	P	P
P-Xylene	P	P	P
Ethylbenzene	P	P	P
Water Vapour	P	P	P
Carbon Dioxide	P	P	P

where "P" = Pass and "F" = Fail

M22 FTIR SAMPLING DETAILS & QUALITY ASSURANCE

							REACTIVE GAS CHECK
		Check Gas Check - Pre Test	**Units**	**NO**	**CO**	**SO_2**	**C_3H_8**	**SO_2**
		Response Time, T_{90}	s	160	160	160	160	160
		Reverse Response Time, RT_{90}	s	160	**(performed against decreasing H_2O)**			
		Allowable Response Time	s	200	200	200	200	200
		Response Time Acceptable	-	Yes	Yes	Yes	Yes	Yes
		Response Time from ASC, ASC T_{90}	s	120	120	120	120	120
		System Lag Time [ASC T_{90} - T_{90}]	s	40	40	40	40	40
		Check Gas Reference Number	-	Cyl 12.0106	Cyl 12.0106	Cyl 12.0106	Cyl 12.0106	Cyl 12.0106
CAL 1	**03/04/2018**	Check Gas Value	ppm	408.7	94.8	100.6	87.7	100.6
		Check Gas Reading on Analyser	ppm	411.0	95.8	97.5	83.8	100.0
		Difference	ppm	2.3	1.0	-3.1	-3.9	-0.6
		Allowable Difference	± ppm	20.4	4.7	5.0	4.4	10.1
		Check Gas Acceptable	-	Yes	Yes	Yes	Yes	Yes

		Check Gas Check - Post Test	**Units**	**NO**	**CO**	**SO_2**	**C_3H_8**	**SO_2**
CAL 1	**06/04/2018**	Check Gas Reading - Pre Test	ppm	411.0	95.8	97.5	83.8	100.0
		Check Gas Reading - Post Test	ppm	405.6	96.0	98.1	83.0	99.2
		Difference	ppm	-5.4	0.2	0.6	-0.8	-0.8
		Drift	%	-1.3	0.2	0.6	-1.0	
		Allowable Drift	± %	5.0	5.0	5.0	5.0	
		Drift Acceptable	-	Yes	Yes	Yes	Yes	

NOTE: Drift correction will be automatically applied to the data if the maximum check gas drift is between 2 - 5%.

APPENDIX 4 – PW ENCLOSED FLARE DESIGN

*** Page Left Blank Intentionally ***

PWWT

landfill systems
engineering a better environment

Enclosed Well Test Gas Flare EWT 9.5

Max thermal Capacity: 5.0MWth

Nominal Flow: 250MSCFD.

1. General Description

Landfill Systems and PW Well Test have collaborated to design and manufacture the EWT range of gas flares for initial and extended gas well testing applications.

The model nomenclature is defined by the range type and the maximum capacity; e.g. “EWT 9.5” denotes an enclosed well test gas flare with a height of 9.5m and a nominal flow capacity modified to restrict capacity to 250 MSCFD.

The flare design is based on a 2-stage burner for a varied range in flow rates. The capacity is restricted by reducing the number of burner nozzles in the second stage. The first stage will contain around 50 burner nozzles. The second stage has been reduced from 50 to 25 burner nozzles to cap capacity whilst keeping the flexibility to allow the unit to maintain efficient combustion.

The plant components are mounted on a substantial galvanised steel underbed (“skid”). The weatherproof control enclosure is also mounted on the skid. The control system is PLC based with control interface and process indications provided by a colour HMI touch-screen panel.

The plant has a compact footprint. Typically, it is delivered ready assembled on a single vehicle. If the vehicle has an on-board crane of sufficient capacity, it can be used to off-load the gas flare in a very short time. Once the gas, electrical and pneumatic supplies are connected, the plant is ready to run.

a. Applications

The plant is an economical solution for gas well testing and safely flaring well gas. It can be used for new well testing and extended well testing.

b. Principal Features

- UK EA emissions compliant.
- Safe and controlled combustion process.
- Ignition of the gas via proprietary high integrity propane ignition lance.
- Concealed combustion process.
- Automatic temperature control.
- Rapid installation and commissioning.
- Ready to run.

- Easy maintenance.
- High quality components.
- Rugged construction.
- Remote Monitoring & Control by Smart Phone or Internet enabled PC.

c. Safety Features

The design incorporates all the safety features required for the safe handling and combustion of well test gas. Construction is in accordance with guidance contained in ***BS EN 60079-0*** (ATEX).

2. Specification

Gas Plant EWT 9.5

Gas flow capacity:	**max.**	**250 MSCFD**
Methane fraction:		**40 to 100%**
Combustion temperature:		**1,000 – 1,150°C**
Retention time:		**>0.4s**
Turn down Ratio:		**>5:1**
Flare combustion capacity:	**max.**	**5.0MW**
	min.	**≈ 1.0MW**
Target Nox:		**<100mg/m^3**
Target CO:		**<50mg/m^3**
Target Total VOC's:		**<10mg/m^3**
Target NMVOC's:		**<5mg/m^3**
Gas inlet temp.	**max.**	**25°C**
Inlet flange:		**Class#150**
Power supply:		**230VAC, 1Ph, 50Hz.**
Compressed air supply:		**7bar,clean & dry.**
Expected noise emissions at 3m x 1m height:		**<78dB(A) (t.b.c.)**
Footprint (approx.):		**2,500 x 2,800mm.**
Height:		**≤9,540mm.**

3. Main Components

a. Underbed (Skid):

150 x 150 x 75mm MS channel frame, hot dip galvanised to ISO 1461.

b. Downstream of the gas connection flange:

Manual burner flow control valve.
Pipework in stainless steel 304.
Pressure gauge, 0…2Bar.

Quick closing electro-pneumatic actuated valve ("Slam Shut Valve"), ATEX approved (logged).
Gas pressure transmitter (logged).
Gas distribution manifold.
High burner feed temperature monitoring system (shutdown, logged).

c. Flare Stack:

Steel support structure, hot dip galvanised.
Flare stack cylinder, hot dip galvanised.
4 x PN16 DN125 emissions monitoring ports, flanged and blanked, 1m below exhaust (EA guidance compliant).
High temperature insulating lining, refractory ceramic fibre, 1260 C rated.
Combustion air flow control louvres x 3.
JE170 Propane Ignition Lance.
UV flame detector.
Stack temperature monitor thermocouple. Type N (shutdown and control, logged).

d. Control System:

IP65 weatherproof enclosure.
Colour HMI operating panel, with process value displays and operator interfaces in the English language, under an environmental cover.
Flame monitoring (UV sensor).
Automatic control of gas ignition and re-ignition.
Automatic control of stack temperature.
Hazardous area interface devices.
Text out alarms.*
Remote text status enquiry.*
Remote control via text (Start, Stop, Reset, Pressure / Flow setting)*
SD Card data logging of selected parameters.

*Only with telemetry options.

Displays:

Process Mimic.
Stack temperature.
Run state.
Flame state.
Flare hours.
Alarm state.
Gas inlet pressure.
Slam Shut Valve state.
Recent History (rolling graph).
External warning beacon (Alarm indication).

Shut Down Conditions:

Stack high high temperature.
Burner feed high high temperature.
Flame failed to light.

External Signals:

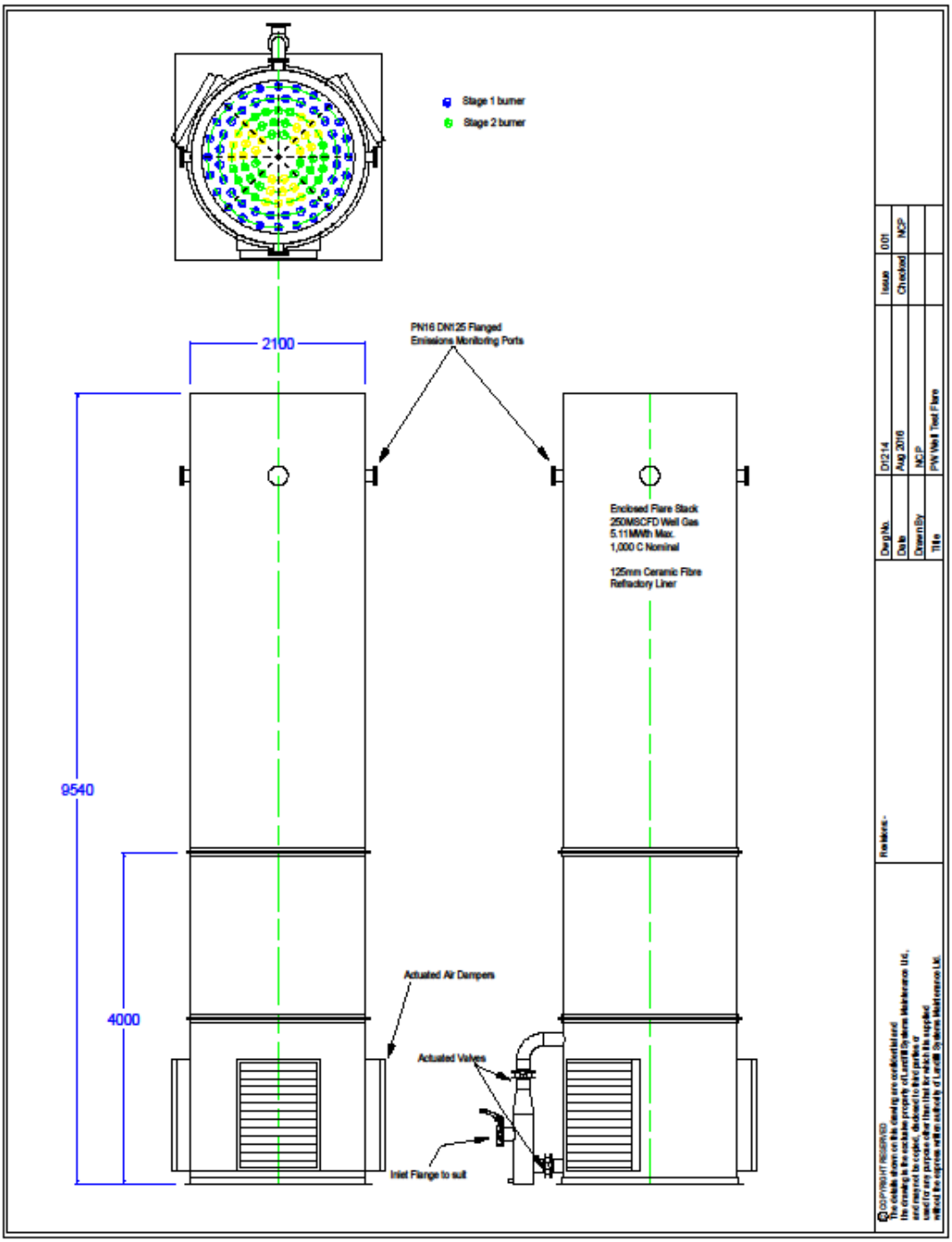
External start / stop (DI through external volt free contact)
Emergency Stop (DI through external volt free safety circuit)
Fault condition (DO – volt free contact).

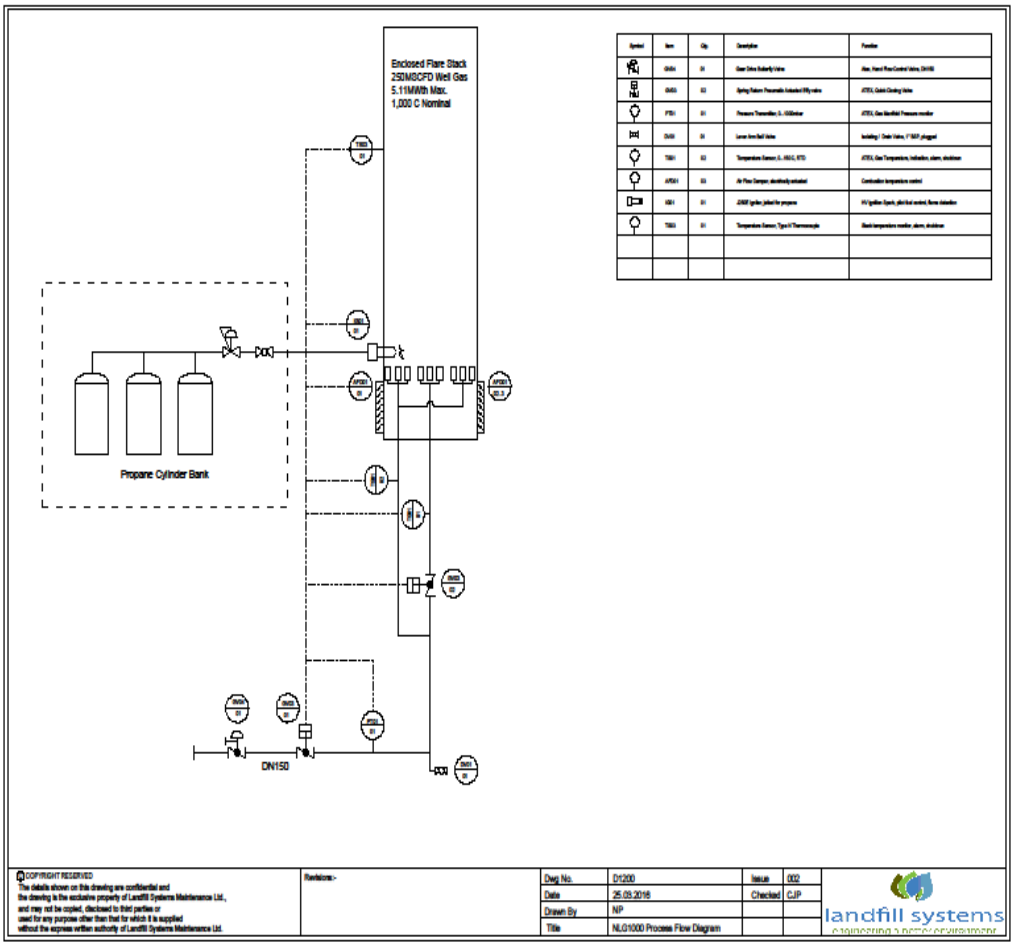
e. Documentation:

Operating and routine maintenance manual in the English language, including:
Operating Instructions.
General arrangement drawing.
Main component manufacturer's technical documentation (included in O&M manual).

PWWT

Stack Drawing



PWWT

Process Flow Diagram