AURORA ENERGY RESOURCES LIMITED

Air quality assessment of an exploratory well site development

Altcar Moss Wellsite (PEDL 164)

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0 SUMMARY

Aurora Energy Resources propose to drill and core vertical and horizontal boreholes which will subsequently undergo hydraulic fracture stimulation at the Altcar Moss wellsite near Great Altcar. Flow testing will then be undertaken to determine viability. The temporary project is expected to last a minimum of two (2) years, however the overall duration may extend further due to breaks that may be taken between operational phases.

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 of any produced natural gas by flaring. 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.

Maximum pollutant process contributions from the site operations are localised and occur within the wellsite site boundary. Beyond the location of maximum process contributions reduce significantly with distance. Process contributions at the site boundary are relatively high and generally well above the Environment Agency's screening criteria and in some cases above air quality standards. However, it is not considered that statutory air quality standards would be applicable in these are areas due to the infrequency of human exposure.

At the neighbouring residential locations and along the Cheshire Lines multi-use route, where frequent human exposure might be expected, all pollutant process contributions were considered insignificant based on Environment Agency assessment criteria and unlikely to threaten ambient air quality standard attainment. The air quality impact significance of all process contributions at the neighbouring residential locations, based on Institute of Air Quality Management descriptors, is considered to be 'negligible'.

At the sites sensitive to nitrogen and acid deposition (Ribble and Alt Estuaries SPA and Sefton Coast SAC) maximum process contributions are considered to be insignificant based on Environment Agency assessment criteria. While the maximum process contributions at the sites with an ecological designation are above the screening criteria for nitrogen oxides, this is considered unlikely to pose any threat to or have any substantial influence on the continued attainment of critical levels.

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 wellsite 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.

1 INTRODUCTION

Aurora Energy Resources Limited placed a contract with SOCOTEC UK Limited (SOCOTEC) to undertake an assessment of the impact on local air quality of a proposed exploratory wellsite development near Great Altcar, Lancashire.

1.1 Scope of study

Aurora Energy Resources propose to construct a well site, known as the Altcar Moss wellsite, on farmland at Sutton's Lane, Great Altcar. The area is within Petroleum Exploration and Development Licence (PEDL) 164. The aim is to drill and core vertical and horizontal boreholes which will subsequently undergo hydraulic fracture stimulation. Each borehole will be flow tested to determine viability. If unsuccessful both boreholes 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 last a minimum of two (2) years, however the overall duration may extend further up to five (5) calendar years due to breaks that may be taken between operational phases.

As part of the planning and permitting process Aurora Energy Resources have asked that the dispersion of releases to atmosphere associated with the proposed operations at the Altcar Moss wellsite 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 from the combustion of diesel fuel are nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs), sulphur dioxide (SO_2) and particulate matter (PM_{10} and $PM_{2.5}$). 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 wellsite.
- Establish the locations of any sensitive areas that might be impacted by releases from the site including residential properties and nature conservation areas.
- Obtain information on local background concentrations of important pollutants.
- Obtain 5 years' recent meteorological data from a measurement station representative of the wellsite 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 Altcar Moss wellsite near Great Altcar. 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

Aurora Energy Resources Limited propose to construct a wellsite, known as the Altcar Moss wellsite, on farmland at Sutton's Lane, Great Altcar. The area is within Petroleum Exploration and Development Licence (PEDL) 164. The aim is to drill and core vertical and horizontal boreholes which will subsequently undergo hydraulic fracture stimulation. Each borehole will be flow tested to determine viability. If unsuccessful both boreholes 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 last a minimum of two (2) years, however the overall duration may extend further due to breaks that may be taken between operational phases.

The Altcar Moss wellsite is near Great Altcar and is in a rural area approximately 2 km to the east of Formby and around 1 km from the nearest residential location. The surrounding land is agricultural with the Downholland Moss geological site of special scientific interest (geological designation) bordering the wellsite and the Cheshire Lines multi-use route running around 0.7 km to the east.

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 Altcar Moss wellsite, in addition a survey of planning and permitting applications provides no indication of any significant developments in the area which might 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. It is in this context that, 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 (NO_x), carbon monoxide and fine particulate matter. Oxides of nitrogen are generally considered to comprise primarily of nitrogen monoxide (NO) and nitrogen dioxide (NO_2). While NO_x from road transport is a major contributor to ground level concentrations, emissions from combustion processes are also 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 (CO) 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 (VOCs) which can give rise to odours and influence ground level ozone formation.

There will also be a release of sulphur dioxide (SO_2) 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 phases of the project, to dispose of the 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 phases 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 (maximum 150 days) is considered unlikely to be significant and as such fugitive releases are not considered within this assessment.

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)

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 2018.

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 Altcar Moss wellsite and on the Cheshire Lines multi-use route neighbouring the site. 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 Great Altcar

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 Great Altcar 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 1 km radius of the Altcar Moss well site (centre 332690 407510) were used for this assessment. Within this area there were 9 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 9 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 (2016)	annual mean	9.30	7.99
Total nitrogen oxides (2016)	annual mean (as NO_2)	12.72	10.80
Nitrogen monoxide (2016)[a]	annual mean	2.24	1.84
PM_{10} (2016)	annual mean	13.44	12.42
$PM_{2.5}$ (2016)	annual mean	7.55	7.32
Carbon monoxide (2010)	maximum 8 hour rolling mean	1471	1454
Sulphur dioxide (2016)	Annual mean	1.37	1.25
Benzene (2016)	annual mean	0.24	0.22

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.

Sefton Council[8] undertakes both automatic and non-automatic air quality monitoring, although the nearest automatic station is around 10 km from the Altcar Moss wellsite, with the nearest non-automatic monitoring around 6.5 km to the south. These activities are largely concentrated around the 5 designated AQMAs in the Crosby area (around 6 km to the south west). Other AQMAs designated by West Lancashire District Council (Ormskirk – 9 km east) and Liverpool City Council (Liverpool – 7 km SE) are also subject to automatic and non-automatic air quality monitoring. However, it is considered that there are no automatic or non-automatic monitoring stations within the area considered to be influenced by releases from proposed operations at the Altcar Moss wellsite and that the nearest stations are unlikely to be representative of conditions in Great Altcar.

In the absence of locally measured background concentrations the maximum values 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 Great Altcar area.

The annual mean background concentration of methane employed in this assessment (1356 µg/m^3) is based on the Northern Hemisphere average[9] and is slightly higher than the background measurements reported by the Environment Agency for 2001-2003 (1278 µg/m^3)[10].

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.

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.

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	1471	15
Nitrogen dioxide (NO_2)	1 hour mean [a]	18.6	9
	annual mean	9.3	23
Sulphur dioxide (SO_2)	15 minute mean[b]	3.7	1
	1 hour mean[a]	2.7	<1
	24 hour mean[c]	1.6	1
PM_{10}	24 hour mean[d]	15.9	32
	annual mean	13.4	34
$PM_{2.5}$	annual mean	7.6	30
Benzene[e]	annual mean	0.24	5
Environmental assessment levels			
Carbon monoxide	hourly mean[f]	2104	7
Benzene[e]	hourly mean[a]	0.5	<1
Nitrogen monoxide (NO)	hourly mean[a]	4.5	1
	annual mean	2.2	<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.

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, 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[11] (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 wellsite 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.

3.1 Assessment area

The area over which the assessment was undertaken is a 1 km x 1 km area with the wellsite (332690 407510) located approximately at the centre. Figure 3.1 illustrates the assessment area, location of the site, the surrounding area and nearest residential locations and the Cheshire Lines multi-use route.

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

A general grid with receptors spaced at 10 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 highlighted 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, 40 receptors (1 to 40 in Figure 3.1) were positioned at residential locations in the vicinity of the wellsite. 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 most frequent human exposure in the vicinity of the wellsite.

It is also expected that there will be frequent human exposure along the Cheshire Lines multi-use route which passes to the east of the well site. In order to monitor the likely impact of wellsite releases on air quality, 113 receptors were placed, at a height of 1.5m, along the length of the route as illustrated in Figure 3.1. 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.

Receptors are also located at the site boundary to determine the maximum off-site process contributions to pollutant concentrations and around the perimeter of the Downholland Moss SSSI. These receptors are described in Annex G. It is noted that this SSSI has a geological designation and as such does not require assessment with regard to air quality impact.

Figure 3.1 Location of the Altcar Moss wellsite

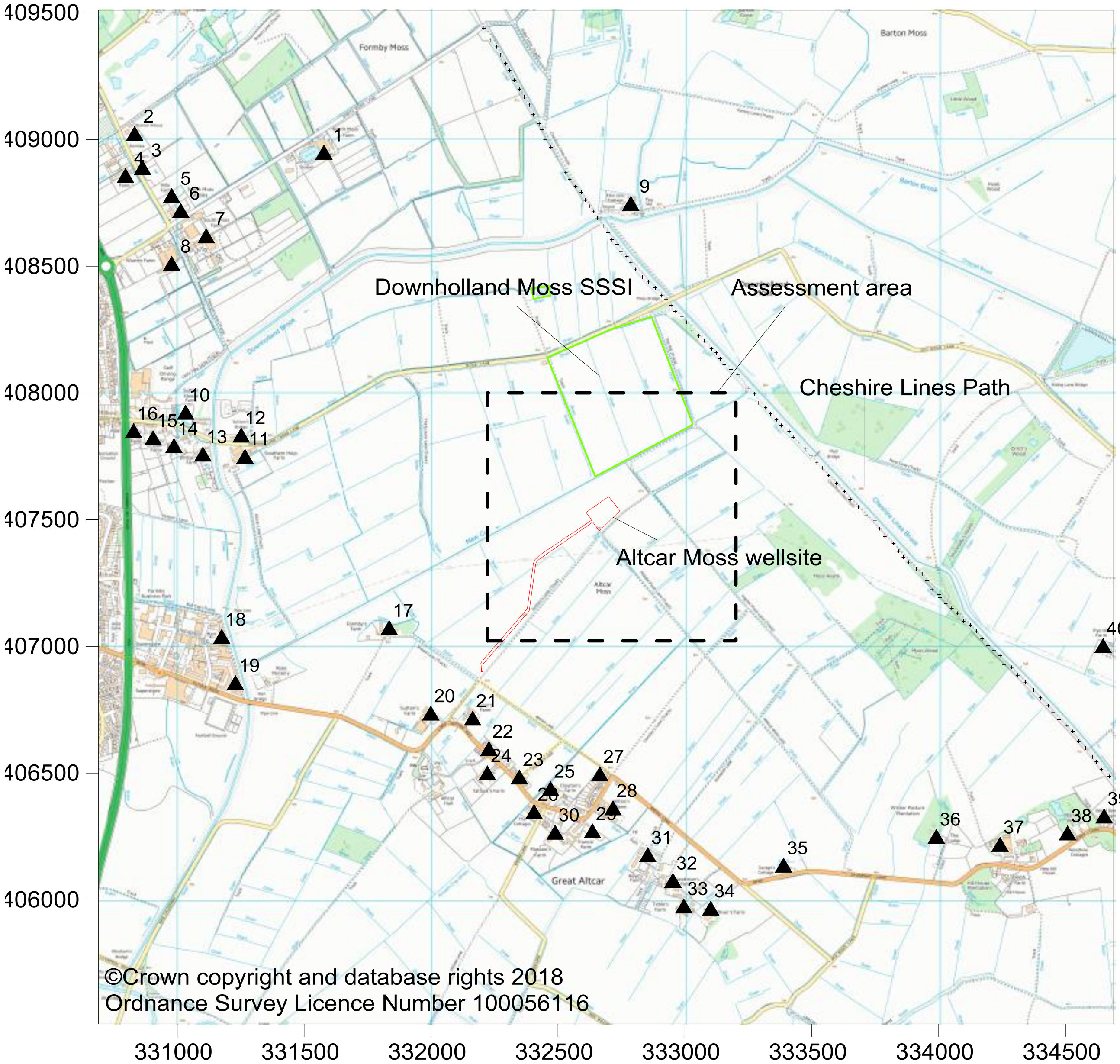
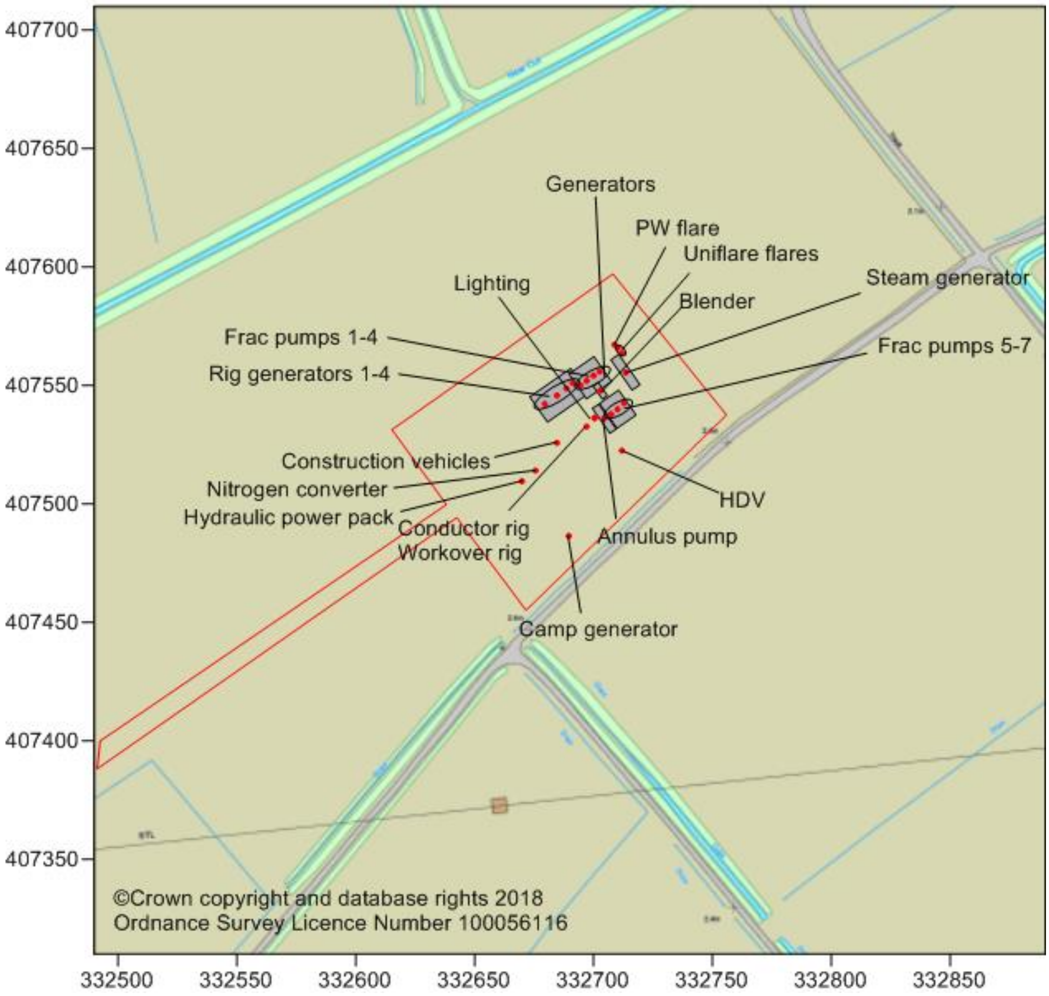


Figure 3.2 Altcar Moss wellsite layout



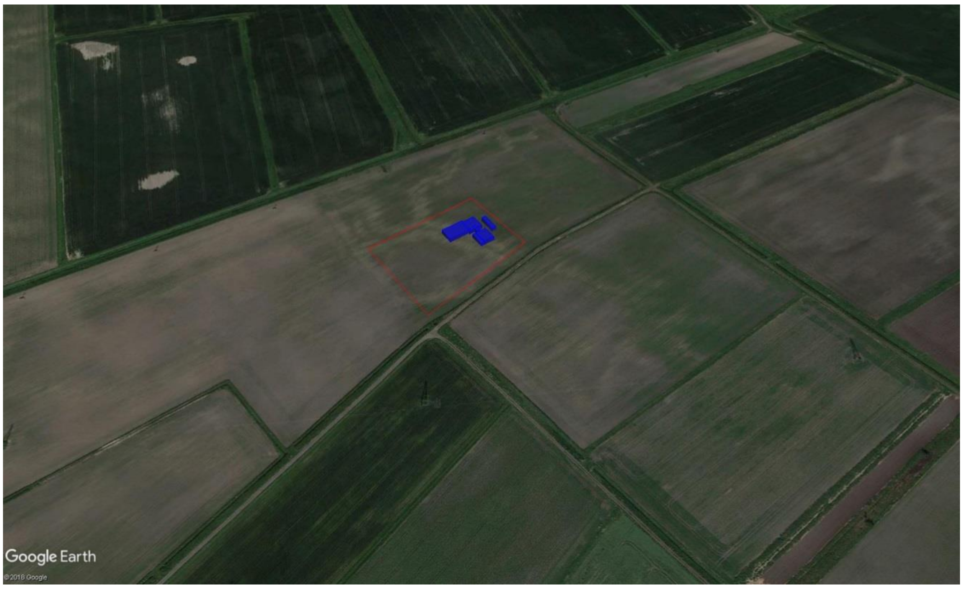


Table 3.1 Location of residential receptors

Receptor (see Figure 3.1)	Position[a]	Easting (m)	Northing (m)
1 North Moss Farm	1819 m NW	331578	408950
2 Warren House	2397 m NW	330832	409024
3 Thorn Hey	2290 m NW	330863	408890
4 Rose Farm	2325 m NW	330796	408858
5 Villa Farm	2131 m NW	330978	408779
6 North Moss Stables	2067 m NW	331014	408720
7 South Moss Farm	1928 m NW	331114	408620
8 Warren Farm	1983 m NW	330978	408511
9 Fine Jane Cottage	1242 m N	332787	408748
10 Sutton House Farm	1708 m W	331033	407924
11 Southern Heys Farm	1443 m W	331267	407750
12 Sutton's Bridge	1474 m W	331252	407834
13 Bridge Inn Farm	1608 m W	331101	407759
14 Brook Farm	1726 m W	330987	407792
15 Moss Side Farm	1812 m W	330905	407823
16 Little Hey Farm	1893 m W	330828	407851
17 Formby's Farm	960 m SW	331835	407074
18 Stephenson Way 1	1587 m W	331175	407039
19 Stephenson Way 2	1600 m SW	331229	406857
20 Sutton's Farm	1037 m SW	331999	406737
21 Tyrer's Farm	952 m SW	332164	406717
22 Lord Sefton Way 1	1023 m SW	332228	406597
23 Lord Sefton Way 2	1081 m S	332348	406485
24 Tatlock's Farm	1112 m SW	332222	406501
25 Clayton's Farm	1093 m S	332471	406439
26 The Cottages	1196 m S	332406	406348
27 Aspinall Crescent	1013 m S	332665	406497
28 Hilton's Farm	1147 m S	332717	406363
29 Francis' Farm	1239 m S	332636	406272
30 Massam's Farm	1259 m S	332489	406267
31 Heye's Farm	1342 m S	332854	406178
32 Speakman's Farm	1457 m S	332953	406077
33 Tickles Farm	1564 m S	332996	405976
34 Oliver's Farm	1597 m S	333102	405967
35 Savage's Cottage	1541 m SE	333389	406137
36 The Lodge	1811 m SE	333991	406250
37 Delph Farm	2019 m SE	334242	406219
38 Woodbine Cottages	2204 m SE	334508	406264
39 Wood Barn Cottage	2289 m SE	334652	406331
40 Pye Hill Farm	2023 m E	334648	407003

a. Location of the receptor relative to the centre of the Altcar Moss wellsite.

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 conservation sites, met the criteria for assessment (see 2.5.3) as described in Table 3.2.

Table 3.2 Location of receptors at nature conservation sites

Receptor		Position[a]	Easting (m)	Northing (m)
A	Downholland Moss SSSI	0.2 km N	332646	407685
B	Ribble and Alt Estuaries SPA, RAMSAR	4.7 km NW	330242	411547
C	Sefton Coast SAC, SSSI	5.7 km N	330861	412933
D	Liverpool Bay SPA	6.2 km NW	327804	411385

a. Location of the edge of the habitat closest to the Altcar Moss wellsite.

The Downholland Moss SSSI is close to the Altcar Moss wellsite boundary, although it has a geological designation and is not sensitive to nitrogen or acid deposition. The other three sites are more distant although all have ecological designations.

At the Downholland SSSI the process contribution from the Altcar Moss wellsite operations is estimated using 61 discrete receptors placed around the perimeter of the site closest to the wellsite (see Annex G). At the remote nature conservation sites a receptor is located at the edge of the site closest to the wellsite as described in Table 3.2.

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 wellsite 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 2 to 4 where it is expected that the greatest releases to atmosphere will occur due to the deployment of multiple generators and pumps. 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 Aurora Energy Resources[12] the main parameters describing these modules were estimated as described in Table 3.3.

Table 3.3 Parameters describing major site structures

Building (see Figure 3.2)	Building centre grid reference		Height (m)	Angle (° from north)	Length (m)	Width (m)
	Easting	Northing				
Rig generators 1-4	332686	407546	4.0	55	21.0	13.0
Fracturing pumps 1-4	332699	407553	4.0	55	12.8	12.8
Fracturing pumps 5-7	332710	407540	4.0	55	9.8	12.8
Annulus pump	332704	407536	4.0	55	3.2	12.8
Blender	332703	407548	4.0	55	2.6	6.8
Steam generator	332713	407556	4.0	55	4.0	15.6

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 40) compared with base case of the Rig Generators as main structure			
	Short term average		Long term average	
	Mean	Maximum	Mean	Maximum
Fracturing pumps 1-4	0	0	0	0
Fracturing pumps 5-7	0	0	0	0.3
Annulus pump	0	0	0	0.3
Blender	0	0	0	0.3
Steam generator	0	0	0	0
No structure	1.0	0.2	-0.1	0.2

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 that the structures considered have little influence on dispersion of site releases and as such the above simplifying approach is not likely to significantly affect the assessment outcome. For this assessment the Rig Generators are selected as the main structure.

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 group containing portable lighting towers, the all terrain fork lift and welfare units 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 flares are each treated as individual sources and are located as indicated in project phase site plans provided by Aurora Energy Resources[12].

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)	Easting (m)	Northing (m)
NRV	All construction equipment used in Phases 1 and 8	3.5	332685	407526
HDV	Heavy duty vehicles entering and leaving site during all phases	3.5	332712	407523
LIGHTS	Portable lighting used in Phases 1 to 8, welfare units in Phases 1 and 8 and all terrain forklift used in Phases 2 and 3	3.5	332697	407533
CAMP	Camp generator (Phases 2 to 7)	4.5	332690	407487
GEN1	Rig generator 1 (Phases 2 to 4)	4.5	332685	407546
GEN2	Rig generator 2 (Phases 2 and 3)	4.5	332689	407549
GEN3	Rig generator 3 (Phases 2 and 3)	4.5	332691	407551
GEN4	Rig generator 4 (Phases 2 and 3)	4.5	332680	407542
STIM1	Fracture stimulation pump 1 (Phase 4)	4.5	332694	407550
STIM2	Fracture stimulation pump 2 (Phase 4)	4.5	332697	407552
STIM3	Fracture stimulation pump 3 (Phase 4)	4.5	332700	407554
STIM4	Fracture stimulation pump 4 (Phase 4)	4.5	332703	407556
STIM5	Fracture stimulation pump 5 (Phase 4)	4.5	332707	407538
STIM6	Fracture stimulation pump 6 (Phase 4)	4.5	332710	407540
STIM7	Fracture stimulation pump 7 (Phase 4)	4.5	332713	407543
ANN	Annulus pump (Phase 4)	4.5	332704	407536
BLEND	Blender(Phase 4)	4.5	332703	407548
COND	Conductor setting rig (Phases 2 and 3)	4.5	332700	407536
WORIG	Workover rig (Phase 7)	4.5	332700	407536
HPP	Hydraulic power pack (Phase 4)	4.5	332670	407510
N2	Nitrogen converter (Phase 4)	4.5	332676	407514
STEAM	Steam generator (Phases 5 and 6)	4.5	332714	407556
FLAREPM	PW Well Test flare for Phase 5	12.2	332709	407567
FLAREU1	Uniflare UF10 flare 1 for Phase 6	7.9	332710	407566
FLAREU2	Uniflare UF10 flare 2 for Phase 6	7.9	332712	407564

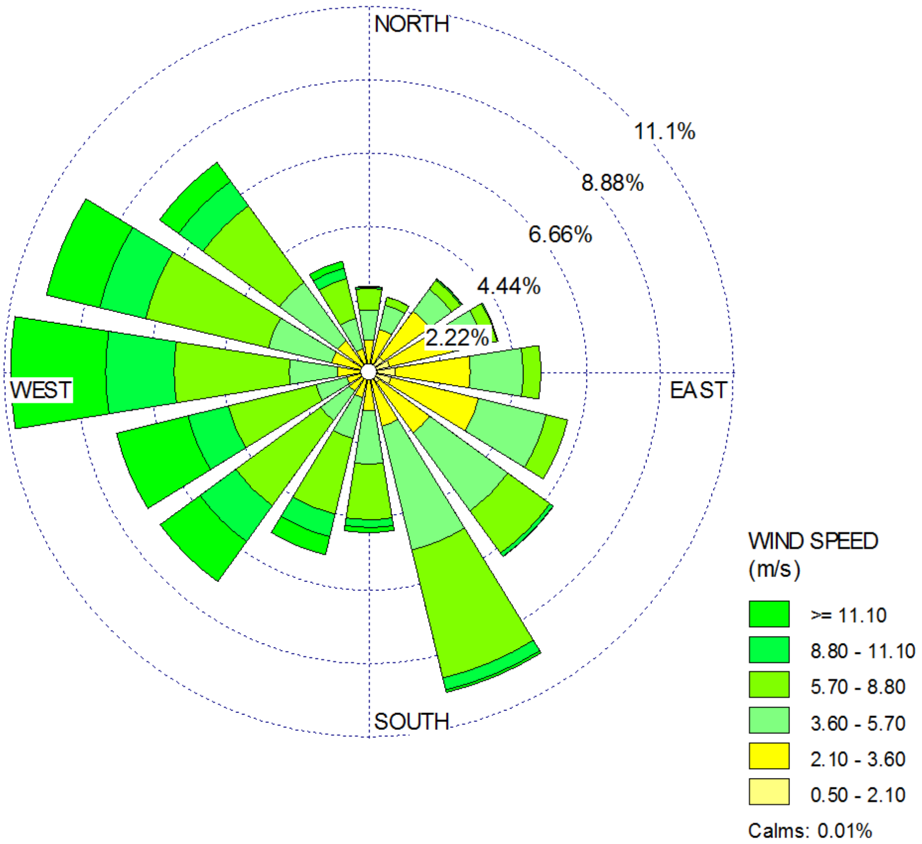
3.3 Meteorology

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 Crosby station and covered the 5 year period 2013 to 2017. The Crosby station is around 7 km south of the Altcar Moss wellsite at an elevation of 9 m, compared with the site elevation of around 3 m. There are four other stations in the area which were also considered as possible sources of meteorological data:

Station	Position	Elevation	Data coverage
Blackpool	28 km N	10 m	Missing cloud data
Preston Moor Park	31 km NE	33 m	Missing cloud and wind data
Rhyl No.2	41 km SW	77 m	Complete
Harwarden Airport	41 km S	11 m	Complete

Based on advice provided by the Met Office, the proximity of the station, near-coastal location, elevation and data coverage, it was considered that data from the Crosby station provided measurements most representative of the conditions in Great Altcar.

Figure 3.3 Composite windrose for the Crosby station (2013 to 2017)



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

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 aldebo
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 Altcar Moss wellsite is located in a rural location largely surrounded by flat agricultural land. The nearest residential location is around 1 km 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 40, see Figure 3.1):

Surface roughness (m)	Change (%) in predicted PC of nitrogen dioxide over the residential receptors (1 to 40) compared with base case of a surface roughness of 0.3 m			
	Short term average		Long term average	
	Mean	Maximum	Mean	Maximum
0.1	-2.3	-6.4	5.6	11.3
0.2	-0.7	-2.8	-0.7	3.8
0.5	-0.9	0	1.6	-2.4
0.8	-3.0	0.6	-9.1	-5.4
1.0	-5.0	-1.2	-11.1	-7.9

It is considered that the selected surface roughness is representative of the area of influence, and 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, but with some warming effects due to the deployment of significant energy intensive equipment. A minimum Monin Obukhov length of 10 m has been employed. A sensitivity analysis has been undertaken considering minimum Monin Obukhov lengths in the range 1 to 50 m. This resulted in the following variations in predicted hourly and annual process contributions of nitrogen dioxide over the residential receptors (1 to 40, see Figure 3.1):

Minimum Monin Obukhov length (m)	Change (%) in predicted PC of nitrogen dioxide over the residential receptors (1 to 40) compared with base case of a minimum Monin Obukhov length of 10 m			
	Short term average		Long term average	
	Mean	Maximum	Mean	Maximum
1	3.1	2.5	0.3	0
5	0.9	0.8	0.2	0
30	7.4	9.1	1.9	-2.3
50	4.6	4.8	0.8	-2.3

The variations are largely insignificant 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 Priestly 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 40, see Figure 3.1).

Priestley Taylor parameter	Change (%) in predicted PC of nitrogen dioxide over the residential receptors (1 to 40) compared with base case of a Priestley Taylor parameter of 1			
	Short term average		Long term average	
	Mean	Maximum	Mean	Maximum
1.5	1.3	-0.1	4.6	0
0.5	-1.3	-1.3	-0.4	0
0	-2.9	-3.0	-0.7	0

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).

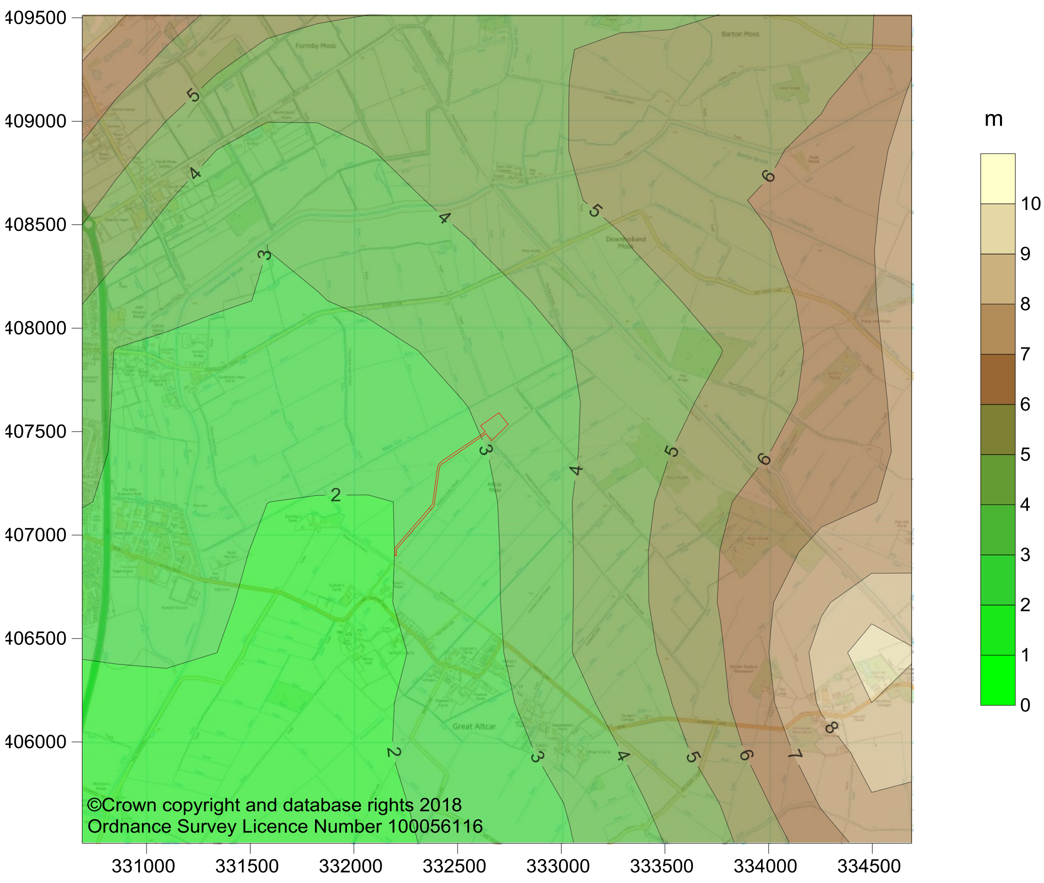
Land use	Bowen ratio (-variation with season)
Water	0.1
Deciduous forest	0.6-2.0
Coniferous forest	0.6-2.0
Swamp	0.2-2.0
Cultivated land	1.0-2.0
Grassland	1.0-2.0
Urban	2.0-4.0
Desert shrubland	5.0-10.0

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 a very small change in general elevation across the main assessment area. The ground rises from the west to the east over the assessment area (rising around 10 m over a distance of around 4 km) at an average gradient of less than 1% 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 40, 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 40) compared with base case of flat assessment area			
	Short term average		Long term average	
	Mean	Maximum	Mean	Maximum
Elevated	0.2	-6.5	-1.8	-2.5

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 appears to provide generally higher predicted 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

Aurora Energy Resources[12] 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 Aurora Energy Resources[12] during the project.

The engine specifications indicate compliance with either European Union or United States emission standards. The engines are assumed to operate at the emission standards. The steam generator is assumed to operate at the emission factors for diesel combustion in industrial boilers as specified in US EPA AP42[13]. 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).

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 3.5 Stationary engines and performance

Equipment		Diesel fuel consumption		Power output[b]	Emission standard
		l/h	kg/h[a]	kWh	
a	Lighting	1.6	1.4	6.7	EU Stage 3A
b	Welfare unit	3.7	3.2	15.2	EU Stage 3A
c	Camp generator	81	71	350	EU Stage 3A
d	Rig generator	394	345	1678	US Tier 2
e	Stimulation pump	394	345	1678	US Tier 2
f	Annulus pump	93	82	388	US Tier 2
g	Blender	93	82	388	US Tier 2
h	Conductor rig	65	56	269	EU Stage 2
i	Steam generator	200	175	2077 (input)	AP42 1.3
j	All terrain fork lift	13.2	11.5	55	EU Stage 3B
k	Workover rig	85	74	354	US Tier 2
l	Hydraulic powerpack	100	87	365	US Tier 2
m	Nitrogen converter	100	87	365	US Tier 2

a. Based on a fuel density of 0.874 kg/l (at 0^{o}C).
b. Assumes a brake specific fuel consumption of 0.21 kg/kWh, where not specified.

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	0.01	0.001	0.013	0.001	0.0000078	1.2
Welfare unit	0.02	0.002	0.030	0.003	0.000018	2.9
Camp generator	0.34	0.029	0.360	0.019	0.0003933	63
Rig generator	1.63	0.220	2.763	0.093	0.0019134	306.2
Stimulation pump	1.63	0.220	2.763	0.093	0.0019134	306.2
Annulus pump	0.38	0.051	0.638	0.022	0.0004525	72.4
Blender	0.38	0.051	0.638	0.022	0.0004525	72.4
Conductor rig	0.26	0.075	0.447	0.015	0.0003132	50.1
Steam generator	0.03	0.002	0.133	0.013	0.000971	155.4
All terrain fork lift	0.08	0.003	0.050	0.0004	0.0000641	10.3
Workover rig	0.34	0.047	0.583	0.020	0.00041	66.1
Hydraulic powerpack	0.36	0.048	0.602	0.020	0.00049	77.7
Nitrogen converter	0.36	0.048	0.602	0.020	0.00049	77.7

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.

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] (^oC)
Lighting	3.5	0.1	1.6	150
Welfare unit	3.5	0.1	3.8	150
Camp generator	3.5	0.2	40.4	550
Rig generator	4.5	0.4	50.2	568
Stimulation pump	4.5	0.4	50.2	568
Annulus pump	4.5	0.2	46.4	550
Blender	4.5	0.2	46.4	550
Conductor rig	4.5	0.2	27.0	550
Steam generator	4.5	0.45	9.0	150
All terrain fork lift	3.5	0.1	12.1	150
Workover rig	4.5	0.2	35.6	550
Hydraulic powerpack	4.5	0.2	41.8	550
Nitrogen converter	4.5	0.2	41.8	550

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.

It is assumed that all stationary engines operate at 100% load continuously when operational (see Tables 3.17 and H.2).

3.5.2 Construction vehicles

Aurora Energy Resources[12] specified the principal vehicles 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
n 360 excavator	114	23.9	EU Stage 3B
o Dumper truck	70	14.7	EU Stage 3A
p Large roller	56	11.8	EU Stage 3B
q D5 tracked dozer	78	16.4	EU Stage 3B
r Mini digger	15	3.2	EU Stage 3A
s Roller	24	5.0	EU Stage 3A
t Tarmac Paving Machine	135	28.4	EU Stage 3A
u Piling Rig	179	37.6	EU Stage 3A
v Trenching machine	169	35.5	EU Stage 4

a. Assumes a brake specific fuel consumption of 0.21 kg/kWh.

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
360 excavator	0.158	0.006	0.105	0.001	0.00013	21.3
Dumper truck	0.097	0.007	0.085	0.008	0.00008	13.1
Large roller	0.078	0.003	0.051	0.000	0.00007	10.5
D5 tracked dozer	0.108	0.004	0.072	0.001	0.00009	14.6
Mini digger	0.023	0.002	0.029	0.003	0.00002	2.8
Roller	0.037	0.004	0.046	0.004	0.00003	4.5
Tarmac Paving Machine[d]	0.131	0.011	0.139	0.008	0.00016	25.2
Piling Rig[d]	0.174	0.015	0.184	0.010	0.00021	33.4
Trenching machine	0.807	0.052	0.710	0.033	0.00078	31.6

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. Only used during Phase 1 (Construction) of the project. All other equipment is used in both Phase 1 and Phase 8 (Restoration) of the project.

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 3.5 m with a velocity of 21 m/s and exhaust temperature of 150^{o}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[14, 15, 16, 17]. 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[18].

Table 3.10 Emission factors for HDV idling

Parameter		Rahman[14]	DIESELNET[15]	Christoher Frey[16]	Khan[17]	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.

Aurora Energy Resources[12] have provided details of maximum daily HDV movements for the various phases of the project (see Table H.3). It is assumed that movements of HDVs occur between 0700 and 1900 on each working day. 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

Project phase	HDVs arriving on site	HDV working hours	HDVs idling /working hour	Fuel consumption l/working hour
1	1050	1024	1.0	1.9
2	532	1800	0.3	0.6
3	465	1800	0.3	0.5
4	1639	720	2.3	4.3
5	419	720	0.6	1.1
6	112	1080	0.1	0.2
7	172	336	0.5	1.0
8	954	512	1.9	3.5

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 and employed in the assessment.

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 3.5 m with a velocity of 7 m/s and exhaust temperature of 150^{o}C.

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
1	0.0079	0.0039	0.0202	0.0007	0.000009	1.51
2	0.0023	0.0011	0.0058	0.0002	0.000003	0.43
3	0.0020	0.0010	0.0051	0.0002	0.000002	0.38
4	0.0176	0.0086	0.0448	0.0016	0.000021	3.35
5	0.0045	0.0022	0.0115	0.0004	0.000005	0.86
6	0.0008	0.0004	0.0020	0.0001	0.000001	0.15
7	0.0040	0.0019	0.0101	0.0004	0.000005	0.75
8	0.0144	0.0070	0.0367	0.0014	0.000017	2.74

3.5.4 Flares

Three flares are proposed for use during the flow test phases of the project. For Phase 5 a PW Well Services shrouded ground flare is proposed for disposal of up to 6.5 MMscfd of natural gas. For the extended flow test in Phase 6 two off Uniflare UF10-2500 systems are is proposed, each with a maximum disposal rate of 2.24 MMscfd of natural gas.

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

Table 3.13 Natural gas composition

Parameter		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		PW (w)	Uniflare (x,y)
Disposal rate	MMscfd	6.5	2.24 (per flare)
	Nm^3/s	2.0	0.7
Heat release[a]	MW	80.3	27.7
Exhaust gas temperature[b]	^{o}C	1000	1000
Exhaust gas flow rate (actual)[c]	m^3/s	221.4	76.3
Flue diameter	m	2.0	2.9
Velocity	m/s	70.5	11.6
Flame length[d]	m	5.7	3.4
Carbon dioxide release[e]	g/s	4070	1403
Water vapour release[e]	g/s	3247	1119

a. Based on 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].

Table 3.15 Pollutant releases from flare operations

Flare		PW	Uniflare
Disposal rate	MMscfd	6.5	2.24 (per flare)
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		4.837 (0.129)	1.667 (0.045)
Nitrogen oxides		2.349 (2.329)	0.810 (0.803)
Carbon monoxide		10.710 (12.803)	3.691(4.412)
Sulphur dioxide[b]		0.201	0.069

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

Release rates determined based on the corresponding EMEP-EEA emission factors[20] 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.

3.5.5 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 factors of 2.1gN_2O/GJ and 0.5 gN_20/GJ (heat input) for diesel and natural gas combustion respectively[19] 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 (2013 to 2017).

The plant above have been considered to operate as specified over the period of the project. The project programme is summarised in Table 3.16 and indicates the number of working days for each phase of the operation.

Table H.1 provides more detail on expected equipment usage during each phase of the project on a day to day basis. This is summarised in Table 3.17.

Table 3.16 Project programme

Phase of project		Equipment used	Duration days
1	Wellsite construction	Monday to Friday 07:00 – 19:00 Saturday 0700 to 1300	112
2	Drilling and coring of vertical borehole		
2a	Conductor setting	24 hours/day, 7days/week	21
2b	Main drilling	24 hours/day, 7days/week	129
3	Drilling and coring of horizontal borehole		
3a	Conductor setting	24 hours/day, 7days/week	21
3b	Main drilling	24 hours/day, 7days/week	129
4	Hydraulic fracture stimulation	24 hours/day, 7days/week Fracturing 4 hours per fracture	60
5	Initial flow testing	24 hours/day, 7days/week	60
6	Extended flow testing	24 hours/day, 7days/week	90
7	Decommissioning and abandonment	24 hours/day, 7days/week	28
8	Site restoration	Monday to Friday 07:00 – 19:00 Saturday 0700 to 1300	56

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

For the purposes of this assessment it is assumed that the once commenced the programme will run continuously. In practice it is likely that there will be breaks between operational phases. The assumed schedule 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. In order to account for possible variations due to seasonal conditions the modelling considers project commencement on the first day of each month over the five years considered. There is generally no work on Sundays and Bank Holidays in phases 1 and 8 and there are restricted working hours during week days and Saturdays. For all other phases continuous 24 hours per day, 7 days per week operation is considered.

It may be noted that air quality benchmarks are expressed as a mean over a calendar year while the project operations span two consecutive calendar years. Since start dates for each month of each year are considered there is confidence that a representative measure of the worst case combination of operational and meteorological conditions will be assessed.

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.

Table 3.17 Equipment usage

Phase of Development		Hours of Operation	Equipment	Hours
1	Wellsite and access track construction	Lighting and welfare	a(2),b(2)	24 hours per day
		Construction vehicles	n,o,p,q,r,s,t,u,v	8 hours per working day and 4 hours on Saturdays
		HDV	-	12 hours per working day, 6 hours on Saturday
2	Drilling and coring of vertical borehole			
2a	Conductor setting	Lighting and fork lift	a(2),j	24 hours per day for lighting and 12 hours per day for the fork lift
		Engines	c,h	24 hours per day
		HDV	-	12 hours per working day
2b	Main drilling	Lighting and fork lift	a(4),j	24 hours per day for lighting and 12 hours per day for the fork lift
		Engines	c,d(4)	24 hours per day
		HDV	-	12 hours per working day
3	Drilling and coring of horizontal borehole			
3a	Conductor setting	Lighting and fork lift	a(2),j	24 hours per day for lighting and 12 hours per day for the fork lift
		Engines	c,h	24 hours per day
		HDV	-	12 hours per working day
3b	Main drilling	Lighting and fork lift	a(4),j	24 hours per day for lighting and 12 hours per day for the fork lift
		Engines	c,d(4)	24 hours per day
		HDV	-	12 hours per working day
4	Hydraulic fracture stimulation	Lighting	a(8)	24 hours per day
		Engines	c,d	24 hours per day
			f,g	6 hours per day
			l,m	5 hours per day
			e(7)	4 hours per fracture
		HDV	-	12 hours per working day
5	Initial flow testing	Lighting	a(5)	24 hours per day
		Engines	c, i	24 hours per day
		Flare	v	24 hours per day
		HDV	-	12 hours per working day
6	Extended flow testing	Lighting	a(3)	24 hours per day
		Engines	c, i	24 hours per day
		Flares	w,x	24 hours per day
		HDV	-	12 hours per working day

Table 3.17 (continued)

Phase of Development		Hours of Operation	Equipment	Hours
7	Decommissioning and abandonment	Lighting	a(4)	24 hours per day
		Engines	c,d,k	24 hours per day
		HDV		12 hours per working day
8	Site restoration	Lighting and welfare	a(2),b	24 hours per day
		Construction vehicles	n,o,p,q,r,s,v	8 hours per working day and 4 hours on Saturdays
		HDV	-	12 hours per working day, 6 hours on Saturday

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 Altcar Moss wellsite boundary and very close to the sources as would be expected for such low level releases. Substantial process contributions are present at the site boundary, although these decrease rapidly with distance.

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 hour	2014	12009	120	1471	13480	135
Nitrogen dioxide	1 hour	2014	3346	1673	18.6	3364	1682
	annual	2017	381	953	9.3	390	976
Sulphur dioxide	15 min	2013	98	37	3.7	102	38
	1 hour	2015	83	24	2.7	85	24
	24 hour	2015	55	44	1.6	56	45
PM_{10}	24 hour	2015	59	119	15.9	75	150
	annual	2015	23	57	13.4	36	91
$PM_{2.5}$	annual	2015	23	92	7.6	31	122
Benzene	annual	2015	65	1295	0.24	65	1299
Carbon monoxide	1 hour	2013	27913	93	2104	30017	100
Benzene	1 hour	2013	3185	1633	0.5	3185	1634
Nitrogen monoxide	1 hour	2013	16894	384	4.5	16898	384
	annual	2017	356	115	2.2	358	116

The maximum process contributions for most pollutants generally represent a significant proportion of the corresponding environmental standard with exceedances of the applicable standards for all pollutants considered with the exception of sulphur dioxide and PM_{10} on a long term basis.. It should be considered that these concentrations are the maxima determined over the assessment area for the five years' meteorological conditions, with the worst case operational scheduling. All maximum concentrations occur within or on the wellsite boundary. Process contributions at other locations of interest and at other times and with alterative scheduling will be lower and often considerably lower.

Maximum concentrations outside of the site occur on site boundary. Discrete receptors were located around the wellsite boundary as described in Annex G. The maximum process contributions determined at the site boundary are summarised in Table 4.2 and represent the maximum off-site process contribution.

Table 4.2 Maximum process contributions and predicted environmental concentrations at the site boundary

Pollutant	Averaging basis	Process contribution		Background	Predicted environmental concentration	
		$\mu g/m^3$	% std	$\mu g/m^3$	$\mu g/m^3$	% std
Carbon monoxide	8 hour	6473	65	1471	7944	79
Nitrogen dioxide	1 hour	2051	1026	18.6	2070	1035
	annual	228	571	9.3	238	594
Sulphur dioxide	15 min	98	37	3.7	102	38
	1 hour	83	24	2.7	85	24
	24 hour	55	44	1.6	56	45
PM_{10}	24 hour	38	76	15.9	54	107
	annual	12	29	13.4	25	63
$PM_{2.5}$	annual	12	46	7.6	19	77
Benzene	annual	65	1295	0.24	65	1299
Carbon monoxide	1 hour	10227	34	2104	12331	41
Benzene	1 hour	3185	1633	0.5	3185	1634
Nitrogen monoxide	1 hour	6190	141	4.5	6194	141
	annual	213	69	2.2	215	69

It may been seen that, while in most cases maximum process contributions at the site boundary are substantially lower than at the point of maximum impact, the process contributions are still significant with exceedances in applicable standards for some pollutants. Maximum contributions on a short term basis for sulphur dioxide and benzene occur on the site boundary.

As shown in Figure A.1 the greatest impact on a short term basis is on the north west site boundary. On the long term basis the highest off-site process contribution is around the north eastern site boundary, as shown in Figure A.2. In both cases, process contributions fall rapidly with distance from the wellsite boundary.

Air quality standards with respect to human health are not considered to be applicable around 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 or designated footpaths.

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 Cheshire Lines multi-use route. 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 wellsite releases at locations of frequent human exposure discrete receptors were located at the residential locations in the vicinity of the Altcar Moss wellsite (Table 3.1 and Figure 3.1) and along the Cheshire Lines multi-use route (see Figure 3.1 and Table G.1). These are considered to be the only locations in the vicinity of the wellsite to which the public normally have access and where human exposure for the air quality standard averaging periods is likely. Table 4.3 compares the maximum process contributions over each group of receptors with the screening criteria headroom.

Table 4.3 Maximum process contributions at locations of human exposure

Pollutant	Averaging basis	Criteria headroom[a] % std	Maximum process contribution (% std)	
			Residential	Cheshire Lines
Carbon monoxide	8 hour	17.1	0.5	0.6
Nitrogen dioxide	1 hour	18.1	14.4	16.6
	annual	46.8	3.6	7.4
Sulphur dioxide	15 min	19.7	0.1	0.2
	1 hour	19.8	0.1	0.1
	24 hour	19.7	0.1	0.2
PM_{10}	24 hour	13.6	0.6	1.0
	annual	36.5	0.2	0.4
$PM_{2.5}$	annual	13.9	0.3	0.6
Benzene	annual	65.2	3.3	10.8
Carbon monoxide	1 hour	18.6	0.5	0.9
Benzene	1 hour	19.9	6.2	9.8
Nitrogen monoxide	1 hour	20.0	2.2	3.6
	annual	69.3	0.4	0.9

a. Criteria headroom is the maximum process contribution, which meets the screening assessment criteria (i.e. the short term process contribution is less than 20% of the short term environmental standard less the corresponding background and/or the long term predicted environmental concentration is less than 70% of the long term environmental standard).

For both the residential locations and the Cheshire Lines multi-use route the maximum process contributions for all pollutants considered are within the Environment Agency's screening criteria (i.e. the short term process contribution is less than 20% of the short term environmental standard less the corresponding background and/or the long term predicted environmental concentration is less than 70% of the long term environmental standard). In all cases the maximum process pollutant concentrations at these sensitive receptors are considered to be insignificant in terms of air quality impact. Nitrogen dioxide and volatile organic compounds, assessed as benzene, provide the largest process contributions relative to their air quality standards. Table G.2 summarises the maximum process contribution of these pollutants at each residential location.

At all residential locations the predicted environmental concentration is less than 75% of the long term air quality standard and the maximum process contribution is below 6% of the long term air quality standard for nitrogen dioxide, benzene, PM_{10}, $PM_{2.5}$ and nitrogen monoxide. Based on Environmental Protection UK (EP UK) and the Institute of Air Quality Management (IAQM) classification (section 2.5.4) the impact significance of these releases is considered to be 'negligible' in all cases.

It is therefore considered that pollutant releases from proposed operations at the Altcar Moss wellsite will not have a significant impact on air quality at the nearest locations of human exposure and are unlikely to compromise continued attainment of ambient air environmental standards.

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 Altcar Moss wellsite as discussed in section 3.1. The main pollutants of interest at the nature conservation sites are nitrogen oxides, nitrogen dioxide and sulphur dioxide. It may be seen that there is a SSSI (Downholland Moss) within 100 m of the wellsite, although this has a geological designation. There are two SPAs and an SAC within 4 to 6 km of the wellsite which require inclusion in the assessment. For the purposes of the assessment of process contributions at these sites a discrete receptor was placed on the site boundary closest to the Altcar Moss wellsite as described in Table 3.2. For completeness process contributions at the Downholland Moss SSSI were also assessed using 63 discrete receptors located along the site boundary as described in Annex G.

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 4.4.

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.

The background concentrations at each site, as obtained from APIS, are summarised in Table 4.5. 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 precautionary approach.

Table 4.4 Site relevant critical loads and levels

Site		A Downholland Moss SSSI	B Ribble & Alt Estuaries SPA	C Sefton Coast SAC	D Liverpool Bay SPA
Critical levels for nitrogen oxides and sulphur dioxide (see Table 2.2)					
Annual mean NO_x	$\mu gNO_2/m^3$	No ecological designation	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		Not sensitive	Raised & blanket bogs	Coastal stable dune grasslands-acid type	Not sensitive
N deposition CL	kgN/ha/y		5-10	8-10	
Critical loads for acid deposition					
Most sensitive habitat		Not sensitive	Bogs	Acid grassland	Not sensitive
Minimum CLminN	keq		0.321	0.223	
Minimum CLmaxS	keq		0.161	0.410	
Minimum CLmaxN	keq		0.482	0.848	

a. Critical levels and critical loads are the minimum specified for most sensitive habitat within the site.
b. No critical loads or levels are provided for those sites where there is no sensitivity to nitrogen or acid deposition.

Table 4.5 Site relevant background concentrations

Site		A Downholland Moss SSSI	B Ribble & Alt Estuaries SPA	C Sefton Coast SAC	D Liverpool Bay SPA
Nitrogen oxides annual mean	$\mu gNO_2/m^3$	12.64	21.98	23.62	25.76
Sulphur dioxide annual mean	$\mu gSO_2/m^3$	1.60	0.97	1.05	1.11
Nitrogen deposition	kgN/ha/y	13.44	12.74	15.12	15.96
Nitrogen acid deposition	keq/ha y	1.10	0.91	1.08	1.14
Sulphur acid deposition	keq/ha y	0.19	0.35	0.31	0.35

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 4.6.

Table 4.6 Maximum process contributions of nitrogen oxides and sulphur dioxide at the conservation sites

Site		A Downholland Moss SSSI	B Ribble & Alt Estuaries SPA	C Sefton Coast SAC	D Liverpool Bay SPA
Nitrogen oxides[a]					
Maximum annual mean PC	µgNO_2/m^3	74.47	0.47	0.37	0.34
	% CL	-	1.6	1.2	1.1
Background concentration	µgNO_2/m^3	12.64	21.98	23.62	25.76
Maximum annual mean PEC	µgNO_2/m^3	87.1	22.5	24.0	26.1
	% CL	-	75	80	87
Maximum daily mean PC	µgNO_2/m^3	671	4.16	3.49	3.93
	% CL	-	5.5	4.7	5.2
Back ground concentration	µgNO_2/m^3	25.28	43.96	47.24	51.52
Maximum daily mean PEC	µgNO_2/m^3	696	48.1	50.7	55.5
	% CL	-	64	68	74
Sulphur dioxide					
Maximum annual mean PC	µgSO_2/m^3	0.08	0.0011	0.0011	0.0009
	% CL	-	<0.1	<0.1	<0.1
Background concentration	µgSO_2/m^3	1.60	0.97	1.05	1.11
Maximum annual mean PEC	µgSO_2/m^3	1.68	0.97	1.05	1.11
	% CL	-	10	11	11

a. Total nitrogen oxides are expressed as NO_2.

For the three ecological designations considered maximum process contributions of sulphur dioxide are equivalent to less than 1% of the applicable critical load in all cases and as such may be considered insignificant.

The maximum annual mean process contributions of nitrogen oxides at these sites are just above 1% of the applicable critical level, although the corresponding predicted environmental concentrations are within the applicable critical load, albeit somewhat above the screening criterion of 70% of critical load. The daily mean nitrogen oxides process contribution at these sites is relatively low at less than 10% of the critical load with corresponding predicted environmental concentrations well within the applicable critical load. While the process contributions of nitrogen oxides cannot be screened out as being insignificant, the precautionary approach to the assessment should be taken into consideration (see section 4.5). The process contributions determined represent the worst case, but nonetheless are relatively small in comparison to the existing background and are unlikely to have any substantial influence on critical load compliance at these sites and unlikely to pose any threat to continued critical load attainment. Under different assumed operating conditions (see section 4.5), these process contributions could fall comfortably below the screening criteria.

The determination of nitrogen deposition at the selected nature conservation sites is summarised in Table 4.7. The determination was undertaken in accordance with the guidance in AQTAG 06[21] and considered dry deposition only. Guidance indicates that wet deposition over relatively short distances is unlikely to be significant.

Table 4.7 Nitrogen deposition at the conservation sites

Site		A Downholland Moss SSSI	B Ribble & Alt Estuaries SPA	C Sefton Coast SAC	D Liverpool Bay SPA
Maximum process N deposition	$\mu gNO_2/m^2/s$ [a]	0.0782	0.00049	0.00039	0.00035
	kgN/ha/y	7.507	0.047	0.037	0.034
	% CL [b]	not sensitive	0.9	0.5	not sensitive
Back ground concentration	kN/ha y	13.44	12.74	15.12	15.96
Maximum annual mean PEC	kN/ha y	20.95	12.79	15.16	15.99
	% CL [b]	not sensitive	256	189	not sensitive

a. Determination of deposition is based on the deposition velocity for grassland terrain[21].
b. The critical load selected is the minimum of the range specified for the most sensitive habitat over the entire site.

The process contributions to nutrient nitrogen deposition at the Ribble Alt and Estuaries SPA and Sefton Coast SAC were less than 1% of the critical loads and are therefore considered insignificant. While there is exceedance of the critical loads at 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. Neither the Downholland Moss SSSI nor the Liverpool Bay SAC are sensitive to nitrogen deposition.

The determination of the process contribution to acid deposition at these sites is summarised in Table 4.8.

Table 4.8 Acid deposition at conservation sites

Site		A Downholland Moss SSSI	B Ribble & Alt Estuaries SPA	C Sefton Coast SAC	D Liverpool Bay SPA
Nitrogen acid deposition	$\mu gNO_2/m^2/s$ [a]	0.0782	0.00049	0.00039	0.00035
	kgN/ha/y	7.507	0.047	0.037	0.034
	keq/ha y	0.5360	0.0033	0.0027	0.0024
Sulphur acid deposition	$\mu gSO_2/m^2/s$ [a]	0.001004	0.000013	0.000013	0.000010
	kgS/ha/y	0.1583	0.0021	0.0020	0.0016
	keq/ha y	0.00989	0.00013	0.00012	0.00010
Total process acid deposition	keq/ha/y	0.5459	0.0035	0.0028	0.0025
	% CL [b,c]	not sensitive	0.7	0.3	not sensitive
Total background acid deposition	keq/ha/y	1.29	1.26	1.39	1.49
Maximum annual mean PEC	keq/ha y	1.84	1.26	1.39	1.49
	% CL [b,c]	not sensitive	262	164	not sensitive

a. Determination of deposition is based on the deposition velocity for grassland terrain[21].
b. Calculations of process contribution and predicted environmental concentrations were undertaken using the APIS critical load tool.
c. The critical loads selected are the minimum specified for all habitats over the entire site.

The process contributions to acid deposition at the Ribble Alt and Estuaries SPA and Sefton Coast SAC are less than 1% of the critical load in both cases and as such are considered insignificant. While there is exceedance of the critical load at these sites, this is due to an existing large background deposition and it is not considered that the process contribution has any significant influence on critical load compliance. Neither the Downholland Moss SSSI nor the Liverpool Bay SAC are sensitive to acid deposition.

At the sites sensitive to nitrogen and acid deposition maximum process contributions are considered to be insignificant. While the maximum process contributions at the sites with an ecological designation are above the screening criteria for nitrogen oxides, this is considered unlikely to pose any threat to or have any substantial influence on the continued attainment of critical levels.

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. All environmental standards are considered on the basis of a calendar year (see section 2.3). The phased nature of the project and the substantial differences in pollutant releases associated with each phase provides the potential for considerable variations in process contribution over a calendar year depending on the assumed commencement date.

A sensitivity analysis was undertaken to determine the influence of meteorological conditions, project scheduling and model selection on the findings of the assessment and hence provide some measure of their robustness.

4.4.1 Meteorological conditions

Table 4.9 summarises the influence of meteorological conditions on maximum process contributions for the discrete receptor groups describing the neighbouring residential locations, the Cheshire Lines multi-use route, the wellsite boundary and ecological conservation sites (see Annex G and Table 3.2).

Table 4.9 Influence of meteorological conditions on maximum process contribution

Pollutant	Averaging basis	Maximum process contribution (ratio of maximum to minimum year)			
		Residential	Cheshire Lines	Site boundary	Conservation sites
Carbon monoxide	8 hour	1.2	1.4	1.7	2.0
Nitrogen dioxide	1 hour	1.2	1.3	1.1	1.3
	annual	1.8	1.7	1.5	1.8
Sulphur dioxide	15 min	2.8	4.1	23.7	4.1
	1 hour	1.4	1.8	2.0	1.9
	24 hour	4.1	6.5	23.6	4.7
PM_{10}	24 hour	2.0	1.5	1.3	1.8
	annual	1.7	1.7	1.4	1.7
$PM_{2.5}$	annual	1.7	1.7	1.4	1.7
Benzene	annual	1.3	1.6	3.5	1.7
Carbon monoxide	1 hour	1.3	1.6	1.5	1.4
Benzene	1 hour	1.3	1.7	5.1	1.3
Nitrogen monoxide	1 hour	1.3	1.6	1.5	1.4
	annual	1.8	1.7	1.5	1.8

Annual variations in meteorological conditions on average show up to a twofold difference between maximum and minimum process contributions. The variations are greater for sulphur dioxide, although these process contributions are generally low (see section 4.1). 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 Project scheduling

Table 4.10 summarises the influence of project scheduling on maximum process contributions for the discrete receptor groups describing the neighbouring residential locations, the Cheshire Lines multi-use route, the wellsite boundary and ecological conservation sites (see Annex G and Table 3.2).

Maximum process contributions have been examined for project commencement dates at the beginning of each month of the year for each of the five meteorological years considered (i.e. 60 possible start dates)

Table 4.10 Influence of project scheduling on maximum process contribution

Pollutant	Averaging basis	Maximum process contribution (ratio of maximum to minimum project start date)			
		Residential	Cheshire Lines	Site boundary	Conservation sites
Carbon monoxide	8 hour	1.7	1.9	3.8	2.8
Nitrogen dioxide	1 hour	1.7	1.4	1.9	2.4
	annual	3.8	2.7	2.4	3.0
Sulphur dioxide	15 min	3.9	6.0	32.6	8.0
	1 hour	5.1	7.7	32.9	9.7
	24 hour	8.8	12.6	40.7	12.9
PM_{10}	24 hour	5.1	2.6	2.7	2.9
	annual	3.6	2.7	2.3	3.1
$PM_{2.5}$	annual	3.6	2.7	2.3	3.1
Benzene	annual	2.4	2.5	5.7	2.5
Carbon monoxide	1 hour	1.4	1.8	1.8	2.4
Benzene	1 hour	1.4	1.8	7.5	1.9
Nitrogen monoxide	1 hour	1.4	1.8	1.8	2.4
	annual	3.8	2.7	2.4	3.0

It may be seen that project scheduling can have a substantial impact on the maximum process contributions at a given location, with a variation for most pollutants of a factor of around 2 to 3. For nitrogen dioxide phases 2 and 3 provide the maximum release rates, whereas phases 1 and 8 have the minimum releases. The maximum process contribution for nitrogen dioxide will therefore be achieved where both phases 2 and 3 occur in the same calendar year. Project commencement at the beginning of November or December will mean most of phases 2 and 3, and phase 4, being accommodated in the following year. This provides for maximum calendar year releases of nitrogen dioxide. Minimum releases, and hence process contributions of nitrogen dioxide, occur when phases 2 and 3 are split over consecutive calendar years corresponding to a start date of around July. For volatile organic compounds and carbon monoxide the highest releases occur during the flaring of natural gas in phases 5 and 6. Hence maximum and minimum releases occur at a different commencement date to nitrogen dioxide, although these pollutants have a somewhat lower air quality impact.

In the assessment the greatest process contribution at each location, for each pollutant for all of the 60 commencement dates considered has been reported. This will therefore be an overestimate in practice, in the range shown in Table 4.10, for most pollutants and most locations.

4.4.3 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 2013 meteorological conditions. Table 4.11 illustrates the comparison between the ADMS and AERMOD model predictions averaged over residential and ecological receptors (see Tables 3.1 and 3.2).

Table 4.11 Maximum process contributions (variation with model)

Pollutant	Averaging basis	Maximum process contribution (ratio of ADMS to AERMOD)			
		Residential	Cheshire Lines	Site boundary	Conservation sites
Carbon monoxide	8 hour	1.6	1.3	11.0	0.8
Nitrogen dioxide	1 hour	1.1	1.0	5.9	0.7
	annual	1.1	1.3	7.8	0.8
Sulphur dioxide	1 hour	1.3	1.1	5.7	0.7
	24 hour	1.6	1.4	11.1	0.8
PM_{10}	24 hour	1.9	1.4	12.0	0.9
Benzene	annual	1.1	1.3	7.8	0.8

In general the AERMOD model provides a somewhat lower predicted ambient process contribution compared with ADMS for all averaging bases at the human receptors considered. AERMOD gives higher process contributions at the ecological conservation sites which are relatively remote from the wellsite at a distance of 4 to 6 km. 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.

4.5 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 all engines and flares on a continuous 24 hour per day basis for the entire duration of the project phase except where specifically limited by working hours or Aurora Energy Resources' project schedule. 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 2 and 3) and flow testing (phases 5 and 6). In these phase 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. In addition, a continuous programme is assumed whereas in practice there are likely to be breaks between operational phases. This is likely to result in an overestimate of long term impacts which are determined over a calendar year.

- The release rates upon which the assessment is based are consistent with the operation of engines and flares 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[22], indicating a likely overestimate of the significance of process releases (see Annex C and Table G.1) 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[19] 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. The assessment has shown significant differences depending on the assumed starting date for the project. This assessment is based on the project start date providing the maximum impact for each location and each pollutant and as such is likely to be an overestimate for most cases in practice.

- 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. ADMS, on average, provides a somewhat higher predicted ambient impact compared with AERMOD for locations within 2 km or so of the site. AERMOD shows slightly higher process contributions at more distant locations such as the ecological conservation sites considered.

- 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.

4.6 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 4.12 on the basis of operating conditions in section 3.5.

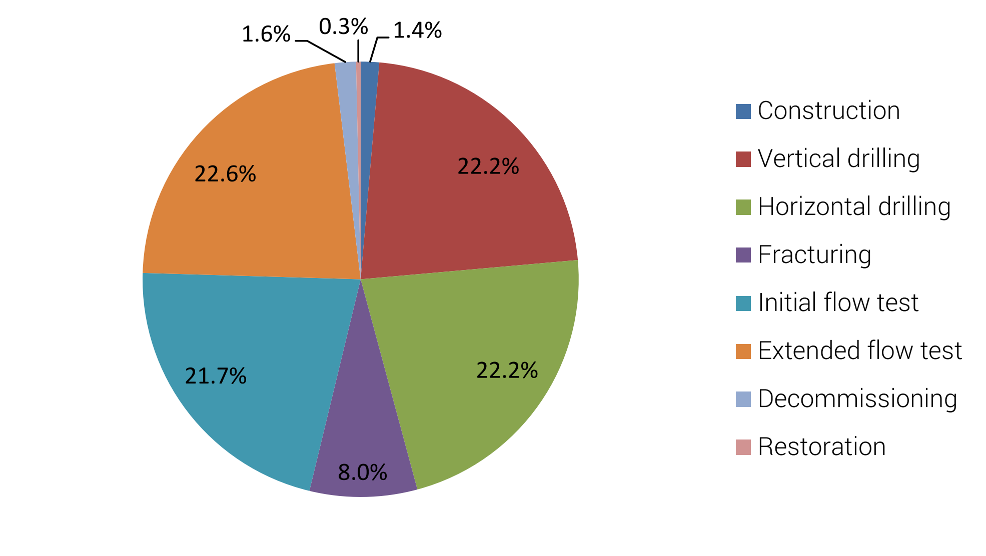
Table 4.12 Calculation of POCP related releases

Pollutant	Release over project (t)				POCP (t)
	NO_2	CO	SO_2	Benzene	
POCP factor	2.8	2.7	4.8	21.8	
1 Construction	6.76	7.08	<0.01	0.5	49
2 Vertical drilling	129.68	78.57	0.09	10.4	802
3 Horizontal drilling	129.68	78.57	0.09	10.4	802
4 Fracturing	46.52	28.19	0.03	3.7	288
5 Initial flow test	15.08	68.55	1.05	25.3	783
6 Extended flow test	16.74	71.75	1.08	26.2	817
7 Decommissioning	9.1	5.7	0.01	0.7	57
8 Restoration	1.62	1.81	<0.01	0.1	12
TOTAL	355	340	2	77	3610

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 3610 (tonnes).

Figure 4.1 illustrates the phase contribution to POCP and identifies the initial and extended flow testing operations (Phases 5 and 6), where produced natural gas is being flared, and the vertical and horizontal drilling phases (Phases 2 and 3) as the greatest contributors to POCP, each with a similar contribution.

Figure 4.1 Project phase contributions to POCP



4.7 Global warming potential

Some of the pollutants released are greenhouse gases and it is required that the impact on global warming 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[23], provides a standardised methodology for determination of the impact on global warming of a release on the basis of the equivalent mass release of carbon dioxide.

In the case of the proposed plant it is considered that releases of carbon dioxide, methane and nitrous oxide have implications for global warming. The annual release of each of these is assessed in Table 4.13 on the basis of operating conditions in section 3.5 and represents the total release for the project duration. Tthe global warming potential factors for methane and nitrous oxide use the values specified in the Intergovernmental Panel on Climate Change's 4th Assessment Report.

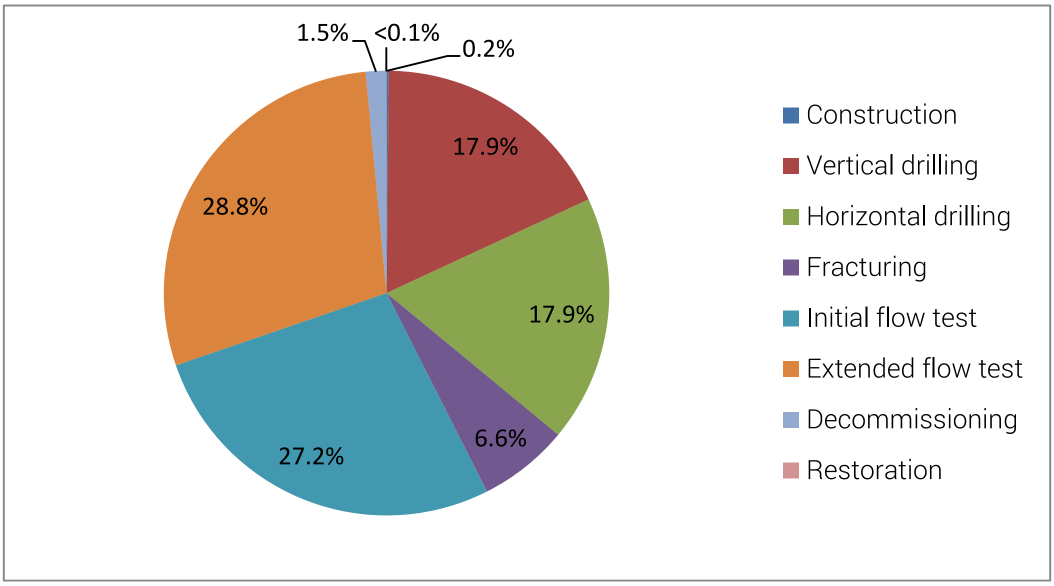
Table 4.13 Calculation of greenhouse gas releases

Greenhouse gas	Release over project (t)			Impact (t CO_2 equivalent)
	CO_2	N_2O	CH_4	
Global warming potential (relative to CO_2, 100 years)	1	298	25	
1 Construction	120	0.0204	0.52	139
2 Vertical drilling	14687	0.4124	10.39	15070
3 Horizontal drilling	14687	0.4124	10.39	15070
4 Fracturing	5378	0.1514	3.72	5516
5 Initial flow test	22262	0.0327	25.26	22903
6 Extended flow test	23546	0.1576	26.19	24248
7 Decommissioning	1065	0.4667	0.73	1222
8 Restoration	27	0.0041	0.12	31
TOTAL	81772	1.658	77.3	84199

The assumptions made in relation to releases are considered to represent the worst case for the proposed operations. The determination indicates a global warming impact equivalent to 84,199 tCO_2.

Figure 4.2 illustrates the phase contribution to global warming potential. Initial and extended flow testing operations (Phases 5 and 6) are the greatest contributors to greenhouse gas releases.

Figure 4.2 Project phase contributions to Global Warming Potential



4.8 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[24] 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'.

4.9 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[25] and the IAQM[11].

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.

4.10 Cumulative impacts

This assessment has quantified the likely air quality impact of the development at Great Altcar 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 Altcar Moss wellsite was considered. The postcodes within this area are DL37, L39, L29, L38, L31, L23, and PR8. These were used as the search criteria within the Sefton Council's e planning portal and the Environment Agency's register of permits issued and applications made. All planned and current developments from 2016 onwards in these postcodes were considered and initially screened for contribution of affected pollutants and distance from the Altcar Moss wellsite. 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 Altcar Moss wellsite. Details of the search are summarised in Table 4.14.

Table 4.14 Cumulative impact development search

Site	Permit	Date	Location	Impact
Sefton Council e planning				
No relevant developments				
Environment Agency Notice of applications made				
No relevant developments				
Environment Agency Notice of permits issued				
Brookfield House Farm (L39 0EE)	AP3036MK	4.6.18	9.5 km SE	New poultry units with 0.5 ME biomass boiler. No significant impact on existing backgrounds of relevant pollutants.
White Moss Horticulture (L38 1QA)	BB3004XT	2.2.17	3.0 km SW	Increase in annual throughput of composting facility. No significant impact on existing backgrounds of relevant pollutants.

The assessment indicates that there are no current or planned developments which are likely to have any significant impact on the existing background concentrations of the pollutants of interest in the area of influence around the Altcar Moss wellsite.

5 CONCLUSIONS

Aurora Energy Resources propose to drill and core vertical and horizontal boreholes which will subsequently undergo hydraulic fracture stimulation at the Altcar Moss wellsite near Great Altcar. Flow testing will then be undertaken to determine viability. The temporary project is expected to last a minimum of two (2) years, however the overall duration may extend further due to breaks that may be taken between operational phases.

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 of any produced natural gas by flaring. 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.

Maximum pollutant process contributions from the site operations are localised and occur within the wellsite site boundary. Beyond the location of maximum process contributions reduce significantly with distance. Process contributions at the site boundary are relatively high and generally well above the Environment Agency's screening criteria and in some cases above air quality standards. However, it is not considered that statutory air quality standards would be applicable in these are areas due to the infrequency of human exposure.

At the neighbouring residential locations and along the Cheshire Lines multi-use route, where frequent human exposure might be expected, all pollutant process contributions were considered insignificant based on Environment Agency assessment criteria and unlikely to threaten ambient air quality standard attainment. The air quality impact significance of all process contributions at the neighbouring residential locations, based on Institute of Air Quality Management descriptors, is considered to be 'negligible'.

At the sites sensitive to nitrogen and acid deposition (Ribble and Alt Estuaries SPA and Sefton Coast SAC) maximum process contributions are considered to be insignificant based on Environment Agency assessment criteria. While the maximum process contributions at the sites with an ecological designation are above the screening criteria for nitrogen oxides, this is considered unlikely to pose any threat to or have any substantial influence on the continued attainment of critical levels.

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 wellsite 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.

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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 under the conditions (including commencement date) 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 1 km x 1km which includes the immediate area around the Altcar Moss well site and over an area of 4 km x 4 km (see Figure 3.1) which includes the 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 these levels 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 – 2014 for a November 2013 commencement)

Figure 2 Predicted maximum process contributions of nitrogen dioxide
(AAD limit annual mean - 2017 for a December 2016 commencement)

Figure A.1 Predicted maximum process contributions of nitrogen dioxide
(AAD limit 99.8 percentile of 1 hour means – 2014 for a November 2013 commencement)

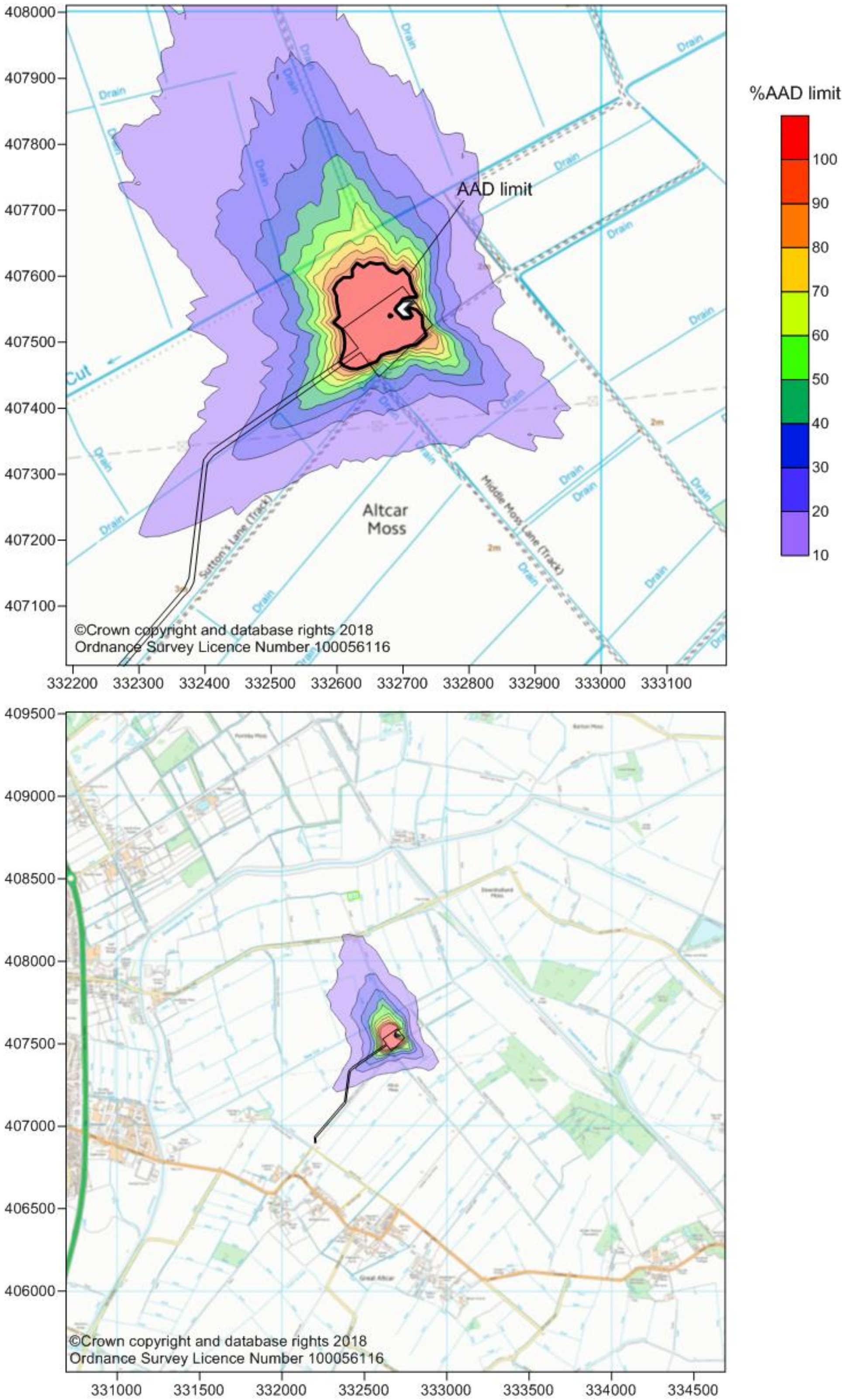
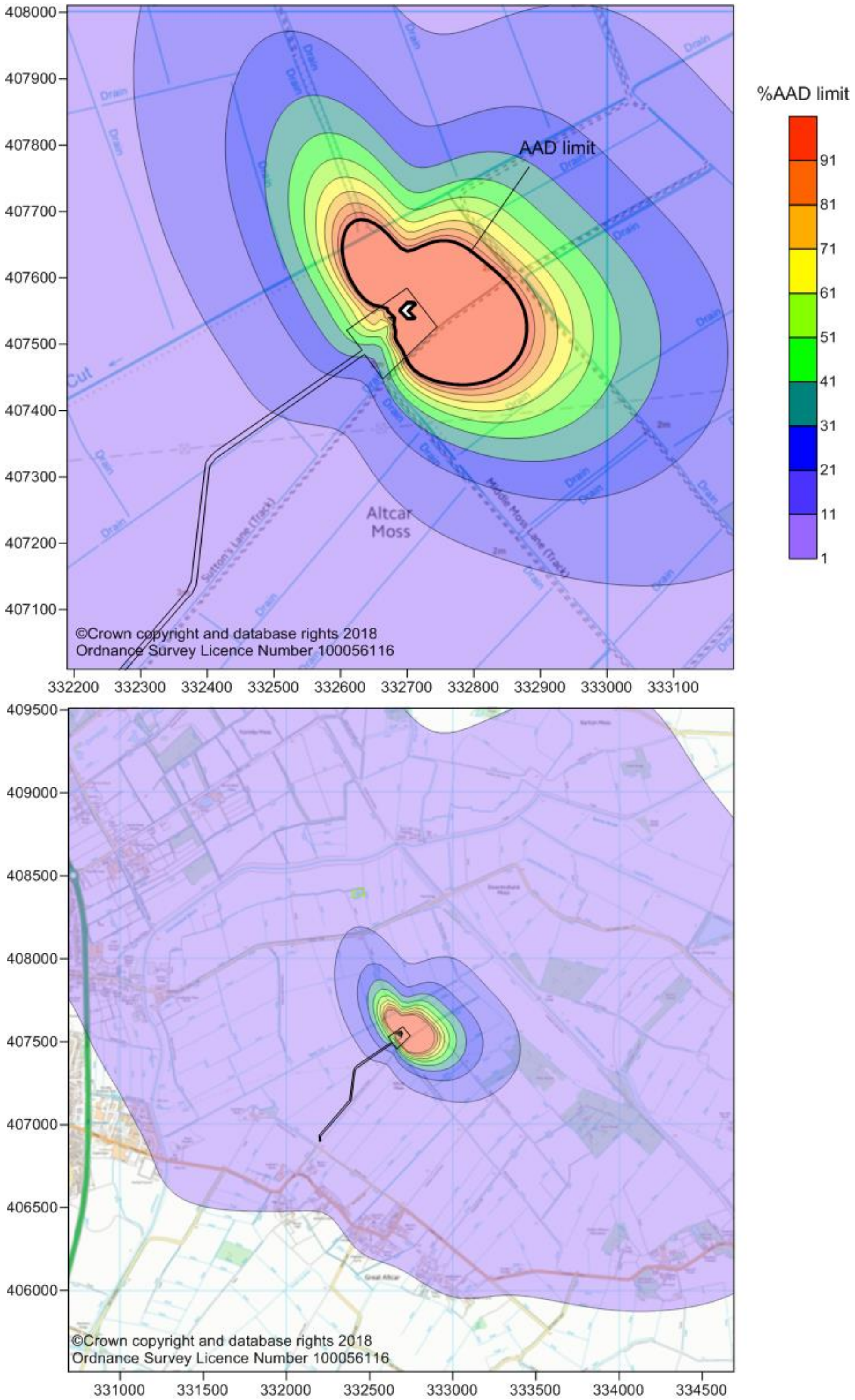


Figure A.2 Predicted process contributions of nitrogen dioxide (AAD limit annual mean - 2017 for a December 2016 commencement)



ANNEX B Model input data

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 of all pollutants considered have been provided as detailed below:

Carbon monoxide (CO)	8 hour mean	AER 2014 Nov Y2.APL
Nitrogen dioxide (NO_2)	1 hour mean	AER 2014 Nov Y2.APL
	annual mean	AER 2017 Dec Y2.APL
Sulphur dioxide (SO_2)	15 minute mean	AER 2013 Jul Y2.APL
	1 hour mean	AER 2015 Jul Y2.APL
	24 hour mean	AER 2015 Jul Y2.APL
PM_{10}	24 hour mean	AER 2015 Jul Y2.APL
	annual mean	AER 2015 Dec Y2.APL
$PM_{2.5}$	annual mean	AER 2015 Dec Y2.APL
Benzene[e]	annual mean	AER 2015 Dec Y2.APL
Carbon monoxide	hourly mean	AER 2013 Mar Y1.APL
Benzene[e]	hourly mean	AER 2017 Jul Y2.APL
Nitrogen monoxide (NO)	hourly mean	AER 2013 Mar Y1.APL
	annual mean	AER 2017 Dec Y2.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[22] 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)

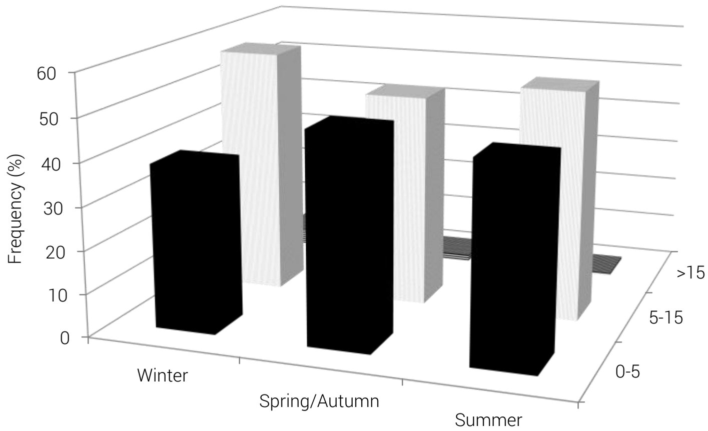
Background ozone concentration (ppb)	Wind speed at plume height (m/s)					
	0-5		5-15		>15	
	A	α	A	α	A	α
20-30	0.67	0.10	0.67	0.10	0.67	0.10
30-40	0.74	0.10	0.74	0.15	0.74	0.25
40-60	0.81	0.15	0.81	0.25	0.81	0.35
60-120	0.88	0.20	0.88	0.35	0.88	0.45
120-200	0.93	0.40	0.93	0.65	0.93	0.80

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 Crosby station over the period employed in this assessment (2013 to 2017) 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	57.7	4.1	6.9
Spring/Autumn	48.9	49.6	1.4	5.8
Summer	45.8	53.6	0.6	5.7

Seasonal wind speed

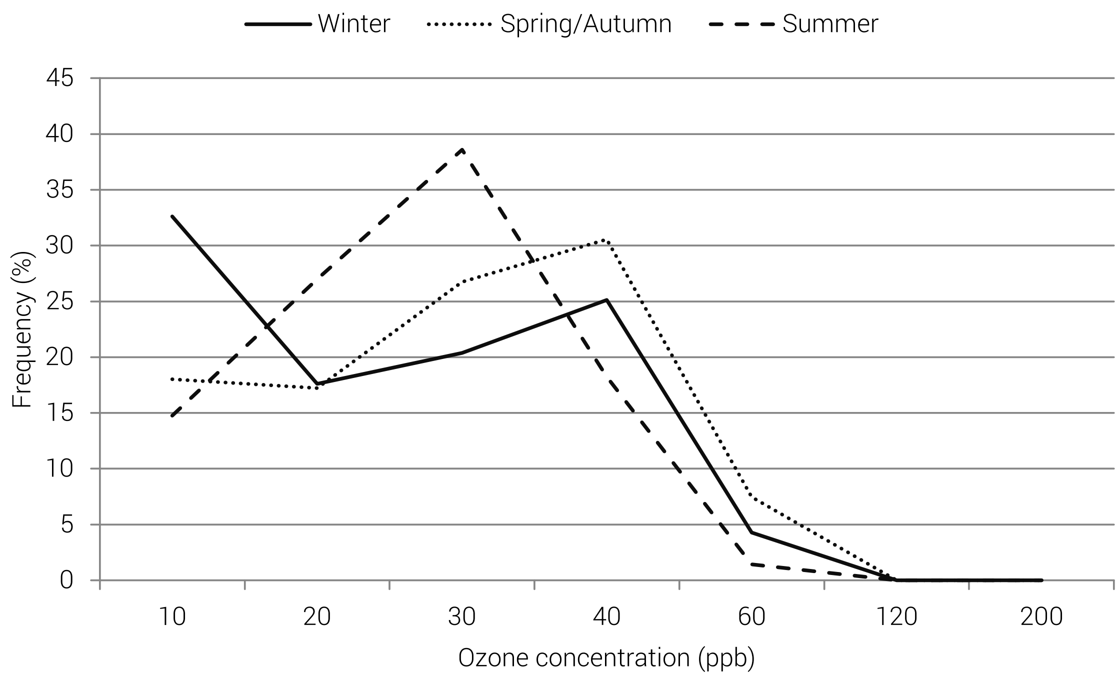


The wind speed is largely below the 15 m/s category for all seasons, with an overall average of 6.0 m/s.

The nearest automatic station monitoring station which includes measurement of ozone is the Wigan Centre station (UKA00482) which is located around 25 km east of Great Altcar (357816 406024). An analysis of hourly average data for 2017 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	32.6	17.6	20.4	25.1	4.3	0.0	0.0	19.3
Spring/Autumn	18.0	17.2	26.7	30.5	7.5	0.0	0.0	24.0
Summer	14.7	27.0	38.6	18.3	1.4	0.0	0.0	21.3

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	30-40	0.87	0.07
Spring/Autumn	5-15	30-40	0.80	0.10
Summer	5-15	30-40	0.74	0.15

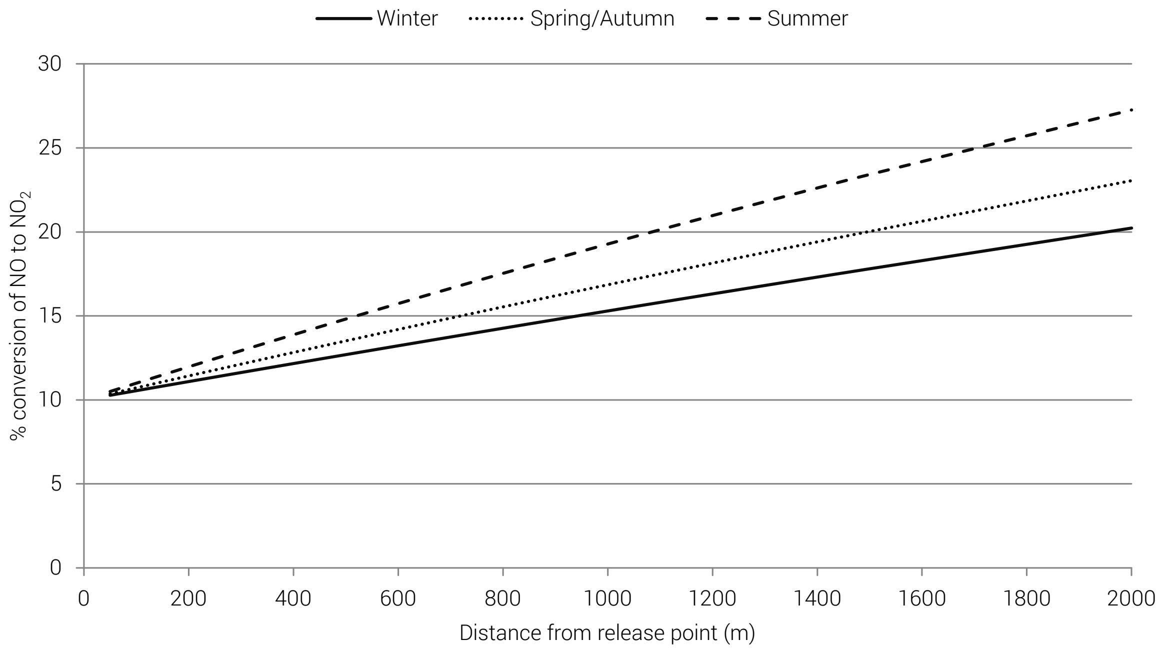
It is likely that a small amount of the nitrogen oxides emitted will be in the form of nitrogen dioxide. For the purposes of this assessment it is assumed that 10% of nitrogen oxides comprise nitrogen dioxide and as such Janssen's relationship for this situation is described by:

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

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 2 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 Crosby station was employed and covered the 5 year period 2013 to 2017. 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 2013 to 2017 is presented. The windroses for each individual year of data used are illustrated below.

Figure D.1 Crosby 2013

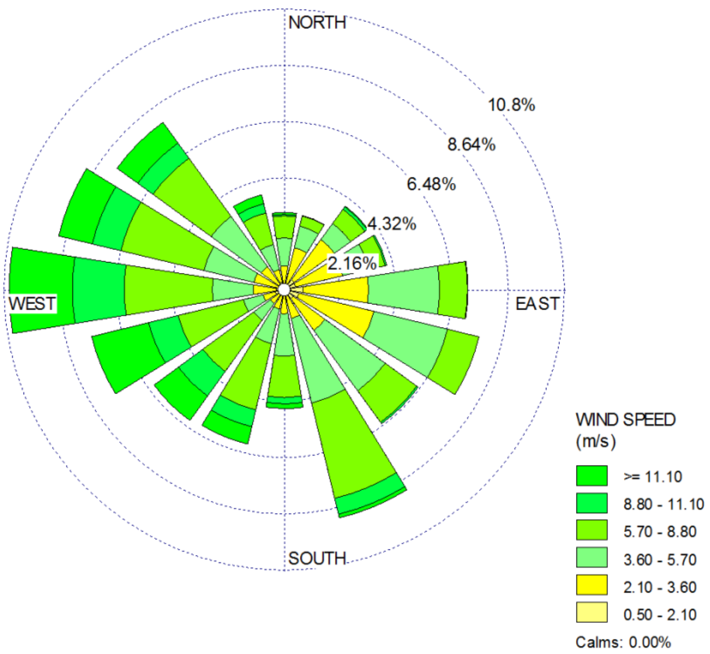


Figure D.2 Crosby 2014

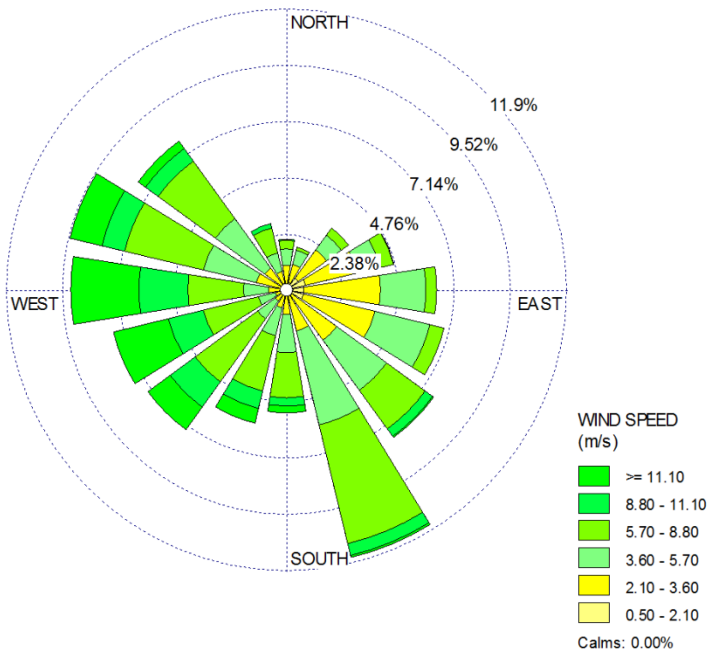


Figure D.3 Crosby 2015

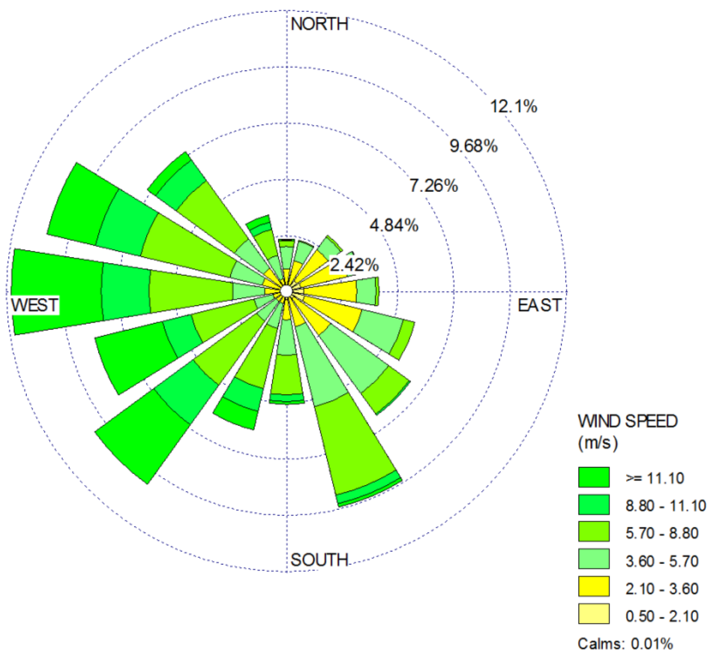


Figure D.4 Crosby 2016

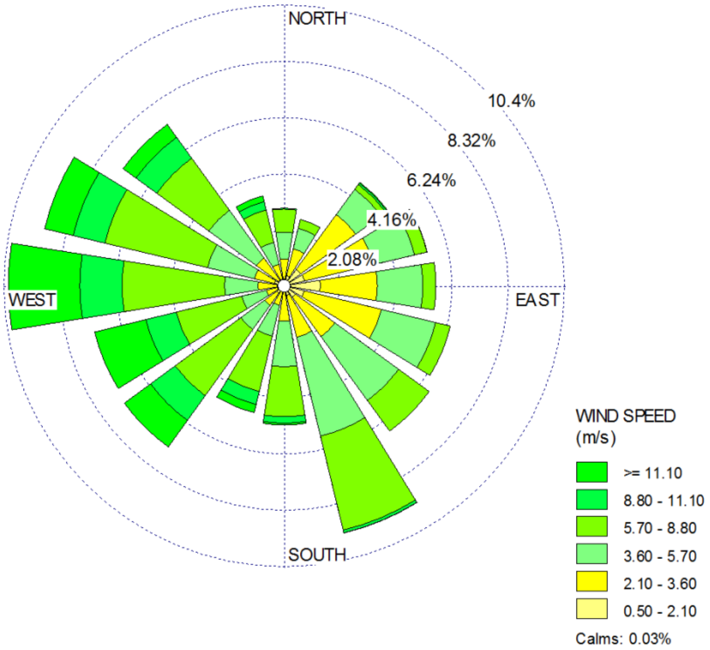
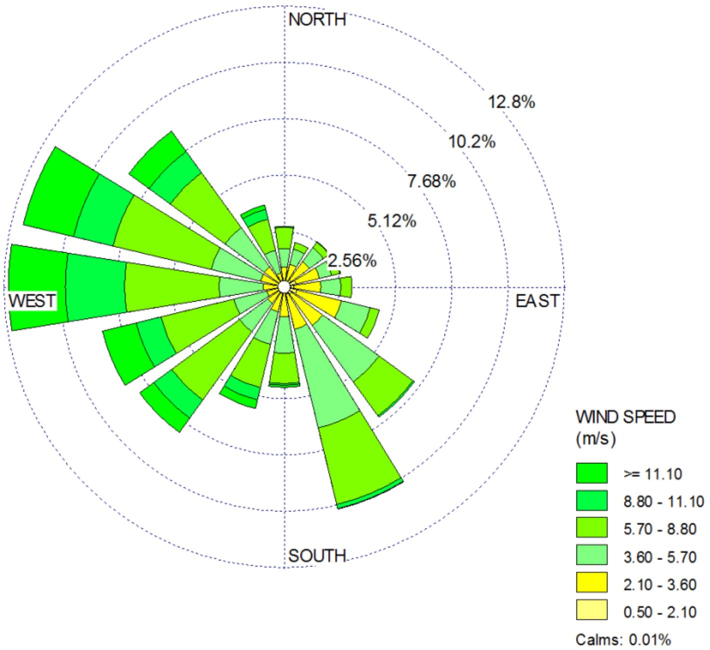


Figure D.5 Crosby 2017



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 2013 to 2017.

Table D.1 Wind speed and direction (2013 to 2017) for Crosby

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	0.6	1.7	1.9	1.4	0.2	0.1	5.9
NE	1.0	3.0	1.5	0.5	0.1	0.0	6.1
E	1.7	5.2	3.3	1.1	0.0	0.0	11.4
SE	0.8	3.3	5.4	3.3	0.4	0.0	13.3
SE	0.6	2.3	4.8	5.3	0.9	0.5	14.4
SW	0.5	0.9	1.9	5.0	2.4	2.3	12.9
W	0.6	1.6	3.2	7.3	4.3	5.9	23.0
NW	0.5	1.5	3.4	4.6	1.8	1.2	13.0
Calm							<0.1

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

Table D.2 Rainfall and wind direction (2013 to 2017) for Crosby

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	5.3	0.2	0.2	0.0	0.0	0.0	0.1
NE	5.6	0.2	0.1	0.0	0.0	0.0	0.1
E	10.4	0.3	0.3	0.1	0.1	0.0	0.1
SE	11.6	0.6	0.5	0.1	0.1	0.1	0.3
SE	12.4	0.6	0.6	0.2	0.2	0.1	0.3
SW	11.4	0.4	0.4	0.1	0.1	0.1	0.3
W	20.2	1.0	0.8	0.2	0.3	0.1	0.3
NW	11.9	0.4	0.3	0.1	0.1	0.1	0.1
Calm	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Total	89.3	3.8	3.1	0.8	1.0	0.4	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 (2013 to 2017) for Crosby

No. days data	1826		
No. hours data	43824		
No. calm hours (<0.3 m/s)	5	0.01	%
No. dry hours (<0.1 mm/h)	39134	89.65	%
Mean wind speed (m/s)	6.0		
No. missing records	170	0.39	%
Available records	43654	99.61	%

ANNEX E Construction dust risk assessment

E.1 Introduction

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

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)[24]. 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 the upgrading of Sutton's, Lane and construction of an access track and the wellsite will be in Phase 1 of the project and last around 40 days. The subsequent restoration of the site will be undertaken in Phase 8 of the project and is scheduled for a duration of 56 days and will include the break up and removal of the wellsite and access track and restoration of the land to agricultural use. No major construction activities likely to cause related dust releases are scheduled in Phases 2 to 7 of the project which are of 538 days 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 wellsite boundary. The Downholland Moss SSSI is around 90m from the nearest site boundary and has a geological designation. Site traffic will leave the site via the paved access track and upgraded Sutton's Lane and the largely head south west along Lord Sefton Way in the direction of Formby. At no time does this main access route come within 50 m of the SSSI. Ecological receptors are therefore not considered within this assessment.

There are no human receptors within 350 m of the wellsite boundary. The nearest residential location is at Formby's Farm, which is around 900 m from the main wellsite. There will be a need to construct an access track from Sutton Lane to the wellsite. The nearest residential locations to this activity are Tryers Farm and Sutton's Farm which are around 140 m from the access track junction with Sutton Lane. The activities likely to give rise to the greatest releases of dust will be undertaken on the access track and wellsite which are mostly over 350 m from the nearest residential locations, although some consideration may be given to the proximity of these residential locations to the main access route which is within 50 m.

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 wellsite area is around 9,400 m^2, with a further estimated 3,200 m^2 of access track and upgraded road.	Medium
Soil type	Moderately dusty soil	Medium
Earth moving vehicles operating	Maximum of 10 or fewer vehicles operating at any one time (see Table 3.8)	Medium
Material moved	Expected that around 14,000 tonnes of materials will be moved including the removal of existing subsurface and delivery of aggregates and concrete.	Small
Presence of bunds	Bunds of less than 4 m height are expected.	Small
Operating times	The construction and restoration phases of the project will last for around 4 and 1 months respectively, although the scheduling is as yet unknown.	Small
Overall rating	Conservative estimate of effects.	Medium

Construction of the access track branching off Sutton's Lane and the subsequent surface preparations for the well site are in excess of 50 m from the nearest residential locations and considered unlikely to have a significant impact on the nearest human receptors. These are likely to be the elements of earthworks which have the greatest potential for dust release.

It should also be considered that in Phase 8 of the project (lasting 56 days) the well site and access track surface will be broken up and removed, although the upgrade to Sutton's Lane will remain. These activities are mostly undertaken in excess of 350 m from the nearest residential locations, although parts of the access track are within 140 m. The activities within 350 m of the nearest human receptors are likely to be limited to around 10 days.

The dust emission magnitude for the earthworks associated with the project is considered to be 'Medium', although this is inherently a conservative assessment as most of the works with the greatest potential for dust release are conducted over 350 m from the nearest residential locations. The residual activities within 350 m are considered to have a much lower potential for dust release.

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.	
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 involve the construction of two drilling cellars and the installation of a cess tank and interceptor, will be confined to the wellsite which is in excess of 350 m from the nearest residential location. These activities will be conducted over a relatively short duration of around 10 days. While the dust magnitude is classified as 'Medium' this is considered a precautionary assessment, particularly for the nearest human receptors.

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.	Medium
Surface material	Moderately dusty.	Medium
Length of unpaved road	The access track, which will be prepared with a stone base and covered with track panels, is around 780 m in length	Small
Overall rating	Conservative estimate of effects.	Medium

The access track from the main well site is around 780 m in length and will be constructed with a geotextile membrane, a 500 mm layer of aggregate and paved with track panels. The access track joins Sutton's Lane at the Broad Lane junction. There is a further 100 m before the route passes within 50 m of the nearest residential location. 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 140 m from the nearest locations of earthworks (Sutton's Lane) associated with the project. Construction activities are confined to the wellsite, which is in excess of 900 m from the nearest residential locations and around 700 m from the nearest footpath (Cheshire Lines).

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 Sutton's Lane at Broad Lane. Tyrers Farm is around 140 m from the access track entrance and around 50 m from the main construction traffic route along Sutton's Lane.

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)	>50	700-900	>50
	Sensitivity of area	Low	Low	Low
Human health	Receptor sensitivity	High	High	High
	Number of receptors	1-10	1-10	1-10
	Distance from site (m)	50-100	700-900	50-100
	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 dustsoiling 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 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 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[25] 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 from the Formby direction onto Sutton's Lane and the wellsite 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 (days)	Maximum HDV[a] movements	
			Inbound	Outbound
1	Wellsite construction	112	1050	1050
2	Drilling and coring of vertical borehole	150	532	532
3	Drilling and coring of horizontal borehole	150	465	465
4	Hydraulic fracture stimulation	60	1639	1639
5	Initial flow testing	60	419	419
6	Extended flow testing	90	112	112
7	Decommissioning and abandonment	28	172	172
8	Site restoration	56	954	954

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

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[a] 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

a. AADT – annual average daily traffic

In this case none of the main routes to and from the Altcar Moss wellsite 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 wellsite. 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 15.

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 Cheshire Lines multi-use route, the site boundary and the perimeter of the Downholland Moss SSSI 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.

The locations of the residential receptors are included for completeness.

The receptors fall into the following groups:

1 to 40 Residential locations (see Table 3.1)
41 to 153 Cheshire Lines route
154 to 238 Altcar Moss wellsite boundary
239 to 299 Perimeter of the Downholland Moss SSSI

Table G.1 Receptor locations

Receptor (see Figure 3.1)	Position[a]	Easting	Northing	NO to NO_2 conversion rate (%)
1	1819 m NW	331578	408950	25.9
2	2397 m NW	330832	409024	30.1
3	2290 m NW	330863	408890	29.4
4	2325 m NW	330796	408858	29.6
5	2131 m NW	330978	408779	28.2
6	2067 m NW	331014	408720	27.8
7	1928 m NW	331114	408620	26.7
8	1983 m NW	330978	408511	27.1
9	1242 m N	332787	408748	21.3
10	1708 m W	331033	407924	25.1
11	1443 m W	331267	407750	23.0
12	1474 m W	331252	407834	23.2
13	1608 m W	331101	407759	24.3
14	1726 m W	330987	407792	25.2
15	1812 m W	330905	407823	25.9
16	1893 m W	330828	407851	26.5
17	960 m SW	331835	407074	18.9
18	1587 m W	331175	407039	24.1
19	1600 m SW	331229	406857	24.2
20	1037 m SW	331999	406737	19.6
21	952 m SW	332164	406717	18.9
22	1023 m SW	332228	406597	19.5

Table G.1 continued

Receptor (see Figure 3.1)	Position[a]	Easting	Northing	NO to NO_2 conversion rate (%)
23	1081 m S	332348	406485	20.0
24	1112 m SW	332222	406501	20.2
25	1093 m S	332471	406439	20.1
26	1196 m S	332406	406348	20.9
27	1013 m S	332665	406497	19.4
28	1147 m S	332717	406363	20.5
29	1239 m S	332636	406272	21.3
30	1259 m S	332489	406267	21.5
31	1342 m S	332854	406178	22.1
32	1457 m S	332953	406077	23.1
33	1564 m S	332996	405976	23.9
34	1597 m S	333102	405967	24.2
35	1541 m SE	333389	406137	23.7
36	1811 m SE	333991	406250	25.8
37	2019 m SE	334242	406219	27.4
38	2204 m SE	334508	406264	28.7
39	2289 m SE	334652	406331	29.4
40	2023 m E	334648	407003	27.4
41	1988 m N	332209	409439	27.2
42	1969 m N	332228	409424	27.0
43	1937 m N	332236	409393	26.8
44	1905 m N	332259	409366	26.6
45	1871 m N	332275	409334	26.3
46	1833 m N	332294	409300	26.0
47	1803 m N	332309	409272	25.8
48	1761 m N	332329	409234	25.5
49	1723 m N	332348	409199	25.2
50	1689 m N	332368	409168	24.9
51	1655 m N	332387	409137	24.6
52	1614 m N	332403	409098	24.3
53	1575 m N	332426	409063	24.0
54	1550 m N	332437	409040	23.8
55	1510 m N	332449	409001	23.5
56	1476 m N	332472	408970	23.2
57	1439 m N	332492	408935	22.9
58	1406 m N	332507	408904	22.7
59	1368 m N	332531	408869	22.4
60	1339 m N	332546	408842	22.1

Table G.1 continued

Receptor (see Figure 3.1)	Position[a]	Easting	Northing	NO to NO_2 conversion rate (%)
61	1310 m N	332569	408815	21.9
62	1285 m N	332593	408791	21.7
63	1253 m N	332608	408760	21.4
64	1229 m N	332624	408737	21.2
65	1209 m N	332639	408718	21.0
66	1181 m N	332655	408690	20.8
67	1149 m N	332678	408659	20.5
68	1122 m N	332697	408632	20.3
69	1095 m N	332713	408605	20.1
70	1076 m N	332732	408586	19.9
71	1050 m N	332748	408559	19.7
72	1032 m N	332771	408539	19.6
73	1010 m N	332787	408516	19.4
74	986 m N	332806	408489	19.2
75	958 m N	332833	408458	18.9
76	943 m N	332857	408438	18.8
77	925 m N	332884	408415	18.6
78	900 m N	332907	408384	18.4
79	890 m N	332926	408368	18.3
80	873 m N	332946	408345	18.2
81	856 m N	332961	408322	18.0
82	847 m N	332988	408302	17.9
83	832 m N	333008	408279	17.8
84	812 m NE	333027	408248	17.6
85	802 m NE	333054	408225	17.6
86	796 m NE	333078	408205	17.5
87	783 m NE	333105	408174	17.4
88	781 m NE	333124	408159	17.4
89	770 m NE	333140	408136	17.3
90	761 m NE	333155	408112	17.2
91	763 m NE	333182	408093	17.2
92	767 m NE	333210	408074	17.2
93	763 m NE	333229	408050	17.2
94	759 m NE	333252	408019	17.2
95	761 m NE	333276	407996	17.2
96	751 m NE	333291	407961	17.1
97	762 m NE	333318	407942	17.2
98	766 m NE	333338	407918	17.2

Table G.1 continued

Receptor (see Figure 3.1)	Position[a]	Easting	Northing	NO to NO_2 conversion rate (%)
99	774 m NE	333361	407895	17.3
100	779 m NE	333380	407872	17.3
101	797 m NE	333411	407848	17.5
102	801 m NE	333427	407825	17.5
103	816 m E	333450	407806	17.7
104	832 m E	333477	407779	17.8
105	842 m E	333497	407751	17.9
106	857 m E	333520	407724	18.0
107	875 m E	333543	407705	18.2
108	892 m E	333567	407674	18.3
109	917 m E	333598	407643	18.6
110	944 m E	333629	407612	18.8
111	964 m E	333652	407581	19.0
112	994 m E	333683	407550	19.2
113	1024 m E	333714	407519	19.5
114	1059 m E	333749	407495	19.8
115	1079 m E	333768	407464	20.0
116	1100 m E	333788	407433	20.1
117	1137 m E	333823	407406	20.4
118	1160 m E	333842	407375	20.6
119	1182 m E	333861	407352	20.8
120	1204 m E	333881	407332	21.0
121	1239 m E	333912	407305	21.3
122	1265 m E	333935	407286	21.5
123	1289 m E	333955	407259	21.7
124	1315 m E	333974	407224	21.9
125	1346 m E	334001	407204	22.2
126	1353 m E	334005	407193	22.2
127	1381 m E	334028	407170	22.5
128	1408 m E	334052	407150	22.7
129	1436 m E	334075	407131	22.9
130	1467 m E	334098	407100	23.2
131	1497 m E	334125	407084	23.4
132	1526 m E	334149	407061	23.6
133	1558 m E	334172	407030	23.9
134	1588 m E	334195	407003	24.1
135	1617 m E	334218	406983	24.3
136	1645 m E	334242	406964	24.6

Table G.1 continued

Receptor (see Figure 3.1)	Position[a]	Easting	Northing	NO to NO_2 conversion rate (%)
137	1671 m E	334257	406929	24.8
138	1705 m E	334288	406917	25.0
139	1737 m E	334311	406886	25.3
140	1776 m E	334343	406859	25.6
141	1816 m E	334374	406828	25.9
142	1853 m SE	334401	406797	26.2
143	1894 m SE	334432	406766	26.5
144	1923 m SE	334451	406739	26.7
145	1955 m SE	334474	406712	26.9
146	1993 m SE	334505	406688	27.2
147	2024 m SE	334529	406665	27.4
148	2061 m SE	334552	406626	27.7
149	2097 m SE	334579	406599	28.0
150	2137 m SE	334606	406564	28.3
151	2160 m SE	334622	406545	28.4
152	2191 m SE	334641	406514	28.7
153	2231 m SE	334672	406487	28.9
154	57 m W	332636	407493	10.6
155	58 m W	332633	407501	10.6
156	62 m W	332628	407505	10.6
157	67 m W	332623	407512	10.7
158	71 m W	332620	407517	10.7
159	75 m W	332617	407522	10.7
160	80 m W	332612	407527	10.8
161	77 m W	332615	407531	10.8
162	70 m W	332625	407536	10.7
163	67 m NW	332629	407540	10.7
164	66 m NW	332635	407546	10.7
165	63 m NW	332640	407549	10.6
166	62 m NW	332644	407551	10.6
167	62 m NW	332649	407556	10.6
168	60 m NW	332654	407558	10.6
169	60 m NW	332659	407562	10.6
170	61 m NW	332664	407565	10.6
171	63 m N	332670	407570	10.6
172	64 m N	332675	407573	10.6
173	67 m N	332678	407576	10.7
174	68 m N	332684	407578	10.7

Table G.1 continued

Receptor (see Figure 3.1)	Position[a]	Easting	Northing	NO to NO_2 conversion rate (%)
175	71 m N	332687	407581	10.7
176	76 m N	332690	407586	10.8
177	78 m N	332695	407588	10.8
178	79 m N	332697	407589	10.8
179	81 m N	332699	407591	10.8
180	77 m N	332701	407587	10.8
181	77 m N	332704	407586	10.8
182	72 m N	332705	407580	10.7
183	70 m N	332712	407577	10.7
184	67 m N	332713	407573	10.7
185	64 m NE	332718	407567	10.6
186	62 m NE	332719	407564	10.6
187	62 m NE	332727	407560	10.6
188	60 m NE	332721	407561	10.6
189	59 m NE	332729	407555	10.6
190	58 m NE	332732	407550	10.6
191	59 m NE	332738	407545	10.6
192	58 m NE	332740	407541	10.6
193	60 m NE	332744	407535	10.6
194	55 m NE	332741	407532	10.6
195	51 m E	332738	407529	10.5
196	49 m E	332736	407525	10.5
197	44 m E	332732	407522	10.4
198	38 m E	332727	407519	10.4
199	35 m E	332725	407513	10.3
200	32 m E	332721	407512	10.3
201	28 m E	332718	407508	10.3
202	24 m E	332714	407505	10.2
203	22 m E	332711	407502	10.2
204	21 m SE	332708	407499	10.2
205	20 m SE	332704	407496	10.2
206	21 m SE	332700	407491	10.2
207	23 m S	332697	407488	10.2
208	20 m SE	332702	407495	10.2
209	26 m S	332694	407484	10.3
210	28 m S	332692	407482	10.3
211	29 m S	332689	407481	10.3
212	33 m S	332687	407477	10.3

Table G.1 continued

Receptor (see Figure 3.1)	Position[a]	Easting	Northing	NO to NO_2 conversion rate (%)
213	37 m S	332684	407473	10.4
214	39 m S	332680	407472	10.4
215	43 m S	332678	407469	10.4
216	46 m S	332675	407467	10.5
217	50 m S	332673	407462	10.5
218	53 m S	332670	407461	10.5
219	57 m SW	332667	407458	10.6
220	60 m SW	332665	407456	10.6
221	59 m SW	332663	407458	10.6
222	58 m SW	332658	407461	10.6
223	56 m SW	332658	407463	10.6
224	55 m SW	332656	407467	10.5
225	55 m SW	332655	407468	10.5
226	55 m SW	332652	407471	10.5
227	55 m SW	332649	407473	10.6
228	55 m SW	332648	407475	10.5
229	55 m SW	332645	407477	10.5
230	54 m SW	332644	407481	10.5
231	54 m SW	332644	407482	10.5
232	55 m SW	332642	407483	10.5
233	55 m SW	332641	407484	10.6
234	54 m SW	332641	407486	10.5
235	55 m SW	332639	407488	10.6
236	58 m W	332636	407490	10.6
237	57 m W	332635	407496	10.6
238	510 m N	332517	407990	14.9
239	499 m N	332524	407981	14.8
240	488 m N	332526	407969	14.7
241	475 m N	332533	407958	14.6
242	460 m N	332538	407944	14.4
243	450 m N	332540	407935	14.4
244	437 m N	332542	407921	14.2
245	421 m N	332551	407907	14.1
246	405 m N	332554	407891	13.9
247	388 m N	332565	407877	13.8
248	370 m N	332568	407859	13.6
249	355 m N	332572	407845	13.5
250	339 m N	332574	407829	13.3

Table G.1 continued

Receptor (see Figure 3.1)	Position[a]	Easting	Northing	NO to NO_2 conversion rate (%)
251	326 m N	332586	407819	13.2
252	307 m N	332593	407801	13.0
253	292 m N	332597	407787	12.9
254	278 m N	332600	407773	12.7
255	263 m N	332607	407759	12.6
256	247 m N	332609	407743	12.4
257	231 m N	332618	407729	12.3
258	219 m N	332621	407718	12.2
259	209 m N	332625	407709	12.1
260	193 m N	332634	407695	11.9
261	183 m N	332639	407686	11.8
262	168 m N	332637	407670	11.7
263	167 m N	332657	407674	11.7
264	176 m N	332674	407686	11.7
265	183 m N	332685	407693	11.8
266	192 m N	332697	407702	11.9
267	197 m N	332711	407706	11.9
268	208 m N	332734	407713	12.0
269	220 m N	332745	407723	12.2
270	235 m N	332761	407734	12.3
271	251 m N	332782	407743	12.5
272	259 m NE	332791	407748	12.5
273	267 m NE	332803	407753	12.6
274	281 m NE	332814	407762	12.7
275	290 m NE	332826	407766	12.8
276	307 m NE	332844	407776	13.0
277	316 m NE	332853	407780	13.1
278	337 m NE	332872	407794	13.3
279	326 m NE	332865	407785	13.2
280	350 m NE	332888	407799	13.4
281	366 m NE	332902	407808	13.6
282	383 m NE	332918	407817	13.7
283	396 m NE	332932	407824	13.8
284	410 m NE	332946	407831	14.0
285	421 m NE	332960	407833	14.1
286	438 m NE	332976	407842	14.2

Table G.1 continued

Receptor (see Figure 3.1)	Position[a]	Easting	Northing	NO to NO_2 conversion rate (%)
287	450 m NE	332985	407849	14.3
288	469 m NE	333001	407861	14.5
289	477 m NE	333013	407861	14.6
290	493 m NE	333024	407872	14.7
291	506 m NE	333036	407879	14.9
292	508 m NE	333024	407893	14.9
293	516 m NE	333020	407907	15.0
294	519 m NE	333010	407919	15.0
295	527 m NE	333006	407932	15.1
296	533 m NE	333003	407942	15.1
297	540 m NE	332992	407958	15.2
298	557 m NE	332992	407979	15.3
299	561 m NE	332985	407988	15.4

a. Position of receptor relative to the centre of the Altcar Moss wellsite.

Table G.2 details the results of the assessment for the discrete residential receptors. The maximum process contributions for nitrogen dioxide and benzene, identified as the largest contributors of the pollutants considered, are provided for each residential location expressed as a proportion of the applicable air quality standard.

Table G.2 Maximum process contributions at residential locations

Receptor (see Figure 3.1 and Table 3.1)		Maximum process contribution (% air quality standard)			
		Nitrogen dioxide		Benzene	
		1 hour	annual	annual	1 hour
1	North Moss Farm	6.8	2.3	2.4	3.9
2	Warren House	6.1	1.5	1.5	2.8
3	Thorn Hey	6.6	1.7	1.6	3.2
4	Rose Farm	6.4	1.7	1.6	3.3
5	Villa Farm	6.7	1.9	1.7	3.5
6	North Moss Stables	6.9	2.0	1.8	3.7
7	South Moss Farm	7.5	2.2	2.0	4.0
8	Warren Farm	7.4	2.2	2.0	4.5
9	Fine Jane Cottage	8.7	2.3	2.6	4.8
10	Sutton House Farm	9.0	2.9	2.7	4.2
11	Southern Heys Farm	10.6	3.6	3.3	4.7
12	Sutton's Bridge	10.5	3.6	3.2	4.7
13	Bridge Inn Farm	9.7	3.1	2.8	4.2
14	Brook Farm	8.7	2.8	2.6	4.0
15	Moss Side Farm	8.5	2.7	2.4	3.9
16	Little Hey Farm	8.3	2.5	2.3	3.7
17	Formby's Farm	14.4	3.3	3.0	5.8
18	Stephenson Way 1	9.1	2.1	1.9	3.5
19	Stephenson Way 2	8.8	1.9	1.7	3.8
20	Sutton's Farm	12.3	2.5	2.2	5.5
21	Tyrer's Farm	14.0	2.6	2.4	6.1
22	Lord Sefton Way 1	13.1	2.3	2.1	4.6
23	Lord Sefton Way 2	11.8	2.0	1.8	5.7
24	Tatlock's Farm	11.9	2.0	1.9	4.6
25	Clayton's Farm	12.0	1.9	1.7	5.1
26	The Cottages	10.1	1.7	1.5	4.2
27	Aspinall Crescent	11.8	2.0	1.9	5.0
28	Hilton's Farm	10.5	1.6	1.6	5.2
29	Francis' Farm	10.1	1.5	1.4	4.0
30	Massam's Farm	9.6	1.5	1.4	4.6
31	Heye's Farm	8.4	1.4	1.5	5.5
32	Speakman's Farm	7.7	1.3	1.4	5.2
33	Tickles Farm	7.3	1.2	1.2	4.7
34	Oliver's Farm	6.7	1.1	1.2	4.5
35	Savage's Cottage	6.3	1.4	1.5	6.2
36	The Lodge	6.8	1.6	2.3	5.1
37	Delph Farm	5.7	1.4	2.2	3.4
38	Woodbine Cottages	4.9	1.3	2.1	2.5
39	Wood Barn Cottage	4.5	1.3	2.0	2.9
40	Pye Hill Farm	5.0	1.8	2.9	4.4

ANNEX H Site equipment specification

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

The expected movements of HDVs over the phases of the project are summarised in Table H.2.

Table H.1 Site equipment specification

Equipment	Type	Description	Reference
Lighting	Site light 908	Perkins 403D-11G engine, 8.8 kVA standby power, EU stage 3A	Bruno Generators, Site light 908P specification
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
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
Rig generator	Caterpillar 3512b	1678 kW, fuel consumption 394 l/h, claimed US Tier 2 compliant.	Caterpillar , Engine emission data , 09003, 20 March 2009
Stimulation pumps	SPF 343 trailer mounted pumper with Caterpillar 3512b engine	1678 kW, fuel consumption 394 l/h, claimed US Tier 2 compliant.	Caterpillar , Engine emission data , 09003, 20 March 2009. Schlumberger SPF 343, v1.4, 15 March 2017
Conductor rig	MAN 33.364 engine	360 hp, fuel consumption 65 l/h, EU Stage II compliant	Marriott, Rig 9 summary inventory
Annulus pump	Caterpillar C13 engine	388 kW, fuel consumption 93 l/h, US Tier 2 compliant	Caterpillar, Engine emission data, LGK03991, 16 November 2015
Blender			
Workover rig	Detroit Series 60	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
Hydraulic powerpack	Caterpillar 3406C DITA	365 kW, fuel consumption 100 l/h, US Tier 2 compliant	Prior Diesel, Caterpillar 3406C DITA Petroleum diesel engine
Nitrogen converter			
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
D5 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)
Paver	BOMAG, Paver	BF800CDeutz TCD 2012 L06 engine, 135 kW, EU stage 3A compliant	BOMAG, Paver BF800C specification, PRE 837 19 010

Table H.1 (continued)

Equipment	Type	Description	Reference
Piling 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
Dumper truck	Alldrive 9 front tip	Perkins 1100 D engine, 70 kW, EU stage 3A compliant	Twaites, Alldrive 9 specification, February 2009.
Roller	Caterpillar CB22B Utility Compactor	Cat C1.5 engine, 24 kW, EU stage 3A compliant	Caterpillar, BB22B utility compactor specification, QEHQ1699-01 (10-2013)
Vibratory roller	Dynapac CA1300D	Kubota V3307 CR-TE4 engine, 56 kW, EU stage 3B compliant	Dynapac CA 1300D single drum vibratory rollers specification, 122357, 10 November 2017
Trencher	Mastenbroek 15/15 trencher	Volvo 169 kW engine, EU stage 4 compliant	Mastenbroek 15/15 specification, 6 July 2018
360 excavator	Caterpillar 320EL hydraulic excavator	Cat C6.6 ACERT engine, 114 kW, EU stage 3B compliant	Caterpillar, A 6.6 ACERT Industrial engine, LEHH0022-03 (2-12)
Mini digger	Caterpillar 302.7D mini hydraulic excavator	Yanmar 3TNV76 engine, 15 kW, EU stage 3A compliant	Caterpillar, Mini hydraulic excavator, 6 July 2018, specification
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.

Table H.2 HDV movements during project phases

Phase	Duration days	Working days[a]	Working hours	HDV movements	HDV visits to site	Vehicles idling /h
1	112	88	1024	2099	1050	1.0
2	150	150	1800	1064	532	0.3
3	150	150	1800	930	465	0.3
4	60	60	720	3278	1639	2.3
5	60	60	720	838	419	0.6
6	90	90	1080	224	112	0.1
7	28	28	336	344	172	0.5
8	56	56	512	1908	954	1.9

a. HDVs are assumed to be restricted to an operational period of 0700 to 1900 (12 hours) during each normal 24 hour working day.

The highest number of HDV movements over a period of 365 consecutive days is 5381 equivalent to an annual average daily traffic (AADT) count of 14.7.

END OF REPORT

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