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RJS Civil Engineering Ltd

Parry's Quarry Environmental Permit Application

Final Revised Air Dispersion Modelling

3 June 2014

AMEC Environment & Infrastructure UK Limited

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Report for

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Contents

1. Introduction

1.1 Background

In 2011 Robin Jones and Sons Limited has commissioned AMEC Environment and Infrastructure (UK) Limited (AMEC) to carry out a dispersion model of area source emissions from the landfill surface and point source emissions from the proposed landfill gas power plant at Parry's Quarry in order to assess the potential impact from the proposed installation. The air quality assessment present herein has been prepared to support an application for an Environmental Permit to restore the Parry's Quarry site by the landfill of non-hazardous wastes.

Following a review of the report by the Environment Agency Wales, now Natural Resources Wales (NRW), a Schedule 5 Notice was issued by NRW which contained several identified issues with the air quality and odour impact assessments. Detailed responses have been made to these Schedule 5 issues and these are contained in a separate document but a summary of the main points and responses to them are included below.

This report contains an updated impact assessment of emissions of NOx from the landfill gas electricity generation plant and landfill gas flare that will be operational on the site and also an evaluation of the fugitive emissions of hydrogen sulphide (H_2S), carbon disulphide (CS_2) and odour from the landfilling operations.

1.2 Aims and Objectives

AMEC has assessed the impact of atmospheric emissions from the proposed landfill site and gas plant under worst case normal operating conditions. Surface emission flux values for H_2S and CS_2 have been derived from GasSim as detailed in the LFGRA submitted in support of the application. Benchmark Emission Limit Values (ELVs), taken from the Environment Agency's Technical Guidance Note LFTGN08v2[1], have been used to represent the upper bound emission scenarios from the landfill gas engine. Benchmark ELVs for the flare were taken from the Environment Agency's Guidance on landfill Gas Flaring LFTGN05 Version 2. Benchmark odour emissions from the landfill surfaces were taken from the recently published SNIFFER report[2]

The air quality assessment considers the impact of the emissions on background air quality.

The dispersion of emissions is predicted using an appropriate dispersion model, with results presented in tabular form and as contours of ground level concentrations on a background map of the area. In accordance with the recommendations of tier 1 screening, the assessment has considered short-term effects in relation to the air quality standards set in legislation and in Government and international guidance. The evaluation criteria used to assess the results of the modelling are based on Directive 2008/50/EC, the Air Quality Standards Regulations 2010, the

[1] The Environment Agency (2010) Guidance for Monitoring Landfill Gas Engine Emissions v2, LFTGN08. Updated March 2011.
[2] SNIFFER (2013) Odour Monitoring and Control on Landfill Sites. Report ER31.

Air Quality Regulations 2000, as amended, and the Environment Agency's Horizontal Guidance Note H1 Annex (f)[3].

1.3 Site Description

Robin Jones and Sons Ltd currently operates a waste transfer station and conducts mineral extraction activities at the Parry's Quarry site. This site is located 1km to the northeast of the village of Alltami, Flintshire, northeast Wales.

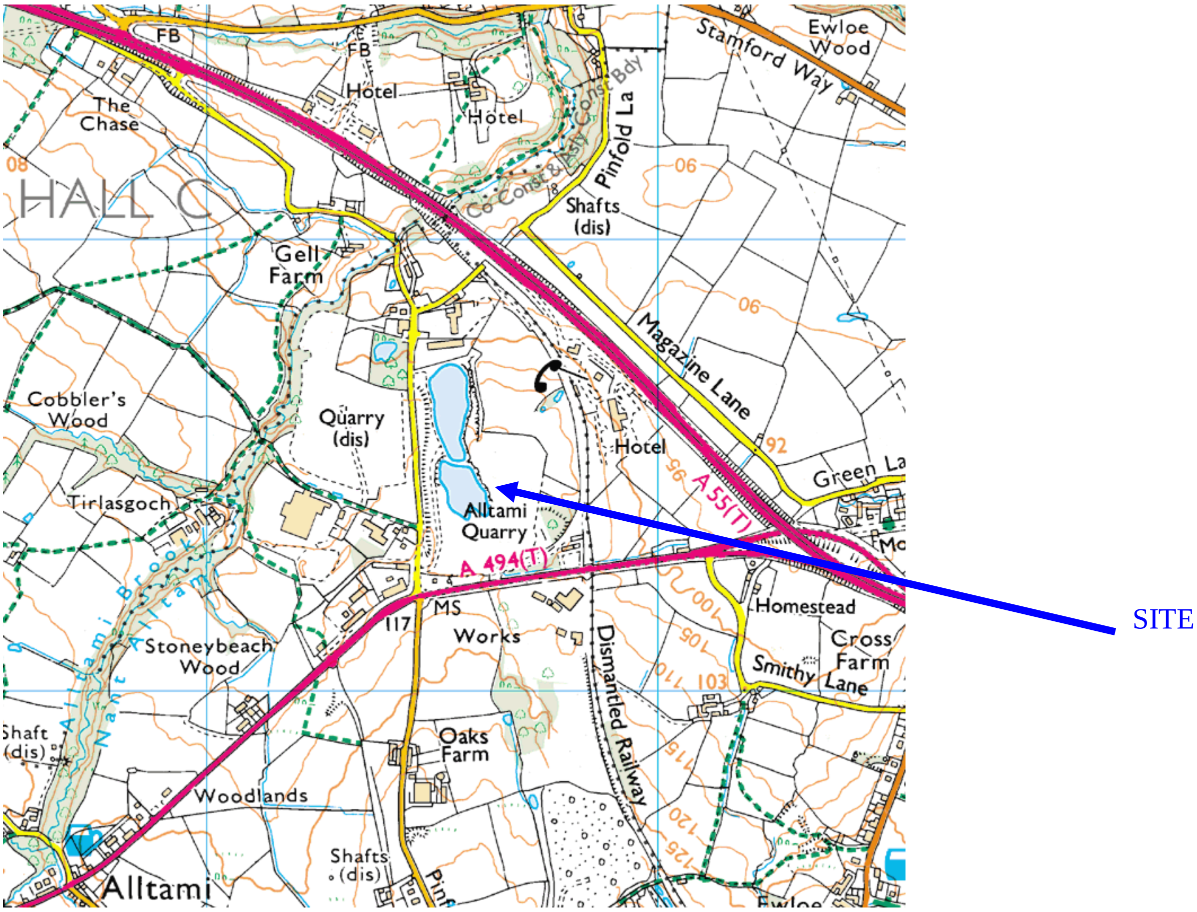
Landfill activities at the site are proposed to progress in parallel with the continuation of the quarrying activities. The site will be filled in a series of 4 No. cells from Cell 1 (north east quadrant) clockwise round to Cell 4. The cells will then be restored commencing with Cell 4 followed by Cells 1, 2 and finally 3. The landfill gas utilisation plant will be located adjacent to the north-eastern site boundary. Based upon the predicted waste input into the site the landfill is predicted to generate sufficient gas to sustain one 1.0MWe spark ignition engines to utilise the landfill gas. During the early years of landfilling and during the later years, insufficient gas will be produced to sustain an engine, so an enclosed flare will be used to combust the landfill gas.

It is the impact of emissions to air of H_2S, CS_2 and odours from the landfill surface and NOx and NO_2 from the gas engine and flare that have been identified as requiring further assessment that form the basis of this report.

The location of the site is shown in Figure 1.1.

[3] Environment Agency, 2010. 'Horizontal Guidance Note H1 – Annex (f)'.

Figure 1.1 Location Map



Note: Based on Ordnance Survey Maps with the permission of the controller of Her Majesty's Stationery Office ©. AMEC UK Limited AL100001776.

1.4 Sources of Information

The information used to assess air quality includes:

- Emissions data calculated by AMEC;
- Site layout from Robin Jones & Sons Limited and Ordnance Survey mapping;
- Baseline air quality data from surveys undertaken by Government bodies, Local Authorities and third parties[4];
- Ordnance Survey (OS) maps of the local area;
- Meteorological data supplied by ADM Ltd; and

[4] http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html

- Terrain data supplied by Emapsite[5].

1.5 Structure of the Assessment

The remainder of the report is set out as follows:

Table 1.1 Report Structure

Section	Aims and Objectives
Section 2	Describes the dispersion model, assessment methodology, model inputs and assumptions used in the assessment and describes the ambient air quality in the area
Section 3	Sets out standards and guidelines used to assess the air quality impacts of the process
Section 4	Presents an assessment of the potential impacts arising from the site emissions
Section 5	Summarises the findings of the assessment

[5] Emapsite (2011): http://www.emapsite.com

2. Assessment Methodology

2.1 The Dispersion Model

The model used in this assessment is the ADMS 5.1 advanced atmospheric dispersion model that has been developed and validated by Cambridge Environmental Research Consultants (CERC). This is the current version of the dispersion model. The model was used to predict the ground level concentrations of hydrogen sulphide (H_2S), carbon disulphide (CS_2) and odour emissions from the surface of the proposed landfill installation in addition to combustion products, specifically NO_x, emitted to atmosphere from the 1MWe engine at the proposed landfill gas compound. The model has been used extensively throughout the UK for regulatory compliance purposes and is accepted as an appropriate air quality modelling tool by the Environment Agency and local authorities.

A number of complex modules, including the effects of plume rise, complex terrain and buildings effects, are also included in the model, as well as the facility to calculate long-term averages of hourly mean concentration, dry and wet deposition fluxes, and percentile concentrations, from either statistical meteorological data or hourly average data.

A range of input parameters is required including, among others, data describing the local area, meteorological measurements, emissions data and stack flow rate parameters. The data used in modelling the plant emissions are given in the following sections of this chapter.

2.2 Process Emissions

This assessment has considered H_2S and CS_2 emissions from the landfill cell surfaces, calculated by GASSIM. It also has considered odour emissions from the landfill surfaces, based upon data contained in a recent SNIFFER report[6], in addition to projected NO_x emissions from the continuous operation, at full capacity, of the two 1 MWe landfill gas engines.

This assessment has considered one worst-case emissions scenario derived from the tier 1 assessment in the LFGRA; based on the 95th percentile emission rates for the projected peak surface emissions year (2026) for H_2S and CS_2 from the landfill surface. In addition, projected NO_x emissions from the 1 MWe landfill gas engine and, in the earlier and later years of landfill operation, an enclosed landfill gas flare have been considered.

Odour emissions from the landfill surfaces have been calculated from data contained in the SNIFFER ER 31 report. As a worst-case assumption, it has been assumed that Cell 4 is the active cell, with cells 1, 2 and 3 having been filled and capped. The following emission sources across cell 4 were assumed:

- 60% of the area under temporary capping;

[6] SNIFFER (2013) Odour monitoring and control on landfill sites.

- 30% of the area under daily cover; and
- 10% of the area as the uncovered working face (exposed waste).

It has been assumed that the remaining landfill cells 2, 3 and 4 are under permanent capping and gas extraction.

It is proposed that the engine and flare will be located within the main landfill gas utilisation compound.

Tables 2.1 and 2.2 detail the model input data.

Table 2.1 Model Input Data – Point Source Parameters

Emission Source	Location (X,Y)	Stack Height (m)	Stack Diameter (m)	Efflux Temp (ºC)	Efflux Velocity (ms^{-1})	NO_x Emission Rate (gs^{-1})
1 MWe Engine 1[1]	327700, 366810	7	0.35	450[2]	34.5	0.553
500 m^3/h Flare	327700, 366809	6	1.2	850[2]	4.78	0.2

Note:
1. Stack on engine container
2. Assumed temperature
3. The emission concentrations for the proposed engine are based on Environment Agency benchmark ELVs. (LFTGN 08)

Table 2.2 Model Input Data – Area Source Emission Rates

Emission Source	Area (m^2)	Surface Flux		
		H_2S ($g\ m^2\ s^{-1}$)	CS_2 ($g\ m^2\ s^{-1}$)	Odour $ou_E m^{-2}\ s^{-1}$
Cell 1	14958	0.00000004	0.00000002	0.0067
Cell 2	17808	0.00000002	0.00000001	0.0067
Cell 3	26309	0.00000004	0.00000002	0.0067
Cell 4	19732	0.00000028	0.00000014	1.051

This assessment considers one emission scenario, namely peak emission year (2026) for the surface flux of landfill gas, as derived from GasSim simulations, and worst case operation, *i.e*. one engine operating at 100% MCR continuously over the period of a year (*i.e*., 8760 hours of operation) and one flare operating at full rating over a year. This represents a conservative assessment and will over-estimate the actual impact of emissions.

2.3 Meteorology

For meteorological data to be suitable for dispersion modelling purposes, a number of meteorological parameters need to be measured on an hourly basis. These parameters include wind speed, wind direction, cloud cover and temperature. There are only a limited number of sites where the required meteorological measurements are made. The year of meteorological data that is used for a modelling assessment can also have a significant effect on ground level concentrations.

Hawarden meteorological station is situated approximately 7 km to the east south-east of the site and is the nearest representative meteorological station with current data available. This station measures meteorological parameters on an hourly basis and therefore provides data suitable for input to the dispersion model.

Meteorological data measured at Hawarden meteorological station for 2005 to 2009 inclusive have been used in this assessment. These years are the most recent available with sufficient data capture, with the exception of 2007, for which 61% of the cloud data was missing. Missing cloud data has been taken, therefore, from Liverpool Airport meteorological station, which is located approximately 21.6 km to the north-east of the site. The following figures illustrate the frequency of wind directions and wind speeds at Hawarden for the years considered.

The wind roses depict a prevailing south-easterly component over the modelled area, with lesser westerly and north-westerly components.

Figure 2.1 2005 Wind Rose

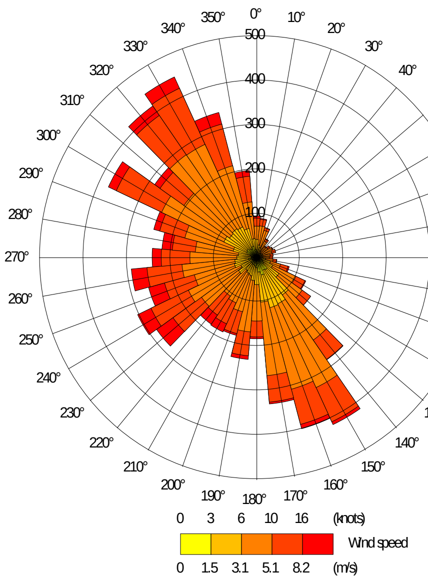


Figure 2.2 2006 Wind Rose

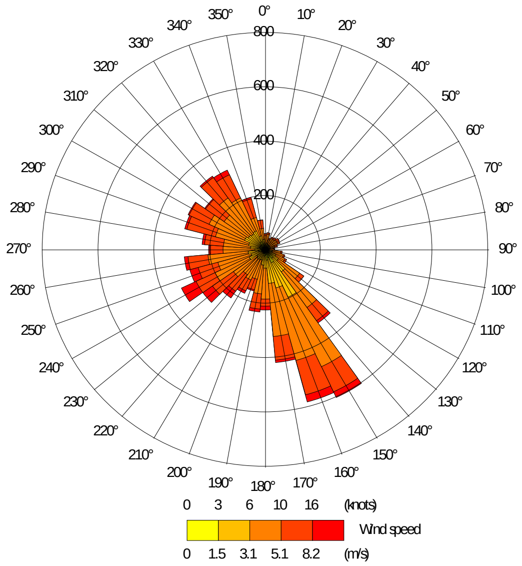


Figure 2.3 2007 Wind Rose

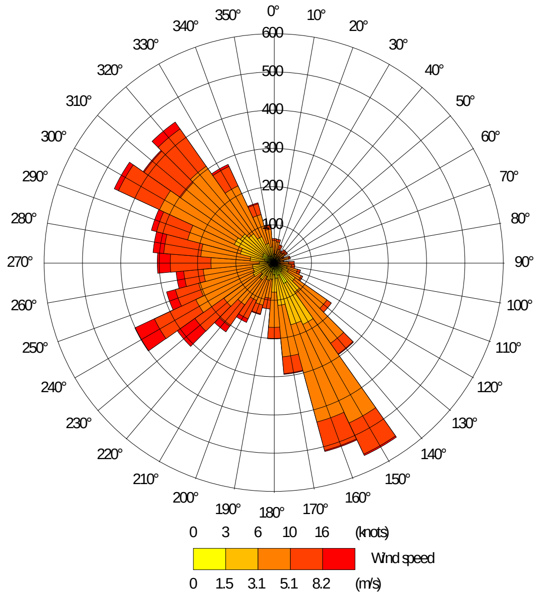


Figure 2.4 2008 Wind Rose

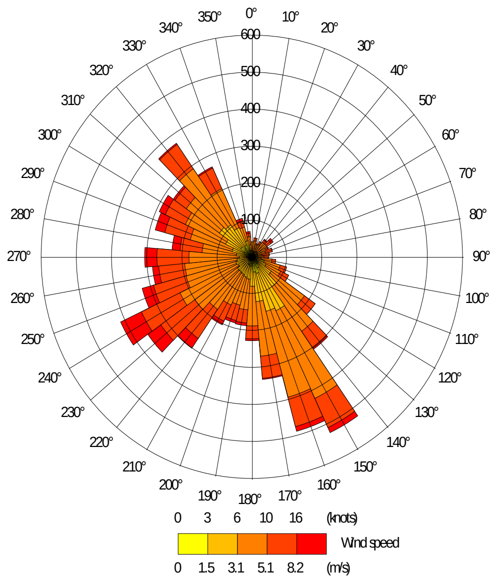
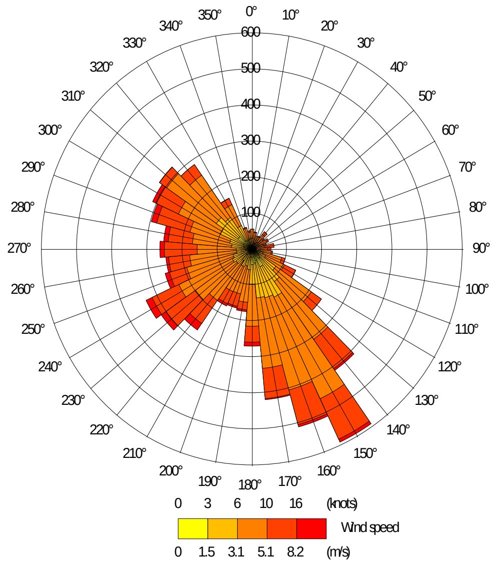


Figure 2.5 2009 Wind Rose



2.4 Surface Characteristics

The predominant surface characteristics and land use in a model domain have an important influence in determining turbulent fluxes and, hence, the stability of the boundary layer and atmospheric dispersion. Factors pertinent to this determination are detailed below.

2.4.1 Surface Roughness

Roughness length, z_0, 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. Thus, it follows that surface roughness is higher in urban and congested areas than in rural and open areas. Oke (1987)[7] and CERC (2003)[8] suggest typical roughness lengths for various land use categories (Table 2.3).

[7] Oke, T.R., 1987. 'Boundary Layer Climates'. 2nd Edition, Meuthen.
[8] CERC, 2003. 'The Met Input Module'. ADMS Technical Specification ADMS 3 P05/01N/03.

Table 2.3 Typical Surface Roughness Lengths for Various Land Use Categories

Type of Surface	z0 (m)
Ice	0.00001
Smooth snow	0.00005
Smooth sea	0.0002
Lawn grass	0.01
Pasture	0.2
Isolated settlement (farms, trees, hedges)	0.4
Parkland, woodlands, villages, open suburbia	0.5-1.0
Forests/cities/industrialised areas	1.0-1.5
Heavily industrialised areas	1.5-2.0

Increasing surface roughness increases turbulent mixing in the lower boundary layer. This can often have conflicting impacts in terms of ground level concentrations:

- The increased mixing can bring portions of an elevated plume down towards ground level, resulting in increased ground level concentrations closer to the emission source; however
- The increased mixing increases entrainment of ambient air into the plume and dilutes plume concentrations, resulting in reduced ground level concentrations further downwind from an emission source.

The overall impact on ground level concentration is, therefore, strongly correlated to the distance and orientation of a receptor from the emission source.

In the original air dispersion report, a composite surface roughness length of 0.75m was used to take account of the respective land use categories in the model domain and the impact of the quarry on air flow over the land. Upon review of the comment (see section 1.1 above) from NRW concerning selection of a surface roughness value, this has been re-visited. The prevailing winds, from inspection of the wind roses in Figures 2.1 to 2.5, blow from the south-east and west/north-west directions. The land uses in these directions from the site within approximately 1 km are essentially agricultural pasture but there are built-up areas (Buckley) to the south and south-east beyond 1 km. In addition, the landfill area itself will increase the overall surface roughness and there are scattered buildings, trees and hedgerows within the model domain. On this basis, it is considered that a more appropriate, worst-case surface roughness measure for the model would be 0.5 m, but that anything lower than this would not be truly representative of the actual land characteristics within the model domain.

2.4.2 Surface Energy Budget

One of the key factors governing the generation of convective turbulence is the magnitude of the surface sensible heat flux. This, in turn, is a factor of the incoming solar radiation. However, not all solar radiation arriving at the earth's surface is available to be emitted back to atmosphere in the form of sensible heat. By adopting a surface energy budget approach, it can be identified that for fixed values of incoming short and long wave solar radiation, the surface sensible heat flux is inversely proportional to the surface albedo and latent heat flux.

The surface albedo is a measure of the fraction of incoming short-wave solar radiation reflected by the Earth's surface. This parameter is dependent upon surface characteristics and varies throughout the year. The latent heat flux is dependent upon the amount of moisture present at the surface. The modified Priestly-Taylor parameter can be used to represent the amount of 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. Oke (1987) recommends average surface albedo values of 0.6 for snow covered ground and 0.23 for non-snow covered ground whilst Holstag and van Ulden (1983)[9] suggest Priestly-Taylor parameter values of 0.45 and 1.0 for dry grassland and moist grassland respectively.

Selection of Appropriate Surface Characteristic Parameters for the Installation

A detailed analysis of the effects of surface characteristics on ground level concentrations by Auld et al. (2002)[10] led them to conclude that, with respect to uncertainty in model predictions:

"…the energy budget calculations had relatively little impact on the overall uncertainty"

In this regard, it is not considered necessary to vary the surface energy budget parameters spatially or, temporally, and annual averaged values have been adopted throughout the model domain for this assessment.

As snow covered ground is only likely to be present for a small fraction of the year, the surface albedo of 0.23 for non-snow covered ground advocated by Oke (1987) has been used whilst the model default Priestly-Taylor parameter value of 1.0 has also been retained.

2.5 Terrain

The concentrations of an emitted pollutant found in elevated, complex terrain differ from those found in simple level terrain. There have been numerous studies on the effects of topography on atmospheric flows. A summary of the main effects of terrain on atmospheric flow and dispersion of pollutants are summarised below:

Plume interactions with windward facing terrain features;

- Plume interactions with terrain features whereby receptors on hills at a similar elevation to the stack experience elevated concentrations;

[9] van Ulden, A.P. and Holstag, A.A.M., 1983. 'The Stability of the Atmospheric Surface Layer during Nighttime'. American Met. Soc., 6th Symposium on Turbulence and Diffusion.
[10] Auld, V., Hill, R. and Taylor, T.J., 2002. 'Uncertainty in Deriving Dispersion Parameters from Meteorological Data'. Atmospheric Dispersion Modelling Liaison Committee (ADMLC). Annual Report 2002-2003.

- Direct impaction of the plume on hill slopes in stable conditions; and
- Flow over hills in neutral conditions can experience deceleration forces on the upwind slope, reducing the rate of dispersion and increasing concentrations.

Plume interactions with lee sides of terrain features;

- Regions of recirculation behind steep terrain features can rapidly affect pollutants towards the ground culminating in elevated concentrations; and
- Releases into the lee of a hill in stable conditions can also be recirculated, resulting in increased ground level concentrations.

Plume interactions within valleys;

- Releases within steep valleys experience restricted lateral dispersion due to the valley sidewalls. During stable overnight conditions, inversion layers develop within the valley essentially trapping all emitted pollutants. Following sunrise and the erosion of the inversion, elevated ground level concentrations can result during fumigation events; and
- Convective circulations in complex terrain due to differential heating of the valley side walls can lead to the impingement of plumes due to crossflow onto the valley sidewalls and the subsidence of plume centrelines, both having the impact of increasing ground level concentrations.

These effects are most pronounced when terrain gradients vary by more than 1 in 10, *i.e.*, 100 m change in elevation within 1 km distance in the horizontal direction. It should be noted that areas such as quarries and landfill sites are not included in the digital terrain data files. While the gradients surrounding the site do not exceed this criterion, terrain data has been included within the model.

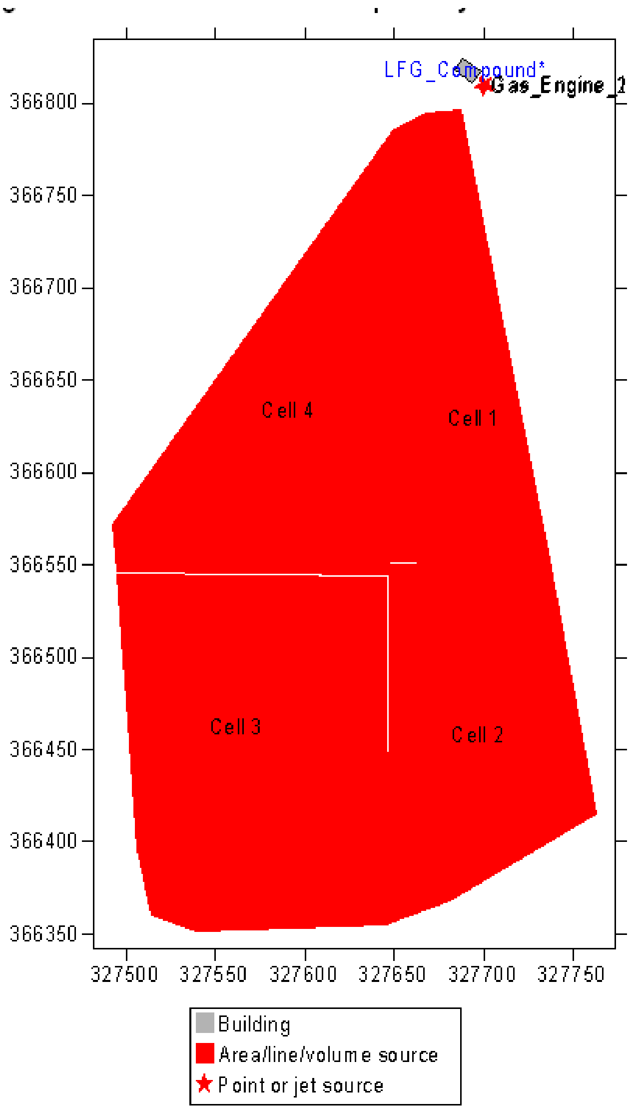
2.6 Buildings

Any large, sharp-edged object has an impact on atmospheric flow and air turbulence within the locality of the object. This can result in maximum ground level concentrations that are significantly different (generally higher) from those encountered in the absence of buildings. The building 'zone of influence' is generally regarded as extending a distance of 5L (where L is the lesser of the building height or width) from the foot of the building in the horizontal plane and three times the height of the building in the vertical plane. The proposed structures, namely the landfill gas utilisation compound, that will be present in the vicinity of the gas engine and flare are detailed in Table 2.4 and Figure 2.6 and consequently, included in the model.

Table 2.4 Buildings Modelled

Building	X (m)	Y (m)	Height (m)	Length (m)	Width (m)	Angle (°)
Gas Plant	327690	366817	5	12.24	7.86	36.6

Figure 2.6 Building Visualisation and Location of Emissions to Air Locations at Parry's Quarry



2.7 Modelled Domain and Receptors

2.7.1 Modelled Domain

A 1.5 km square grid centred on the approximate centre of the application area was modelled, with an approximate resolution of 15 m, to assess the impact of atmospheric emissions, including that of emissions from the proposed 7 m engine stack and 6 m flare stack at the site on local air quality. ADMS only allows a maximum of 101 receptor points in both the X and Y co-ordinate reference frames. This resolution will allow for the maximum on the grid to be identified and show how the pollutant levels decrease with distance as shown in the contour plots in Section 4.

Concentrations at specified receptors outside this domain have been assessed by including these receptors as discrete receptor points within the model.

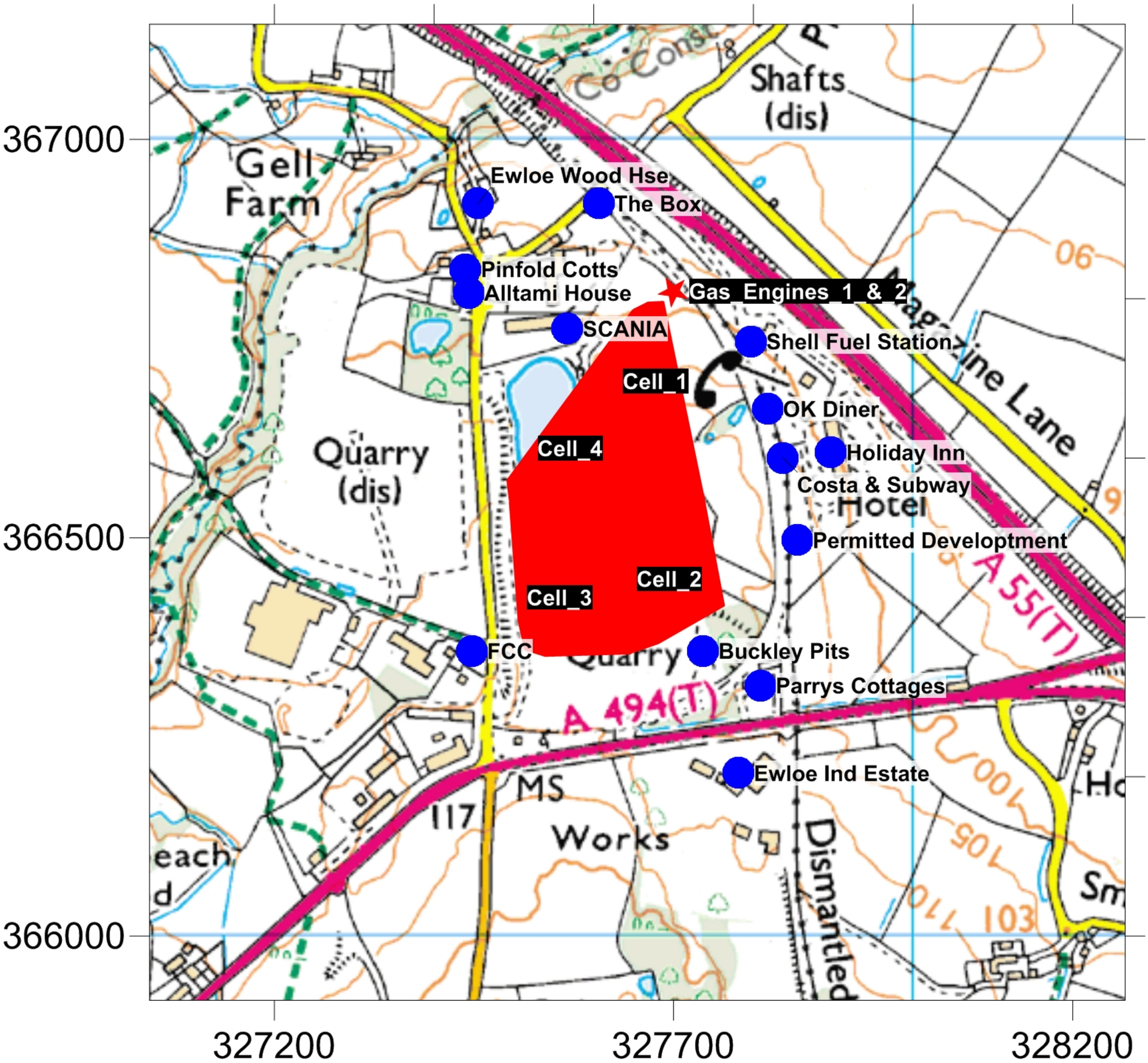
2.7.2 Human Receptors

The receptors considered were chosen based on locations where people may be located and judged in terms of the likely duration of their exposure to pollutants and proximity to the site. Details of the locations of human receptors are given in Table 2.5 and Figure 2.7 below.

Table 2.5 Details of Sensitive Human Receptors

Receptor Name		Easting (m)	Northing (m)
1	Parry's Cottages	327808	366314
2	Holiday Inn	327897	366607
3	Shell Service Station	327799	366746
4	The Box	327606	366919
5	Alltami House	327443	366807
6	Pinfold Cottage	327439	366837
7	Ewloe Wood House	327455	366919
8	Costa & Subway Outdoor Eating Areas	327836	366600
9	Ewloe Barns Industrial Estate	327781	366204
10	SCANIA and other business/industrial units (to north of site)	327567	366762
11	FCC and other office/ business units (to south-west of site)	327447	366357
12	OK Diner Restaurant	327817	366661
13	Permitted Development (to south-east of site)	327855	366497

Figure 2.7 Locations of Modelled Human Receptors



2.7.3 Ecological Receptors

The Environment Agency's Horizontal Guidance Note H1 Annex (f) requires detailed dispersion modelling to be carried out based on local receptors. With regard to ecological receptors, page 12 of H1 Annex (f) states:

"Note that conservation sites need only be considered where they fall within set distances of the activity:

- *Special Protection Areas (SPAs), Special Areas of Conservation (SACs) or Ramsar sites within 10km of the installation (or 15km coal or oil-fired power station)*
- *Sites of Special Scientific Interest (SSSIs), National Nature Reserves (NNRs), Local Nature Reserves (LNRs), local wildlife sites and ancient woodland within 2km of the location.*

Some larger emitters may be required to screen to 10km or 15km for SSSIs."

The following ecological receptors identified within in Table 2.6 are within 10 km of the site. Consequently, impacts on ecologically-designated sites have been considered in this assessment. The closest wildlife site is Buckley Clay Pits and Commons SSSI. The SSSI lies to the south of the planning application boundary and supports a population of great crested newts (*Triturus cristatus*). It is currently protected from existing quarrying operations and will be protected from future landfilling operations by a permanent newt enclosure fence.

Table 2.6 Details of nearby Ecological Designated Sites

Name	Designation	Grid Ref. Of Closest Point	Area (ha)	Distance (km) to Closest Point
Buckley Clay Pits & Commons	SSSI	327736, 366358	207.52	0.035
The Dee Estuary	SPA/Ramsar/SAC	328385, 371066	13085	7.0

2.7.4 Deposition

The predominant route by which emissions will affect land in the vicinity of a process is by deposition of atmospheric emissions. Potential ecological receptors can be sensitive to the deposition of pollutants, particularly nitrogen and sulphur compounds, which can affect the character of the habitat through eutrophication and acidification.

Deposition processes in the form of dry and wet deposition remove material from a plume and alter the plume concentration. Dry deposition occurs when particles are brought to the surface by gravitational settling and turbulence. They are then removed from the atmosphere by deposition on the land surface. Wet deposition occurs due to rainout (within cloud) scavenging and washout (below cloud) scavenging of the material in the plume. These processes lead to a variation with downwind distance of the plume strength and may alter the shape of the vertical concentration profile as dry deposition only occurs at the surface.

Near to sources of pollutants (< 2km), dry deposition is the predominant removal mechanism (Fangmeier et al. 1994). Dry deposition may be quantified from the near-surface plume concentration and the deposition velocity (Chamberlin and Chadwick, 1953);

$$F_d = v_d C(x, y, 0)$$

where:

F_d = dry deposition flux (μg m^{-2} s^{-1})

v_d = deposition velocity (m s^{-1})

$C(x,y,0)$ = ground level concentration (μg m^{-3})

Assuming irreversible uptake, the wet deposition rate is found by integrating through a vertical column of air;

$$F_w = \int_0^z \Lambda C \; dz$$

where:

F_w = wet deposition flux (μg m^{-2} s^{-1})

Λ = washout co-efficient (s^{-1})

C = local airborne concentration (μg m^{-3})

z = height (m)

The washout co-efficient is an intrinsic function of the rate of rainfall.

Draft Environment Agency guidance AQTAG06 (Environment Agency, 2006) recommends deposition velocities for various pollutants, according to land use classification (Table 2.7).

Table 2.7 Recommended Deposition Velocities for Grassland

Pollutant	Deposition Velocity (m s^{-1})	
	Short Vegetation	Long Vegetation/ Forest
NOx	0.0015	0.003

Source: Environment Agency (2006) 'Technical Guidance on Detailed Modelling Approach for an Appropriate Assessment for Emissions to Air', AQTAG06 Working Draft Version 9, 12/05/06

In order to assess the impacts of deposition, habitat-specific critical loads and critical levels have been created. These are generally defined as (e.g., Nilsson and Grennfelt, 1988):

"a quantitative estimate of exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge"

It is important to distinguish between a critical load and a critical level. The critical load relates to the quantity of a material deposited from air to the ground, whilst critical levels refer to the concentration of a material in air. The UK Air Pollution Information System (APIS) provides critical load data for ecological sites in the UK.

The critical loads used to assess the impact of compounds deposited to land which result in eutrophication and acidification are expressed in terms of kilograms of nitrogen deposited per hectare per year (kg N ha^{-1} y^{-1}) and kilo equivalents deposited per hectare per year (keq ha^{-1} y^{-1}). To enable a direct comparison against the critical loads, the modelled deposition flux must be converted into an equivalent value.

For a continuous release, the annual deposition flux of nitrogen can be expressed as:

$$F_{NTot} = \left(\frac{K_2}{K_3}\right) \cdot t \cdot \sum_{i=1}^{T} F_i \left(\frac{M_N}{M_i}\right)$$

where:

F_{NTot} = Annual deposition flux of nitrogen (kg N ha^{-1} y^{-1})

K_2 = Conversion factor for m^2 to ha (= 1x10^4 m^2 ha^{-1})

K_3 = Conversion factor for µg to kg (= 1x10^9 µg kg^{-1})

t = Number of seconds in a year (= 3.1536 x10^7 s y^{-1})

i = 1,2,3…….T

T = Total number of nitrogen containing compounds

F = Modelled deposition flux of nitrogen containing compound (µg m^{-2} s^{-1})

M_N = Molecular mass of nitrogen (kg)

M = Molecular mass of nitrogen containing compound (kg)

The unit eq (1 keq ≡ 1,000 eq) refers to molar equivalent of potential acidity resulting from *e.g.* sulphur, oxidised and reduced nitrogen, as well as base cations. Conversion units are provided in AQTAG(06);

1 keq ha^{-1} y^{-1} = 14 kg N ha^{-1} y^{-1}

For the purposes of this assessment, dry deposition rates of nitrogen at the local wildlife receptors have been calculated at by applying both the ‘Short Vegetation’ and ‘long vegetation’ deposition velocities (as detailed in Table 2.7) as appropriate to the modelled annual mean concentrations of NO_x. Wet deposition has not been assessed since this is not a significant contributor to total deposition over shorter ranges where the impact will be at its greatest (Fangmeier et al. 1994; Environment Agency, 2006).

The Fine Resolution Atmospheric Multi-pollutant Exchange (FRAME) model, developed by CEH provides predicted background deposition rates of nutrient nitrogen and total acid deposition for the UK. Data from the FRAME model can be extracted via the Air Pollution Information Service (APIS) website (http://www.apis.ac.uk). Table 2.8 provides the estimated deposition rates for the ecological receptors considered in this study as extracted from the FRAME output lodged on the APIS website. It should be noted that the level of uncertainty associated with these modelled estimates is relatively high and the results are presented from the model across the UK on a coarse 5 km grid square resolution.

Table 2.8 Estimated Background Deposition Rates

Receptor		Background Nitrogen Deposition (kg N ha^{-1} y^{-1})
Buckley Clay Pits	SSSI	37.4
The Dee Estuary	SPA/Ramsar/SAC	14.4

Source: Air Pollution Information Service (APIS) website (http://www.apis.ac.uk)

2.8 Conversion of NO to NO_2

Emissions of NO_x from combustion processes are predominantly in the form of nitric oxide (NO). Excess oxygen in the combustion gases and further atmospheric reactions cause the oxidation of NO to nitrogen dioxide (NO_2). NO_x chemistry in the lower troposphere is strongly interlinked in a complex chain of reactions involving VOCs and Ozone (O_3). Two of the key reactions interlinking NO and NO_2 are detailed below:

$$NO_2 + hv \xrightarrow{O_2} NO + O_3 \qquad \text{(R1)}$$

$$NO + O_3 \longrightarrow NO_2 + O_2 \qquad \text{(R2)}$$

Where hv is used to represent a photon of light energy (*i.e.*, sunlight).

Taken together, reactions R1 and R2 produce no net change in O_3 concentrations and NO and NO_2 adjust to establish a near steady state reaction (photo-equilibrium). However, the presence of VOCs and CO in the atmosphere offer an alternative production route of NO_2 for photolysis, allowing O_3 concentrations to increase during the day with a subsequent decrease in the NO_2:NO_x ratio.

However, at night, the photolysis of NO_2 ceases, allowing reaction R2 to promote the production of NO_2, at the expense of O_3, with a corresponding increase in the NO_2:NO_x ratio. Similarly, near to an emission source of NO, the result is a net increase in the rate of reaction R2, suppressing O_3 concentrations immediately downwind of the source, and increasing further downwind as the concentrations of NO begin to stabilise to typical background levels (Gillani and Pliem 1996).

Given the complex nature of NO_x chemistry, the Environment Agency's Air Quality Modelling and Assessment Unit (AQMAU) have adopted a pragmatic, risk based approach in determining the conversion rate of NO to NO_2 which dispersion model practitioners can use in their detailed assessments[11]. The AQMAU guidance advises that the source term should be modelled as NO_x (as NO_2) and then suggests a tiered approach when considering ambient NO_2:NO_x ratios:

- Screening Scenario: 50 % and 100 % of the modelled NO_x process contributions should be used for short-term and long-term average concentration, respectively. That is, 50 % of the predicted NO_x concentrations should be assumed to be NO_2 for short-term assessments and 100 % of the predicted NO_x concentrations should be assumed to be NO_2 for long-term assessments;

- Worst Case Scenario: 35 % and 70 % of the modelled NO_x process contributions should be used for short-term and long-term average concentration, respectively. That is, 35 % of the predicted NO_x concentrations should be assumed to be NO_2 for short-term assessments and 70 % of the predicted NO_x concentrations should be assumed to be NO_2 for long-term assessments; and

- Case Specific Scenario: Operators are asked to justify their use of percentages lower than 35 % for short-term and 70 % for long-term assessments in their application reports.

In line with the AQMAU guidance, this assessment has used the 'Worst Case Scenario' approach in determining the conversion rate of NO to NO_2 as a robust assumption.

2.9 Existing Ambient Data

2.9.1 Continuous Monitoring Data

A network of continuous air quality monitoring stations is sponsored by Defra as part of the Automatic Urban and Rural Network (AURN). One such station, Mold AURN, is an urban background monitoring site. The site (OS grid reference 323549, 363408) has been operational since 1st December 2009. However, it is considered that this location is insufficiently close to Alltami to be a representative of air quality at the site. There is currently one local authority operated continuous monitor located at a roadside location at the A5119 Sychdyn/New Brighton Road junction near Mold and has been measuring concentrations of oxides of nitrogen since 2008. However, data from this roadside monitoring location will not provide suitable background data for the rural/ suburban location around the existing Parry's Quarry site.

[11] http://www.environment-agency.gov.uk/static/documents/Conversion_ratios_for__NOx_and_NO2_.pdf

2.9.2 Passive Monitoring Data

There are a large number of passive monitoring locations within Flintshire County Council area; recent monitoring data can be found within the Updating and Screening Assessment (July 2012)[12] and the LAQM Progress Report (July 2013)[13].

The closest to the site are located on Mold Road, Alltami (kerbside monitoring site No. 11) and Park View, Northop (urban background monitoring site No. 46) approximately 1km to the south-west and 15km to the northwest respectively. Results for monitoring station No. 11 (Mold Road) are included in Table 2.9. Urban background monitoring location No. 46 is situated 51m from the nearest kerbside. Recent monitoring data for this location is presented in Table 2.10.

Table 2.9 Nitrogen Dioxide Passive Monitoring Data – Kerbside Location 11

Year	Site No. 11 Annual Mean NO_2 Concentration (μgm^{-3})
2010	36.2
2011	31.9 (49.1)
2012	35.9 (44.9)

Figures in brackets are bias-corrected results using locally-derived correction factors.

The reason for the pairs of reported results in 2011 and 2012 is that both the national and a locally-derived bias correction factor has been applied to the diffusion tube monitoring results. The locally-derived factor in both years has been considerably higher than the national factor, thus indicating that there may be a breach of the air quality objective for annual average NO_2 at this kerbside location. This location is, therefore, unlikely to be representative of background air quality in the area around the proposed landfill site.

Table 2.10 Nitrogen Dioxide Passive Monitoring Data – Urban Background Location 46

Year	Site No. 46 Annual Mean NO_2 Concentration (μgm^{-3})
2010	16.2
2011	13.5 (20.8)
2012	14.9 (18.6)

Figures in brackets are bias-corrected results using locally-derived correction factors.

As shown, the diffusion tube monitoring results at urban background location No. 46 have been below the objective value, irrespective of whether national or locally-derived bias correction actors are used. Accounting for the

[12] Flintshire County Council (July 2012) 2012 Air Quality Updating and Screening Assessment for Flintshire County Council.
[13] Flintshire County Council (July 2013) LAQM Progress Report 2013.

distance between the site and the passive diffusion tube monitoring location; it is considered that the results at location No.46 would not be representative of background levels in the locale of the site.

2.9.3 Defra Mapped Background Concentrations

Defra maintains a nationwide model of existing and future background air quality concentrations at a 1 km grid square resolution. The data includes annual average concentration estimates for NO_x, NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2 and benzene. The model used is semi-empirical in nature; it uses the national atmospheric emissions inventory (NAEI) emissions to model the concentrations of pollutants at the centroid of each 1km grid square but then calibrates these concentrations in relation to actual monitoring data.

The background mapped concentrations in 2014 for the 1 km^2 covering the site are given in Table 2.11. Background mapped concentrations of NO_x in 2014 for each 1km grid square closest to the ecological receptors are detailed in Table 2.12.

Table 2.11 Short-Term and Long-Term Ambient Background Concentrations at Human Receptors

Pollutant	Short-term Mean 2014	Long-term Mean 2014
NO_2 ($\mu g\ m^{-3}$)	30.0	15.0
NO_x ($\mu g\ m^{-3}$)	40.0	20.0

Notes:
Based on Defra mapped background concentration data base 2010
Background concentrations for H_2S and CS_2 are not available.

Table 2.12 Long-Term Ambient Background Concentrations at Ecological Receptors

Receptor	NO_X Long-Term (Annual) Mean ($\mu g\ m^{-3}$)
Buckley Clay Pits	20.0
The Dee Estuary	18.6

Notes:
Values based on 2010 mapped data.

2.10 Local Air Quality Management

No AQMAs exist within Flintshire County. Flintshire County Council completed the fourth round of Updating and Screening Assessment (USA) of air quality in 2012. The new monitoring data did not show anything which contradicted previous assessment findings in the vicinity of the proposed landfill site. While NO_2 remains the priority pollutant for the area, the objectives and standards were met for all pollutants.

2.11 Background Concentrations used in the Assessment

Annual mean background concentrations for NO_x and NO_2 for 2014 have been derived from the Defra maps and will provide a worse case assessment. For all of the pollutants, conservative short-term ambient levels have been derived from the estimated annual mean data.

The annual average process contribution is added to the annual average background concentration, to give a total concentration at each receptor location. This total concentration can then be compared against the relevant AQS and the likelihood of an exceedence determined.

The annual average process contribution is added to the annual average background concentration to give a total concentration at each receptor location. This total concentration can then be compared against the relevant AQS and the likelihood of an exceedence determined.

It is not technically rigorous to add predicted short-term or percentile concentrations to ambient background concentrations not measured over the same averaging period, since peak contributions from different sources would not necessarily coincide in time or location. Without hourly ambient background monitoring data available it is difficult to make an assessment against the achievement or otherwise of the short-term AQS. For the current assessment, conservative short-term ambient levels have been derived by applying a factor of two to the annual mean background data as per the recommendation in H1 Annex (f).

2.12 Sensitivity Analysis and Uncertainty

2.12.1 Sensitivity Analysis

Wherever possible, this assessment has used worst-case scenarios, which will exaggerate the impact of the emissions on the surrounding area, including emissions, operational profile, ambient concentrations, meteorology and surface roughness. This assessment has considered the years predicting the highest ground-level concentrations at the nearest sensitive receptor for comparison with the AQS.

2.12.2 Model Uncertainty

Process emissions have been modelled under normal operation using the standard steady state algorithms in ADMS to determine the impact on local human and ecological receptors. In order to model atmospheric dispersion using standard Gaussian methods, the following assumptions and limitations have to be made:

- Conservation of mass – the entire mass of emitted pollutant remains in the atmosphere and no allowance is made for loss due to chemical reactions or deposition processes (although the standard Gaussian model can be modified to include such processes, as is the case with ADMS). Portions of the plume reaching the ground are assumed to be dispersed back away from the ground by turbulent eddies (eddy reflection);

- Steady state emissions – emission rates are assumed to be constant and continuous over the time averaging period of interest. This is unlikely to be the case for the majority of industrial sources where volume flows, and hence mass emission rates, can vary over short time periods;

- Steady state meteorology – no variations in wind speed, direction or turbulent profiles occur during transport from the source to the receptor. This assumption is reasonable within a few kilometres of a source but may not be valid for receptor distances in the order of tens of kilometres. For example, for a receptor 50 km from a source and with a wind speed of 5 ms^{-1} it will take nearly three hours for the plume to travel this distance during which time many different processes may change (e.g., the sun may rise or set and clouds may form or dissipate affecting the turbulent profiles). For this reason, Gaussian models are practically limited to predicting concentrations within ~20km of a source.

Dispersion modelling is inherently uncertain, but is nonetheless a useful tool in plume footprint visualisation and prediction of ground level concentrations. The use of dispersion models has been widely used in the UK for both regulatory and compliance purposes for a number of years and is an accepted approach for this type of assessment.

This assessment has incorporated a number of worst-case assumptions, as described above, which will result in an overestimation of the predicted ground level concentrations from the process. Therefore, the actual predicted ground level concentrations would be expected to be lower than this and, in some cases, significantly lower.

The model is well validated with observed concentrations for a number of scenarios; however, as the complexity of the modelled domain increases, modelled concentrations deviate from observed concentrations. For this modelling assessment, it was not considered suitable to scope out the inclusion of buildings in the model due to the nature of the site. However, the inclusion of buildings in the model introduces a further element of uncertainty but provides a better representation of plume dispersion and downwash.

3. Assessment Criteria

3.1 Relevant Legislation and Guidance

3.1.1 EU Legislation

Directive 2008/50/EC on Ambient Air Quality and Cleaner Air for Europe

Directive 2008/50/EC (the 'Directive'), which came into force in June 2008, consolidates existing EU-wide air quality legislation (with the exception of Directive 2004/107/EC) and provides a new regulatory framework for $PM_{2.5}$.

The Directive sets limits, or target levels, for selected pollutants that are to be achieved by specific dates and details procedures EU Member States should take in assessing ambient air quality. The limit and target levels relate to concentrations in ambient air. At Article 2(1), the Directive defines ambient air as:

"…outdoor air in the troposphere, excluding workplaces as defined by Directive 89/654/EEC where provisions concerning health and safety at work apply and to which members of the public do not have regular access."

In accordance with Article 2(1), Annex III, Part A, paragraph 2 details locations where compliance with the limit values does not need to be assessed:

"Compliance with the limit values directed at the protection of human health shall not be assessed at the following locations:

a) Any locations situated within areas where members of the public do not have access and there is no fixed habitation;

b) In accordance with Article 2(1), on factory premises or at industrial installations 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.''

3.1.2 UK Legislation

The Air Quality Standards Regulations 2010

The Air Quality Standards Regulations 2010 (the 'Regulations') came into force on the 11th June 2010 and transpose Directive 2008/50/EC into UK legislation. The Directive's limit values are transposed into the Regulations as 'Air Quality Standards' (AQS) with attainment dates in line with the Directive.

These standards are legally binding concentrations of pollutants in the atmosphere which can broadly be taken to achieve a certain level of environmental quality. The standards are based on the assessment of the effects of each pollutant on human health including the effects of sensitive groups or on ecosystems.

Similar to Directive 2008/50/EC, the Regulations define ambient air as:

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

with direction provided in Schedule 1, Part 1, Paragraph 2 as to where compliance with the AQS' does not need to be assessed:

"Compliance with the limit values directed at the protection of human health does not need to be assessed 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."*

The Air Quality Strategy for England, Scotland, Wales and Northern Ireland

The 2007 Air Quality Strategy for England, Scotland Wales and Northern Ireland provides a framework for improving air quality at a national and local level and supersedes the previous strategy published in 2000.

Central to the Air Quality Strategy are health-based criteria for certain air pollutants; these criteria are based on medical and scientific reports on how and at what concentration each pollutant affects human health. The objectives derived from these criteria are policy targets often expressed as a maximum ambient concentration not to be exceeded, without exception or with a permitted number of exceedences, within a specified timescale. At paragraph 22 of the 2007 Air Quality Strategy, the point is made that the objectives are:

"…a statement of policy intentions or policy targets. As such, there is no legal requirement to meet these objectives except where they mirror any equivalent legally binding limit values…"

The air quality objectives (AQOs), based on a selection of the objectives in the Air Quality Strategy, were incorporated into UK legislation through the Air Quality Regulations 2000, as amended.

Paragraph 4(2) of The Air Quality (England) Regulations 2000 states:

"The achievement or likely achievement of an air quality objective prescribed by paragraph (1) shall be determined by reference to the quality of air at locations:

a) *which are situated outside of buildings or other natural or man-made structures above or below ground; and*

b) *where members of the public are regularly present''*

Consequently, compliance with the AQOs should focus on areas where members of the general public are present over the entire duration of the concentration averaging period specific to the relevant objective.

Local Air Quality Management

Part IV of the Environment Act 1995 requires that Local Authorities periodically review air quality within their individual areas. This process of Local Air Quality Management (LAQM) is an integral part of delivering the Government's AQOs.

To carry out an air quality Review and Assessment under the LAQM process, the Government recommends a three-stage approach. This phased review process uses initial simple screening methods and progresses through to more detailed assessment methods of modelling and monitoring in areas identified to be at potential risk of exceeding the objectives in the Regulations.

Review and assessments of local air quality aim to identify areas where national policies to reduce vehicle and industrial emissions are unlikely to result in air quality meeting the Government's air quality objectives by the required dates.

For the purposes of determining the focus of Review and Assessment, Local Authorities should have regard to those locations where members of the public are likely to be regularly present and are likely to be exposed over the averaging period of the objective.

Where the assessment indicates that some or all of the objectives may be potentially exceeded, the Local Authority has a duty to declare an Air Quality Management Area (AQMA). The declaration of an AQMA requires the Local Authority to implement an Air Quality Action Plan (AQAP), to reduce air pollution concentrations so that the required AQOs are met.

3.1.3 Other Guideline Values

In the absence of statutory standards for the other prescribed substances that may be found in the emissions, there are several sources of applicable air quality guidelines.

Air Quality Guidelines for Europe, the World Health Organisation (WHO)

The aim of the WHO Air Quality Guidelines for Europe (WHO, 2000) is to provide a basis for protecting public health from adverse effects of air pollutants and to eliminate or reduce exposure to those pollutants that are known or likely to be hazardous to human health or well-being. These guidelines are intended to provide guidance and information to international, national and local authorities making risk management decisions, particularly in setting air quality standards.

Environmental Assessment Levels (EALs)

The Environment Agency's Horizontal Guidance Note H1 provides methods for quantifying the environmental impacts of emissions to all media. H1 Annex (f) contains long and short-term Environmental Assessment Levels (EALs) and Environmental Quality Standards (EQS) for releases to air derived from a number of published UK and international sources. For the pollutants considered in this study, these EALs and EQS are equivalent to the AQS and AQOs set in force by the Air Quality Strategy for England, Scotland Wales and Northern Ireland.

H1 Annex (f) provides a three-tiered approach to assessing the significance of emissions to atmosphere. The first stage is to 'screen out' insignificant emissions to air; these are emissions which are emitted in such small quantities that they are unlikely to cause a significant impact on the receiving environment. This procedure is detailed in Box 3.1.

Box 3.1 Screening Out Insignificant Emissions to Air

Identify which emissions can be excluded from further assessment by applying the criteria below:

- Long-term Process Contribution (PC) < 1% of the relevant long-term EAL
- Short-term PC < 10% of the relevant short-term EAL

Those releases which **satisfy the above criteria** can be classed as **insignificant** and excluded from further assessment. Those releases which **do not satisfy the above criteria** can be classed as **not insignificant** and warrant further assessment.

The second stage is to assess the need for detailed dispersion modelling of emissions to air (Box 3.2). If the second stage indicates that further investigation is warranted, a detailed assessment of emissions to air should be undertaken using an appropriate dispersion model, such as ADMS or AERMOD (the third stage assessment). It should be noted that once a decision has been made to proceed to detailed modelling, the insignificance criteria described in Box 3.1 are no longer relevant and shouldn't be used in the assessment of impact. Rather, the impact assessment should focus only on achievement with the appropriate EAL.

Box 3.2 Identifying the Need for Detailed Modelling of Emissions to Air

For those releases which cannot be screened by the criteria detailed in Box 1, the following approach should be used in identifying whether detailed modelling of emissions to air is required.

Long Term Impacts

1. Obtain information on the annual mean background concentrations (BG) of releases to air
2. Calculate the Predicted Environmental Concentration (PEC) of that substance by summing the PC and BG, i.e., **PEC = PC + BG**
3. Detailed dispersion modelling **is required** if **PEC > 70% of the EAL**

Short Term Impacts

1. Calculate the difference between the long-term background concentration and short-term EAL (model headroom)
2. Detailed dispersion modelling **is required** if the **short-term PC > 20% of model headroom**
3. Short-term Process Contributions not exceeding 20% of the short-term EAL “may be considered to be tolerable”.

3.2 Air Quality Impacts of the Process

The atmospheric emissions of a number of pollutants have been identified as requiring detailed dispersion modelling. The emitted pollutants of primary concern to the local environment are:

- Oxides of nitrogen (NO_x as NO_2);
- Hydrogen sulphide (H_2S);
- Carbon disulphide (CS_2); and
- Odour.

A brief description of each pollutant is given in Table 3.1.

Table 3.1 Summary of the Pollutants Assessed

Pollutant	Description and Effect on Human Health and the Environment	Principal Sources
Oxides of Nitrogen (NO_X)[14, 15, 16]	Nitrogen dioxide (NO_2) and Nitric oxide (NO) are both collectively referred to as oxides of Nitrogen (NO_X). It is NO_2 that is associated with adverse effects on human health. Most atmospheric emissions are in the form of NO which is converted to NO_2 in the atmosphere through reactions with Ozone. The oxidising properties of NO_2 theoretically could damage lung tissue, and exposure to very high concentrations of NO_2 can lead to inflammation of lung tissue, affect the ability to fight infection. The greatest impact of NO_2 is on individuals with asthma or other respiratory conditions, but consistent impacts on these individuals is at levels of greater than 564 μgm^{-3}, much higher than typical UK ambient concentrations.	All combustion processes produce NO_X emissions, and the principal source of NO_X is road transport, which accounted for 32% of total UK emissions in 2008. Emissions from power stations contributed a further 20%.
Hydrogen sulphide (H_2S) [17]	Exposure to lower concentrations (10–20ppm) can result in eye irritation, a sore throat and cough, shortness of breath. Long-term, low-level exposure may result in fatigue, loss of appetite, headaches and poor memory. 320–530ppm leads to pulmonary edema with the possibility of death.	Wide variety of sources, both natural and anthropogenic. About 10% of total global emissions of H_2S are due to human activity. The largest industrial source of H_2S occurs in petroleum refineries.
Carbon disulphide (CS_2) [18]	Severe eye and respiratory irritant. Readily absorbed through the skin. Chronic exposure may cause liver, kidney and central nervous system damage, or impaired vision. At high levels, carbon disulfide may be life-threatening due to affects on the nervous system.	A variety of sources, both natural (volcanic eruptions and marshes) and anthropogenic (principally manufacturing).

3.3 Criteria Appropriate to the Assessment

3.3.1 Air Quality Standards and Critical Levels

Table 3.2 sets out those AQS, AQOs and EALs that are relevant to this assessment.

Given that the exact speciation of the NMVOC group of compounds is not known, this assessment has adopted a pragmatic, worst-case approach by assessing the total group modelled contributions against the benzene AQS, this being one of the most stringent assessment metrics of any VOC within the group. Furthermore, as the vast majority of total VOC emissions from the engines and flare will comprise of unburned methane during combustion, and as there is no AQS/AQO/EAL for methane, total VOC emissions have not been subject to a detailed impact assessment.

[14] Defra, 2009, Part IV of the Environment Act 1995 Local Air Quality Management: Technical Guidance LAQM.TG(09).
[15] Harrison, R.M., *Air Pollution: Sources, Concentrations and Measurements.* In: Harrison, R.M., 2000, *Pollution: Causes, Effects and Controls*, 4th Edition Royal Society of Chemistry.
[16] Walters, S. and Ayers, J., *The Health Effects of Air Pollution*. In: Harrison, R.M., 2000, *Pollution: Causes, Effects and Controls*, 4th Edition Royal Society of Chemistry.
[17] MSDS (2005) Hydrogen Sulphide (http://msds.chem.ox.ac.uk/HY/hydrogen_sulfide.html)
[18] MSDS (2006) Carbon Disulphide (http://physchem.ox.ac.uk/msds/CA/carbon_disulfide.html)

Table 3.2 Summary of Relevant Air Quality Standards (AQS), Objectives (AQOs) and Environmental Assessment Levels (EALs) for Human Receptors

Pollutant	AQS/AQO/EAL	Averaging Period	Value ($\mu g\ m^{-3}$)
Nitrogen dioxide (NO_2)	AQS	Annual mean	40
	AQS	1-hour mean, not more than 18 exceedences a year (equivalent of 99.79 Percentile)	200
Hydrogen Sulphide (H_2S)	EAL	Maximum 1-hour mean	150
Carbon disulphide (CS_2)	EAL	Maximum 1-hour mean	100
Odour	Indicative benchmark (H4)	98th percentile of hourly means over a calendar year	3 ou_E/m^3

3.4 Critical Levels and Loads Appropriate to this Assessment

A summary of the relevant air quality standards that apply to the emissions from the proposed gas engines and its combined impact on ecological receptors are given in Table 3.3.

Table 3.3 Summary of Relevant Air Quality Standards (AQS), Objectives (AQOs) and Environmental Assessment Levels (EALs) for Ecological Receptors

Pollutant	AQS/AQO/EAL	Averaging Period	Value ($\mu g\ m^{-3}$)
Oxides of nitrogen (NO_x)	AQS	Annual mean	30
Oxides of nitrogen (NO_x)	EAL	Daily mean	75[1]

Only if SO_2 or O_3 are also present at or above their critical levels.

The Air Pollution Information System (APIS) provides specific information on the potential effects of nitrogen deposition on various habitats and species. This information, relevant to habitats of some of the ecological receptors considered in this assessment is presented in Table 3.4.

Table 3.4 Habitat and Species Information Concerning Nitrogen Deposition from APIS

Habitat and Species Specific Information	Critical Load (kg N ha-1 yr-1)	Specific Information Concerning Nitrogen Deposition
Salt marsh	**30-40**	**Many salt marshes receive large nutrient loadings from river and tidal inputs. It is unknown whether other types of species-rich saltmarsh would be sensitive to nitrogen deposition.** **Increase in late-successional species, increased productivity but only limited information available for this type of habitat.**
Littoral Sediments	20 - 30	Increase late successional species, increase productivity increase in dominance of graminoids.
Coastal Stable Dune Grasslands	10-20	Foredunes receive naturally high nitrogen inputs. Key concerns of the deposition of nitrogen in these habitats relate to changes in species composition.
Alkaline Fens and Reed beds	10-35	Nitrogen deposition provides fertilization. Increase in tall graminoids (grasses or Carex species) resulting in loss of rare species and decrease in diversity of subordinate plant species.
Temperate and boreal forests	**10-20**	**Increased nitrogen deposition in mixed forests increases susceptibility to secondary stresses such as drought and frost, can cause reduced crown growth. Also can reduce the diversity of species due to increased growth rates of more robust plants.**
Hay Meadow	20-30	The key concerns are related to changes in species composition following enhanced nitrogen deposition. Indigenous species will have evolved under conditions of low nitrogen availability. Enhanced Nitrogen deposition will favour those species that can increase their growth rates and competitive status e.g. rough grasses such as false brome grass (Brachypodium pinnatum) at the expense of overall species diversity. The overall threat from competition will also depend on the availability of propagules
Acid Grasslands	10-25	Nitrogen deposition provides fertilization to acid grasslands, this increase robust grass growth that may limit other species reducing diversity.
Oak Woodland	10-15	Increased nitrogen deposition in Oak forests increases susceptibility to secondary stresses such as drought and frost, can cause reduced crown growth

Note: Habitats relevant to this assessment given in bold.
The SPAs are all designated for birds in tidal salt marsh areas. The local wildlife sites are mainly open water or woodland areas and a value for temperate and boreal forest has been selected to represent the critical loads for these receptors in the absence of site specific values.

4. Assessment of Impact

This section sets out the results of the dispersion modelling and compares predicted ground level concentrations to ambient air quality standards. The predicted concentrations resulting from the process are presented with background concentrations and the percentage contribution that the predicted environmental concentrations would make towards the relevant AQS/AQO/EAL.

The impact of the plant has been modelled for the emission conditions described in section 1.2 and on a 1.5 km square grid. Example contour plots of the results from nitrogen dioxide for the year 2007 are provided (Figures 4.1 and 4.2) for illustrative purposes to show the general pattern of dispersion. Figure 4.3 contains a contour plot of 98th percentile odour concentrations around the site, arising from landfill surface emissions.

Results are presented for the meteorological year resulting in the highest ground level concentrations at each individual receptor, as a worst case assumption, since there will not be a single annual meteorological data set that yields the maximum concentration at all receptors. The worst-case was determined by running each of the models for all of the identified receptors for all five meteorological years (2005-2009). The results were then post-processed using a bespoke spreadsheet application and the maximum recorded concentration at each of the receptors was used in the assessment.

4.1 Impacts at Human Receptors

Tables 4.1 to 4.5 detail the results of the NO_2, H_2S, CS_2 and odour impact assessments at the human receptors considered in this study for the proposed landfill and gas compound installation (engine and flare). It has been assumed, realistically, that the engine and flare will not operate simultaneously.

Table 4.1 NO_2 Impacts at Nearby Human Receptors - Engine

Receptors	Annual Mean				99.79 Percentile of 1-Hour Mean			
	AQS µg m^{-3}	PC µg m^{-3}	PEC µg m^{-3}	% PEC OF AQS	AQS µg m^{-3}	PC µg m^{-3}	PEC µg m^{-3}	% PEC OF AQS
Parrys Cottages	**40**	0.32	15.32	38.3%	**200**	2.44	32.44	16.2%
Holiday Inn	**40**	1.28	16.28	40.7%	**200**	5.38	35.38	17.7%
The Box	**40**	3.16	18.16	45.4%	**200**	12.39	42.39	21.2%
Alltami House	**40**	0.25	15.25	38.1%	**200**	5.43	35.43	17.7%
Pinfold Cottages	**40**	0.26	15.26	38.2%	**200**	5.18	35.18	17.6%
Ewloe Wood House	**40**	0.48	15.48	38.7%	**200**	5.64	35.64	17.8%
Ewloe Ind Est	**40**	0.19	15.19	38.0%	**200**	1.94	31.94	16.0%

Table 4.1 (continued) NO_2 Impacts at Nearby Human Receptors - Engine

Receptors	Annual Mean				99.79 Percentile of 1-Hour Mean			
	AQS µg m^{-3}	PC µg m^{-3}	PEC µg m^{-3}	% PEC OF AQS	AQS µg m^{-3}	PC µg m^{-3}	PEC µg m^{-3}	% PEC OF AQS
SCANIA	**40**	0.59	15.59	39.0%	**200**	10.68	40.68	20.3%
FCC	**40**	0.09	15.09	37.7%	**200**	2.02	32.02	16.0%
Permitted Development	**40**	0.89	15.89	39.7%	**200**	4.23	34.23	17.1%
OK Diner	**40**	2.43	17.43	43.6%	**200**	9.03	39.03	19.5%
Shell Fuel Station	**40**	4.58	19.58	48.9%	**200**	16.21	46.21	23.1%
Costa & Subway	**40**	1.61	16.61	41.5%	**200**	6.27	36.27	18.1%

AQS = Air Quality Standard; PC = Process Contribution; PEC = Predicted Environmental Concentration (PC + Background)

Table 4.2 NO_2 Impacts at Nearby Human Receptors - Flare

Receptors	Annual Mean				99.79 Percentile of 1-Hour Mean			
	AQS µg m^{-3}	PC µg m^{-3}	PEC µg m^{-3}	% PEC OF AQS	AQS µg m^{-3}	PC µg m^{-3}	PEC µg m^{-3}	% PEC OF AQS
Parrys Cottages	**40**	0.10	15.1	37.8%	**200**	0.71	30.7	15.4%
Holiday Inn	**40**	0.42	15.4	38.5%	**200**	1.60	31.6	15.8%
The Box	**40**	1.13	16.1	40.3%	**200**	4.38	34.4	17.2%
Alltami House	**40**	0.08	15.1	37.7%	**200**	1.70	31.7	15.9%
Pinfold Cottages	**40**	0.09	15.1	37.7%	**200**	1.64	31.6	15.8%
Ewloe Wood House	**40**	0.16	15.2	37.9%	**200**	1.75	31.8	15.9%
Ewloe Ind Est	**40**	0.06	15.1	37.7%	**200**	0.57	30.6	15.3%
SCANIA	**40**	0.21	15.2	38.0%	**200**	3.75	33.7	16.9%
FCC	**40**	0.03	15.0	37.6%	**200**	0.65	30.6	15.3%
Permitted Development	**40**	0.29	15.3	38.2%	**200**	1.28	31.3	15.6%
OK Diner	**40**	0.81	15.8	39.5%	**200**	2.92	32.9	16.5%
Shell Fuel Station	**40**	1.63	16.6	41.6%	**200**	5.67	35.7	17.8%
Costa & Subway	**40**	0.53	15.5	38.8%	**200**	1.98	32.0	16.0%

AQS = Air Quality Standard; PC = Process Contribution; PEC = Predicted Environmental Concentration (PC + Background)

Table 4.3 Short-term H_2S Impacts at Nearby Human Receptors

Receptors	EAL µg m^{-3}	Maximum 1-Hour Mean PC µg m^{-3}	PEC µg m^{-3}	% PEC of AQS
Parrys Cottages	**150**	1.8	1.8	1.2%
Holiday Inn	**150**	1.8	1.8	1.2%
The Box	**150**	2.4	2.4	1.6%
Alltami House	**150**	2.3	2.3	1.5%
Pinfold Cottages	**150**	2.0	2.0	1.4%
Ewloe Wood House	**150**	1.7	1.7	1.1%
Ewloe Ind Est	**150**	1.8	1.8	1.2%
SCANIA	**150**	4.6	4.6	3.1%
FCC	**150**	3.4	3.4	2.3%
Permitted Development	**150**	2.0	2.0	1.3%
OK Diner	**150**	2.5	2.5	1.7%
Shell Fuel Station	**150**	2.7	2.7	1.8%
Costa & Subway	**150**	2.3	2.3	1.6%

Table 4.4 Short-term CS_2 Impacts at Nearby Human Receptors

Receptors	EAL µg m^{-3}	Maximum 1-Hour Mean PC µg m^{-3}	PEC µg m^{-3}	% PEC of AQS
Parrys Cottages	**100**	1.1	1.1	1.1%
Holiday Inn	**100**	1.1	1.1	1.1%
The Box	**100**	1.5	1.5	1.5%
Alltami House	**100**	1.4	1.4	1.4%
Pinfold Cottages	**100**	1.3	1.3	1.3%
Ewloe Wood House	**100**	1.0	1.0	1.0%
Ewloe Ind Est	**100**	1.1	1.1	1.1%
SCANIA	**100**	2.9	2.9	2.9%
FCC	**100**	2.1	2.1	2.1%
Permitted Development	**100**	1.2	1.2	1.2%
OK Diner	**100**	1.5	1.5	1.5%
Shell Fuel Station	**100**	1.6	1.6	1.6%
Costa & Subway	**100**	1.4	1.4	1.4%

Table 4.5 Odour Impacts at Nearby Human Receptors (98th Percentile Concentrations)

Receptors	AQS ouE m-3	PC	% PC of AQS
Parrys Cottages	**3**	1.21	40.3%
Holiday Inn	**3**	1.21	40.3%
The Box	**3**	2.89	96.3%
Alltami House	**3**	3.26	108.7%
Pinfold Cottages	**3**	2.75	91.7%
Ewloe Wood House	**3**	2.70	90.0%
Ewloe Ind Est	**3**	0.54	17.9%
SCANIA	**3**	11.10	370.0%
FCC	**3**	0.56	18.5%
Permitted Development	**3**	2.37	79.0%
OK Diner	**3**	1.81	60.3%
Shell Fuel Station	**3**	1.81	60.3%
Costa & Subway	**3**	1.71	57.0%

Table 4.1 indicates that the PEC of NO_2 emitted from the engine is below 49% of the respective long-term assessment criterion at worst and below 24% of the short-term assessment criterion even when the existing background concentration is included. For the flare operation, the PEC of NO_2 emitted is below 42% of the respective long-term assessment criterion at worst and below 18% of the short-term assessment criterion even when the existing background concentration is included.

Predicted H_2S and CS_2 concentrations are below 4% of the respective short-term metric at all human receptors. Consequently, emissions to air from the landfill and gas plant installations are not expected to cause adverse impacts to the health of the local population.

Maximum 98th percentile odour concentrations arising at the sensitive receptors are predicted to be at risk of exceeding the 3 ou_E m^{-3} indicative odour threshold at two locations – the Scania trucks facility and Alltami House. In addition, concentrations at The Box and Pinfold Cottages are forecast to be just below the criterion. These are only slightly in excess of the criterion and it is considered that additional mitigation measures, applied during the normal course of landfill operation, should be able to reduce these concentrations as far as is practicable. Such measures would include limiting the area of active working face with uncovered deposited waste, progressive daily covering of the waste during daily operations, temporary capping of daily covered areas of waste as soon as is feasible and early installation of temporary landfill gas extraction systems.

4.2 Impacts at Ecological Receptors

4.2.1 Atmospheric Concentrations

Tables 4.6 and 4.7 detail the results of the impact assessment of aerial concentrations of NOx at the ecological receptors considered in this study, for the engine and flare emissions, respectively.

Table 4.6 NO_x Impacts at Nearby Ecological Receptors (Engine)

Receptors	Annual Mean				Maximum 24-hour Mean			
	AQS $\mu g\ m^{-3}$	PC $\mu g\ m^{-3}$	PEC $\mu g\ m^{-3}$	% PEC of AQS	EAL $\mu g\ m^{-3}$	PC $\mu g\ m^{-3}$	PEC $\mu g\ m^{-3}$	% PEC of EAL
Dee Estuary	**30**	0.02	20.0	66.7%	**75**	0.4	30.4	40.5%
Buckley Pits	**30**	0.40	20.4	68.0%	**75**	4.2	34.2	45.6%

AQS = Air Quality Standard; PC = Process Contribution; PEC = Predicted Environmental Concentration (PC + Background)
Figures in bold indicate a value above the AQS/EAL

Table 4.6 indicates annual mean and daily mean PECs of NO_x are below the respective assessment metric at the closest point on all ecological receptor locations for the current scenario. Consequently, emissions to air from the installation are not expected to cause adverse impacts with respect to aerial concentrations for this scenario.

4.2.2 Deposition

Table 4.7 contains the results of the deposition analysis for nitrogen and Table 4.8 those for total acidity. Reviewing the citations for the Natura 2000 sites indicates that they are not sensitive to acid deposition[19,20]. The values in Table 4.8 are included for information only.

Table 4.7 Nitrogen Deposition Rates at Ecologically-Designated Sites

Receptor	CL (kg N ha^{-1} yr^{-1})	Maximum Predicted PC (kg N ha^{-1} yr^{-1})	Background Deposition Rate (kg N ha^{-1} yr^{-1})	PEDR (kg N ha^{-1} yr^{-1})	%PEDR of CL_{min}
Dee Estuary	30 - 40	0.0003	14.4	14.4	48.0%
Buckley Pits	10 – 20	0.057	37.4	37.5	375%

CL = Critical load – the CL selected for each designated site relates to its most N-sensitive habitat (or a similar surrogate) listed on the site citation for which data on Critical Loads are available and is also based on a precautionary approach using professional judgement.
PC = Process contribution; PEDR = Predicted environmental deposition rate (= PC + background)

[19] Natura 2000 Dee Estuary Citations Available online: (http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=UK9013011&release=End2010&form=Clean)
[20] Natura 2000 Bucklkey Pits Citations Available online: (http://natura2000.eea.europa.eu/natura2000/SDF.aspx?site=UK0030132)

Table 4.8 Total Acid Deposition Rates at Ecologically-Designated Sites

Receptor	CL (kg eq ha^{-1} yr^{-1})	Maximum Predicted PC (kg eq ha^{-1} yr^{-1})	Background Deposition rate (kg eq ha^{-1} yr^{-1})	PEDR (kg eq ha^{-1} yr^{-1})	%PC of CL_{min}
Dee Estuary	NA	<0.01	1.27	1.27	NA
Buckley Pits	NA	<0.01	2.96	2.96	NA

CL = Critical load – the CL selected for each designated site relates to its most N-sensitive habitat (or a similar surrogate) listed on the site citation for which data on Critical Loads are available and is also based on a precautionary approach using professional judgement.
PC = Process contribution
PEDR = Predicted environmental deposition rate (= PC + background)

The deposition of nitrogen predicted at the Dee Estuary Ramsar/SPA/SAC site is below the minimum critical load for the SPAs even when the existing background deposition is included; therefore there is unlikely to be a negative impact on the habitat.

For the Buckley Clay Pits and Commons SSSI (Deeside and Buckley Newt Sites SAC), the existing background deposition is already significantly higher than the assumed critical load for these sites. The site consists of a former clay pits which are now ponds and is designated primarily for its large breeding population of great crested newt. The designation does not raise air pollution or deposition as an issue and, consequently, it is unlikely that emissions from the installation would have detrimental impacts.

4.3 Contour Plots

The following figures show the example ground level concentration dispersion patterns for nitrogen dioxide (engine and flare), hydrogen sulphide, carbon disulphide and odour.

Figure 4.1 Ground Level Concentration of NO_2 – Annual Mean Process Contribution from Engine (µg/m^3)

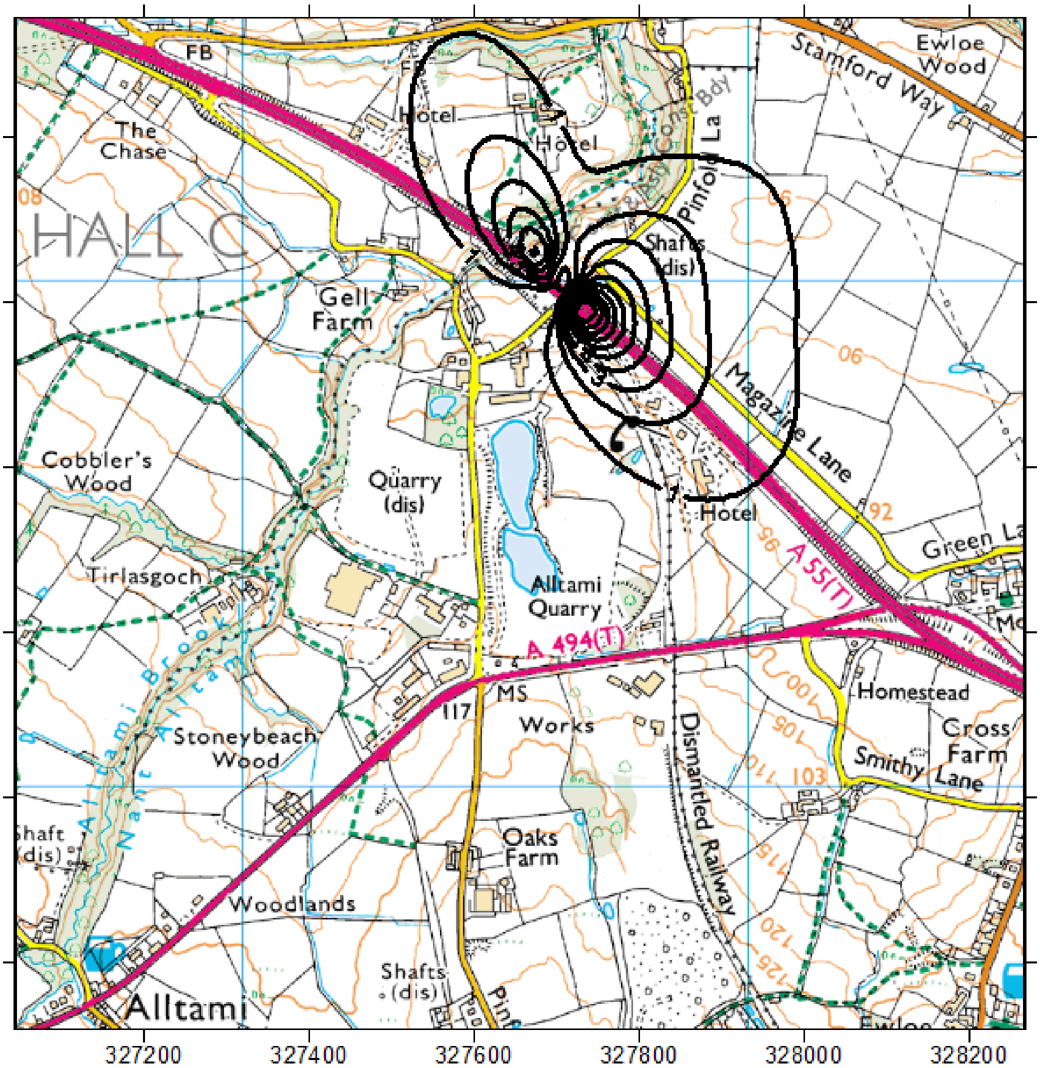


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Figure 4.2 Ground level Concentration of NO_2 – 99.79%-ile – 1-hour Mean Process Contribution from Engine (µg/m^3)

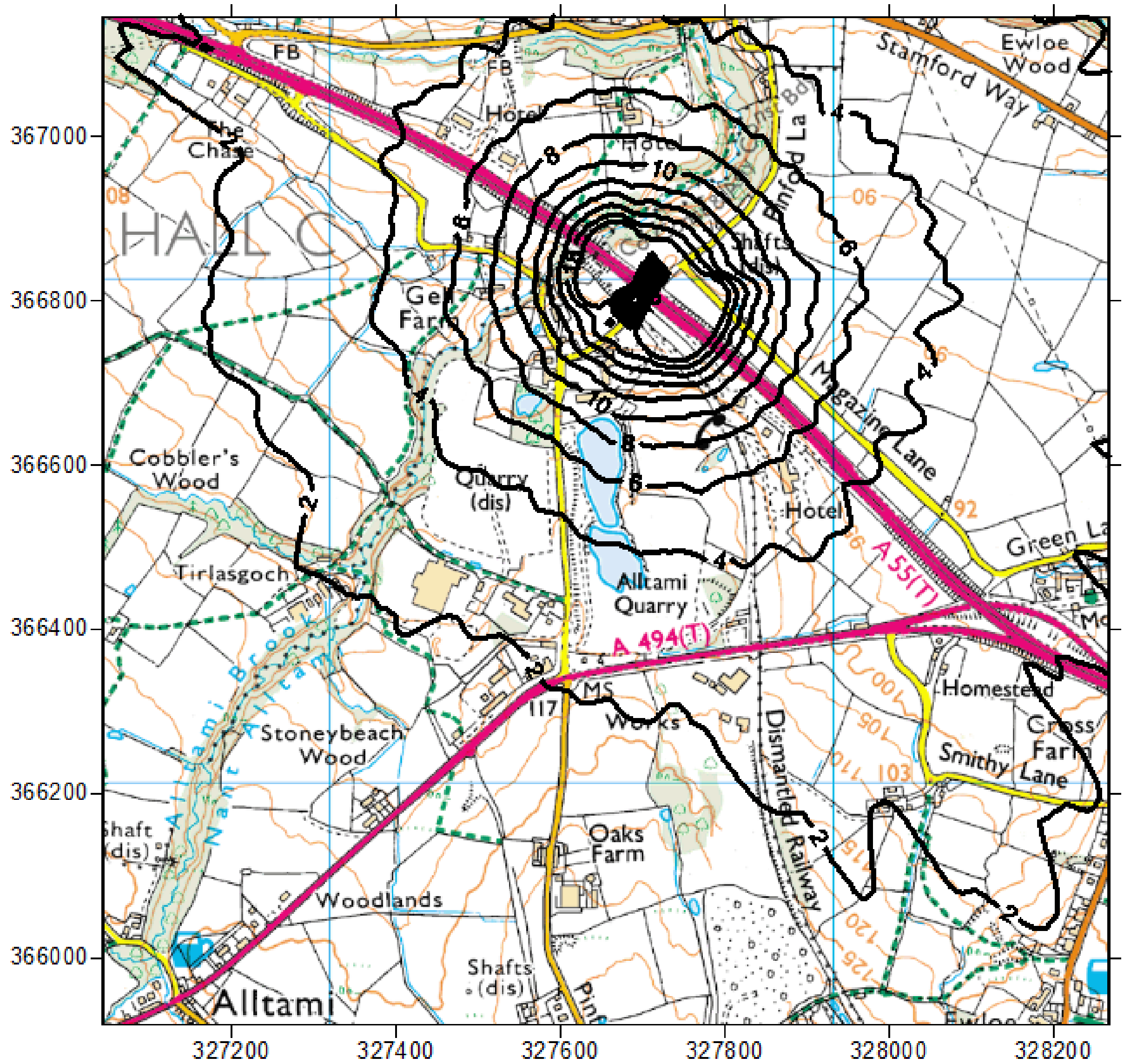

Figure 4.3 Ground Level Concentration of NO_2 – Annual Mean Process Contribution from Flare (μg/m^3)

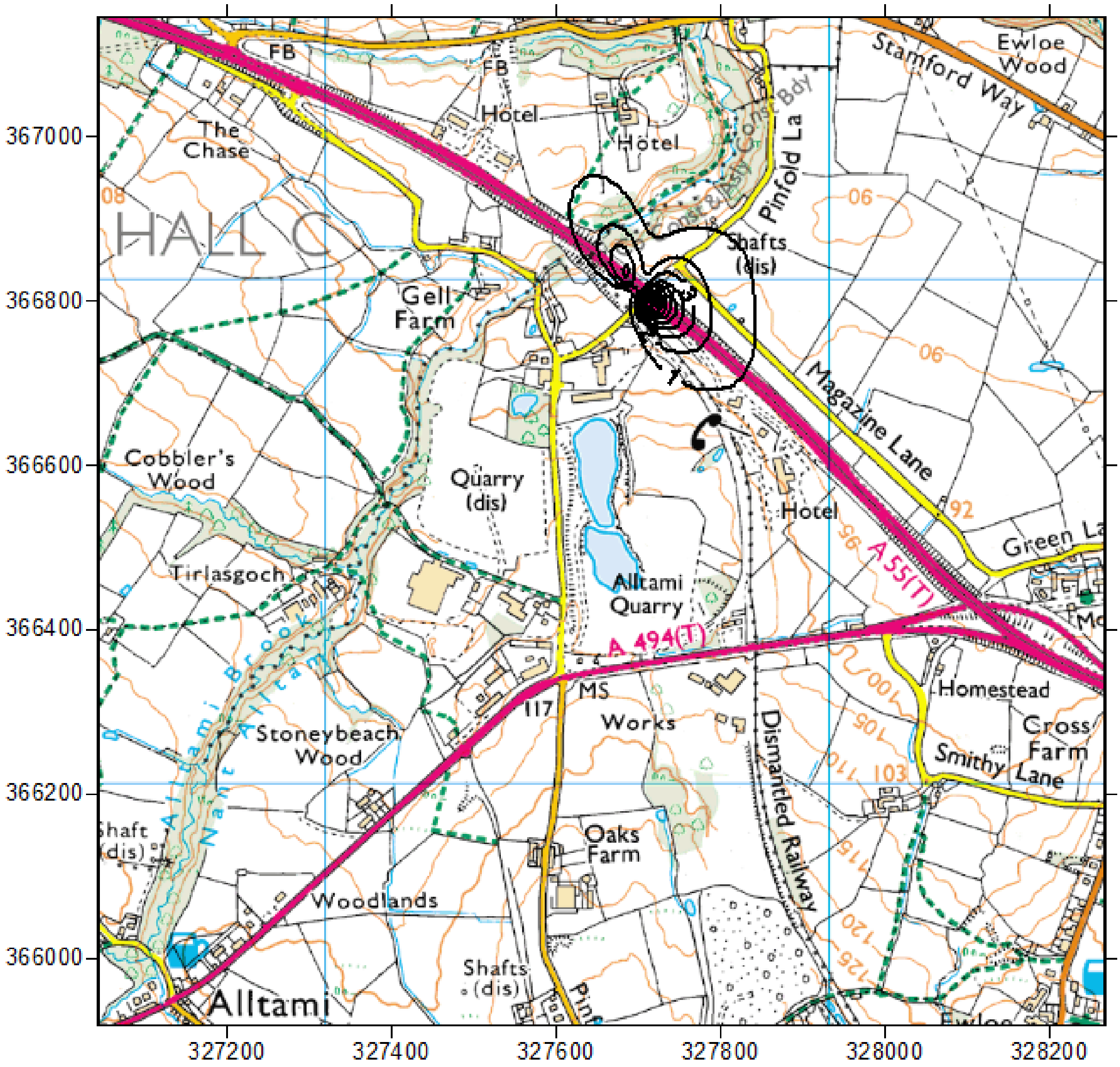

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Figure 4.4 Ground level Concentration of NO_2 – 99.79%-ile – 1-hour Mean Process Contribution from Flare (µg/m³)

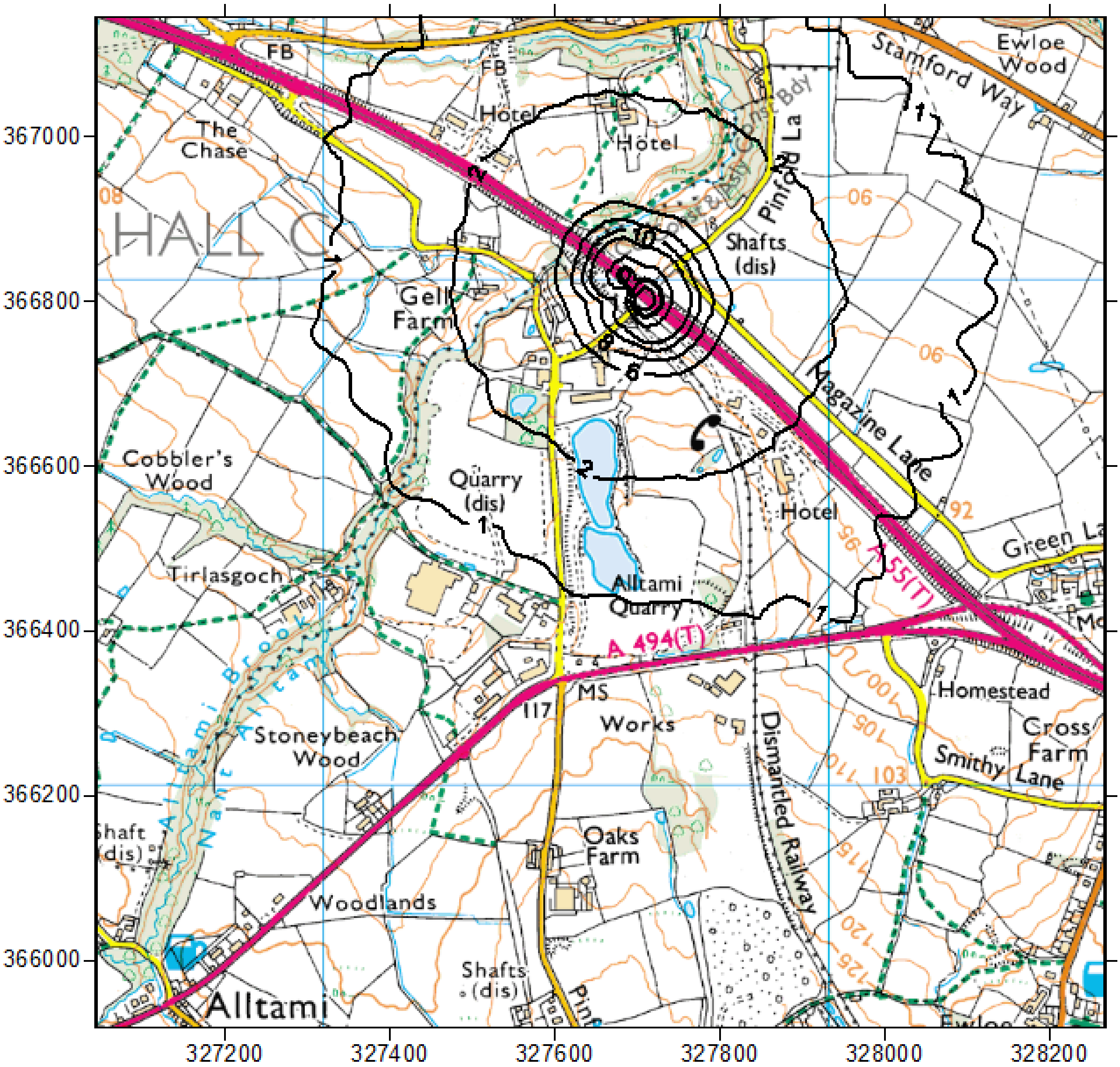

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Figure 4.5 Ground Level Concentration of H_2S – Maximum 1-hour Mean Process Contribution (µg/m^3)

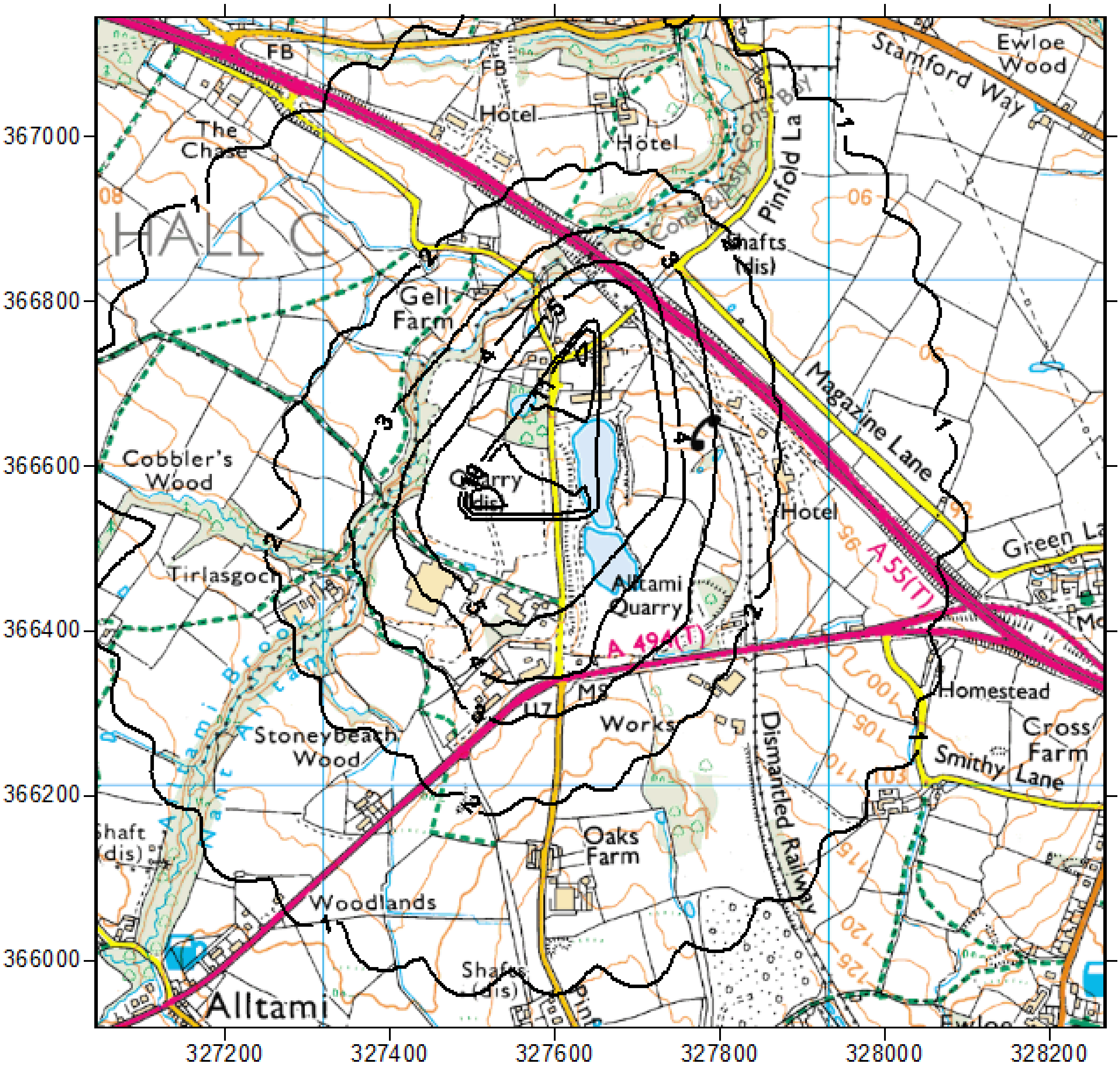

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Figure 4.6 Ground Level Concentration of CS_2 – Maximum 1-hour Mean Process Contribution (µg/m^3)

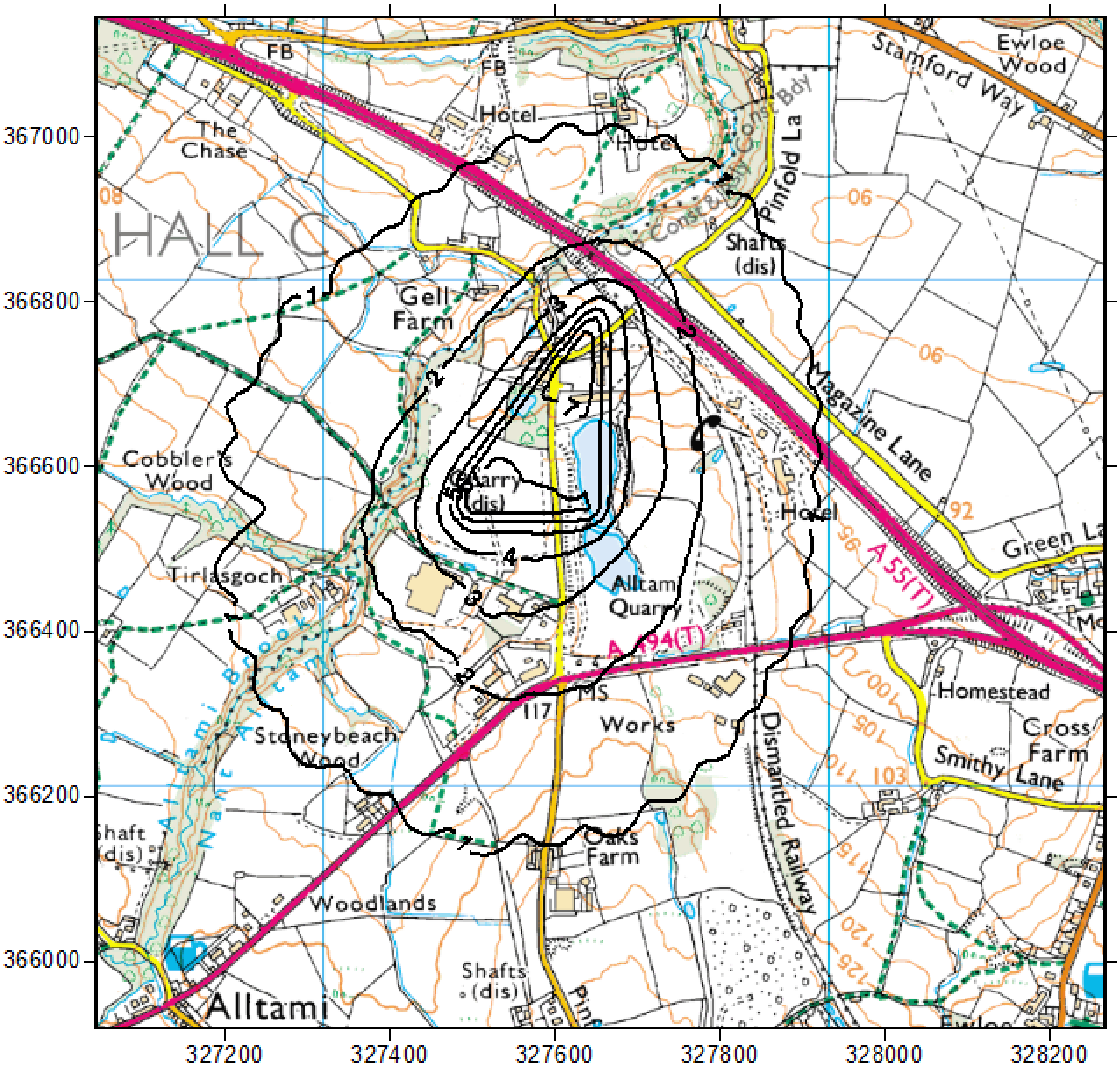

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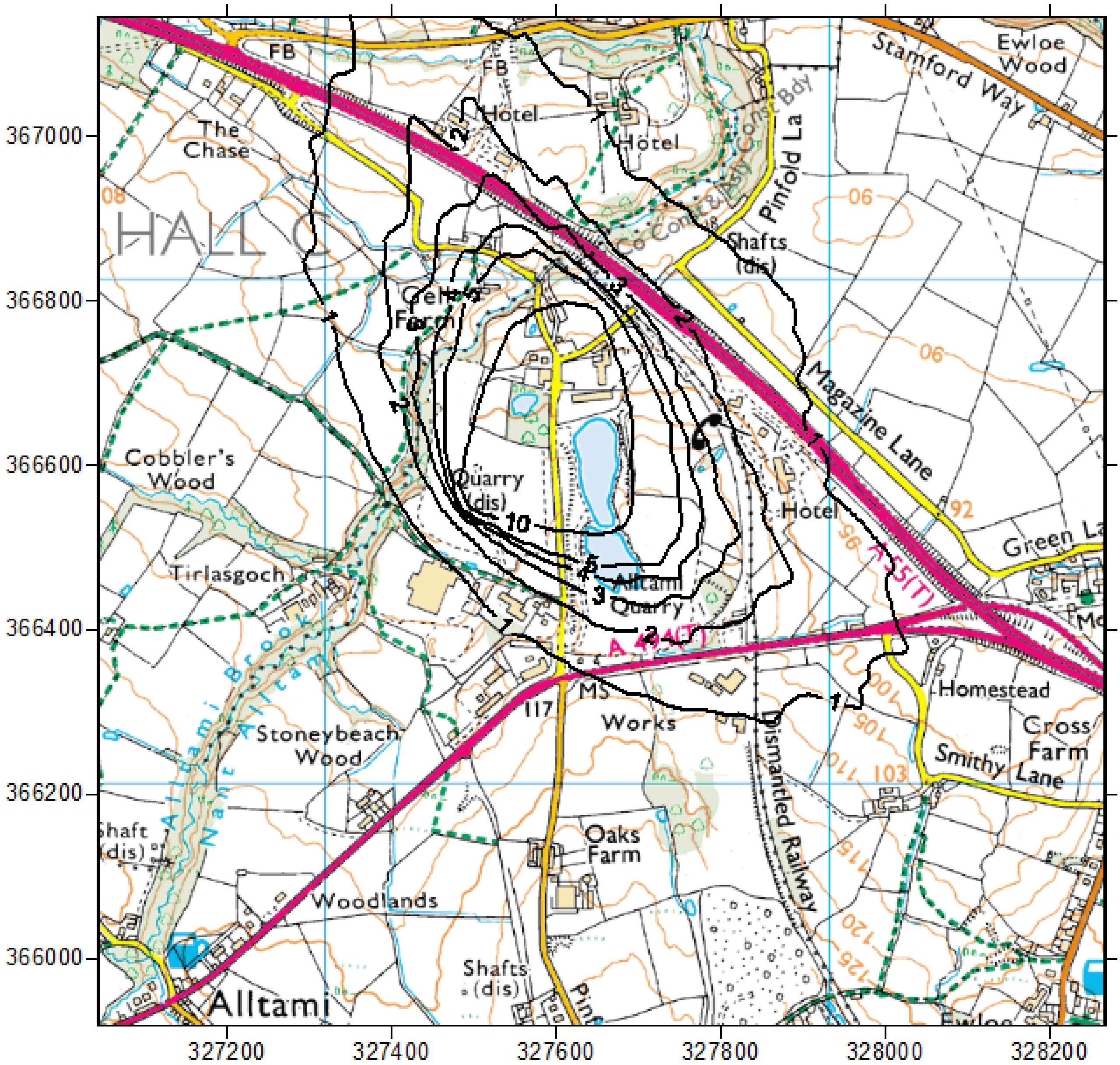
Figure 4.7 Ground Level Concentration of Odour – 98th Percentile Process Contribution (ou_E/m^3)



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5. Conclusions

This assessment has utilised detailed dispersion modelling to undertake an impact assessment of the emissions to air from a proposed landfill site and associated gas plant infrastructure (engine and flare) at Robin Jones and Sons Limited existing Parry's Quarry site, Flintshire, north-east Wales.

AMEC has assessed the impact of atmospheric emissions from the proposed landfill site and gas plant components under worst case normal operating conditions. Surface emission flux values have been derived from GasSim as detailed in the LFGRA submitted in support of the application. Based upon the predicted waste input into the site, the landfill is predicted to generate sufficient gas to sustain one 1.0 MWe engine. Benchmark Emission Limit Values (ELVs), taken from the Environment Agency's Technical Guidance Note LFTGN08, have been used to represent the upper bound emission scenarios from the landfill gas engine. Benchmark ELVs for the flare were taken from the Environment Agency's Guidance on Landfill Gas Flaring LFTGN05 Version 2. The pollutants covered by the assessment included:

- Oxides of nitrogen (NO_X as NO_2);
- Hydrogen sulphide (H_2S); and
- Carbon disulphide (CS_2).

The impact assessment has demonstrated that, under the proposed operational profile of the gas plant activities, *i.e*. one engine and one flare operating independently and continuously, the predicted environmental concentrations of NO_2 at human receptor locations are below the air quality standards and guideline levels even when the background concentrations are included.

The evaluation has also demonstrated that under the proposed operational profile of the landfill activities, *i.e*. based on the 95th percentile of peak surface emissions rates for 2026, the predicted environmental concentrations of H_2S and CS_2 at human receptor locations are below the air quality standards and guideline levels. Therefore the operation of the 1MWe engine or flare at maximum loads will not significantly increase the impact on the environment above that assessed for the proposed activity.

Aerial concentrations at all the identified ecological receptors are below the relevant guideline values at the closest point on each of the receptors; the average over the whole site will be much lower than that predicted. Therefore the potential impact of the proposed operation is negligible.

The deposition of nitrogen predicted at the Dee Estuary Ramsar/SPA/SAC site is below the minimum critical load for the SPAs even when the existing background deposition is included; therefore there is unlikely to be a negative impact on the habitat.

For the Buckley Clay Pits and Commons SSSI (Deeside and Buckley Newt Sites SAC), the existing background deposition is already significantly higher than the assumed critical load for these sites. The site is designated primarily for its large breeding population of great crested newt. The designation does not raise air pollution or deposition as an issue. Consequently, it is unlikely that predicted emissions from the installation will have detrimental impacts, particularly given the very small predicted process contribution relative to background concentrations. This assessment has incorporated a number of worst-case assumptions for buildings, metrological data, emissions and operating hours, which will result in an over-estimation of the predicted ground level concentrations from the process. Therefore, the actual predicted ground level concentrations would be expected to be lower than this and, in some cases, significantly lower.

Maximum 98th percentile odour concentrations arising at the sensitive receptors are predicted to be at risk of exceeding the 3 ou_E m^{-3} indicative odour threshold at two locations – the Scania trucks facility and Alltami House. In addition, concentrations at The Box and Pinfold Cottages are forecast to be just below the criterion.

Appendix A
ADMS Model Files on CD