Report No: WR4446/GRA
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LANDFILL GAS RISK ASSESSMENT

for

PEN-Y-BONT LANDFILL, PENTRE CHIRK, WREXHAM

Prepared for
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Project Quality Assurance
Information Sheet

Landfill Gas Risk Assessment
Pen-Y-Bont Landfill Site

WRG WASTE SERVICES LIMITED

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Report Date	:	November 2004			
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1.0 INTRODUCTION

1.1 Report Context

1.1.1 This Report identifies the risk associated with landfill gas (LFG) that will be generated during the final stages of the installation life cycle at Pen-Y-Bont Landfill. Waste disposal commenced at the Installation in 1997. The Installation consists of 3 engineered disposal cells, all of which are fully contained. Landfilling is currently taking place in Cell 3.

1.1.2 Through appropriate design and development of the LFG collection infrastructure, LFG from the landfill is collected and utilised in two 1.15MW Caterpillar G3516LE gas engines to recover the thermal content of the LFG and generate electricity. The procedures for managing the gas will be detailed in the Installation's Landfill Gas Management Plan and will be accompanied by appropriate monitoring to demonstrate that migration and generation of fugitive emissions have been minimised.

1.1.3 The Report establishes the profile and nature of LFG generated, potential pathways for LFG release and nearby sensitive receptors. The means of control and monitoring that will be in place to minimise risks are then identified. The Report extends the source-pathway-receptor evaluation identified in the Conceptual Site Model that accompanies the PPC Permit Application.

1.2 Conceptual Landfill Gas Site Model (Hazard Identification and Risk Screening)

1.2.1 Landfill Gas Generation

LFG is generated through a series of complex reactions within the landfill including aerobic hydrolysis, hydrolysis and fermentation, acetogenesis and methanogenesis. Due to the complex number of reactions in the breakdown of biodegradable waste, gas generated in the landfill will contain a variety of components, many of which are odorous in nature.

LFG comprises mainly methane (CH_4) and carbon dioxide (CO_2) with the relative proportions depending on the nature of material deposited, stage of decomposition and the level of oxidation that occurs in the upper levels of the landfill. Other minor components include hydrogen along with a mixture of 100 or more components. The odorous nature of landfill gas is attributable to some of these minor components, including sulphur-containing compounds that have very low odour thresholds. Minimising the release of LFG reduces the emissions of these odorous components.

1.2.2 Nature of Waste Deposited

Detailed composition data of wastes received at the Installation to date has been used in this assessment. The Installation is currently permitted to receive the following types of non-hazardous waste:

- household
- commercial and industrial
- inert

A waste breakdown for the year 2003 is summarised below:

Table GRA1 : Waste Breakdown (2003)

Waste Type	2003 (%)
Domestic	42
Commercial	52
Inert	6

Waste inputs have varied over the lifetime of the site, however it is believed that the average input into the Installation has been approximately 200,000 tonnes per year, however input is expected to drop to approximately 100,000 tonnes per year for future years. The Installation is currently permitted to accept up to 249,999 tonnes per annum.

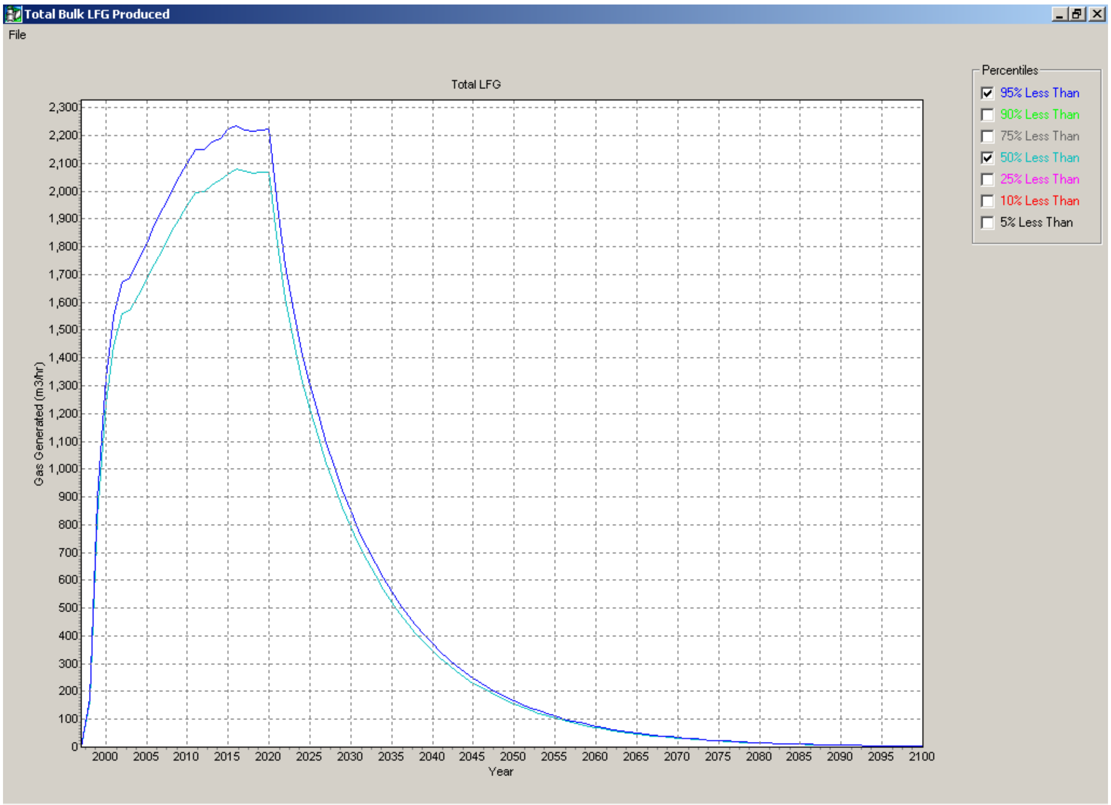
The LFG risk assessment has been prepared based on these anticipated proportions of wastes for each year of the Installation's lifetime.

1.2.3 Quantities of LFG Predicted to be Generated

LFG generation rates have been predicted using the GasSim model (v1.51). The model is included in Appendix GRA1 in electronic format and in Appendix GRA2 in hardcopy. The model predicts the highest LFG generation rate will occur in the year 2016 with the peak gas generation rates of bulk LFG being approximately 2,230 m^3/hr (presented as the 95%ile value). A methane content of 60% within the LFG at the point of production within the landfill has been included in this risk assessment.

The variation in generation rates of LFG over the lifetime of the Installation is graphically illustrated in Figure 1:

Figure GRA1 : LFG Generation over the Lifetime of the Installation



Max Value = *ca* 2,230 m^3/hr (2016)

The Landfill Regulations require LFG from all landfills receiving biodegradable waste to be collected, treated and where possible utilised. The quantity of LFG is above the Environment Agency's initial screening benchmark of 50 to 100 m^3/hr [1] whereby flaring or utilisation should be considered and above the Agency's benchmark of 600 m^3/hr when LFG utilisation is likely to be required.

Two 1.15MW Caterpillar engines are currently in operation at the Installation, with gas utilisation currently running at approximately 60% of capacity. The Installation currently has two flares including a free-standing flare of 1,500 m^3/hr capacity and a 2,500 m^3/hr flare associated with the gas utilisation compound. The site flare provides thermal treatment for any excess LFG not utilised by the gas engines and is a contingency measure in the event of failure of a gas engine or maintenance being required. Equipment redundancy (standby capacity) is therefore provided between the gas engines and flares to combust or utilise all LFG collected from the Installation in the event of equipment maintenance or malfunction. This is in addition to call out contracts with maintenance engineers in the event of equipment failure.

This gas risk assessment demonstrates that exhaust stacks used to disperse combustion products are of sufficient height to effectively disperse releases and ensure any emissions are not prejudicial to health. The design of the scheme ensures that emissions do not lead to an exceedance of Air Quality

[1] Guidance on the Management of Landfill Gas, Environment Agency, September 2004, LFTGN03.

Strategy objectives (Air Quality Strategy 2000 and associated Addendum, DEFRA, Feb 2003).

The LFG risk assessment for the Installation will include the following considerations:

- full containment is provided by a 1m engineered clay basal and side liner. In addition, basal and sidewall HDPE liner is also provided as described in the ESID Report;

- all areas will have an impervious geomembrane or engineered mineral cap to minimise water ingress and passive venting of LFG;

- an active collection system has been progressively installed into each cell in turn to prevent LFG build up, minimise fugitive emissions and remove LFG for subsequent treatment; and

- a gas flaring/utilisation scheme is present, which will convert LFG and its components into principally carbon dioxide and water. Flaring and gas utilisation will minimise the release of compounds with high global warming or ozone depleting potentials, reduce possible health effects and destroy odorous elements within the LFG.

The LFG risk assessment has focussed on (i) LFG, its constituent compounds and their emission, and (ii) the flaring and utilisation of LFG and associated emissions.

1.2.4 Containment System

The Environmental Setting and Installation Design (ESID) Report identifies the landfill design and operating principles. Capping is undertaken within operational constraints to minimise the period of passive venting without a cap being in place. The design of the landfill is summarised below in Table GRA2 and contains parameters for input into the GasSim model.

Table GRA2 : Landfill Characteristics

Characteristic	Material	Thickness (m)	Hydraulic Permeability (m s^{-1})
Lining	Engineered mineral liner	UNIFORM(1.0, 1.3)	LOGTRIANGULAR(1.00E-10, 5.00E-10, 1.00E-9)
	HDPE	UNIFORM(1.80E-3, 2.2E-3)	LOGTRIANGULAR(1.00E-12, 5.00E-12, 1.00E-11)
Cap	VLDPE/LLDPE	UNIFORM(9.00E-4, 1.1E-3)	LOGTRIANGULAR(1.00E-12, 5.00E-12, 1.00E-11)

The capping layers meet the low permeability requirements to minimise the ingress of surface water and the uncontrolled release of LFG. Measures are in place to maximise the collection efficiency of LFG.

1.2.5 Collection System

LFG is collected by a series of gas extraction wells distributed across the body of waste. Gas wells in existing waste deposition areas are distributed at a spacing of approximately 25-30 metres. A spacing of 30m to 40m is anticipated for future cells. Closer spaced wells can be installed if required in areas close to residential locations and buildings. Each well exerts a negative pressure to remove LFG. The wells will thereby provide effective LFG collection from the body of waste and are a critical part of the strategy to prevent gas accumulation and migration.

The extraction wells comprise HDPE pipe surrounded by a non-calcareous gravel annulus to reduce the restriction of flow into the pipe. A plain section of the pipe extends from the gas well down into the waste and is sealed by a bentonite plug. The pipe is thereafter slotted to extract LFG. Each pipe is installed to a depth of typically a few metres above the basal liner to ensure leachate and gas phases are kept separate, and to prevent accidental breach of basal lining systems. The design of the extraction wells is illustrated in the Installation's Gas Management Plan.

Horizontal extraction systems are built into the waste mass at regular intervals, to assist in odour control and gas extraction as landfilling proceeds. A network of pin wells is present, again to assist in localised extraction and odour control; these features are described in the ESID report.

Wellheads consist of medium density polyethylene pipe that is inserted into the borehole and surrounded by a bentonite plug. The pipe is then connected to the gas collection pipe by flexible hosing and sealed in place. The wellheads and pipework are currently above ground to aid visual inspection and maintenance.

The collection pipes feed into a gas ring main via a manifold chamber. Each pipe is fitted with an isolation valve to allow the isolation of each individual gas well and collection line and to aid balancing of the gas extraction system. Gas sampling points are installed for each line. The design aims to ensure a gradient between the gas main and manifold to allow condensate removal.

The gas wells will maintain the body of waste under negative pressure to prevent migration of LFG and fugitive emissions.

1.2.6 Treatment and Utilisation System

Collected gas is extracted to the gas engines for utilisation or the back-up flare, which will have the capacity to fully treat the anticipated rate of LFG generation. The current utilisation scheme comprises two gas engines with an output of up to 2.3MW and will be progressively expanded, if necessary, to meet LFG generation rates. At full load, an electrical generation efficiency approaching 40% of the energy content of fuel is expected.

The flare and gas engines will meet required emission performance standards and the impact assessment described later in this gas risk assessment will demonstrate that emissions will not significantly impact on the environment or human health. Pre-treatment of LFG prior to combustion is not considered necessary other than particulate filtration for the gas engines to protect the equipment.

All plant and equipment employed in the utilisation of LFG is maintained by WRG in accordance with the manufacturer's specification.

All construction and operation activities associated with the utilisation plant is carried out in strict accordance with WRG's Health and Safety Policy and Management System including the preparation of safe working method statements and risk assessments.

The engine management systems for the gas engines installed at Pen-y-Bont include continuous input monitoring for gas quality and volume together with engine diagnostics and emissions parameters. The above system is linked via telemetry to WRG's in-house call out centre and WRG engineers are supported by Caterpillar for non-routine maintenance and repairs.

1.2.7 Pathways of Exposure

LFG can theoretically be released to air by several pathways including:

- Passive release prior to the installation of the cap and extraction of LFG under negative pressure;
- Horizontal migration from the cell (sub-surface migration through the ground or along pipelines or service channels);
- Diffusion through the cap;
- Releases from cracks or fissures in the cap and junction between cap and lateral walls;
- Wells and sumps engineered into the landfill for monitoring or gas extraction if left open for any reason;
- Releases from leaks and in the event of extraction failure; and
- Intrusive investigation or excavation.

Potential exposure can theoretically occur subsequent to LFG migration if compounds associated with LFG are taken up by vegetation.

1.2.8 Receptors

Several residential properties are located between 90m and 370m, to the west, south-west and south of the Installtion. These properties include Pen-y-Bont Farm, Hayside and Waterside, Llwyn Afon and Pen-y-Bont cottages , Pen-Y-Bont and Ty-Maen. A number of environmentally sensitive sites are located nearby. These sites include the River Dee, which borders the Installation to the north, east and south. The River is designated a Site of Special Scientific Interest (SSSI) and candidate Special Area of Conservation (cSAC). Within 2 km of the Installation are the Nant y Belan and Prynela Wood SSSIs. Further afield are the Berwyn and South Clywd Mountains and Johnstown Newt Sites (all cSACs). Sensitive locations that have been included as part of the gas risk assessment (including dispersion modelling) are summarised below in Table GRA3.

Table GRA3 : Sensitive locations

Receptor	Receptor Type	Representative Grid Location		Distance and Direction from the Gas Utilisation Plant	Distance from Edge of Nearest Operational Area
		Easting	Northing		
Hayside Barn, Wateride Barn & Pen-y-Bont Farm	Residential	328905	341805	475m 291°	110m
Pen-Y-Bont Cottages & Adjacent Properties	Residential	328850	341800	287m 232°	90m
Ty-Maen	Residential	329100	341200	527m 206°	369m
River Dee Catchment	SSSI, cSAC	329450	341950	197m 100°	60m

(Receptors are shown on Drawing No. ESID13A)

Table GRA3 and Drawing ESID13A show Pen-y-Bont cottages, Pen-y-Bont Farm, Hayside Barn and Wateride Barn to be the closest residential properties to the Installation. These sensitive locations are located upwind of the prevailing wind direction and any emissions from the Installation will therefore be dispersed away from, rather than towards these locations for the majority of time.

Background Air Quality

Local authorities have a statutory responsibility to assess certain pollutants against ambient air quality standards identified in the UK's Air Quality Strategy. Where the potential for exceedance of any of these standards is identified, the local authority must declare an Air Quality Management Area (AQMA) and identify policies and actions to reduce pollutant concentrations to within the air quality standards.

The Installation is not within an AQMA. Concentrations of pollutants covered by the Air Quality Strategy are therefore within ambient air quality standards and background air quality is good within the locality of the Installation. The pollutants measured or predicted as part of the local authority assessment process of relevance to potential emissions included in LFG include benzene, carbon monoxide and 1,3 butadiene. Combustion emissions from any flare or gas engine stack may additionally include emissions of oxides of nitrogen (including nitrogen dioxide) and sulphur dioxide. Carbon monoxide is both produced within the landfill as well as being a combustion product.

The LFG from the Installation is not considered a significant source of fine particulate matter with the potential to penetrate deep into the lungs (PM_{10}). A review of background air quality shows that PM_{10} levels are well within air quality limits. Provided suitable dust management plans are followed including the use of suppression and containment techniques, emissions of PM_{10} are not considered to be significant. Whilst being a source of PM_{10}, the flares and gas engines produce relatively low concentrations of particulate due to the gaseous nature of the fuel (LFG) and which is then rapidly dispersed to levels below the Air Quality Strategy objective. Flare and gas engines are subsequently rarely regulated for releases of particulate.

Background concentrations for the pollutants of relevance have been taken from pollution maps prepared for the UK. The maps are based on a 1km by 1km grid and identify the background concentration of pollutants for relevant assessment years. The maps are derived from monitoring and modelling predictions. They include arterial road networks and background sources but exclude local roads and industrial sources to allow site-specific assessments. The concentrations corresponding to the grid reference for the Pen-Y-Bont Landfill Site (taken as NGR 329500,341500) are identified below in Table GRA4.

Table GRA4 : Background Concentrations and Air Quality Standards for Relevant UK Air Quality Strategy Pollutants and Acid Halides (2004)

Pollutant	Background Concentration ($\mu g/m^3$ as an annual average)	Applied Air Quality Standard or Guideline	% of air quality standard
1,3 Butadiene	0.07	2.25 g/m^3 as a running annual mean to be achieved by 31 Dec 2003	3.1%
Benzene	0.22	5$\mu g/m^3$ as an annual mean to be achieved by 31 Dec 2010	4.4%
Carbon monoxide	170	10,000$\mu g/m^3$ as a maximum daily 8-hour running mean to be achieved by 31 Dec 2003	1.7%
Oxides of nitrogen (NOx)	21.3	30 $\mu g/m^3$ as an annual average (NO and NO_2) for the protection of ecosystems	Not fully applicable within 5km of installation – nearest SSSIs includes River Dee and the Nant-Y-Belan and Prynela Woods. 71%
Nitrogen dioxide	15.8	40 $\mu g/m^3$ as an annual average	39.5%
Sulphur dioxide	2.7	20 $\mu g/m^3$ as an annual average for the protection of ecosystems 30 $\mu g/m^3$ as an annual average for the protection of health	Not fully applicable within 5km of installation 13.5% 9%
Hydrogen fluoride	Not measured or predicted. No other significant sources close to the installation and background assumed to be near zero.	TA Luft Standard (3 $\mu g/m^3$ as a 98th percentile of hourly values WHO – 0.3$\mu g/m^3$ as a long term average	Assumed to be 0%
Hydrogen chloride	Not measured or predicted. No other significant sources close to the installation and background assumed to be near zero.	TA Luft Standard (100 $\mu g/m^3$ as a 98th percentile of hourly values	Assumed to be 0%

Source: Pollution maps available at www.airquality.co.uk/archive/laqm/tools

All concentrations are concentrations for 2004. Where modelling data for 2004 is not available, approved year adjustment factors identified in LAQM Technical Guidance have been used except for SO_2 (based for 2001 data).

Ambient air quality standards and objectives identified in the Air Quality Limit Value Regulations 2001. Additional standards for sulphur dioxide exist. These include a 15-minute standard of 266 $\mu g/m^3$ (as a 99.9%ile), 1-hour standard of 350 $\mu g/m^3$ (as a 99.73%ile) and a 24-hour standard of 125 $\mu g/m^3$ (as a 99.18%ile).

The ambient air quality standard for carbon monoxide is expressed as an eight-hour running mean (10,000 $\mu g/m^3$). Whilst concentrations of CO are presented in the Table as an annual mean, the low concentration for the annual mean means it is highly unlikely the eight-hour standard will be exceeded. Guidance to local authorities identified in Technical Guidance TG3, identifies it can be assumed that where the annual average concentration is less than 2,000 $\mu g/m^3$, the 8-hour objective will not be exceeded. Background concentrations of CO are an order of magnitude less than this. All other predicted concentrations are also well within applied ambient air quality standards and objectives.

Other Air Quality Strategy standards are present for nitrogen dioxide and sulphur dioxide over different periods of potential exposure. The most relevant standards have been presented in this risk assessment to illustrate background air quality conditions.

The background concentrations of other components potentially present in LFG have initially been assumed to be zero in subsequent risk evaluations to establish their significance in comparison with derived environmental assessment levels (EAL).

The year 2004 has been used to illustrate current air quality conditions. It is anticipated that future air quality will continue to improve in line with national trends and hence better air quality is anticipated in the year of the highest LFG generation (2016). Incorporating 2004 background data in the assessment to cover operations for years 2005 and onwards is a conservative approach that will lead to the over prediction of pollutant concentrations in ambient air quality when site contributions are taken into account.

1.2.9 Outline Source – Pathway – Receptor Evaluation

A source-pathway-receptor evaluation for all phases of the landfill lifecycle is given in Table GRA5.

The use of an impervious cap, engineered linings and a comprehensive gas collection and extraction system will ensure a slight negative pressure is maintained within the landfill cell thereby reducing migration risk. Maintaining a negative pressure will reduce the potential for LFG to dissolve in leachate, which can then dissociate outside the cell when leachate is removed.

Boundary monitoring wells/boreholes are used to monitor and evaluate any potential LFG migration during the operational, capped and post-restoration phases. A total of 17 gas boreholes and 13 gas and water monitoring wells are currently positioned around the landfill boundary and their locations are identified on Drawing No. ESID8. Elevated concentrations of carbon dioxide have been identified previously within some of these wells with readings greater than 1.5% for carbon dioxide being measured on occasion during

2004 (mainly from gas wells G7 to G15 and water monitoring wells T4 to T11). Methane however has not been detected during this monitoring and it is therefore unlikely that the CO_2 is solely derived from landfill gas; alluvial deposits could contribute to these observations of carbon dioxide.

All measures to control LFG will minimise global warming contributions (principally from methane), odour, and other effects associated with trace gas components. The management of LFG will be described in the Gas Management Plan. Predictions of lateral (horizontal) migration have been considered later in this risk assessment.

Table GRA5 : Source- Pathway – Receptor Evaluation for Landfill Gas Releases from Pen-Y-Bont Landfill (Normal Operation)

Source	Pathway	Receptor	Potential Issues	Sensitivity of Receiving Environment to Pathway and its potential Significance	Environmental Assessment Level or design benchmark	Design Considerations
Bulk gases within LFG	Passive release to air from deposited waste prior to capping Passive release through capping layer Leaks in gas collection system	Nearby housing and sensitive locations	Risk of explosion or asphyxiation if accumulates	Low	1% methane content and 1.5% carbon dioxide content at location. (represent 20% of lower explosive limit and occupational exposure limit respectively) Also see trace gas considerations.	LFG extraction system will assist in managing horizontal migration and accumulation of LFG within waste body. Gas wells and extraction system have been progressively introduced as waste is deposited. The body of waste is then maintained under negative pressure where possible to minimise release. Engineered cap installed on all areas following waste deposition. Liners will have very low permeability and high durability to minimise passive releases of LFG to air and ensure high collection efficiency. Collected LFG is utilised with flare back up, thereby converting methane and other components with high global warming potential to carbon dioxide (with lower global warming potential). As the gas collection system is maintained under negative pressure, losses from the extraction system are not considered a significant pathway.
		Global Ecosystem	Climate change - Global warming releases of methane (GWP of 21) and carbon dioxide (GWP of 1)	Moderate	Minimise release through application of best practice. Maximise collection of LFG for flaring/utilisation.	

Source	Pathway	Receptor	Potential Issues	Sensitivity of Receiving Environment to Pathway/ Significance	Environmental Assessment Level	Design Considerations
Bulk gases within LFG	Horizontal migration and sub-surface emissions through ground or pipelines/ or service channels.	Local flora and fauna	Eco-toxicity by oxygen displacement around roots. Release to air from soils Potential movement of LFG along gas and leachate pipes in event of extraction system failure.	Moderate	Methane and carbon dioxide concentration of 5.3% (20% of threshold where vegetative stress likely)	All cells have engineered clay liner. Solid geology below comprises Ruabon Marl. Elevated levels (above trigger thresholds) previously identified from horizontal migration for CO_2 only. No methane however detected during 2004 monitoring to date (See ESID Table 5). Nearest housing or sensitive building is located 90 m from nearest operational area. Extensive gas extraction and collection system is present to maintain slight negative pressure within landfill. Higher localised suction on gas wells can be applied near potential source of migration if required. Leachate management is present. 17 gas monitoring wells and 13 gas and water (aquifer) monitoring wells currently installed to detect any migration. Gas detection systems installed into onsite buildings. Man made sub-surface coverings, pipes and distribution cables present, but do not penetrate the lining systems.
		Buildings and Sub-surface voids/ compartments	Gas accumulation and explosive risk	High	1% methane content and 1.5% carbon dioxide content in boundary monitoring wells. (represent 20% of lower explosive limit and occupational exposure limit respectively)	

Source	Pathway	Receptor	Potential Issues	Sensitivity of Receiving Environment to Pathway/ Significance	Environmental Assessment Level	Design Considerations
	Leaks from Open Wells and Sumps	Dwellings and occupied buildings Global ecosystem	Gas accumulation and explosive risk Releases of emissions with global warming potential	Low	1% methane content and 1.5% carbon dioxide content at dwelling (represent 20% of lower explosive limit and occupational exposure limit respectively) Maximise collection efficiency. Also see trace gas considerations.	Gas monitoring wells sealed when not in use. Potential for monitoring wells and sumps to be connected to gas extraction system.

Source	**Pathway**	**Receptor**	**Potential Issues**	**Sensitivity of Receiving Environment to Pathway / Significance**	**Environmental Assessment Level**	**Design Considerations**
Bulk gases in LFG	Intrusive investigation	Dwellings and occupied buildings Global ecosystem	Gas accumulation and explosive risk Releases of emissions with global warming potential and photochemical ozone creation potential (POCP) / ozone depletion potential (ODP)	Low	Infrequent event, none applied other than for methane and carbon dioxide as identified above	Infrequent event. Minimise duration and restore cap or cover as required.
Trace gases in LFG	All of the above	Dwelling, occupied buildings and areas of public amenity Local air quality, global climate/ecosystem	Odour detection and nuisance Health effects of certain trace components Releases of gases with global warming potential and ozone creating potential (tropospheric ozone) and ozone depleting potential (stratospheric ozone)	Low to Moderate	EAL for specific components identified in Table 5. Prevention of odour annoyance Maximising LFG collection efficiency for flaring/utilisation will assist in minimising release of associated components with such effects.	LFG collection and utilisation and progressive capping will minimise release of odour. Potential odour contribution if LFG accumulates following horizontal migration. Nearest residential property approximately 90 metres upwind from installation.

Source	Pathway	Receptor	Potential Issues	Sensitivity of Receiving Environment to Pathway / Significance	Environmental Assessment Level	Design Considerations
Combustion Gas Releases	Flares and utilisation plant	Local air quality, global climate/ecosystem	Health effects associated with combustion gases and impact on sensitive ecosystems. Releases with GWP	Moderate to High	See Sections 1.2.11 and 1.2.12	Appropriate selection of plant location, application of BAT to minimise emissions and suitable stack height to promote dispersion.

1.2.10 Lateral (Horizontal) Migration

The GasSim model (v1.51) has been used to assess potential horizontal migration impacts. Potential horizontal migration is currently monitored by means of 17 gas monitoring wells and 13 gas and water monitoring wells at the cell perimeters. Levels have been identified to exceed threshold level for CO_2 only during 2004 (see Table GRA5). No methane has been detected in the sampling surveys carried out during 2004 to date.

The variation in carbon doxide, hydrogen sulphide and benzene concentration with distance has been predicted and illustrated below in Figures GRA2 to GRA6. The impact on vegetational stress has also been assessed. Hydrogen sulphide can cause odour detection at very low levels and cause respiratory difficulties at higher levels. Benzene has been selected due to its potential impact on human health. It should be noted that the modelling identifies the sub-surface concentration. Actual concentrations of exposure to human inhabitants will be lower in unrestricted locations as any accumulation will disperse in the atmosphere to lower concentrations. The modelling has been carried out for the year 2016 when potential lateral migration is predicted to be highest for the installation.

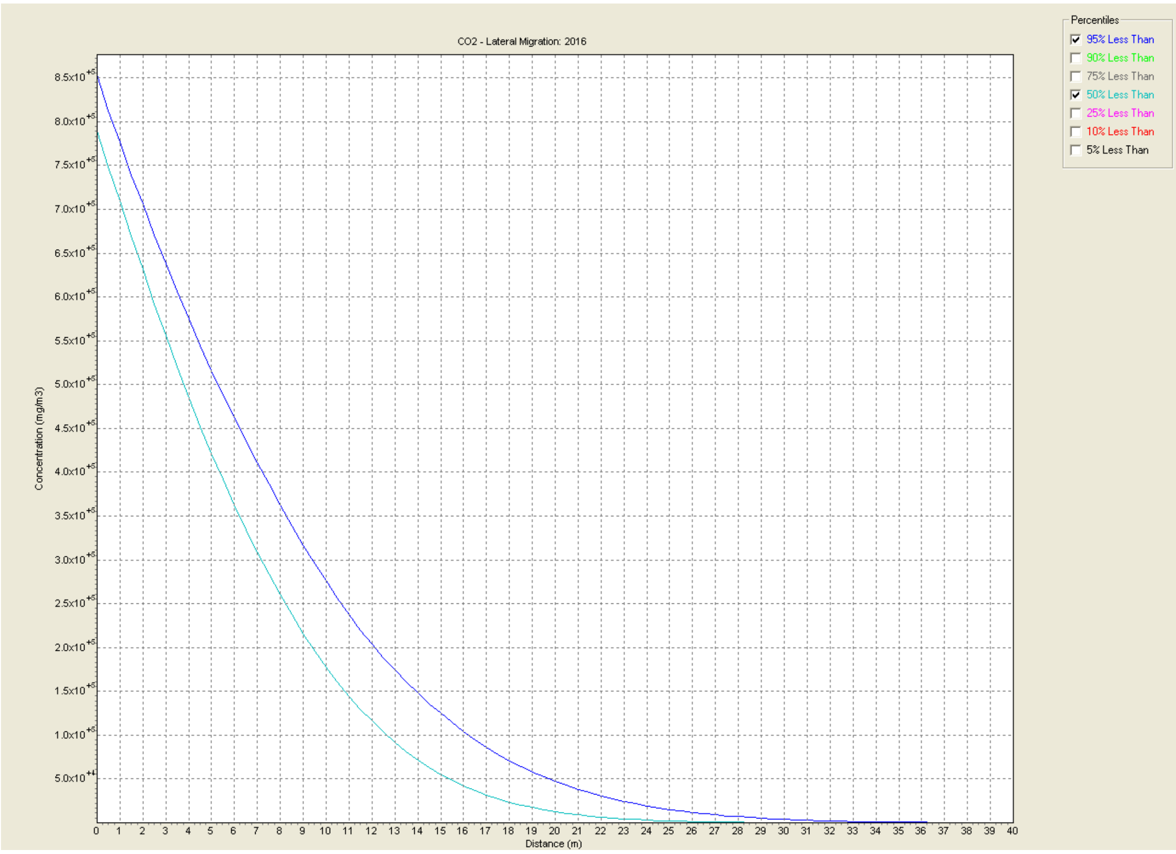


Figure GRA2 : Lateral Migration of Carbon Dioxide (CO_2)

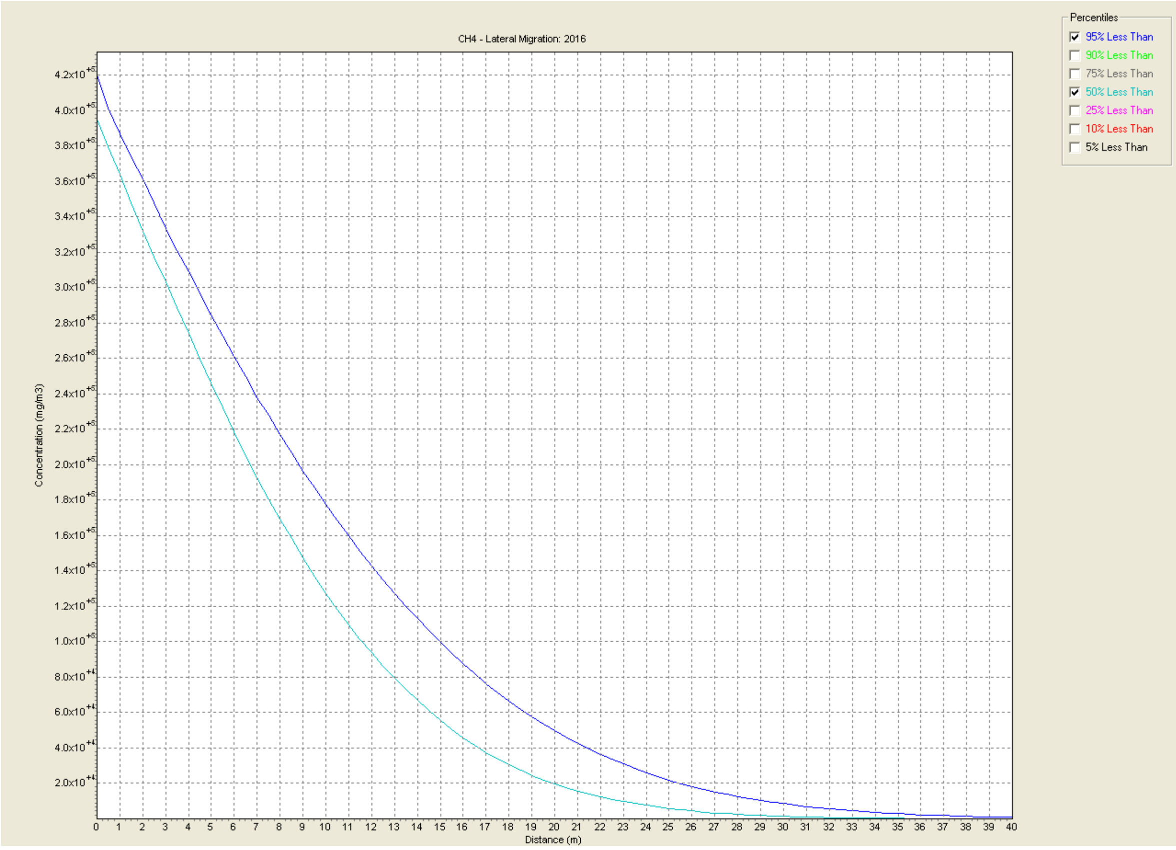


Figure GRA3 : Lateral Migration of Methane (CH_4)

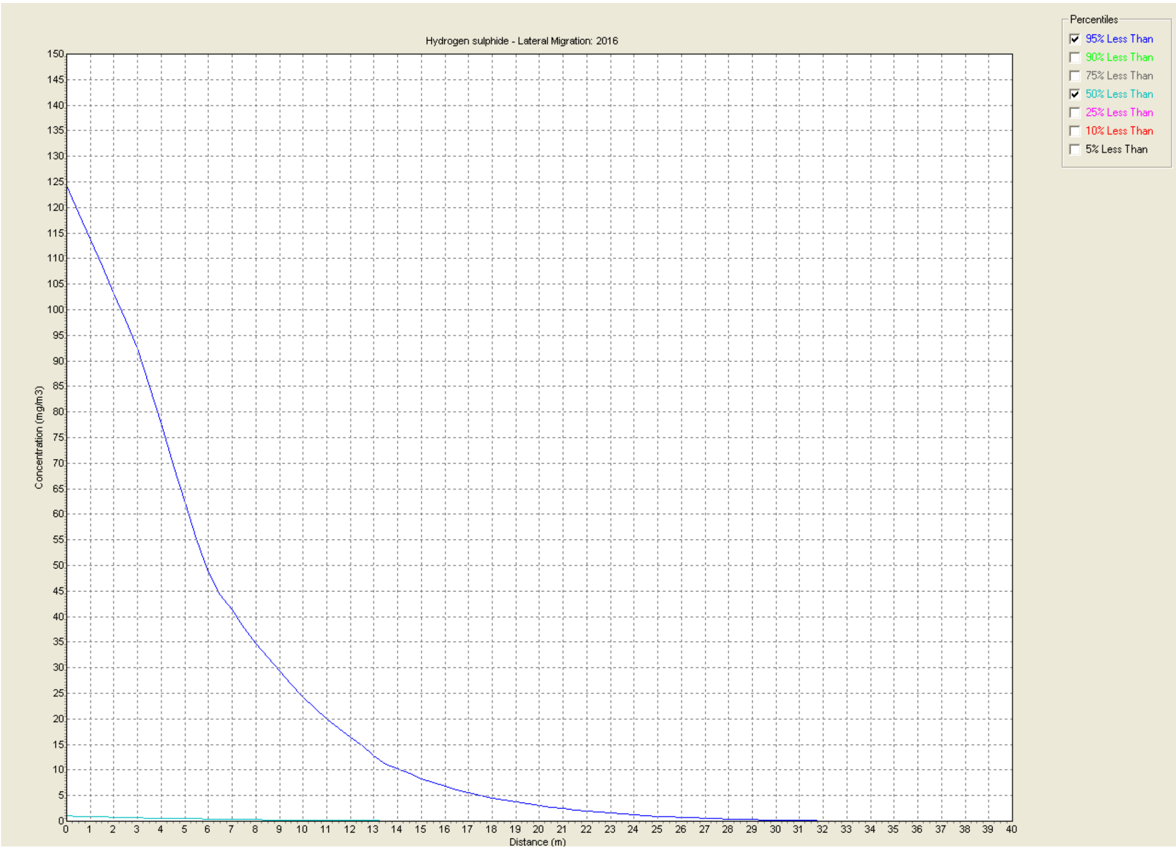


Figure GRA4 : Lateral Migration of Hydrogen Sulphide (H_2S)

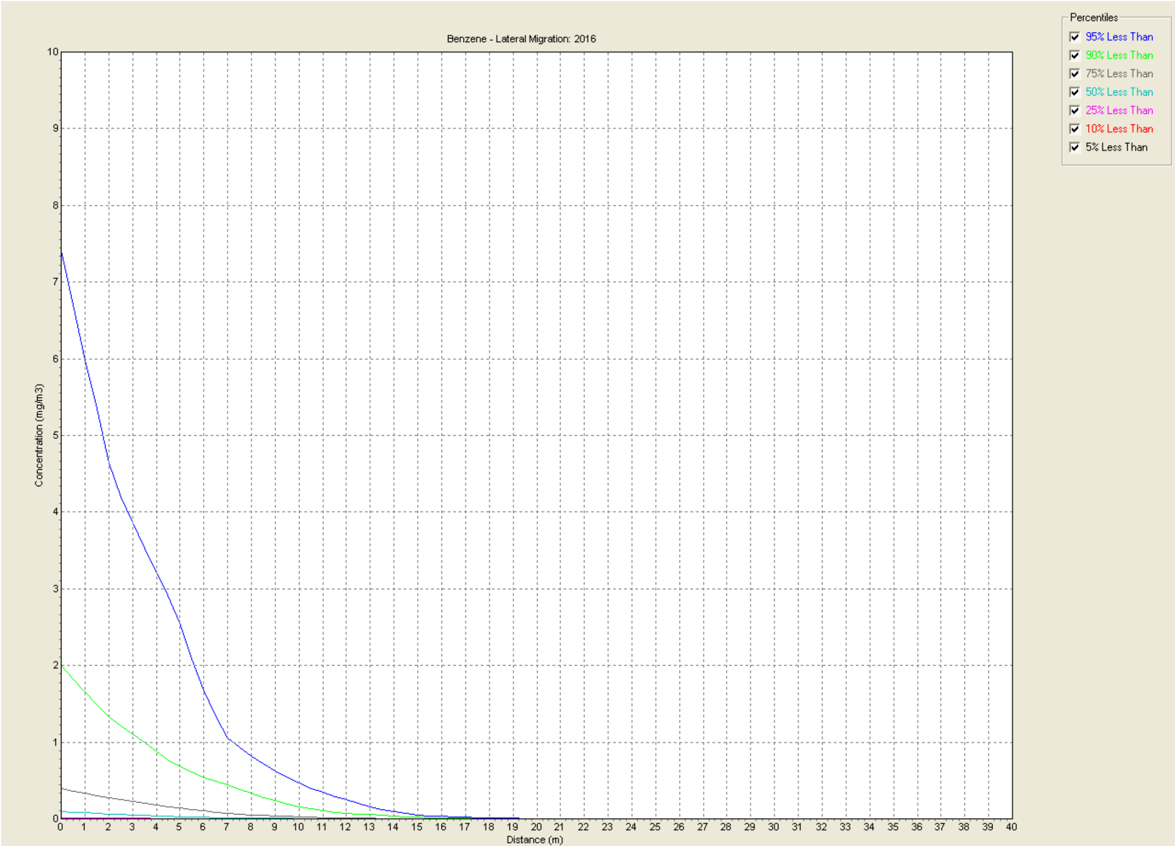


Figure GRA5 : Lateral Migration of Benzene (C_6H_6)

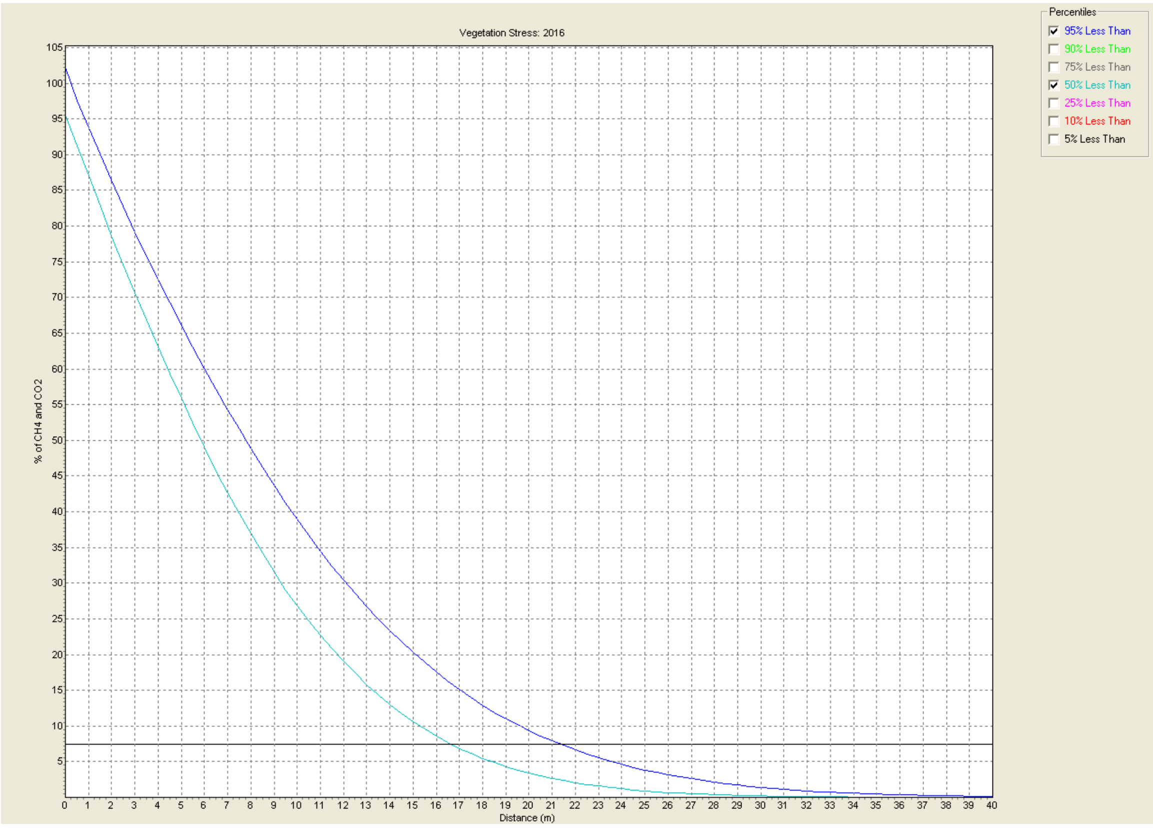


Figure GRA6 : Lateral Migration of CH_4 and CO_2 that can Cause Vegetational Stress

The modelling results demonstrate that concentrations of bulk gas parameters within LFG, that can give rise to the risk of explosion or vegetation stress, will fall rapidly to levels well below threshold levels identified in Table GRA5 within 30 metres of the sidewall. No significant risk due to gas migration is predicted to occur at the nearest sensitive location including Pen-Y-Bont cottages despite this being located in relatively close proximity to the Installation. The same conclusions apply to parameters that can contribute to potential health effects. Whilst hydrogen sulphide can contribute to odour at part per billion levels, any release to air from lateral migration will rapidly disperse in the atmosphere. Monitoring at the boundary monitoring wells will continue to monitor any potential lateral migration.

1.2.11 Environmental Assessment Levels for Carbon Monoxide and Trace Components

The GasSim model has additionally been used to identify projected release rates of carbon monoxide and trace components in LFG. Values are described for the year 2016 when gas generation is highest. The model output files detailing the assumptions used in the model are included in Appendix GRA1. LFG will be combusted in the utilisation scheme to destroy trace components, with a removal efficiency of 98% to 99% expected using systems complying with best available technique. An assessment of combustion products from flares and gas engines is described over the following sections.

Environmental Assessment Levels (EAL) for trace components are provided in Table GRA6 and derive from sources identified in Technical Guidance including Air Quality Strategy objectives, internationally recognised standards, occupational exposure limits divided by an appropriate safety factor, or odour thresholds.

Table GRA6: EALs for CO and Trace Components Released through Combustion & Surface Emissions (worst case)

Component	Annual Mass Emission, year 2016 (grams per year unless otherwise stated)	Short term (1-hour) EAL ($\mu g/m^3$)	Long term (annual average) EAL ($\mu g/m^3$)
Carbon monoxide	127 tonnes	10,000	350
Acetaldehyde	2,000	9,200	370
Benzene	440	208	5
Benzo alpha pyrene	35.70	Not available	0.00025
Chlorobenzene	837	70,200	2,340
Butadiene	1,870	1,320	2.25
Tetrachloromethane	433	3,900	130
Trichloromethane	450	2,970	99
Dimethyl disulphide	145	150* (7)**	140* (7**)
1,4 dichlorobenzene	188	30,600	1,530
Ethyl toluene	60.1	Not available	Not available
Ethylene dichloride	655	Not available	Not available
Formaldehyde	2,050	100	5
Chloromethane	503	21,000	1,050
1,1,1 trichloroethane	16.3	222,000	11,100
Dichloromethane	306	3,000	700
PCDD’s/PCDFs	0.01	Not available	Not available
Tetrachloroethane	379	Not available	Not available
Tetrachloroethene	518	8,000	3,450
Toluene	2,380	8,000	1,910
Trichlorobenzene	48	2,280	76
Trichloroethylene	4,270	1,000	1,100
Trimethylbenzene	246	37,500	1,250
Vinyl chloride	676	504	17
Xylene (all isomers)	296	66,200	4,410

Note : excludes saturated and unsaturated straight chain hydrocarbons due to their relatively low toxicity and low potential for odour.

*based on EALs identified in Guidance on Management of Landfill Gas, EA, Draft for Consultation, Nov 2002. EAL for sulphide / mercaptan components based on hydrogen sulphide as a worst-case assumption.

** based on the 30 minute World Health Organisation standard for hydrogen sulphide to prevent significant odour nuisance (AIR Quality Guidelines for Europe, WHO 2000)

1.2.12 Worst Case Emission Component Associated with Surface Releases

The components with the highest mass release rate compared to either the short or long term EAL are carbon monoxide, benzene, benzo alpha pryene, butadiene and formaldehyde. All other components identified in Table GRA6 will disperse to lower concentrations beyond the Installation boundary relative to their respective EALs. In the case of carbon monoxide which can be produced within the landfill as well as in the gas engines and flares, a worst case approach was adopted of assuming combustion sources emit carbon monoxide at the applicable emission limit, while additionally the total quantity of carbon monoxide predicted to be generated by the GasSim Model (incorporating such combustion sources) has also been assumed to be emitted via surface emissions.

1.2.13 Dispersion Modelling and Impact Assessment of Releases from the installation from Flares and Gas Engines

Ground level concentrations of combustion products from the flare and gas engines currently installed have been assessed for the sensitive locations identified. The assessment was carried out by AEA Technology plc using the dispersion model ADMS 3 prior to the installation of the gas engines in 2002. The dispersion modelling investigated combustion emissions from the two gas engines running in combination with flaring of excess LFG, in addition to a flare only scenario. The modelling considered options whereby 2,500m^3/hr was treated or combusted using a mixture of flaring and/or gas engines. This is a greater volume of LFG than the highest LFG generation rate predicted (year 2016) and incorporated background air quality for the year of study. Predicted concentrations are presented in Table GRA7 for the nearest sensitive location where the highest ground level concentrations are predicted to occur. Lower concentrations are predicted for all other sensitive locations.

Meteorological data from Shawbury (north of Shrewsbury) was included in the ADMS modelling of combustion emissions from the gas engines and flares. Meteorological data from Hawarden (north of Wrexham) was utilised in the GasSim assessment. Emission concentrations of other parameters including for example, untreated emissions released from the landfill surface, have been modelled using GasSim from emission estimates generated by the model itself. The emission rates used in the AEA Technology assessment were based on manufacturer's data and are above emission concentrations currently considered to represent BAT and those predicted for the site. This is therefore a worst-case consideration provided monitoring confirms emissions are within the appropriate emission benchmarks identified by the Environment Agency (see Table GRA11). The AEA Technology Report is reproduced in Appendix GRA4.

The results of the impact assessment are summarised below for the sensitive dwelling where the highest ground level concentrations are predicted (Pen-y-Bont cottages). Lower concentrations are predicted to occur at all other sensitive locations.

Table GRA7: Highest Predicted Ground Level Concentrations at Identified Sensitive Receptors (and Comparison with Air Quality Standards for the Protection of Health)

Parameter	Averaging Period	Highest Predicted Concentration (Process Contribution, μg/m³)	Process Contribution as % EAL	Background Concentration (μg/m³)	Process Contribution and Background (PEC) as % of EAL
Formaldehyde	Annual average	0.00346	0.07%	Assumed to be zero	0.01%
Butadiene	Annual average	0.000809	0.036%	0.07	3.15%
Benzo-alpha-Pyrene	Annual average	0.000035	14%	Assumed to be zero	14%%
Sulphide (as Dimethyl Disulphide)	Annual average	0.000917	0.01%	Assumed to be zero	0.01%
Carbon monoxide	Annual average	105	n/a	170	n/a
Benzene	Annual average	0.000414	<0.01%	0.22	4.5%
Oxides of nitrogen	Annual average	1	n/a	21.3	n/a
Nitrogen dioxide *	Annual average	1	2.5%	15.8	42%
	1-hour average (99.79%ile)	38	19%	65	32.5%
Sulphur dioxide	Annual average	0.00612	0.03%	2.7	13.5%
	15-min average (99.9%ile)	95	36%	5.4	37.7%
Hydrogen fluoride	1-hour	2	67%	Assumed to be zero	67%
Hydrogen chloride	1-hour (100th%ile)	17	17%	Assumed to be zero	17%
PCDD/PCDF	Tolerable Daily Intake	n/a	<1.5%	Not measured	<1.5%

- *Assumes 100% of the oxides of nitrogen are in the form of nitrogen dioxide for annual average. 99.8th percentile of hourly values based on the addition of the process contribution (based on 100% conversion of NOx) to twice the annual average background concentration. Typically only 10% of nitrogen oxides will be in the form of nitrogen dioxide upon release from the flares and gas engines. The other remaining fraction, nitric oxide can be oxidised in the air following release through a complex series of reactions, primarily by ozone. The level of oxidation achieved will depend on the rate of reaction, concentration of oxidants and time taken for emissions to travel from source to sensitive location.
- Background concentrations for short period concentrations have been predicted where appropriate by multiplying the long term average by a factor of two in accordance with Environment Agency guidance (PPC Guidance Note H1, 2003). It is rare for peak short period contributions from different sources to coincide both temporally and spatially.
- Predicted concentrations for HF, CO, SO_2 and HCl apply to the worst case location at or beyond the site boundary. Lower concentrations will be predicted for sensitive locations where people can be exposed for a relevant duration.
- Where no EAL has been identified, this is due to the EAL used applying to the protection of vegetation and ecosystems only (see Table GRA8) and concentration is at levels that will not impact on human health.

Table GRA8: Predicted Ground Level Concentrations at Nearest Sensitive Ecosystem (River Dee SSSI)

Parameter	Highest Predicted Concentration (Process Contribution, μg/m³)	Averaging Period	Process Contribution as % of EAL	Background Concentration (μg/m³)	Process Contribution and Background as % of EAL
Oxides of nitrogen	3	Annual average	10%	21.3	81%
Sulphur dioxide	0.0329	Annual average	0.16%	2.7	14.3%
Hydrogen fluoride	0.0401	Annual average	13.4%	Assumed to be zero	13.4%

* Environmental assessment levels (EAL) applied in Table GRA8 relate to air quality standards designed for the protection of ecosystems.

Lower concentrations are predicted to occur at other sensitive ecosystems in the local area including the Nant-y-Belan and Prynela Wood SSSIs and the Berwyn and South Clywd Mountains and Johnstown Newt Sites (all upwind of the Installation). The geographical variation in predicted ground level concentrations for combustion related releases are illustrated in contour plots provided with the air dispersion modelling report (see Appendix GRA4).

No significant impact on public health and ecosystems is predicted as defined by the Environmental Assessment Levels used. Previous assessments of flare and gas engine emissions carried out at another landfill site (Hafod PPC Permit Application and subsequent additional assessments) as part of an appropriate assessment for determination against the Habitats Directive have also demonstrated that contributions to deposition rates of nitrogen and sulphur are typically not significant.

1.2.14 Mass Releases of Emissions with Global Warming Potential

Potential releases with global warming potential have been included in the GasSim model calculations. The majority of releases derive from the greenhouse gases carbon dioxide and methane. Releases with global warming potential are projected for the year with the highest LFG generation (2016).

Table GRA9: Emissions With Global Warming Potential from the Installation

Year of Highest LFG Generation (2016)	Emission as CO_2 Equivalent (tonnes)
Methane (CH_4)	47,000
Carbon dioxide (CO_2)	29,700
Total (tonnes as CO_2 equivalent)	76,700
Sum of all years	
Methane (CH_4)	1,670,000
Carbon dioxide (CO_2)	811,000
Total (tonnes as CO_2 equivalent)	2,481,000

Note : Other compounds with high global warming potential including CFC, HCFC's and HFC's are not considered significant based on GasSim modelling with contributions of a few percent. CFC and HCFC releases (as compound) are predicted to be 49.5kg and 37.2kg respectively for 2016. Releases of HFC's or PFC's are below the limit of prediction sensitivity.

Once capping has taken place, the gas collection and treatment system (by engines or flaring) will reduce emissions of methane to a minimum. A benchmark figure of 85% of generated methane being treated has been established in technical guidance once the waste deposition phase has been completed. The operator considers that the gas field collection efficiency is actually better than that used in the model, as (inter alia) there is progressive installation of horizontal collection wells into the working face/operational areas.

Methane has a global warming potential 21 times higher than carbon dioxide and there are therefore significant environmental benefits in converting methane present in LFG to carbon dioxide through combustion. Flaring and the use of gas engines has numerous other benefits including the removal of potentially toxic organic compounds and preventing the build up of potentially explosive concentrations of LFG in and beyond the Installation.

1.2.15 Emissions with Ozone Depletion Potential

Certain compounds, particularly those containing chlorine, fluorine and bromine elements can cause the depletion of ozone in the upper reaches of the atmosphere. GasSim has been used to predict the quantity of ozone depleting compounds emitted from the landfill site. During the lifecycle of the Installation, a peak release rate of 0.0166 tonnes per annum of trichlorofluoromethane equivalent is predicted to be emitted. This quantity is not considered to be significant.

1.2.16 Monitoring Considerations

Monitoring of LFG and Trace Components

Monitoring will be carried out to assess sub-surface (via potential lateral migration) and surface releases of LFG. The monitoring will confirm the effectiveness of the containment and collection strategy in place for LFG management. The monitoring will demonstrate the LFG gas treatment and utilisation scheme continues to meet emission performance standards.

22 perimeter monitoring wells are currently in place and their location is illustrated in Drawing No. ESID8.

Technical guidance on the management of landfill gas recommends monitoring boreholes to assess potential migration. The nearest domestic dwelling is within 250 metres from the nearest operational area. Based on the distance to these sensitive locations and the level of containment provided within the landfill design, boreholes to monitor potential migration should ideally be located 20m to 50m apart for the zone of development towards the housing and 50m to 150m apart for all other directions where no housing or buildings are present.

All future boreholes will ideally be positioned at least 20 metres from the body of waste, where this is possible.

Table GRA10 identifies the required monitoring frequency for various control parameters associated with potential LFG releases.

Table GRA10: Monitoring Frequencies for Potential LFG-related Emissions

Monitoring	Frequency During Operational Phase	Frequency During After-Care Phases
Surface emissions	Annual	Annual
Monitoring boreholes external to landfill	Monthly	To be agreed with EA
Monitoring boreholes within landfill	Monthly	Six monthly
Collection wells (bulk gas)	As per gas management plan	Six monthly
Gas line (trace components)	Annually	Annually

Monitoring methods identified in the "Guidance on the Management of Landfill Gas" will be employed. The measurement of CO_2 and CH_4 for example will be carried out using portable infra-red analysers calibrated in accordance with manufacturer recommendations. An environmental monitoring and sampling plan has been prepared to identify the monitoring strategy, target compounds, trigger action thresholds and appropriate quality assurance/control measures. In the event of trigger thresholds being exceeded, the Landfill Gas Monitoring Action Plan will be implemented. The actions and responses in the event of trigger thresholds being exceeded are identified in the Gas Management and Working Plans for the Installation. Monitoring of odour and meteorological parameters will be carried out.

Combustion Releases from Flares and Gas Engines

Combustion gas releases from flares and gas engines will be monitored on a regular basis to demonstrate continued compliance with emission standards. Currently monitoring of flares and engines is carried out in accordance with Annex G of the Site Working Plan. This monitoring will continue until draft guidance on emissions monitoring for flares and engines is finalised.

2.0 LANDFILL GAS RISK ASSESSMENT

2.1 The Nature of the Landfill Gas Risk Assessment

An initial stage 1 assessment has been carried out to develop the conceptual model. This model was described in Section 1 and identified that the most important pathways requiring assessment were likely to be associated with lateral migration of LFG (sub-surface emissions) through the sidewall or other pathways and releases of combustion gases from flaring/utilisation equipment.

The pathways were considered in the context of potential effects on sensitive receptors. These potential effects included toxicity of compounds, eco-toxicity, risk of explosion and asphyxiation, potential to cause odour annoyance, global warming potential and ozone creating and ozone depleting potentials. Mitigation measures and design considerations were considered in terms of the effect they would have on minimising potential releases and achieving identified Environmental Assessment Levels.

2.1.1 Further Assessment

<u>Quantification of LFG Generation Rate and Composition</u>

A simple, second stage assessment using GasSim has been carried out to predict the peak LFG gas generation rate that may arise. The calculations were based on the landfill design for existing and future cells and included planned mitigation measures. Other inputs are as described in Appendix GRA1.

Whilst variability in generation and composition can be anticipated from the predictions included in the simple second stage assessment, the mitigation measures proposed, combined with the results of additional impact assessments on LFG releases, identify that significant variability would be required to change the conclusions of the risk assessment. More complex modelling of generation rates and composition has not been carried out.

<u>Lateral Migration</u>

Additional quantification of potential lateral migration has been carried out and described in Section 1. Boundary borehole monitoring will assist in identifying if migration is occurring and remedial measures will be enacted should trigger thresholds be exceeded. The following considerations will minimise the potential for migration:

- gas collection and extraction via appropriately designed gas wells to a flaring and utilisation system that will maintain a negative pressure within the landfill;
- options to increase the pull of gas from wells close to the sidewall and areas of potential migration; and
- perimeter boreholes at an identified spacing and distance from the cell to monitor any potential migration against EAL's.

Suitable control and trigger thresholds have been identified in Table GRA5. A Gas Management Plan will include corrective measures to reduce any elevated concentrations should they occur.

Surface Emissions

A simple, second stage assessment of releases has been carried out for the peak LFG generation. The impact on air quality (toxicity) and odour potential has been carried out in a second stage assessment incorporating meteorological data from a representative Meteorological Station (Hawarden) and using the dispersion model functions of GasSim. All concentrations are predicted to be within environmental assessment levels and thresholds (using the 95th percentile value as presented by GasSim).

Potential releases of gases with global warming potential were quantified for the year with the highest predicted LFG generation rate. The mitigation measures proposed will work towards the benchmark figure for LFG collection following the final installation of capping. A high collection and destruction efficiency will ensure a high conversion of methane to carbon dioxide in the flare and reduce releases with global warming potential. Such mitigation measures will also minimise potentially odorous releases, explosive and asphyxiation risks and emissions with ozone depleting or ozone creating potential.

The risks associated with other potential pathways are appraised in Section 1. Assumptions and the assessment methodology used in the additional assessment and methodology are described in Section 1 and Appendix GRA1 (for GasSim predictions).

Combustion Releases from Flares and Gas Engines

Additional refined modelling using ADMS3 has been previously carried out by AEA Technology to assess releases from the gas utilisation plant and flare. The modelling identified that Installation's contributions do not exceed EA guidance assessment thresholds either in isolation or in combination with background air quality.

2.2 The Proposed Assessment Scenarios

2.2.1 Lifecycle Phases

The scenarios considered above and in the conceptual model have appraised risks associated with all phases of the Installation's lifecycle. This includes waste deposition, capping, restoration and aftercare. The impact assessments have, however, considered the highest predicted rate of LFG generation or worst case background air quality and hence predict worst-case releases of LFG emissions and anticipated components during any stage.

Any degradation of the liner or the cap in the long term is not considered to have a significant impact on potential emissions ten or twenty years into the aftercare cycle. Much greater longevity will be expected with a liner laid with appropriate CQA procedures, which is the case here. Proposed monitoring will continue to check the integrity of the containment and extraction systems.

2.2.2 Accidents and Their Consequences

A qualitative assessment of potential accidents and their consequences is included below in Table GRA11. The expected likelihood of an accident occurring is also considered and planned measures to minimise the risk and consequence identified. The assessment of potential accidents and their consequences suggests that risks relating to accidents are unlikely to occur frequently and are

unlikely to have any greater impact than normal operational activities in most cases. Any uncontrolled releases will also be rapidly dispersed in the atmosphere.
All risks have been categorised as acceptable based on risk classifications identified in the "Guidance on the Management of Landfill Gas". Additional quantitative assessment has therefore not been undertaken.

Table GRA11 : Appraisal of Accidents and Their Consequences

Scenario	**Consequence**	**Potential Impact (Receptor)**	**Expected frequency of event**	**Severity of Event**	**Magnitude of Risk**	**Design or mitigation measures in place**
Damage to liner and cap for all areas during restoration works	Decrease in containment leading to increased release of LFG to atmosphere or horizontal migration	Odour nuisance at nearby sensitive locations Greater release of emissions with global warming potential and other effects If damage to sidewall or basal liner - potential for higher lateral migration leading to potential ecotoxicity issues and explosive/asphyxiation risk	Somewhat unlikely	Noticeable	Acceptable	Appropriate CQA measures Geotextile protective layer to reduce potential for damage to cap during capping and restoration Monitoring of LFG surface and sub-surface soil conditions to identify loss of containment and integrity of cap.
Vehicle impact or vandalism to gas well or monitoring well	Lower extraction rates of LFG and build up of pressure within landfill, increasing potential for diffusion and migration of LFG	Higher lateral migration leading to potential ecotoxicity issues and explosive/asphyxiation risk Odour nuisance at nearby sensitive locations Greater release of emissions with global warming potential and other effects	Somewhat unlikely	Noticeable	Acceptable	Staff training for vigilance when working on areas with pipework and wells. Monitoring wells to have lockable covers Replacement of wells if damaged
Fire within landfill or at extraction well	Damage to containment or extraction infrastructure	Greater release of LFG to air Release of potentially toxic fumes to air	Unlikely	Noticeable to significant	Acceptable	Highest risk during early phases with higher oxygen levels hence limited risk once reception of waste finishes. In unlikely case of fire, material will be excavated and quenched. Event likely to be short term in nature.

Table GRA11 Continued: Appraisal of Accidents and Their Consequences

Scenario	Consequence	Potential Impact (Receptor)	Expected frequency of event	Severity of Event	Magnitude of Risk	Design or mitigation measures in place
Gas accumulation leading to explosion	Risk of harm to onsite staff Significant migration could lead to off-site risk Release of toxic fumes	Risk of harm to onsite staff and potentially (though much less likely) at locations of public amenity. Release of toxic fumes to air Damage to site containment leading to longer term release of LFG to atmosphere and subsequent effects	Unlikely.	Significant to severe	Acceptable	Collection and extraction system for LFG Identification of LFG build up via gas monitoring wells and offsite. Contingency plan to be put in place (via a Gas Management Plan) in event of trigger thresholds for accumulation being exceeded.
Failure of gas extraction system	Increase in pressure within containment cells	Increased rate of passive venting through cap or liner where present Greater release of LFG to atmosphere and LFG accumulation potential within landfill	Fairly probable to probable	Noticeable	Acceptable	Slight rise in pressure within landfill overnight, which will rapidly reduce upon start-up of extraction system. Backup flare in event of engine failure. Maintenance contracts will ensure rapid response to correct faults to extraction equipment Monitoring systems to check and assess pressure build up
Failure of flare or gas engine	Reduction in available LFG treatment capacity	Potential for release of untreated emissions	Fairly probable to probable	Minimal to noticeable	Acceptable	Spare capacity available between flare and gas engines make scenario highly unlikely. Maintenance contracts will ensure rapid response to correct faults to equipment
Loss of electricity supply to flare or gas engines	Loss of LFG flaring/utilisation	Increased release of passive venting	Fairly probable	Noticeable	Acceptable	Reliability of electricity supply, with any interruptions to supply rare in nature and of short duration. Electricity cables clearly marked to reduce potential for damage by collision or ground intrusion

2.3 The Generated Gases to be Modelled

GasSim was used to identify the mass emissions of potential releases for non-combustion related emissions. The worst case compounds, whose mass emissions were the most significant in comparison to their respective Environmental Assessment Levels, were then identified. The ground level concentrations of these compounds in addition to releases from the flare and gas engines at sensitive locations beyond the Installation boundary were then predicted. Predicted compliance with the EAL for these worst-case compounds also identifies that all other compounds are predicted to be within their respective EAL's.

Combustion emissions were based on data supplied by the flare and gas engine manufacturers that was subsequently incorporated into the ADMS3 dispersion model.

2.4 Numerical Modelling

2.4.1 Justification for Modelling Approach and Software

The model GasSim was used to predict the generation rate of LFG, likely emissions and the likely components within emissions. This information was then augmented with modelling data provided by the state of the art dispersion model, ADMS3, as part of a refined, third tier assessment. The models are considered appropriate by the Environment Agency for this specific purpose and to assist landfill operators assess operational risks and effectiveness of mitigation measures in addition to providing a tool that assists in the preparation of the annual review and reports. Representative hourly sequenced meteorological data was incorporated into the ADMS3 model.

2.4.2 Model Parameterisation

Site-specific data was used utilising operational or detailed design information wherever practicable. Where information was absent, model defaults were applied. Model calibration can be carried out as part of the annual review process using monitoring data and operational experience. The years 2004 and 2016 were used in the impact assessment to consider current day conditions and the year when the highest LFG generation rate is predicted to occur. Dispersion modelling of combustion gas releases from the flares and engines was carried out in 2002. Background air quality is expected to improve with time and hence the assessment for emissions of this nature is likely to be conservative in comparison to results that would be identified for 2016.

Additional gas engines may be installed in future as appropriate. These additional gas engines have not been considered in the dispersion modelling assessment. Additional modelling will be carried out as part of any planning permission or permit variation required to ensure emissions do not significantly impact on human health or ecosystems.

2.4.3 Sensitivity Analysis

A sensitivity analysis of model predictions has not been carried out. Whilst variation in emissions of LFG and its constituents to air can be expected, the assessment identified that resulting concentrations beyond the Installation boundary are expected to be well within environmental assessment levels. Considerable variance in the level of emissions from those modelled here would be required to influence the conclusions of this Risk Assessment.

The emission estimate used the highest LFG generation rate. The emission estimate is therefore worst case in nature and considers all phases in the lifecycle of the Installation. The mitigation measures in place will maximise the collection of LFG.

2.4.4 Model Validation

Model validation can be carried out during future reviews.

2.5 Risks to the Environment and Human Health

A full consideration of the risks to the Environment and Human Health during different stages in the lifecycle of the Installation is included in Section 1. This consideration includes an appraisal of landfill gas emissions, sub-surface migration and vegetation stress. Modelling using GasSim and ADMS3 has identified that air quality and odour assessment levels are unlikely to be exceeded. Monitoring activities identified in Section 1 and the Gas Management Plan will monitor potential emission levels and assess the effectiveness of operating activities and mitigating measures in reducing releases of LFG to the environment.

2.6 Landfill Gas Completion

The predicted period of active LFG generation for the Installation is illustrated in Section 1.2.3. LFG generation is predicted to be less than 100 m^3/hr by the year 2056. The flare currently installed can handle flows down to 300 m^3/hr. A smaller unit will be installed once gas generation rates fall below 300 m^3/hr to provide appropriate gas treatment and redundancy to the remaining gas engines and allow for completion.

3.0 GAS MANAGEMENT PLAN

The Plan will be reviewed on an annual basis to ensure any future recommendations included in technical guidance are fully incorporated into the Gas Management Plan and updated as necessary.

4.0 CONCLUSIONS

4.1 Compliance with the Landfill Regulations, 2002

As identified in this Report, accumulation of LFG, surface emissions and migration risk will be minimised through appropriate mitigating measures including gas collection, extraction and utilisation. Specifically these include:

- very low permeability plastic cap and liners;
- gas collection and extraction via appropriately designed gas wells to a flaring and gas utilisation system that will maintain a negative pressure within the landfill; and
- the ability to increase the localised suction of gas from wells close to the sidewall and areas of potential migration.

The collection and treatment of LFG will be carried out so that damage to or deterioration of the environment and risk to human health is minimised. This includes the application of best practice during the after care stages of the Installation's lifecycle supported by compliance monitoring to confirm that risks are being effectively managed. Impact assessment identified in this Report has predicted that releases to air will be within appropriate Environment Assessment Levels. Risks from accidents are acceptable and ongoing monitoring will continue to be carried out.

The Installation therefore complies with the requirements of the Landfill Regulations with regard to management and monitoring of landfill gas.

APPENDIX GRA1

ELECTRONIC COPY OF GASSIM MODEL

APPENDIX GRA2

HARDCOPY OF GASSIM MODEL

APPENDIX GRA3

SITE WORKING PLAN
ANNEX G – MANAGEMENT OF THE LANDFILL GAS

APPENDIX GRA4

AEA TECHNOLOGY AIR DISPERSION MODELLING REPORT