

Green Frog Power Limited

**Hunshelf - Air Quality Impact
Assessment**

Final Report

November 2011

AMEC Environment & Infrastructure UK Limited

Report for

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**Green Frog Power
Limited****Hunshelf - Air Quality
Impact Assessment**

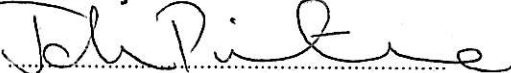
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1. Introduction

1.1 Background, Aims and Objectives

Green Frog Power Limited (GFP) is developing a number of sites to contain multiple small electricity generating engines. Referred to as Short Term Operating Reserve (STOR), these units will be available to meet shortfalls in generating capacity on the public network (e.g. during peak surges or drops in wind generation, etc.).

GFP has been successful in winning contracts to develop 14 sites containing up to 52 operational 300 kWe engines on each site. The preferred generating unit is the Perkins 2506A-E15TAG2. This is a 300 kWe compression ignition engine capable of operating as a back up unit in the event of a loss of power or to generate commercially exported power continuously. The engine will be operated on fuel oil (diesel).

These engines are expected to operate on an intermittent basis as required by National Grid. Once requested to operate by the National Grid, the engines will need to be able to run for at least two hours, three times per week. Based on historic information, the total operating hours for STOR plant is expected to be around 120 hours per year with the maximum operating period being 6 hours and the average period being just 44 minutes. The total number of STOR call ups that Green Frog Power is expecting is likely to be 50 per year with a typical maximum duration of 100 minutes per call, of which around half will be inside business hours

GFP have commissioned AMEC Environment & Infrastructure UK Limited (AMEC) to review the impacts of the emissions to air from the engines on the local environs as part of there environmental management of the developments and to inform the local regulator, if required.

The dispersion of emissions in this assessment 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. The assessment considers short and long-term effects in relation to the air quality standards set in legislation and in Government and international guidance.

1.2 Site Description

The site is located in South Yorkshire, adjacent to the electrical substation off Tofts Lane, approximately 500 m north of the A616, which bypasses Stockbridge. The area is predominately agricultural. Figure 1.1 provides a site location map, which illustrates the site (circled in red) in relation to the local area.

Figure 1.1 Site Location Map



1.3 Sources of Information

The information used to assess air quality includes:

- Process and emission data provided by GFP and F G Wilsons (Engine Supplier);
- Site layout from GFP;
- Baseline air quality data from surveys undertaken by Government bodies, Local Authorities and third parties;
- Ordnance Survey (OS) maps of the local area;
- Meteorological data supplied by Atmospheric Dispersion Modelling Ltd; and
- Terrain data supplied by Emapsite¹.

1.4 Report Structure

The remainder of the report is set out as follows:

¹ Emapsite (2011): <http://www.emapsite.com>

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 details the ambient air quality in the area
Section 3	Details the assessment criteria
Section 4	Presents an assessment of the potential air quality impacts arising from the site emissions
Section 5	Contains a summary and conclusions of the assessment

2. Assessment Methodology

2.1 The Dispersion Model

The model used in this assessment is the ADMS 4.2 advanced atmospheric dispersion model that has been developed and validated by Cambridge Environmental Research Consultants (CERC). The model was used to predict the ground level concentration of combustion products emitted to atmosphere from the engines. 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.

ADMS 4.2 parameterises stability and turbulence in the atmospheric boundary layer (ABL) by the Monin-Obukhov length and the boundary layer depth. This approach allows the vertical structure of the ABL to be more accurately defined than by the stability classification methods of earlier dispersion models such as R91 or ISCST3. In ADMS, the concentration distribution follows a symmetrical Gaussian profile in the vertical and crosswind directions in neutral and stable conditions. However, the vertical profile in convective conditions follows a skewed Gaussian distribution to take account of the inhomogeneous nature of the vertical velocity distribution in the Convective Boundary Layer (CBL).

A number of complex modules, including the effects of plume rise, complex terrain, coastlines, concentration fluctuations, radioactive decay 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 and emissions data. The data used in modelling the emissions are given in the following sections of this chapter.

2.2 Process Emissions

The performance of an engine is determined by the emissions as well as the thermal efficiency though the two are intrinsically linked by the combustion process; efficient combustion leads to an optimisation of emissions.

In order to fully combust the fuel, sufficient oxygen is required to fully oxidise the carbon to carbon dioxide. Balancing the available oxygen is important as excess oxygen promotes the oxidation of the nitrogen present in the air resulting in the release of nitrogen oxides (NO_x) whilst insufficient oxygen will not allow complete combustion of the fuel increasing the emissions of carbon monoxide (CO) and unburnt fuel (hydrocarbons).

Table 2.1 details the indicative releases from the Perkins 2506A-E15TAG2 Engine as supplied by F G Wilsons.

Table 2.1 Indicative Emissions to Air from Perkins 2506A-E15TAG2 Engine

Engine	Rating (kWe)	Pollutant Emission (g/kWh)			
		NO _x	CO	VOC	PM
2506C-E15TAG2A	300 / 400 ^A	5.02	1.24	0.08	0.126

Note A: Engine peak rating 400 kW_e, Maximum continuous rating 300 kW_e

For the input data for the dispersion model, the worst gas data for the engine operating at peak rating (400 kW_e) has been used. This will, in effect, over predict the impact as the engines will not operate at peak load for prolonged periods.

Table 2.2 details the model input data.

Table 2.2 Model Input Parameters

Parameter	Stack
Location of the centre of the compound (X,Y)	426313, 39962
Stack Height (m)	2.26
Stack Diameter (m)	0.2
Efflux Velocity (ms ⁻¹)	51
Efflux Temperature (°C)	550
Emission Rates at Emission Limits (gs ⁻¹)	Emission Rate per Engine
NO _x	0.56
CO	0.14
PM ₁₀	0.014
Total VOC	0.009
SO ₂	0.04

The model is based on the emission of a pollutant at the rate given above for entire hour operating periods. If the operating period is less than one hour, the results presented in this assessment will be over predicted.

The National Grid requests that STOR availability is maintained during the following typical periods shown in table 2.3, but the hours do vary from year to year:

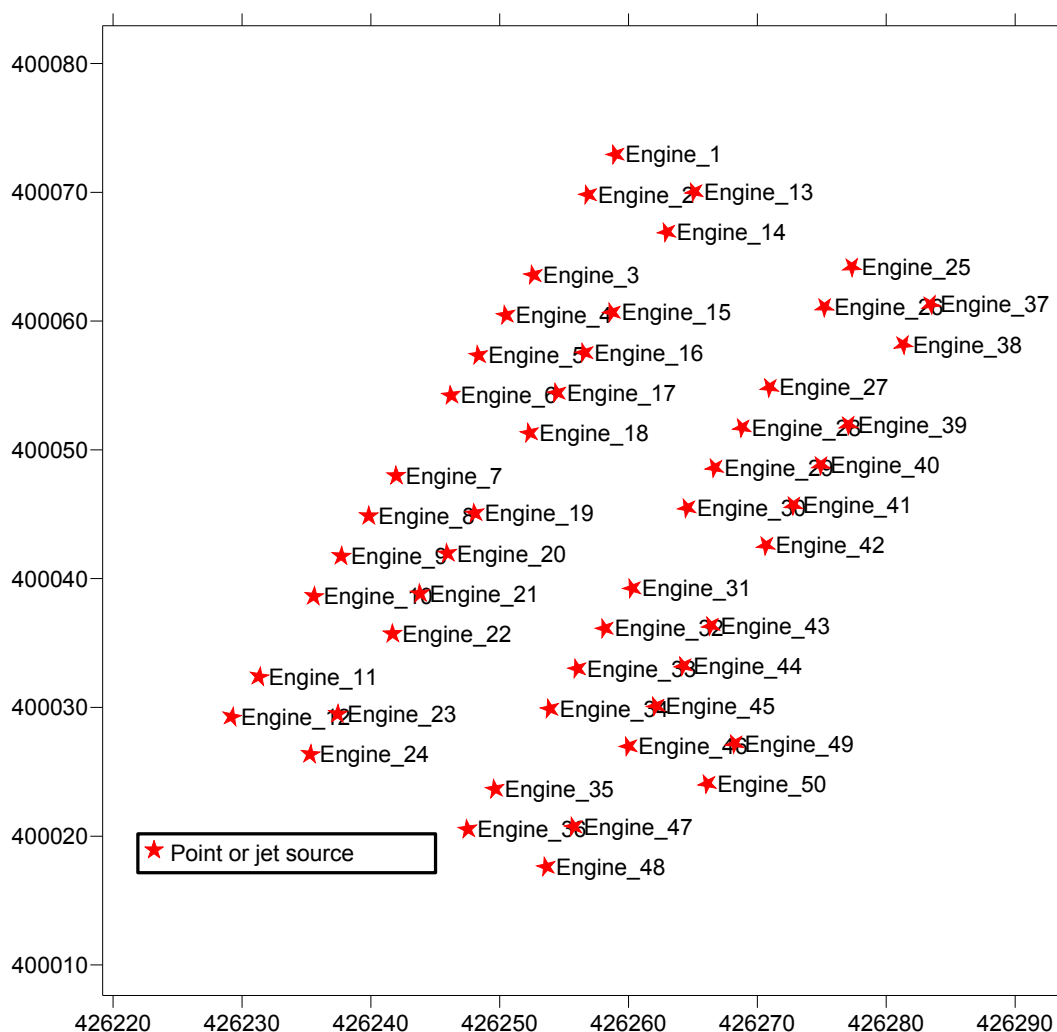
Table 2.3 Typical STOR Hours for 2011 - 2012

Season	Dates	Start Time	End Time	Total Hours
1	1 st April – 25 th April	07:00	14:00	216
		19:00	22:00	
2	25 th April – 15 th August	07:30	14:00	1202.5
		16:00	18:00	
		19:30	22:30	
3	15 th August – 19 th September	07:00	13:30	384
		16:00	22:00	
4	19 th September – 31 st October	07:00	13:30	435
		16:30	21:00	
5	31 st October 2011 – 30 th January 2012	07:00	13:30	982.5
		16:00	21:00	
6	30 th January 2012 – 1 st April 2012	07:00	13:30	654
		16:30	21:00	
				3874

For periods when STOR is not required a time vary file has been set to assign a zero emission (i.e. no engines running) whilst, for the operational hours, the engine emission is set to 100% (i.e. maximum output). This results in the emissions occurring for a total of 3874 hours per year. The annual average is then calculated by applying a correction factor, based on the likely actual hours of operation and that assumed by the model. For short term impacts, the maximum predicted value is reported assuming that the engines operate for the full hour duration which will result in a worst case assumption. This plant is expected to be used for less than this period as it will allow larger, more effective plants to come online and reach full output. The probability of the engine operating during periods conducive to producing maximum ground level concentrations is low as the actual operation of the engines is for so few hours during the potential operating period.

The release points are shown in Figure 2.1 below.

Figure 2.1 Emission Points Visualisation



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.

This assessment has utilised meteorological data recorded at Emley Moor meteorological station during the period 2004-2008. Emley Moor meteorological station is located approximately 15 km to the north-west of the site and, is the nearest synoptic station to the site that offers data in a suitable format for the model. The following figures illustrate the frequency of wind directions and wind speeds for the years considered.

Figure 2.2 2004 Wind Rose

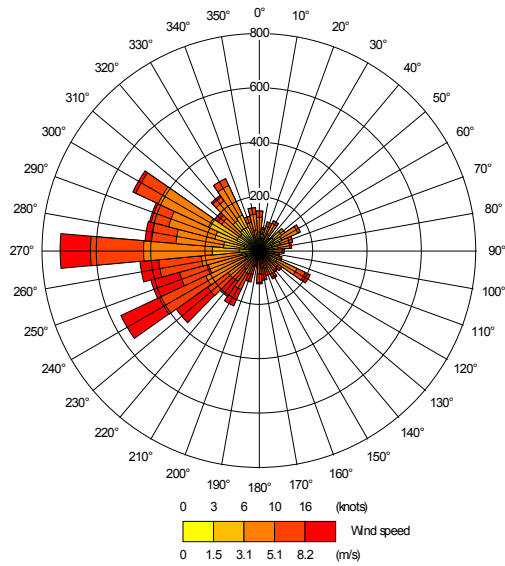


Figure 2.3 2005 Wind Rose

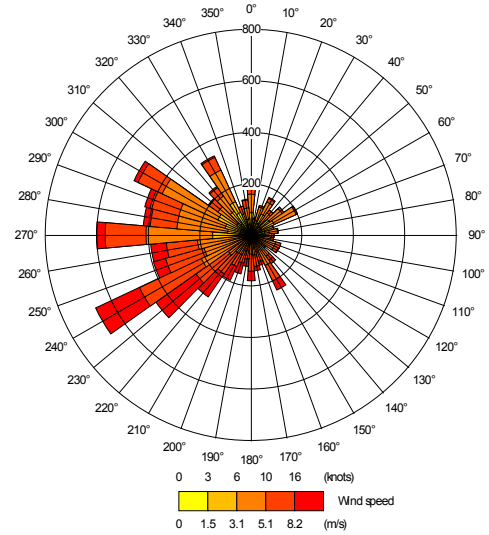


Figure 2.4 2006 Wind Rose

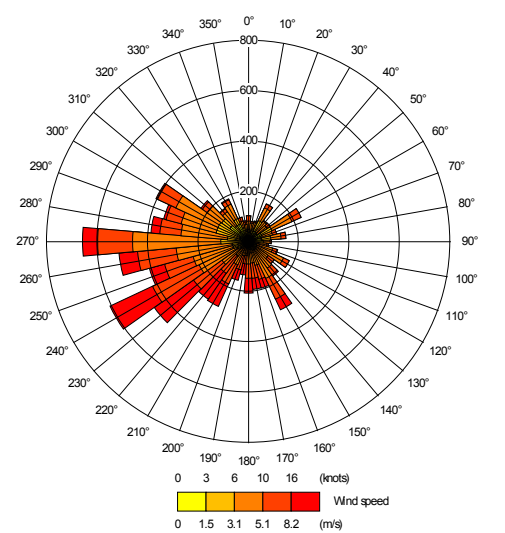


Figure 2.5 2007 Wind Rose

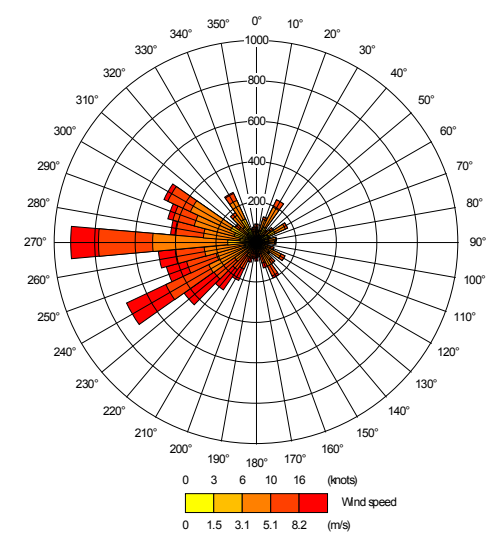
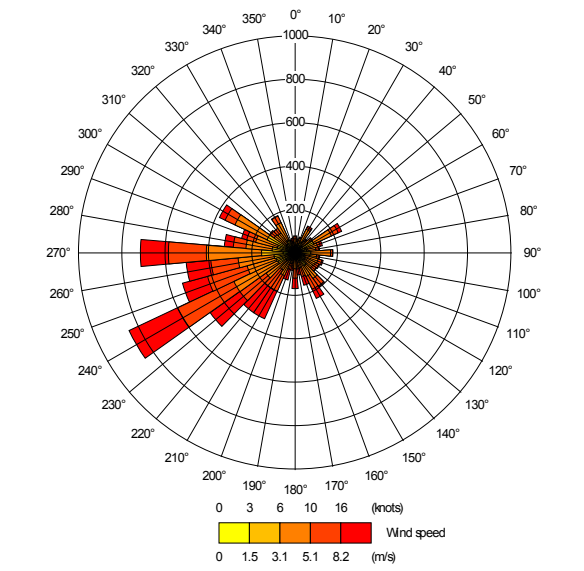


Figure 2.6 2008 Wind Rose



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) and CERC (2003) suggest typical roughness lengths for various land use categories (Table 2.4).

Table 2.4 Typical Surface Roughness Lengths for Various Land Use Categories

Type of Surface	z_0 (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; and
- 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.

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. Oke (1987) recommends average surface albedo values of 0.6 for snow covered ground and 0.23 for non-snow covered ground, respectively.

The latent heat flux is dependent upon the amount of moisture present at the surface. The Priestly-Taylor parameter can be used to represent the amount of moisture available for evaporation:

$$\alpha = \frac{1}{S(B+1)}$$

Where:

α = Priestly-Taylor parameter (dimensionless)

$$S = \frac{s}{s + \gamma}$$

$$s = \frac{de_s}{dT}$$

e_s = Saturation specific humidity (kg H₂O / kg dry air)

T = Temperature (K)

$$\gamma = \frac{c_{pw}}{\lambda}$$

c_{pw} = Specific heat capacity of water (kJ kg⁻¹ K⁻¹)

λ = Specific latent heat of vaporisation of water (kJ kg⁻¹)

B = Bowen ratio (dimensionless)

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. Holstag and van Ulden (1983) suggest values of 0.45 and 1.0 for dry grassland and moist grassland respectively.

2.4.3 Selection of Appropriate Surface Characteristic Parameters for the Site

A detailed analysis of the effects of surface characteristics on ground level concentrations by Auld *et al.* (2002) 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 α value of 1.0 has also been retained.

From examination of 1:10,000 Ordnance Survey maps, it can be seen that within the immediate vicinity of the site, land use is predominately agricultural. Consequently, a composite surface roughness length of 0.5m is appropriate to take account of the respective land use categories in the model domain. However, due to the limitations on buildings within the model an enhanced

surface roughness value of 2 m has been used. This will increase the uncertainty in the predicted results and likely increase the degree of over prediction.

2.5 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 engines are contained within individual containers approximately 5m long, 1.7m wide and 2.1m tall, these would influence the plume dispersion, there is also an acoustic fence surround the site. Due to the limitation within the model of not being able to consider more than 20 buildings, an enhanced surface roughness has been used as a proxy for estimating the magnitude of building induced effects, see section 2.4 above.

2.6 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.
 - Direct impaction of the plume on hill slopes in stable conditions.
 - 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; and
 - Regions of recirculation behind steep terrain features can rapidly advect pollutants towards the ground culminating in elevated concentrations.
 - 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.

- 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 the terrain gradients exceed 1 in 10 i.e., a 100m change in elevation per 1km step in the horizontal plane. The gradients surrounding the site do exceed this criterion and, consequently, terrain data has been included in the model.

As a result of the complex topography of the area surrounding the site, terrain has been incorporated into the dispersion model. Panorama digital terrain mapping for the site was procured from Emapsite¹. The area for which digital terrain data were considered is illustrated in Figure 2.7 below.

Figure 2.7 Terrain Map

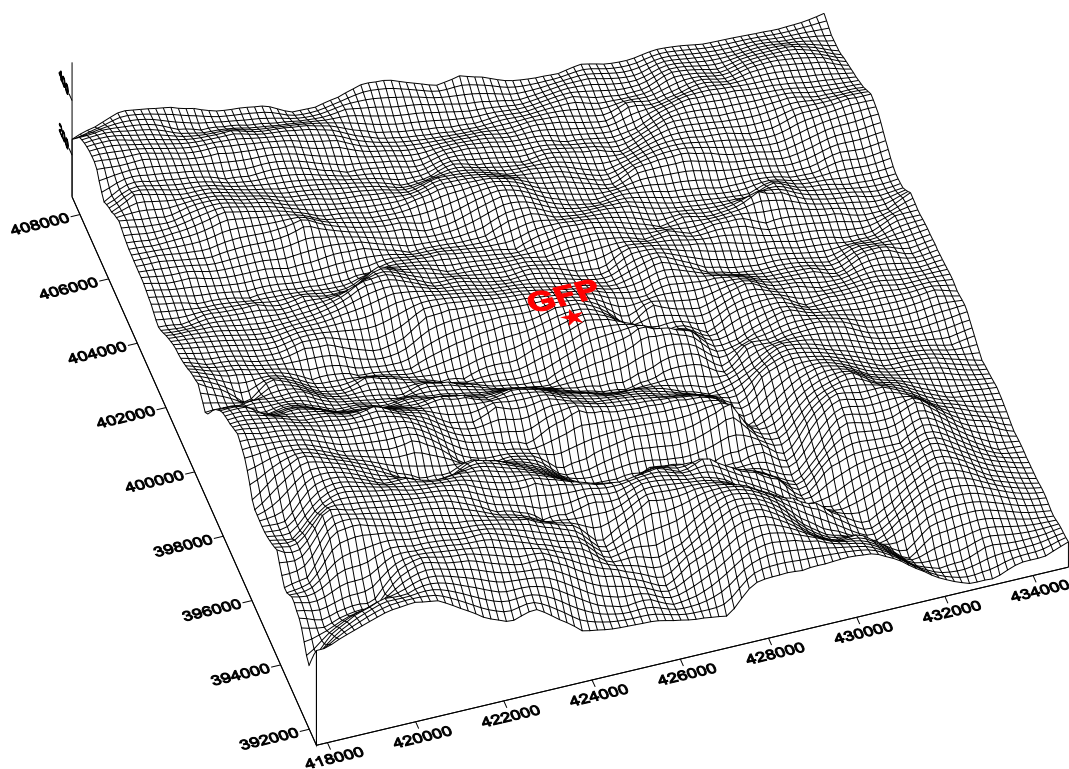


Table 2.5 Details of Modelled Human Receptors

ID	Receptor Name	Easting (m)	Northing (m)
1	Underbank Hall	425581	399653
2	Carr Head Farm	425849	399713
3	Dyson Cote	425849	400429
4	Chapel Farm	426135	400511
5	Snowden Hill	426184	400585
6	Pond Farm	426558	400478
7	Dean Head	426879	400190
8	Horsely House	426114	399375
9	Bridleway: Pond Farm to Oakenshaw Spring	426470	400299
10	Bridleway: Mucky Lane	426262	399738
11	Crimbles Farm	426195	399304
12	Cote House Farm	426851	399255
13	Bridleway: Chapel Farm to Carr Head Farm	426033	400197
14	Avice Royd	425990	399361

2.7 Modelled Domain and Receptors

2.7.1 Modelled Domain

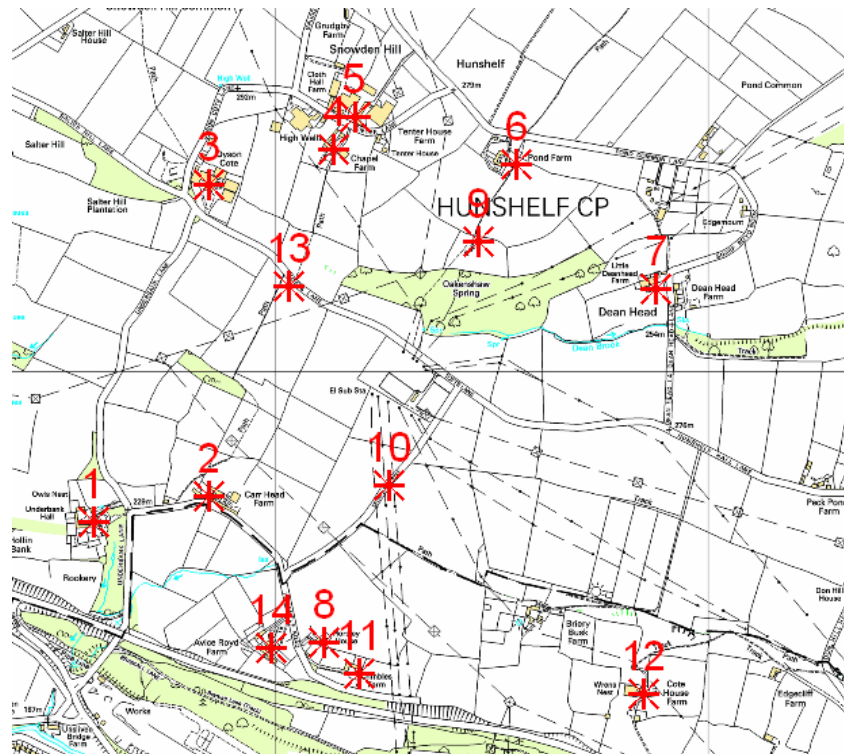
A 3 km x 3 km Cartesian grid centred on the site was modelled, with an approximate receptor resolution of 30 m, to assess the impact of atmospheric emissions from the site on local air quality.

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, following the guidance given in Section 3.4 of this report. Details of the locations of human receptors are given in Table 2.5 and Figure 2.8 below.

Workplace locations have been excluded in accordance with the guidance from Environmental Protection UK and the Air Quality Standard Regulations 2010; these guidance documents are detailed in section 3 of this report.

Figure 2.8 Location 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 10 km or 15 km for SSSIs.”

Following the above guidance, the South Pennine Moors are within the assessment criteria and two receptor points have been chosen to represent this receptor in the model (Table 2.6).

Table 2.6 Details of Modelled Ecological Receptors

Receptor Name	Easting (m)	Northing (m)	Distance from the site (km)
South Pennine Moors 1	423403	398474	3.2
South Pennine Moors 2	423682	398109	3.0

2.8 Special Treatments

2.8.1 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 (< 2 km), 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 ($\mu\text{g m}^{-2} \text{s}^{-1}$)

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

$C(x, y, 0)$ = ground level concentration ($\mu\text{g m}^{-3}$)

Assuming irreversible uptake, the total 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 ($\mu\text{g m}^{-2} \text{s}^{-1}$)

Λ = washout co-efficient (s^{-1})

C = local airborne concentration ($\mu\text{g m}^{-3}$)

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

Pollutant	Deposition Velocity (m s^{-1})	
	Short Vegetation	Long Vegetation/Forest
NO_x	0.0015	0.003
SO_2	0.012	0.024

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 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 ($\text{kg N ha}^{-1} \text{y}^{-1}$) and kilo equivalents deposited per hectare per year ($\text{keq ha}^{-1} \text{y}^{-1}$). To enable a direct comparison against the critical loads, the modelled total wet and dry deposition flux ($\mu\text{g m}^{-2} \text{s}^{-1}$) 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 ($\text{kg N ha}^{-1} \text{y}^{-1}$)

K_2 = Conversion factor for m^2 to ha ($= 1 \times 10^4 \text{ m}^2 \text{ ha}^{-1}$)

K_3 = Conversion factor for μg to kg ($= 1 \times 10^9 \mu\text{g kg}^{-1}$)

t = Number of seconds in a year ($= 3.1536 \times 10^7 \text{ s y}^{-1}$)

$i = 1, 2, 3, \dots, T$

T = Total number of nitrogen containing compounds

F = Modelled deposition flux of nitrogen containing compound ($\mu\text{g m}^{-2} \text{ s}^{-1}$)

M_N = Molecular mass of nitrogen (kg)

M = Molecular mass of nitrogen containing compound (kg)

The unit eq ($1 \text{ keq} \equiv 1,000 \text{ eq}$) 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):

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

$$1 \text{ keq ha}^{-1} \text{ y}^{-1} = 16 \text{ kg S ha}^{-1} \text{ y}^{-1}$$

For the purposes of this assessment, dry deposition rates of nitrogen and acidic equivalents at the identified SSSI have been calculated by applying the 'long vegetation' deposition velocities (as detailed in Table 2.6) to the modelled annual mean concentrations of NO_x and SO_2 . Wet deposition has not been assessed since this is not a significant contributor to total deposition over shorter ranges (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 ($\text{kg N ha}^{-1} \text{ y}^{-1}$)	Background Total Acid Deposition ($\text{keq ha}^{-1} \text{ y}^{-1}$)
South Pennines Moor	26.52	2.44

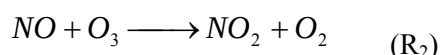
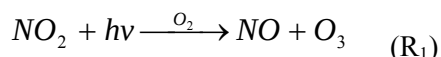
Source: Air Pollution Information Service (APIS) website (<http://www.apis.ac.uk>)

2.8.2 Other Treatments

Specialised model treatments, for short-term (puff) releases, coastal models, fluctuations or photochemistry were not used in this assessment.

2.9 Conversion of NO to NO₂

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 (NO₂). NO_x chemistry in the lower troposphere is strongly interlinked in a complex chain of reactions involving VOCs and Ozone (O₃). Two of the key reactions interlinking NO and NO₂ are detailed below:



Where $h\nu$ is used to represent a photon of light energy (i.e., sunlight).

Taken together, reactions R1 and R2 produce no net change in O₃ concentrations and NO and NO₂ 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 NO₂ for photolysis, allowing O₃ concentrations to increase during the day with a subsequent decrease in the NO₂:NO_x ratio.

However, at night, the photolysis of NO₂ ceases, allowing reaction R2 to promote the production of NO₂, at the expense of O₃, with a corresponding increase in the NO₂:NO_x ratio. Similarly, near to an emission source of NO, the result is a net increase in the rate of reaction R2, suppressing O₃ 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 NO₂ which dispersion model practitioners can use in their detailed assessments². The AQMAU guidance advises that the source term should be modelled as NO_x (as NO₂) and then suggests a tiered approach when considering ambient NO₂: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 NO₂ for short-term assessments and 100 % of the predicted NO_x concentrations should be assumed to be NO₂ 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 NO₂ for short-term assessments and 70 % of the predicted NO_x concentrations should be assumed to be NO₂ 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.

² http://www.environment-agency.gov.uk/static/documents/Conversion_ratios_for__NOx_and_NO2_.pdf

In line with the AQMAU guidance, this assessment has used the 'Worst Case Scenario' approach in determining the conversion rate of NO to NO₂ as a robust assumption.

2.10 Existing Ambient Data

2.10.1 Continuous and Passive Monitoring Data

Sheffield City Council (SCC) operates eight continuous air quality monitors, two of which are owned by the Government's Department of Environment, Food and Rural Affairs (DEFRA). SCC also operates around 90 diffusion tube monitoring stations for NO₂. In addition, Barnsley Metropolitan Borough Council (BMBC) has five different air quality monitoring sites, which use NO₂ diffusion tubes, automatic analysers and pumped samplers. However, none of SCC's or BMBC's monitoring stations are within 2 km of Hunshelf and therefore cannot be considered as representative of the GFP site.

2.10.2 Defra Mapped Background Concentrations

Defra, through its contractor AEA Technology plc, maintains a nationwide model of existing and future background air quality concentrations at a 1 km grid square resolution. The data sets include annual average concentration estimates for NO_x, NO₂, PM₁₀, PM_{2.5}, CO and SO₂. The model used is empirical in nature: it uses the national atmospheric emissions inventory (NAEI) emissions to model the concentrations of pollutants at the centroid of each 1 km grid square but then calibrates these concentrations in relation to actual monitoring data.

2.10.3 Background concentrations used in the Assessment

Annual mean background concentrations have been derived from the Defra maps for the based on the 1 km grid square in which the Hunshelf power station is located (426500, 399500).

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 Air Quality Standard/Objective (AQS/O) and the likelihood of an exceedence determined. As the ecological receptors are located several kilometres away from the source, a different but more appropriate grid square has been used (423500, 398500) when investigating pollutant concentrations at these receptors.

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/O. 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 Environment Agency Horizontal Guidance H1 Annex (f).

Background concentrations used in the assessment are detailed in Table 2.9.

Table 2.9 Background Concentrations used in the Assessment

Grid square (E, N)	Pollutant Concentrations ($\mu\text{g m}^{-3}$)			
	NO ₂	CO	PM ₁₀	SO ₂
426500, 399500	9.58	0.265	12.79	4.78
423500, 398500	9.37	N/A	N/A	4.74

2.11 Sensitivity Analysis and Uncertainty

2.11.1 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.

2.11.2 Model Uncertainty

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.

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.

3.1.3 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 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.

3.1.4 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.

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:

- Carbon monoxide (CO);
- Sulphur Dioxide (SO₂);
- Particulate matter (PM₁₀);
- Oxides of nitrogen (NO_x as NO₂); and

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
Carbon Monoxide (CO) ^{B, C}	The toxicity of CO results in it binding avidly to haemoglobin and thus reducing the oxygen-carrying capacity of the blood. In very high doses, the restriction of oxygen to the brain and heart can be fatal. At lower concentrations, CO can affect higher cerebral function, heart function and exercise capacity.	The principal source of CO is emissions from petrol vehicles, accounting for 54% of total UK emissions in 2008.
Particulate Matter (PM ₁₀ and PM _{2.5}) ^{D, F}	Particulate matter is the term used to describe all suspended solid matter. Particulate matter with an aerodynamic diameter of less than 10 µm (PM ₁₀) is the subject of health concerns because of its ability to penetrate and remain deep within the lungs. The health effects of particles are difficult to assess, and evidence is mainly based on epidemiological studies. Evidence suggests that there may be associations between increased PM ₁₀ concentrations and increased mortality and morbidity rates, changes in symptoms or lung function, episodes of hospitalisation or doctors consultations. Recent reviews by the World Health Organisation (WHO) and Committee on the Medical Effects of Air Pollutants (COMEAP) have suggested exposure to a finer fraction of particles (PM _{2.5}) give a stronger association with the observed health effects. PM _{2.5} typically makes up around two-thirds of PM ₁₀ emissions and concentrations.	Road transport, industrial processes and electricity generation. Other pollutants, including NO ₂ and SO ₂ , have the potential to form secondary particulates which are often smaller than PM ₁₀ .
Sulphur Dioxide (SO ₂) ^B	At high concentrations SO ₂ is a potent bronchoconstrictor, and asthmatic individuals are more susceptible. It is likely that SO ₂ contributes to respiratory symptoms, reduced lung function and rises in hospital admissions. Exposure to high levels of SO ₂ over a long period can result in structural changes in the lungs and may enhance sensitisation to allergens.	The principal source of SO ₂ is the combustion of fossil fuels containing sulphur and, in the UK, this is primarily through the combustion of coal in power stations, oil refining and solid fuel manufacturing, accounting for 57% of total UK SO ₂ emissions in 2008.

Table 3.1 (continued) Summary of the Pollutants Assessed

Pollutant	Description and effect on human health and the environment	Principal Sources
Oxides of Nitrogen (NO _x) ^{A, B, C}	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 µg m ⁻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%.
A	Defra, 2009, Part IV of the Environment Act 1995 Local Air Quality Management: Technical Guidance LAQM.TG(09).	
B	Harrison, R.M., <i>Air Pollution: Sources, Concentrations and Measurements</i> . In: Harrison, R.M., 2000, <i>Pollution: Causes, Effects and Controls</i> , 4 th Edition Royal Society of Chemistry.	
C	Walters, S. and Ayers, J., <i>The Health Effects of Air Pollution</i> . In: Harrison, R.M., 2000, <i>Pollution: Causes, Effects and Controls</i> , 4 th Edition Royal Society of Chemistry.	
D	Defra, 2007, The Air Quality Strategy for England, Scotland, Wales and Northern Ireland	

3.3 Criteria Appropriate to the Assessment

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

Table 3.2 Air Quality Standards, Objectives and Environmental Assessment Levels

Pollutant	AQS/AQO	Averaging Period	Value ($\mu\text{g m}^{-3}$)
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
Carbon monoxide (CO)	AQS	8-hour mean	10,000
	EAL	1-hour mean	30,000
PM_{10}	AQS	Annual mean	40
	AQS	24-hour mean, not more than 35 exceedences per year (90.41 percentile)	50
Sulphur dioxide (SO_2) – Human Receptors	AQS	1-hour mean not to be exceeded more than 24 times a year (equivalent to 99.73 percentile)	350
	AQS	24-hour mean, not to be exceeded more than 3 times a year (equivalent to 99.18 percentile)	125
	AQO	15-min mean, not to be exceeded more than 35 times a year (equivalent to 99.9 percentile)	266
Volatile organic compounds (as Benzene)	AQS	Annual mean	5

3.3.1 Critical Levels and Critical Loads Relevant to the Assessment

A summary of the relevant air quality standards that apply to the emissions from the plant and their 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 ($\mu\text{g m}^{-3}$)
Oxides of nitrogen (NO_x)	AQS	Annual mean	30
Oxides of nitrogen (NO_x)	EAL	Daily mean	75
Sulphur dioxide (SO_2) – Ecological Receptors	AQS	Annual mean	20

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 Typical 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
Saltmarsh	30-40	Many saltmarshes 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 (<i>Brachypodium pinnatum</i>) 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.
Raised bog and blanket bog	5-10	Nitrogen deposition provides fertilization, this increase robust vegetation 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

3.4 Significance Criteria

Although no formal procedure exists for classifying the magnitude and significance of air quality effects from a new development, guidance issued by Environmental Protection UK (EPUK, 2010) suggests ways to address the issue. In the EPUK guidance, the magnitude of impact due to an increase/decrease in annual mean NO₂ and PM₁₀ is described using the criteria in Table 3.3. These criteria are based on the change in concentration brought about by a new development as a percentage of the assessment level, or the equivalent mass basis. When describing the impact at a specific receptor, the actual concentration at that receptor should be taken into account, in combination with the magnitude of change, using the approach detailed in

Table 3.4. It should be noted that an equivalent set of the descriptors in Table 3.4 is available for those developments that would result in a decrease in concentrations. However, as the engines will increase the pollutant loading, only the 'Increase with Scheme' descriptors are replicated.

Table 3.5 Definition of Impact Magnitude for Changes in Annual Mean NO₂ and PM₁₀ Concentration

Magnitude of Change	Annual Mean Concentration
Large	Increase/decrease > 4 µg m ⁻³
Medium	Increase/decrease 2 - 4 µg m ⁻³
Small	Increase/decrease 0.4 - 2 µg m ⁻³
Imperceptible	Increase/decrease < 0.4 µg m ⁻³

Table 3.6 Impact Descriptors for Increases in Annual Mean NO₂ and PM₁₀ Concentration

Absolute Concentration in Relation to Objective	Increase in Concentration		
	Small	Medium	Large
Above objective with scheme (> 40 µg m ⁻³)	Slight Adverse	Moderate Adverse	Substantial Adverse
Just below objective with scheme (36 - 40 µg m ⁻³)	Slight Adverse	Moderate Adverse	Moderate Adverse
Below objective with scheme (30 - 36 µg m ⁻³)	Negligible	Slight Adverse	Slight Adverse
Well below objective with scheme (< 30 µg m ⁻³)	Negligible	Negligible	Slight Adverse

N.B. Those developments that have a magnitude of change classed as 'imperceptible' are considered to have a 'negligible' impact

Public Exposure

Guidance from the UK Government and Devolved Administrations makes clear that exceedences of the health based objectives should be assessed at outdoor locations where members of the general public are regularly present over the averaging time of the objective. Linked to Sections 3.1.1 and 3.1.2, this also excludes workplaces. Table 3.5 provides an indication of those locations that may or may not be relevant for each averaging period.

Table 3.7 Examples of where the Air Quality Objectives should Apply

Averaging Period	Objectives should apply at:	Objectives should generally not apply at:
Annual mean	All locations where members of the public might be regularly exposed Building facades of residential properties, schools, hospitals, care homes etc.	Building facades of offices or other places of work where members of the public do not have regular access. Hotels, unless people live there as their permanent residence. Gardens of residential properties. Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term
24-hour mean and 8-hour mean	All locations where the annual mean objectives would apply, together with hotels Gardens or residential properties¹	Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.
1-hour mean	All locations where the annual mean and 24 and 8-hour mean objectives would apply. Kerbside sites (e.g. pavements of busy shopping streets). Those parts of car parks, bus stations and railway stations etc. which are not fully enclosed, where the public might reasonably be expected to spend one hour or more. Any outdoor locations at which the public may be expected to spend one hour or longer.	Kerbside sites where the public would not be expected to have regular access.
15-minute mean	All locations where members of the public might reasonably be expected to spend a period of 15 minutes or longer.	

Note ¹ For gardens, playgrounds, such locations should represent parts of the garden where relevant public exposure is likely, for example where there is a seating or play areas. It is unlikely that relevant public exposure would occur at the extremities of the garden boundary, or in front gardens, although local judgement should always be applied.

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 emissions has been modelled for the emission conditions described in section 2.2 on a 3x3 km Cartesian grid.

Results are presented for the meteorological year resulting in the highest ground level concentrations, as a worst case assumption. The worst-case meteorological year was determined separately for long- and short-term concentrations at the worst-case receptor location, based on NO₂ process contributions, but the engine emission rate is not adjusted for optimisation of emissions or conversion ratio. Therefore the data in table 4.1 below should only be used to determine the worst case year.

Table 4.1 Determination of Worst-Case Meteorological Year

Year	Predicted Ground Level Concentration due to Process Emissions ($\mu\text{g m}^{-3}$)	
	NO ₂ Annual Mean	NO ₂ 99.79 Percentile of 1-Hour Mean
2004	334	1226
2005	358	1232
2006	341	1252
2007	403	1226
2008	380	1353

Notes:

These concentrations are based on the maximum process contribution at the worst-case receptor location.

From the above predicted ground level concentrations, it can be seen that 2007 meteorological data produces the highest predicted concentrations for long-term means, whilst 2008 meteorological data produces the highest predicted concentrations for short-term means. Therefore, as a worst case assumption, results using 2007 and 2008 data for long-term and short-term means, respectively, are reported in the following sections.

The assessment assumes that, potentially, there are ~3,874 hours per annum when the engines could be operational. However, this approach is likely to overestimate the actual impact of engines emissions, given that it is highly unlikely that the operation of the engines will consistently coincide with 'worst-case' meteorological conditions. The total number of STOR call ups that Green Frog Power is expecting is likely to be 50 per year with a typical maximum

duration of 100 minutes per call (80 hours/year in total), of which around half will be inside business hours. When the STOR call is received, Green Frog Power will operate the engines for the duration of the STOR call period. Once the call period finishes, Green Frog Power do not expect to be called again immediately. Therefore, as explained in Section 2.2, the annual mean concentrations of emissions associated with Hunshelf power station presented in the model results have been re-calculated to account for the assumed annual operational hours.

The short-term impacts are derived from the specific hours of meteorological data producing the highest potential ground level concentrations. It is extremely unlikely that operation of the engines will coincide with these 'worst-case' meteorological conditions and actual values are expected to be significantly lower than that predicted by this assessment.

4.1 Model Results

4.1.1 NO₂ Impacts

Table 4.2 details the results of the impact assessment for NO₂.

Table 4.2 NO₂ Impacts at Human

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
Underbank Hall	40	0.04	9.62	24.0	200	48.09	67.23	33.6
Carr Head Farm	40	0.07	9.65	24.1	200	92.87	112.01	56.0
Dyson Cote	40	0.05	9.63	24.1	200	66.56	85.70	42.8
Chapel Farm	40	0.07	9.65	24.1	200	86.21	105.35	52.7
Snowden Hill	40	0.05	9.63	24.1	200	66.48	85.62	42.8
Pond Farm	40	0.11	9.69	24.2	200	79.53	98.67	49.3
Dean Head	40	0.19	9.77	24.4	200	74.99	94.13	47.1
Horsely House	40	0.04	9.62	24.0	200	49.82	68.96	34.5
Bridleway: Pond Farm to Oakenshaw Spring	40	N/A	N/A	24.7	200	144.45	163.59	81.8
Bridleway: Mucky Lane	40	N/A	N/A	24.3	200	152.92	172.06	86.0
Crimbles Farm	40	0.03	9.61	24.0	200	44.31	63.45	31.7
Cote House Farm	40	0.04	9.62	24.0	200	39.94	59.08	29.5
Bridleway: Chapel Farm to Carr Head Farm	40	N/A	N/A	24.3	200	195.78	214.92	107.5
Avicoyd	40	0.04	9.62	24.1	200	50.48	69.62	34.8

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

Figures in bold indicate a value above the AQS/EAL

Table 4.2 indicates that long-term PECs of NO₂ are below the respective assessment metric at all applicable human receptors. With the exception of the Chapel Farm to Carr Head Farm Bridleway, 99.79 percentile 1-hour mean NO₂ PECs are below the AQS. Although, the PEC marginally exceeds the assessment metric at the Chapel Farm to Carr Head Farm Bridleway, for an exceedence to actually occur would require a member of the public to be present for more than 18 occasions when the plant was operational and which coincided with the worst-case meteorological conditions. Given the plant is only likely to be called up for 50 times per year, the probability of these independent factors coinciding is remote.

NO₂ process contribution isopleths for the annual mean and 1-hour mean can be found in Appendix A.

4.1.2 CO Impacts

Table 4.3 details the results of the impact assessment for CO.

Table 4.3 CO Impacts at Nearby Human Receptors

Receptors	Maximum 1-hour Mean				Maximum Rolling 8-hour Mean			
	EAL $\mu\text{g m}^{-3}$	PC $\mu\text{g m}^{-3}$	PEC $\mu\text{g m}^{-3}$	% PEC OF EAL	AQS $\mu\text{g m}^{-3}$	PC $\mu\text{g m}^{-3}$	PEC $\mu\text{g m}^{-3}$	% PEC OF AQS
Underbank Hall	30000	371.83	609.80	2.0	10000	125.13	363.10	3.6
Carr Head Farm	30000	523.76	761.73	2.5	10000	352.14	590.11	5.9
Dyson Cote	30000	551.58	789.55	2.6	10000	224.60	462.57	4.6
Chapel Farm	30000	468.72	706.69	2.4	10000	329.57	567.54	5.7
Snowden Hill	30000	458.88	696.85	2.3	10000	244.49	482.46	4.8
Pond Farm	30000	541.31	779.28	2.6	10000	204.32	442.29	4.4
Dean Head	30000	416.91	654.88	2.2	10000	201.44	439.41	4.4
Horsely House	30000	453.69	691.66	2.3	10000	174.53	412.50	4.1
Bridleway: Pond Farm to Oakenshaw Spring	30000	673.02	910.99	3.0	10000	382.41	620.38	6.2
Bridleway: Mucky Lane	30000	730.84	968.81	3.2	10000	629.01	866.98	8.7
Crimbles Farm	30000	286.71	524.68	1.7	10000	131.37	369.34	3.7
Cote House Farm	30000	286.77	524.74	1.7	10000	182.76	420.73	4.2
Bridleway: Chapel Farm to Carr Head Farm	30000	824.18	1062.15	3.5	10000	682.42	920.39	9.2
Avic Royd	30000	277.99	515.96	1.7	10000	183.13	421.10	4.2

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

Figures in bold indicate a value above the AQS/EAL

Table 4.3 indicates that PECs of CO are below the respective assessment metric at all applicable human receptors. Consequently, emissions from the engines are not expected to cause adverse effects upon the health of the local population.

4.1.3 PM₁₀ Impacts

Table 4.4 details the results of the impact assessment for PM₁₀.

Table 4.4 PM₁₀ Impacts at Nearby Human Receptors

Receptors	Annual Mean				90.41 percentile of 24-Hour Mean			
	AQS µg m ⁻³	PC µg m ⁻³	PEC µg ₃ m ⁻³	% PEC OF AQS	AQS* µg m ⁻³	PC µg m ⁻³	PEC µg m ⁻³	% PEC OF AQS
Underbank Hall	40	<0.01	12.79	32.0	50	0.10	25.68	51.4
Carr head Farm	40	<0.01	12.79	32.0	50	0.19	25.77	51.5
Dyson Cote	40	<0.01	12.79	32.0	50	0.13	25.72	51.4
Chapel Farm	40	<0.01	12.79	32.0	50	0.18	25.77	51.5
Snowden Hill	40	<0.01	12.79	32.0	50	0.14	25.72	51.4
Pond Farm	40	<0.01	12.79	32.0	50	0.26	25.85	51.7
Dean Head	40	<0.01	12.79	32.0	50	0.26	25.84	51.7
Horsely House	40	<0.01	12.79	32.0	50	0.01	25.59	51.2
Bridleway: Pond Farm to Oakenshaw Spring	40	N/A	N/A	N/A	50	0.59	26.17	52.3
Bridleway: Mucky Lane	40	N/A	N/A	N/A	50	0.08	25.67	51.3
Crimbles Farm	40	<0.01	12.79	32.0	50	0.01	25.59	51.2
Cote House Farm	40	<0.01	12.79	32.0	50	0.06	25.64	51.3
Bridleway: Chapel Farm to Carr Head Farm	40	N/A	N/A	N/A	50	0.46	25.04	52.1
Avice Royd	40	<0.01	12.79	32.0	50	0.02	25.60	51.2

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

Figures in bold indicate a value above the AQS/EAL

Table 4.4 indicates that PECs of PM₁₀ are below the respective assessment metrics at all applicable human receptors. Consequently, emissions from the engines are not expected to cause adverse effects upon the health of the local population.

4.1.4 SO₂ Impacts

Table 4.5 and 4.6 details the results of the impact assessment for SO₂.

Table 4.5 SO₂ 24-hour Mean Impacts at Human

Receptors	99.18 Percentile of 24-Hour Mean			
	AQS $\mu\text{g m}^{-3}$	PC $\mu\text{g m}^{-3}$	PEC $\mu\text{g m}^{-3}$	% PC OF AQS
Underbank Hall	125	35.64	45.20	36.2
Carr Head Farm	125	60.11	69.67	55.7
Dyson Cote	125	57.92	67.48	54.0
Chapel Farm	125	83.34	92.90	74.3
Snowden Hill	125	48.06	57.62	46.1
Pond Farm	125	57.63	67.19	53.8
Dean Head	125	40.20	49.76	39.8
Horsely House	125	23.63	33.19	26.5
Bridleway: Pond Farm to Oakenshaw Spring	125	124.32	133.88	107.1
Bridleway: Mucky Lane	125	78.88	88.44	70.8
Crimbles Farm	125	18.00	27.56	22.1
Cote House Farm	125	24.84	34.40	27.5
Bridleway: Chapel Farm to Carr Head Farm	125	148.44	158.00	126.4
Avice Royd	125	24.83	34.39	27.5

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

Figures in bold indicate a value above the AQS/EAL

Table 4.6 SO₂ 15-minute and 1-hour Mean Impacts at Human

Receptors	99.9 Percentile of 15-Minute Mean				99.73 Percentile of 1-Hour Mean			
	AQO µg m ⁻³	PC µg m ⁻³	PEC µg m ⁻³	% PC OF ST AQO	AQS µg m ⁻³	PC µg m ⁻³	PEC µg m ⁻³	% PC OF AQS
Underbank Hall	266	141.59	151.15	56.8	350	104.08	113.64	32.5
Carr Head Farm	266	291.43	300.99	113.2	350	196.38	205.94	58.8
Dyson Cote	266	184.03	193.59	72.8	350	137.55	147.11	42.0
Chapel Farm	266	238.58	248.14	93.3	350	181.73	191.29	54.7
Snowden Hill	266	177.38	186.94	70.3	350	134.75	144.31	41.2
Pond Farm	266	213.21	222.77	83.7	350	166.78	176.34	50.4
Dean Head	266	228.22	237.78	89.4	350	159.55	169.11	48.3
Horsely House	266	159.68	169.24	63.6	350	105.75	115.31	32.9
Bridleway: Pond Farm to Oakenshaw Spring	266	386.98	396.54	149.1	350	310.89	320.45	91.6
Bridleway: Mucky Lane	266	407.98	417.54	157.0	350	328.73	338.29	96.7
Crimbles Farm	266	126.66	136.22	51.2	350	91.12	100.68	28.8
Cote House Farm	266	127.93	137.49	51.7	350	77.44	87.00	24.9
Bridleway: Chapel Farm to Carr Head Farm	266	496.58	506.14	190.3	350	425.99	435.55	124.4
Avic Royd	266	154.04	163.60	61.5	350	105.96	115.52	33.0

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

Figures in bold indicate a value above the AQS/EAL

Tables 4.5 and 4.6 show that the 24-hour, 1-hour and 15-minute assessment metrics for SO₂ have been exceeded at the bridleway between Chapel Farm and Carr Head Farm. In addition, the SO₂ 15-minute AQO has been exceeded at Carr Head Farm, Mucky Lane and the bridleway linking Pond Farm and Oakenshaw Spring. It should be borne in mind that the exceedences of the 24-hour and 1-hour SO₂ assessment metrics are at bridleways, where members of the public are not expected to spend an hour or longer. Furthermore, as explained in Section 4.1.1, a breach of these Standards require a member of the public to be present for a number of occasions, depending on the metric (see Table 3.2), when the plant is operational and coincide with the worst-case meteorological conditions. Given the plant is only likely to be called up for 50 times per year, the probability of these independent factors coinciding is remote.

SO₂ process contribution isopleths for the 1-hour mean and the 15-minute mean can be found in Appendix B.

4.2 Impacts on Ecological Receptors

4.2.1 Aerial Concentrations

Table 4.7 and 4.8 summarise the results of the dispersion modelling assessment for estimating predicting atmospheric concentrations of NO_x and SO₂ at the ecological receptors considered in this study.

Table 4.7 NO_x Impacts at Nearby Ecological Receptors

Receptors	Annual Mean				Maximum 24-hour Mean			
	AQS µg m ⁻³	PC µg m ⁻³	PEC µg m ⁻³	% PEC OF AQS	EAL µg m ⁻³	PC µg m ⁻³	PEC µg m ⁻³	% PEC OF EAL
South Pennine Moors 1	30	<0.01	9.37	31.2	75	0.03	18.77	25.0
South Pennine Moors 2	30	<0.01	9.37	31.2	75	0.02	18.76	25.0

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

Table 4.8 SO₂ Impacts at Nearby Ecological Receptors

Receptors	Annual Mean SO ₂			
	AQS µg m ⁻³	PC µg m ⁻³	PEC µg m ⁻³	% PEC of AQS
South Pennine Moors 1	20	<0.01	4.74	23.7
South Pennine Moors 2	20	<0.01	4.74	23.7

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

Long-term NO_x PCs at the ecological receptors are below the relevant AQS and no sites are above the 1% threshold in the Environment Agency H1 guidance.

The 24 hour mean NO_x PCs at the ecological receptors are below the relevant AQS and no sites are above the 10% threshold in the Environment Agency H1 guidance.

Long-term SO₂ PCs at the ecological receptors are below the relevant AQS and no sites are above the 1% threshold in the Environment Agency H1 guidance.

4.2.2 Deposition

Table 4.9 contains the results of the deposition analysis for nitrogen and Table 4.10 those for total acidity.

Table 4.9 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)	%PC of CL _{min}
South Pennine Moors 1	5 - 10	0.004	26.527	26.531	<0.1
South Pennine Moors 2	5 - 10	0.003	26.527	26.530	<0.1

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)

Table 4.10 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}
South Pennine Moors 1	0.569 – 1.405	0.0032	2.4429	2.4461	0.56
South Pennine Moors 2	0.569 – 1.405	0.0025	2.4429	2.4454	0.44

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 contribution to the deposition rates from the engines is very small (<1%) when compared to the AQS, and unlikely to result in degradation of the ecologically-designated sites.

4.2.3 Exceedences of Short-term Assessment Metrics

As shown in Table 4.6, the model reported exceedences of the 15-minute AQO for SO₂ at Carr Head Farm and at each of the bridleway locations. As a farm can be considered as a location where a member of the public would be regularly exposed, and that it is reasonable to suggest a

member of the public may spend longer than 15 minutes on a bridleway, the probability of breaching the AQO at these locations has been calculated with the following formula:

$$P(E) = \frac{e^{-\mu} \mu^E}{E!}$$

Where

$$\mu = np$$

n = Number of events

p = Probability of a single event exceeding the AQO concentration

E = Required number of exceedences of the AQO concentration to breach AQO

The probabilities of breaching the 15-minute AQO for SO₂ at each of the locations where exceedences were reported are shown in Table 4.11.

Table 4.11 Probabilities of Breaching the 15-Minute AQO for SO₂

Receptors	$P(E)$
Carr Head Farm	1.54×10^{-43}
Bridleway: Pond Farm to Oakenshaw Spring	6.97×10^{-15}
Bridleway: Mucky Lane	3.66×10^{-21}
Bridleway: Chapel Farm to Carr Head Farm	1.39×10^{-10}

4.3 Assessment of Significance

Table 4.12 details the assessment of significance of increases in annual mean NO₂ and PM₁₀ against the guidance issued by EPUK for each receptor.

Table 4.12 Assessment of Significance

Receptor	Annual Mean NO ₂				Annual Mean PM ₁₀			
	Change in PC ¹ µg m ⁻³	PEC of Future Case µg m ⁻³	Magnitude of Change	Impact Descriptor	Change in PC ¹ µg m ⁻³	PEC of Future Case µg m ⁻³	Magnitude of Change	Impact Descriptor
Underbank Hall	0.04	11.31	Imperceptible	Negligible	4.74×10 ⁻⁴	12.79	Imperceptible	Negligible
Carr Head Farm	0.07	12.85	Imperceptible	Negligible	8.56×10 ⁻⁴	12.79	Imperceptible	Negligible
Dyson Cote	0.05	12.05	Imperceptible	Negligible	6.48×10 ⁻⁴	12.79	Imperceptible	Negligible
Chapel Farm	0.07	12.83	Imperceptible	Negligible	8.63×10 ⁻⁴	12.79	Imperceptible	Negligible
Snowden Hill	0.05	11.93	Imperceptible	Negligible	6.49×10 ⁻⁴	12.79	Imperceptible	Negligible
Pond Farm	0.11	14.87	Imperceptible	Negligible	1.55×10 ⁻³	12.79	Imperceptible	Negligible
Dean Head	0.19	18.62	Imperceptible	Negligible	1.94×10 ⁻³	12.79	Imperceptible	Negligible
Horsely House	0.04	11.45	Imperceptible	Negligible	2.84×10 ⁻⁴	12.79	Imperceptible	Negligible
Crimbles Farm	0.03	11.04	Imperceptible	Negligible	2.31×10 ⁻⁴	12.79	Imperceptible	Negligible
Cote House Farm	0.04	11.31	Imperceptible	Negligible	3.22×10 ⁻⁴	12.79	Imperceptible	Negligible
Avic Royd	0.04	11.69	Imperceptible	Negligible	3.10×10 ⁻⁴	12.79	Imperceptible	Negligible

Note

1. Change in PC between the baseline and future case

Table 4.12 indicates that the impacts of increases in annual mean NO₂ and PM₁₀ at all human receptors can be classed as 'negligible'. Thus, the air quality effects associated with emissions from the Hunshelf STOR power station are not considered to be significant.

5. Conclusions

This assessment has utilised detailed dispersion modelling to undertake an impact assessment of emissions to air from the proposed STOR power station at Hunshelf.

The pollutants covered by the assessment included:

- Oxides of nitrogen (NO_x as NO_2);
- Sulphur dioxide (SO_2);
- Particulate matter (PM_{10}); and
- Carbon monoxide (CO).

The impact assessment demonstrated that under the anticipated operational profile of the power station activities, the impacts at human receptor locations, can be defined as 'negligible' following the guidance issued by Environmental Protection UK.

This dispersion modelling assessment assumes the engines operate for full, hourly periods to predict both the long-term and short-term impacts of engine emissions. Since the operating periods and duration of operation are unknown, it has been assumed, as a worst-case approach, that the engines are operational for each hourly period during the STOR hours. This approach ensures that those meteorological conditions conducive to producing elevated ground level concentrations of pollutants are appropriately considered. If a random distribution of operational hours was assumed, there is the potential for the assessment to underestimate peak short-term ground level concentrations.

The assessment, therefore, assumes that, potentially, there are ~3,874 hours per annum when the engines could be operational. However, this approach is likely to significantly overestimate the actual impact of engines emissions, given that it is highly unlikely that the operation of the engines will consistently coincide with 'worst-case' meteorological conditions. The total number of STOR call ups that Green Frog Power is expecting is likely to be 50 per year with a typical maximum duration of 100 minutes per call, of which around half will be inside business hours. When the STOR call is received, Green Frog Power will operate the engines for the duration of the STOR call period. Once the call period finishes, Green Frog Power do not expect to be called again immediately.

6. References

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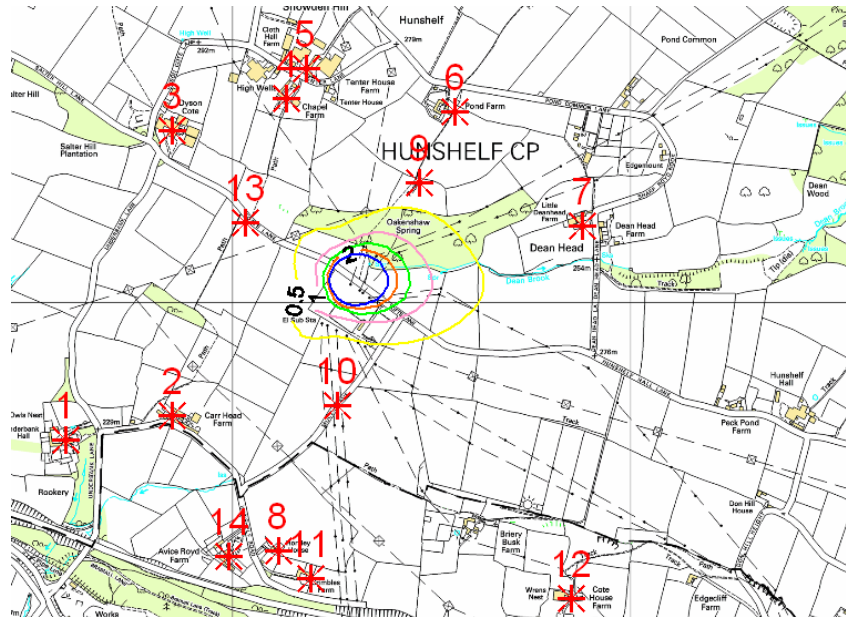
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Appendix A

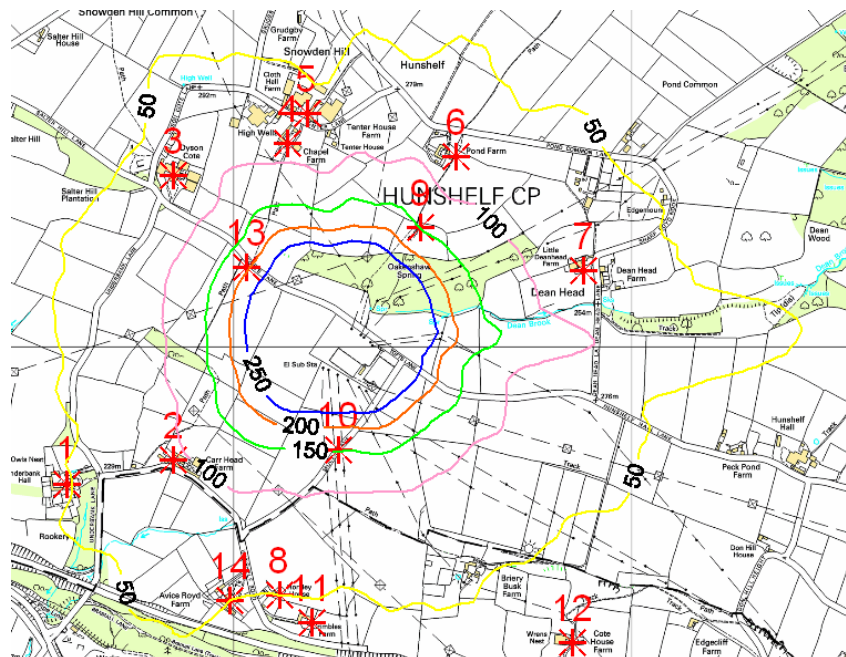
NO₂ Process Contribution Isopleths

1 Page

Annual Mean ($\mu\text{g m}^{-3}$)



99.79 Percentile of 1-Hour Mean ($\mu\text{g m}^{-3}$)

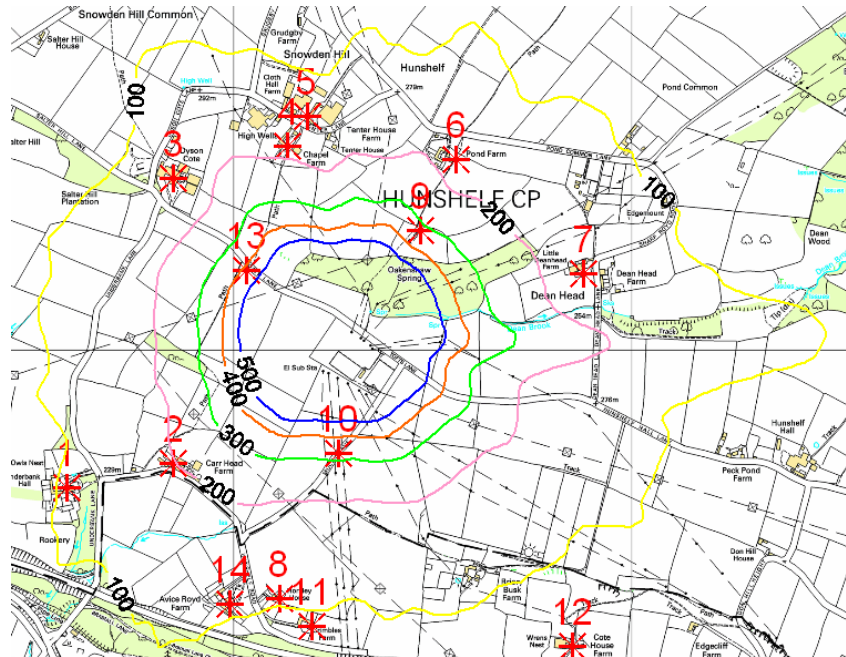


Appendix B

SO₂ Process Contribution Isopleths

1 Page

99.73 Percentile of 1-Hour Mean ($\mu\text{g m}^{-3}$)



99.9 Percentile of 15-Minute Mean ($\mu\text{g m}^{-3}$)

