Air Quality Impact Assessment of Emissions to Atmosphere from Viridis Swansea Capacity Mechanism Power Plant

June 2016

Amec Foster Wheeler Environment
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Report for

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Document revisions

No.	Details	Date
1	Final Report 15103i1	March 2015
2	Final Report 15103i2	November 2015
3	Remodelled with additional receptors Final Report 15103i3	February 2016
4	Final Report 15103i4	June 2016
5	Final Report 15103i5	June 2016

Executive summary

Purpose of this report

This report has been produced for the purpose of assessing the potential impacts on local air quality of emissions associated with the installation of engines generating electrical power at a site owned by Viridis 178 Ltd near Waunarlwydd, Swansea. The total electrical generation capacity of the installation will be approximately 40 MW. This assessment forms part of the Environmental Permit application for the development.

About the assessment

The plant will be operated by Viridis 178 Ltd and will generate electricity under the Capacity Mechanism to meet intermittent shortfalls in generating capacity on the National Grid. This will be one of several such facilities operated by Viridis 178 in the UK. The engines will be operated on natural gas. On average the plant will operate for around 5 hours per day at peak times, and a maximum of 1500 hours per year (though a lower number of hours is more likely based on historical data and projections from DECC).

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. The pollutants covered by the assessment are oxides of nitrogen (NO_x as NO_2) and carbon monoxide (CO). Other pollutants, including particulate matter (PM_{10} and $PM_{2.5}$) and sulphur dioxide (SO_2), have been screened out as unlikely to be of concern.

This assessment assumes the engines operate for full, hourly periods to predict both the long-term and short-term impacts of engine emissions. Concentrations were calculated for each hourly period during the typical availability windows. This approach ensures that those meteorological conditions conducive to producing elevated ground level concentrations of pollutants are appropriately considered. However, given that the engines will only run for about 5 hours a day and a maximum of 1500 hours per year, additional post-processing of raw modelled output has been undertaken, when appropriate.

Summary of conclusions

The impact assessment demonstrates that, under the anticipated operational profile of the plant, exceedances of any AQS, EAL, critical level or critical load are unlikely, or where exceedances are predicted due to the existing baseline concentration or deposition rate, the additional contribution from the plant is not considered to be significant. In addition, the impacts at human receptor locations can be defined as 'negligible' following the guidance issued by Environmental Protection UK. On this basis, air quality factors should not be considered a constraint to development of the site for Capacity Mechanism purposes.

Contents

1. Introduction

1.1 Background, aims and objectives

Amec Foster Wheeler Environment and Infrastructure UK Limited has been commissioned by Viridis 178 to undertake an assessment of the potential impacts resulting from emissions associated with the installation of engines generating electrical power at a site owned by Viridis 178 Ltd near Waunarlwydd, Swansea. The total electrical generating capacity of the installation will be approximately 40 MW. The plant will generate electricity under the Capacity Mechanism to meet intermittent shortfalls in generating capacity on the National Grid. This will be one of several such facilities operated by Viridis 178 in the UK.

The preferred generating unit is the Jenbacher Type 4 engine (J420). This is a spark ignition engine rated at 1298 kW electrical output, and capable of operating as a back-up unit in the event of a loss of power or to generate commercially exported power continuously. The engines will be operated on natural (mains) gas only with no oil back-up available on site. On average the plant will operate for around 5 hours per day at peak times, and a maximum of 1500 hours per year (although a lower number of hours is likely based on historical data and projections from DECC).

The purpose of this report is to assess the impacts of emissions to air from the proposed installation on local air quality in order to support the environmental permit application for the development.

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 proposed site is located in a mixed-use area of south Wales, with agriculture, industry, commercial and domestic usage in the vicinity. The site is about 1 km north of the village of Waunarlwydd and about 5 km west of the centre of Swansea. The grid reference for the site is 260650, 196383. Figure 1.1 provides a site location map.

Figure 1.1 Site location

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1.3 Sources of information

The information used to assess air quality includes:

- Process and emissions data provided by Viridis 178;
- Site layout from Viridis 178;
- Baseline air quality data from surveys undertaken by Government bodies, Local Authorities and third parties;
- Ordnance Survey maps of the local area; and
- Meteorological data supplied by Atmospheric Dispersion Modelling Limited.

1.4 Report structure

The remainder of the report is set out as follows:

Table 1.1 Report structure

Section	Aims and Objectives
Section 2	Describes the dispersion model, assessment methodology, model inputs and assumptions used in the assessment, and 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 5.1 atmospheric dispersion model developed and validated by Cambridge Environmental Research Consultants (CERC). The model was used to predict the ground level concentration of compounds emitted to atmosphere from the installation. 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 5 parameterises stability and turbulence in the atmospheric boundary layer by the Monin-Obukhov length and the boundary layer depth. This approach allows the vertical structure of the boundary layer to be more accurately defined than by the stability classification methods of earlier dispersion models. 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.

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 installation will consist of 27 engines, each within their own container building, with individual stacks a short distance above the top of the containers. Model input parameters are given in Table 2.1 and Table 2.2. The process data has been derived from manufacturer’s performance data provided by Viridis 178. Emissions data are based on manufacturer’s data of 250 mg Nm^{-3} for NO_x and 1000 mg Nm^{-3} for CO at exhaust reference conditions of 273 K, 101.3 kPa, 5% oxygen content and dry gas. Pollutants other than NO_x and CO have been screened out as unlikely to be of concern.

Table 2.1 Modelled stack characteristics

Parameter	Each engine
Release height (m)	7.2
Flue diameter (m)	0.35
Efflux flow rate (m s^{-1})	39
Efflux temperature (°C)	450

Table 2.2 Modelled stack emission rates

Pollutant	Emission rate (per engine) (g s^{-1})
NO_x	0.33
CO	1.33

Capacity Mechanism contracts with the National Grid require operators to guarantee that their plant be available at specific times and days of the week, known as 'availability windows'. This means that the engines will not be running continuously. The availability windows vary by season and year-on-year and are not known more than a year or so in advance. For the current modelling, it was assumed that the facility would be used between the times of 07:00 and 21:00. These windows have been reflected in the model setup by setting the emission rate to 100% of the Table 2.2 values during hours of the availability window, and setting the emission rate to zero outside those hours.

This procedure results in the emissions occurring for a total of 5110 hours per year. In fact, the engines will only operate for a maximum of 1500 hours per year. Therefore, when calculating annual mean concentrations, a correction factor of 1500/5110 ≈ 0.39 has been applied to the raw model results in accordance with the guidance in the EA/NRW's 'Air emissions risk assessment for your environmental permit' guidance:

"When your site doesn't operate all the time… Adjust your figures down, based on the percentage of the year that your site isn't operating. For example, a site that only operates January to June should reduce its PC figures by 50%."

Similarly, the facility is only expected to operate for a maximum of 5 hours per day when called. Therefore, maximum 8-hour mean and daily mean concentrations have been calculated by taking the maximum one-hour concentrations and multiplying by 5/8 = 0.625 and 5/24 = 0.208, respectively.

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 used meteorological data recorded at the Mumbles Head meteorological station from 2010 to 2014. The meteorological station is located approximately 10 km south of the site and is the nearest synoptic station to the site offering data in a suitable format for the model. The following figures show wind roses for each year modelled, illustrating the frequency of monitored wind direction and wind speed.

Figure 2.1 2010 wind rose

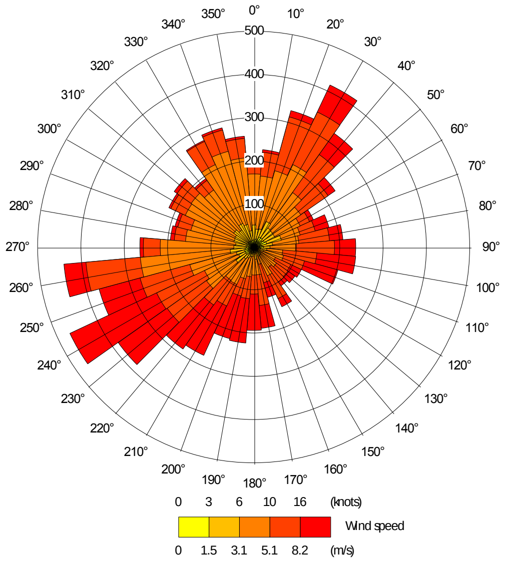


Figure 2.2 2011 wind rose

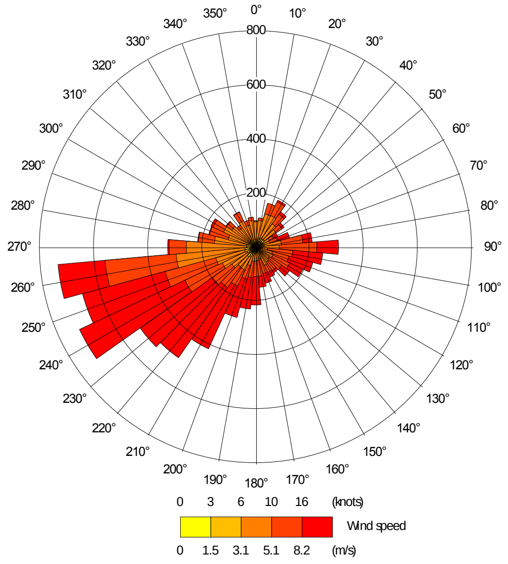


Figure 2.3 2012 wind rose

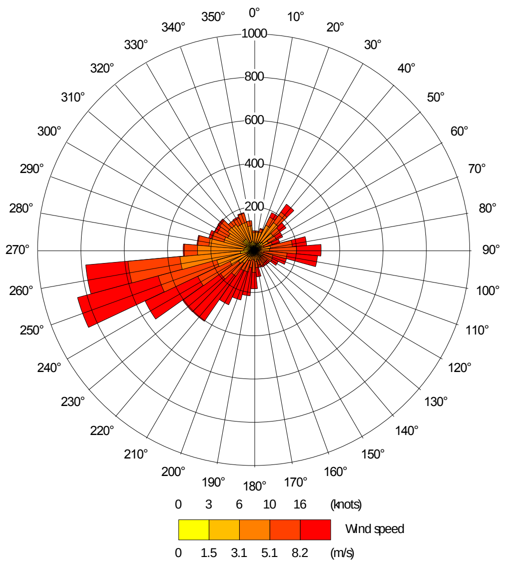


Figure 2.4 2013 wind rose

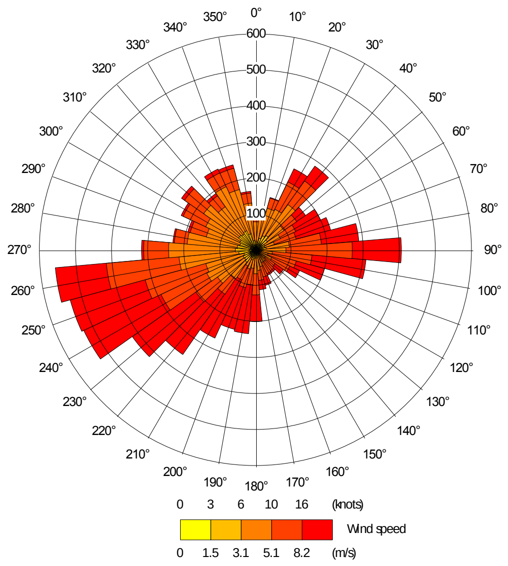
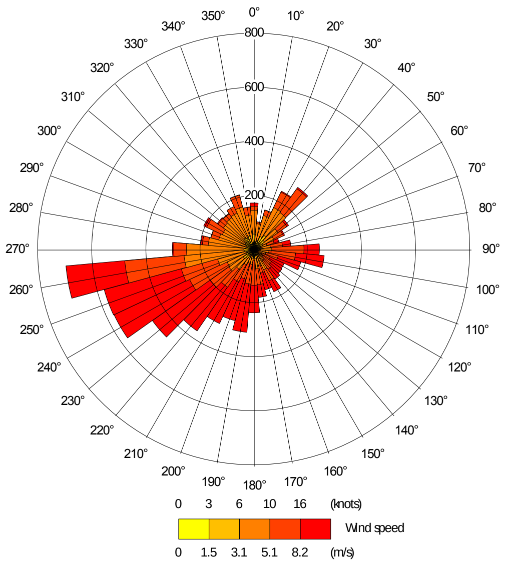


Figure 2.5 2014 wind rose



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.

Surface roughness

Roughness length, z_0, represents the aerodynamic effects of surface friction and is 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 2.3).

Table 2.3 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. With respect to elevated sources under neutral and stable conditions, increasing the roughness length can have complex and conflicting effects on ground level concentrations:

- The increased mixing can bring portions of an elevated plume down towards ground level, resulting in increased ground level concentrations close to the emission source; 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 with the distance of a receptor from the emission source.

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. Areas where moisture availability is greater will experience a greater proportion of incoming solar radiation released back to atmosphere in the form of latent heat, leaving less available in the form of sensible heat and, thus, decreasing convective turbulence. The modified Priestly-Taylor parameter (α) can be used to represent the amount of moisture available for evaporation. Holstag and van Ulden (1983) suggest values of 0.45 and 1.0 for dry grassland and moist grassland respectively.

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.

In view of the mix of built-up and open land around the site, a roughness length of 0.75 m was used.

2.5 Buildings

Any large 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 5*L* (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 containers housing the engines could influence the airflow close to the emissions sources. The engine containers consist of a large number of buildings grouped closely together, so for the purposes of modelling thy have been simplified down to just four buildings. Table 2.4 details the buildings as they are included in the model. ADMS performs further simplification, reducing the buildings to a single effective building, the parameters of which depend on wind direction.

Table 2.4 Buildings modelled

Building	X (m)	Y (m)	Height (m)	Length (m)	Width (m)	Angle (°)
Building1	260661	196414	3	12	23	180
Building2	260653	196391	3	12	31	180
Building3	260650	196376	3	12	39	180
Building4	260644	196353	3	12	51	180

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. The UK ADMLC provides a summary of the main effects of terrain on atmospheric flow and dispersion of pollutants (Hill *et al.*, 2005):

- *"Plume interactions with windward facing terrain features:*
  - *Plume interactions with terrain features whereby receptors on hills at a similar elevation to the plume 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; and*
  - *Recirculation regions on the upwind side of a hill can cause partial or complete entrainment of the plume, resulting in elevated ground level concentrations.*

- *Plume interactions with lee sides of terrain features:*
  - *Regions of recirculation behind steep terrain features can rapidly advect pollutants towards the ground culminating in elevated concentrations; and*
  - *As per the upwind case, releases into the lee of a hill in stable conditions can also be recirculated, resulting in increased ground level concentrations.*
- *Plume interactions within valleys:*
  - *Releases within steep valleys experience restricted lateral dispersion due to the valley sidewalls. During stable overnight conditions, inversion layers develop within the valley essentially trapping all emitted pollutants. Following sunrise and the erosion of the inversion, elevated ground level concentrations can result during fumigation events; and*
  - *Convective circulations in complex terrain due to differential heating of the valley side walls can lead to the impingement of plumes due to crossflow onto the valley sidewalls and the subsidence of plume centrelines, both having the impact of increasing ground level concentrations."*

These effects are most pronounced when the terrain gradients exceed 1 in 10, i.e. a 100 m change in elevation per 1 km step in the horizontal plane. Some of the gradients surrounding the site are above this criterion, so terrain data from the Ordnance Survey's Panorama dataset was included in the model.

2.7 Modelled domain and receptors

Modelled domain

A 2 km × 2 km Cartesian grid centred on the site was modelled, with a receptor resolution of 20 m, to assess the impact of atmospheric emissions from the site on local air quality. This resolution is considered suitable for capturing the maximum process contribution from site emissions, given that the receptors of interest are more than 100 m from the source.

In addition, a 30 km × 30 km Cartesian grid centred on the site was modelled, with a receptor resolution of 300 m, to supplement the specific receptors more than 1 km from the site (particularly the ecological receptors).

Human receptors

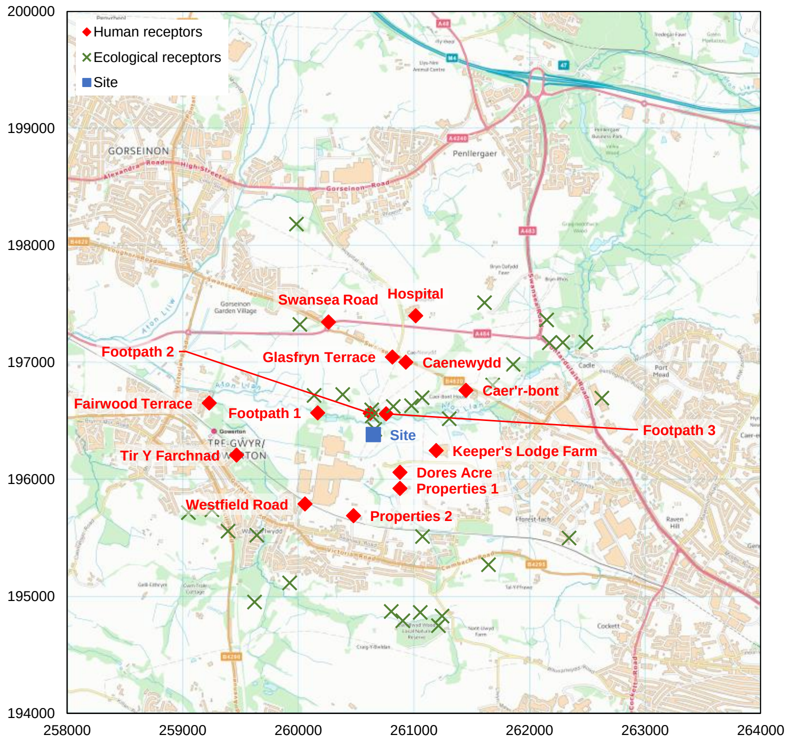
The receptors considered were chosen based on locations where people may be located and judged in terms of the likely duration of their exposure to pollutants and proximity to the site, following the guidance given in Section 3 of this report. Details of the locations of human receptors are given in Table 2.5 and Figure 2.6 below. Note that the Footpath 1–3 receptors are only relevant locations for 1-hour averaging periods, not for 8-hour averaging periods or annual means.

For the purposes of assessing air quality impacts, workplace locations have been excluded from the assessment in accordance with Schedule 1, Part 1, Paragraph 2 of the Air Quality Standards Regulations 2010. These Regulations are detailed in Section 3 of this report and do not differentiate between whether this is a workplace location under the control of the operator, or an off-site workplace location.

Table 2.5 Details of modelled human receptors

ID	Receptor Name	Easting (m)	Northing (m)	Height (m)
1	Keeper's Lodge Farm	261193	196246	1.6
2	Properties 1	260879	195923	1.6
3	Properties 2	260478	195689	1.6
4	Westfield Road	260058	195789	1.6
5	Tir Y Farchnad	259466	196207	1.6
6	Fairwood Terrace	259229	196652	1.6
7	Swansea Road	260261	197346	1.6
8	Hospital	261016	197398	1.6
9	Caer'r-bont	261451	196761	1.6
10	Caenewydd Farm House	260931	197002	1.6
11	Glasfryn Terrace	260815	197046	1.6
12	Dores Acre	260880	196060	1.6
13	Footpath 1	260168	196569	1.6
14	Footpath 2	260622	196565	1.6
15	Footpath 3	260760	196560	1.6

Figure 2.6 Location of modelled receptors near the site



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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 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 10 km of the installation (or 15 km coal or oil-fired power station); and*
> - *Sites of Special Scientific Interest (SSSIs), National Nature Reserves (NNRs), Local Nature Reserves (LNRs), local wildlife sites and ancient woodland within 2 km of the location.*
>
> *Some larger emitters may be required to screen to 10 km or 15 km for SSSIs."*

Following the above guidance, the following ecological receptors have been included in the assessment (Table 2.6, Figure 2.6 above and Figure 2.7). Although several of these are outside the above criteria, they have been included for completeness. Note that the parts of the Burry Inlet SPA and Ramsar site closest to the installation are coincident with the Carmarthen Bay and Estuaries SAC, so a single receptor serves for both sites. Ancient woodland sites within 2 km are shown in Figure 2.8.

Table 2.6 Details of modelled ecological receptors

Receptor Name	Easting (m)	Northing (m)	Height (m)	Receptor Type
Cadle Heath LNR	262627	196694	0	Wet heath with areas of species rich grassland, ponds, scrub and woodland.
Cwmllwyd Wood LNR	260905	194791	0	Mainly oak trees which are about 100 years old and were planted after a previous clearance. Also many birch, holly, willow and rowan as well as some large apple trees.
AW1	259984	198182	0	Ancient Semi Natural Woodland
AW2	260013	197324	0	Ancient Semi Natural Woodland
AW3	260136	196717	0	Ancient Semi Natural Woodland
AW4	260385	196725	0	Restored Ancient Woodland Site
AW5	260635	196594	0	Restored Ancient Woodland Site
AW6	260641	196543	0	Ancient Semi Natural Woodland
AW7	260662	196428	0	Ancient Semi Natural Woodland
AW8	260822	196624	0	Restored Ancient Woodland Site
AW9	260980	196630	0	Restored Ancient Woodland Site
AW10	261071	196698	0	Ancient Semi Natural Woodland
AW11	261306	196518	0	Restored Ancient Woodland Site
AW12	261682	196806	0	Ancient Semi Natural Woodland
AW13	261859	196983	0	Ancient Semi Natural Woodland
AW14	261612	197511	0	Restored Ancient Woodland Site
AW15	262150	197363	0	Restored Ancient Woodland Site

Receptor Name	Easting (m)	Northing (m)	Height (m)	Receptor Type
AW16	262173	197168	0	Ancient Semi Natural Woodland
AW17	262289	197170	0	Restored Ancient Woodland Site
AW18	262489	197174	0	Ancient Semi Natural Woodland
AW19	262343	195499	0	Ancient Semi Natural Woodland
AW20	261645	195271	0	Ancient Semi Natural Woodland
AW21	261075	195512	0	Ancient Semi Natural Woodland
AW22	261244	194832	0	Ancient Semi Natural Woodland
AW23	261213	194749	0	Ancient Semi Natural Woodland
AW24	261055	194863	0	Ancient Semi Natural Woodland
AW25	260805	194870	0	Ancient Semi Natural Woodland
AW26	259926	195115	0	Ancient Semi Natural Woodland
AW27	259621	194951	0	Ancient Semi Natural Woodland
AW28	259641	195522	0	Ancient Semi Natural Woodland
AW29	259392	195557	0	Ancient Semi Natural Woodland
AW30	259253	195740	0	Ancient Semi Natural Woodland
AW31	259049	195715	0	Ancient Semi Natural Woodland
Carmarthen Bay and Estuaries SAC	257866	196746	0	Marine areas, Sea inlets (82.1%) Tidal rivers, Estuaries, Mud flats, Sand flats, Lagoons (including saltwork basins) (13.7%)
Crymlyn Bog SAC	268559	194455	0	Bogs, Marshes, Water fringed vegetation, Fens (86%)
Gower Ash Woods SAC 1	252365	188124	0	Broad-leaved deciduous woodland (90.6%)
Gower Ash Woods SAC 2	255997	190197	0	Broad-leaved deciduous woodland (90.6%)
Gower Ash Woods SAC 3	257595	189297	0	Broad-leaved deciduous woodland (90.6%)
Gower Ash Woods SAC 4	259142	188247	0	Broad-leaved deciduous woodland (90.6%)
Gower Commons SAC 1	251553	191368	0	Heath, Scrub, Maquis and Garrigue, Phygrana (75.2%)
Gower Commons SAC 2	252616	192709	0	Heath, Scrub, Maquis and Garrigue, Phygrana (75.2%)
Gower Commons SAC 3	254947	191811	0	Heath, Scrub, Maquis and Garrigue, Phygrana (75.2%)
Gower Commons SAC 4	256573	187161	0	Heath, Scrub, Maquis and Garrigue, Phygrana (75.2%)
Gower Commons SAC 5	258434	193349	0	Heath, Scrub, Maquis and Garrigue, Phygrana (75.2%)
Killay Marsh LNR	259700	192700	0	Wet woodland, swamp and marsh, fen, wet heath, drier grassland and woodland

Receptor Name	Easting (m)	Northing (m)	Height (m)	Receptor Type
Priors Meadow LNR	257700	193800	0	Secondary mixed deciduous and wet woodland and lowland meadow

Figure 2.7 Location of modelled ecological receptors more than 2 km from the site

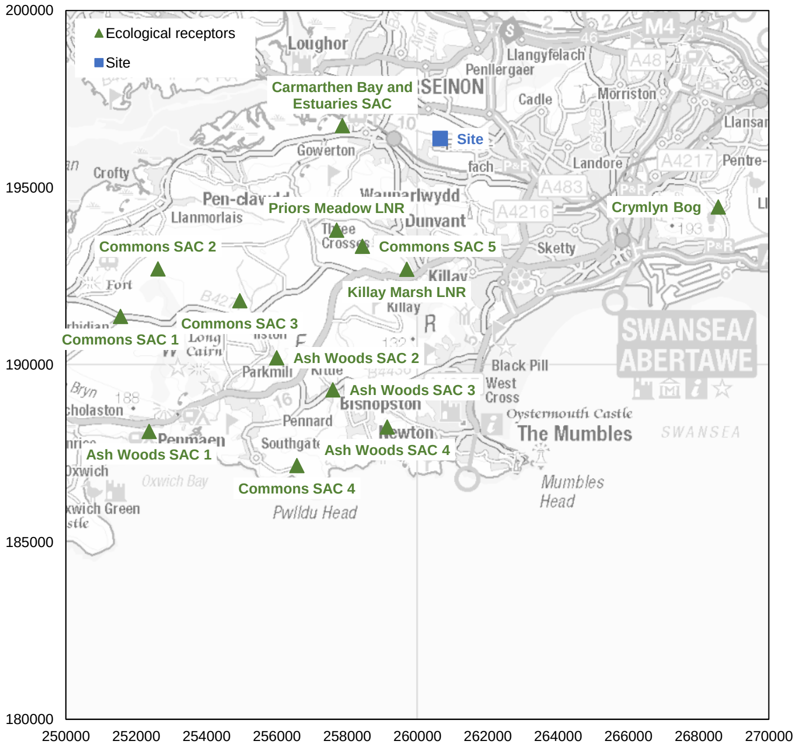

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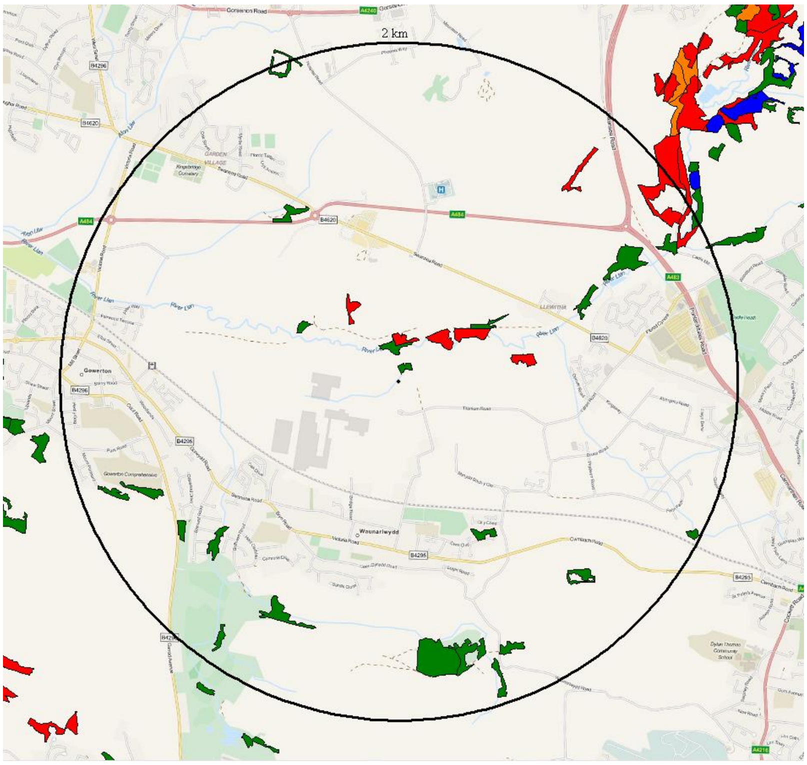
Figure 2.8 Ancient woodland within 2 km of proposed installation



Key:
Green: Ancient Semi Natural Woodland
Red: Restored Ancient Woodland Site
Blue: Plantation on Ancient Woodland Site
Orange: Ancient Woodland Site of Unknown Category
Map data from OpenStreetMap.

2.8 Conversion of NO to NO_2

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

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

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

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

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

However, at night, the photolysis of NO_2 ceases, allowing reaction R2 to promote the production of NO_2, at the expense of O_3, with a corresponding increase in the NO_2:NO_x ratio.

Near to an emission source of NO, the result is a net increase in the rate of reaction R2, suppressing O_3 concentrations immediately downwind of the source, and increasing further downwind as the concentrations of NO begin to stabilise to typical background levels (Gillani and Pliem 1996).

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

- **Screening Scenario:** 50% and 100% of the modelled NO_x process contributions should be used for short-term and long-term average concentration, respectively. That is, 50% of the predicted NO_x concentrations should be assumed to be NO_2 for short-term assessments and 100% of the predicted NO_x concentrations should be assumed to be NO_2 for long-term assessments;
- **Worst Case Scenario:** 35% and 70% of the modelled NO_x process contributions should be used for short-term and long-term average concentration, respectively. That is, 35% of the predicted NO_x concentrations should be assumed to be NO_2 for short-term assessments and 70% of the predicted NO_x concentrations should be assumed to be NO_2 for long-term assessments; and
- **Case Specific Scenario:** Operators are asked to justify their use of percentages lower than 35% for short-term and 70% for long-term assessments in their application reports.

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

2.9 Deposition

The predominant route by which emissions will affect land in the vicinity of a process is by deposition of atmospheric emissions. Ecological receptors can potentially 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 scavenging (within clouds) and washout scavenging (below clouds) 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 generally the predominant removal mechanism for pollutants such as NO_x, SO_2 and NH_3 (Fangmeier *et al.* 1994; Environment Agency, 2011). Dry deposition may be quantified from the near-surface plume concentration and the deposition velocity (Chamberlin and Chadwick, 1953);

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

where:

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

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

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

Environment Agency guidance AQTAG06 (Environment Agency, 2011) recommends deposition velocities for various pollutants dependent upon the habitat type (Table 2.7).

Table 2.7 Environment Agency recommended deposition velocities

Pollutant	Deposition Velocity (m s^{-1})	
	Grassland	Forest
NO_2	0.0015	0.003
SO_2	0.012	0.024
HCl	0.025	0.06
NH_3	0.02	0.03
HNO_3	0.04	0.04
SO_4^{2-} (Sulphate aerosol)	0.01	0.01

Source: Environment Agency (2011)

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

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

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

The critical loads used to assess the impact of compounds deposited to land which result in eutrophication and acidification are expressed in terms of kilograms of nitrogen deposited per hectare per year (kg N ha^{-1} y^{-1}) and kilo-equivalents deposited per hectare per year (keq ha^{-1} y^{-1}). The unit of 'equivalents' (eq) is used for the purposes of assessing acidification, rather than a unit of mass. The unit eq (1 keq ≡ 1,000 eq) refers to molar equivalent of potential acidity resulting from e.g. sulphur, oxidised and reduced nitrogen, as well as base cations. Essentially, it means 'moles of charge' and is a measure of how acidifying a particular chemical species can be.

To convert the predicted concentration in air of NO_2, SO_2, NH_3, or HNO_3, the following algorithm is used.

$$DR_i = C_i v_{d_i} f_i$$

Where:

DR_i = annual deposition of N or S (kg N ha^{-1} y^{-1} or kg S ha^{-1} y^{-1})

C_i = annual mean concentration of the ith chemical species (µg m^{-3})

v_{di} = deposition velocity of ith species (Table 2.7)

f_i = factor to convert from µg m^{-2} s^{-1} to kg ha^{-1} y^{-1} for the ith species

Table 2.8 provides the relevant conversion factors as extracted from AQTAG06.

Table 2.8 Environment Agency factors for converting modelled deposition rates

Pollutant	Conversion factor ($\mu g\ m^{-2}\ s^{-1}$ to $kg\ ha^{-1}\ y^{-1}$ for the *i*th species) Of	f_i
NO_2	N	96
SO_2	S	157.7
HNO_3	N	70.1
NH_3	N	259.7

Source: Environment Agency (2011)

In order to convert deposition of N or S to acid equivalents, the following relationships can be used:

- 1 keq $ha^{-1}\ y^{-1}$ = 14 kg N $ha^{-1}\ y^{-1}$; and
- 1 keq $ha^{-1}\ y^{-1}$ = 16 kg S $ha^{-1}\ y^{-1}$.

With respect to wet deposition, Environment Agency (2011) states:

> *"It is considered that wet deposition of SO_2, NO_2 and NH_3 is not significant within a short range."*

Therefore, the assessment only considers dry deposition of nutrifying and acidifying N and S compounds. The grassland deposition velocities from Table 2.7 are used for the ecological receptors in this assessment.

2.10 Special treatments

Other treatments

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

2.11 Existing ambient data

Continuous monitoring data

The City and County of Swansea has ten continuous monitoring stations within its borders, of which five measure NO_2 (a sixth, Morfa, closed in May 2011) (Swansea 2014). Most of these are roadside locations within the urban area of Swansea. One, Cwm Level Park, is an urban background location within the urban area of Swansea, approximately 5 km east of the Viridis Swansea site; between 2009 and 2013 this site measured annual mean NO_2 levels between 18.5 $\mu g\ m^{-3}$ and 23.4 $\mu g\ m^{-3}$. These locations are considered generally unrepresentative of relevant receptors near the Viridis Swansea site.

Passive monitoring data

The City and County of Swansea operates an extensive passive monitoring network consisting of diffusion tubes recording concentrations of NO_2 at approximately 250 locations within the district (Swansea 2014). All of these are at locations classified as roadside and are within urban areas, so are considered unrepresentative of relevant receptors near the Viridis Swansea site.

Defra mapped background concentrations

Defra, through its contractor Ricardo-AEA, maintains a nationwide model (the Pollution Climate Mapping (PCM) 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, NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2 and benzene. The PCM model is semi-empirical in nature: it uses data from the national atmospheric emissions inventory (NAEI) 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.

Annual mean background data from the PCM model for the receptors considered in this study is detailed in Table 2.9.

Table 2.9 Mapped annual mean background concentrations (µg m^{-3})

Receptor	NO_x	NO_2	CO
Keeper's Lodge Farm	12.31	9.61	218
Properties 1	11.66	9.13	213
Properties 2	11.66	9.13	213
Westfield Road	11.66	9.13	213
Tir Y Farchnad	10.76	8.53	207
Fairwood Terrace	10.76	8.53	207
Swansea Road	12.76	9.95	220
Hospital	13.60	10.57	222
Caer'r-bont	12.31	9.61	218
Caenewydd Farm House	12.76	9.95	220
Glasfryn Terrace	12.76	9.95	220
Dores Acre	10.38	8.19	214
Footpath 1	10.38	8.19	214
Footpath 2	10.38	8.19	214
Footpath 3	10.38	8.19	214
Cadle Heath LNR	16.56	12.66	224
Cwmllwyd Wood LNR	10.22	8.06	215
AW1	13.89	10.83	214
AW2	12.76	9.95	220
AW3	10.38	8.19	214
AW4	10.38	8.19	214
AW5	10.38	8.19	214
AW6	10.38	8.19	214
AW7	10.38	8.19	214
AW8	10.38	8.19	214
AW9	10.38	8.19	214
AW10	12.31	9.61	218
AW11	12.31	9.61	218
AW12	12.31	9.61	218
AW13	12.31	9.61	218
AW14	13.60	10.57	222
AW15	15.06	11.63	228
AW16	15.06	11.63	228
AW17	15.06	11.63	228
AW18	15.06	11.63	228
AW19	16.71	12.71	231
AW20	13.71	10.61	223
AW21	13.71	10.61	223
AW22	11.78	9.22	228
AW23	11.78	9.22	228
AW24	11.78	9.22	228
AW25	10.22	8.06	215
AW26	11.18	8.84	201
AW27	9.70	7.73	199
AW28	11.18	8.84	201
AW29	11.18	8.84	201
AW30	11.18	8.84	201
AW31	11.18	8.84	201
Carmarthen Bay SAC	9.57	7.63	196
Crymlyn Bog	13.36	10.37	225
Gower Ash Woods SAC 1	6.26	5.07	151
Gower Ash Woods SAC 2	7.28	5.88	163
Gower Ash Woods SAC 3	7.90	6.34	171
Gower Ash Woods SAC 4	8.38	6.72	186
Gower Commons SAC 1	6.35	5.15	153
Gower Commons SAC 2	6.39	5.19	157
Gower Commons SAC 3	6.91	5.59	159
Gower Commons SAC 4	6.67	5.39	163
Gower Commons SAC 5	8.77	7.02	188
Killay Marsh LNR	10.98	8.70	194
Priors Meadow LNR	8.04	6.46	180

Background deposition rates

The Air Pollution Information Service (APIS) website provides estimates of background deposition rates of nitrogen and sulphur. The background deposition rates for the ecological receptors considered in this study are detailed in Table 2.10.

Table 2.10 Background deposition rates

Receptor	Nitrogen deposition (kg N ha^{-1} y^{-1})	Acid deposition of nitrogen equivalents (keq ha^{-1} y^{-1})	Acid deposition of sulphur equivalents (keq ha^{-1} y^{-1})
Cadle Heath LNR	15.54	1.11	0.31
Cwmllwyd Wood LNR	13.16	0.94	0.24
AW1	13.72	0.98	0.32
AW2	15.54	1.11	0.31
AW3	15.54	1.11	0.31
AW4	15.54	1.11	0.31
AW5	15.54	1.11	0.31
AW6	15.54	1.11	0.31
AW7	15.54	1.11	0.31
AW8	15.54	1.11	0.31
AW9	15.54	1.11	0.31
AW10	15.54	1.11	0.31
AW11	15.54	1.11	0.31
AW12	15.54	1.11	0.31
AW13	15.54	1.11	0.31
AW14	15.54	1.11	0.31
AW15	15.54	1.11	0.31
AW16	15.54	1.11	0.31
AW17	15.54	1.11	0.31
AW18	15.54	1.11	0.31
AW19	15.54	1.11	0.31
AW20	15.54	1.11	0.31
AW21	15.54	1.11	0.31
AW22	13.16	0.94	0.24
AW23	13.16	0.94	0.24
AW24	13.16	0.94	0.24
AW25	13.16	0.94	0.24

Receptor	Nitrogen deposition (kg N ha^{-1} y^{-1})	Acid deposition of nitrogen equivalents (keq ha^{-1} y^{-1})	Acid deposition of sulphur equivalents (keq ha^{-1} y^{-1})
AW26	13.72	0.98	0.32
AW27	12.74	0.91	0.21
AW28	13.72	0.98	0.32
AW29	13.72	0.98	0.32
AW30	13.72	0.98	0.32
AW31	13.72	0.98	0.32
Carmarthen Bay SAC	13.72	0.98	0.32
Crymlyn Bog SAC	11.34	0.81	0.25
Gower Ash Woods SAC 1	15.12	1.08	0.21
Gower Ash Woods SAC 2	21.14	1.51	0.25
Gower Ash Woods SAC 3	18.48	1.32	0.23
Gower Ash Woods SAC 4	18.48	1.32	0.23
Gower Commons SAC 1	11.06	0.79	0.19
Gower Commons SAC 2	11.06	0.79	0.19
Gower Commons SAC 3	11.06	0.79	0.19
Gower Commons SAC 4	11.2	0.8	0.19
Gower Commons SAC 5	12.74	0.91	0.21
Killay Marsh LNR	12.74	0.91	0.21
Priors Meadow LNR	21.14	1.51	0.25

Local Air Quality Management

The City and County of Swansea, under its Local Air Quality Management (LAQM) obligations, continually reviews and assesses concentrations of key air pollutants in the borough to ascertain the requirement, or otherwise, to declare an Air Quality Management Area (AQMA) (Swansea 2014). Following the review and assessments undertaken to date, the Council has declared an AQMA for annual mean NO_2 covering three parts of Swansea:

- along a section of the A483 near the junction with the A4216 at Fforest-fach Cross, approximately 2 km east of the Viridis Swansea site;
- around the junction of the A4118 with the A4216 in Sketty, approximately 4 km south-east of the Viridis Swansea site; and
- the Hafod district of central Swansea, approximately 5 km east of the Viridis Swansea site.

The included receptors, particularly Keeper's Lodge Farm and Caer'r-bont, will bound the contribution from the site at the AQMAs.

Background concentrations and deposition rates used in the assessment

Annual mean background concentrations and deposition rates for the receptors have been derived from the data in Table 2.9 and Table 2.10.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 exceedance determined.

It is not technically rigorous to add predicted short-term or percentile concentrations to ambient background concentrations, since peak contributions from different sources would not necessarily coincide at the same time or at the same location. Without hourly ambient background monitoring data available it is difficult to make an assessment against the achievement or otherwise of the short-term assessment criteria. 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.

There are three other sources of emissions close to the site, namely Aleris Recycling, Timet UK Ltd and Green Frog Power 214 Ltd. Because of their proximity to the site (and to potentially sensitive receptors), they have been modelled explicitly and added to the background. The Aleris Recycling and Timet UK Ltd sources are listed on the Environment Agency's Pollution Inventory as releasing less than 100 t of NO_x per year each, and have been modelled using estimated stack characteristics and assuming a constant NO_x emission rate of 100 t/year.

Information on the Green Frog Power 214 Ltd installation was obtained from the operator to enable it to be modelled with the same level of accuracy as the subject of this assessment. The Green Frog Power 214 Ltd installation is a Short-Term Operating Reserve (STOR) facility, which is similar to the Capacity Mechanism plant in that it operates for short periods (a few hours per year, approximately 100 hours) when electricity demand exceeds generating capacity. For the purpose of calculating short-term concentrations, it has been assumed that both plants operate at the same time, so the maximum 1-hour concentration results include contributions from both sources.

2.12 Sensitivity analysis and uncertainty

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 5 years of meteorological data, with data reported from the year(s) predicting the highest ground-level concentrations at the nearest sensitive receptor for comparison with the AQS.

In addition, a specific sensitivity test has been run to assess the impact of the surface roughness parameter at selected receptors. For the 2010 met year, receptor concentrations have been calculated using roughness lengths of 0.2 m and 1.5 m in addition to the main 0.75 m used in the main assessment. This used a different configuration of engines that is currently proposed, so results are not exactly the same as those presented elsewhere in this report, but they demonstrate the effect of roughness length on modelled concentrations. The results are given in Table 2.11. This shows that, as expected, at the distances of interest, the increased mixing with larger roughness lengths reduces concentrations. Over the wide range of lengths used in the test, from 0.2 m (representative of pasture or the lower end of agricultural land) to 0.75 (representative of parkland, woodlands, villages, open suburbia) and 0.75 to 1.5 (representative of forests, cities, industrialised areas), the effect is typically up to about 20%. The difference tends to be slightly larger at greater distances from the source, although the correlation is not strong (R^2 = 0.20).

This demonstrates that while it is important to use a sensible value for roughness length (e.g. not to use 1.5 m in a rural area), staying within the range of recommended values for a land-use type will not have a large effect on the modelling results.

Table 2.11 Modelled NO_x concentrations for different roughness lengths

Receptor	Annual mean NO_x			% Difference from 0.75 m	
	0.2 m	0.75 m	1.5 m	0.2 m	1.5 m
Keepers Lodge Farm	2.44	2.45	2.40	0.3%	-1.4%
Properties 1	2.26	2.53	2.08	11.7%	-8.1%
Properties 2	1.13	1.14	1.07	1.0%	-5.1%
Westfield Road	0.88	1.04	0.77	17.9%	-12.0%
Tir Y Farchnad	0.41	0.42	0.39	3.9%	-3.8%
Fairwood Terrace	0.37	0.43	0.34	14.3%	-8.6%
Swansea Road	0.43	0.47	0.42	7.7%	-4.2%
Hospital	0.56	0.59	0.54	5.4%	-3.8%
Caer-r-bont	1.39	1.61	1.25	15.7%	-10.4%
Footpath 1	1.90	2.11	1.78	11.2%	-6.1%
Footpath 2	10.14	9.62	9.96	-5.1%	-1.8%
Footpath 3	13.63	13.67	12.95	0.3%	-5.0%
Carmarthen Bay SAC	0.13	0.15	0.12	15.6%	-7.7%
Crymlyn Bog	0.04	0.05	0.04	25.5%	-7.3%
Gower Ash Woods 1	0.01	0.01	0.01	14.8%	-13.1%
Gower Ash Woods 2	0.03	0.03	0.02	11.0%	-11.7%
Gower Ash Woods 3	0.03	0.03	0.03	9.7%	-7.9%
Gower Ash Woods 4	0.02	0.02	0.02	1.2%	1.0%
Gower Commons SAC 1	0.01	0.02	0.01	20.1%	-12.5%
Gower Commons SAC 2	0.02	0.02	0.01	25.2%	-10.8%
Gower Commons SAC 3	0.02	0.02	0.02	22.0%	-13.9%
Gower Commons SAC 4	0.02	0.02	0.02	9.3%	-6.6%
Gower Commons SAC 5	0.08	0.09	0.07	19.3%	-13.9%
Killay Marsh LNR	0.08	0.09	0.08	3.0%	-3.9%
Priors Meadow LNR	0.05	0.06	0.04	22.9%	-14.3%

Model uncertainty

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

- Conservation of mass - the entire mass of emitted pollutant remains in the atmosphere and no allowance is made for loss due to chemical reactions or deposition processes (although the standard Gaussian model can be modified to include such processes, as is the case with ADMS). Portions of the plume reaching the ground are assumed to be dispersed back away from the ground by turbulent eddies (eddy reflection);
- Steady state emissions - emission rates are assumed to be constant and continuous over the time averaging period of interest; and
- Steady state meteorology - no variations in wind speed, direction or turbulent profiles occur during transport from the source to the receptor. This assumption is reasonable within a few kilometres of a source but may not be valid for receptor distances in the order of tens of kilometres. For example, for a receptor 50 km from a source and with a wind speed of 5 m s^{-1} it will take nearly three hours for the plume to travel this distance during which time many different processes may change (e.g., the sun may rise or set and clouds may form or dissipate affecting the turbulent profiles). For this reason, Gaussian models are practically limited to predicting concentrations within ~20 km of a source.

As a result of the above, and in combination with other factors, not least attempting to replicate stochastic processes (e.g., turbulence) by deterministic methods, 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. As a result of these worst-case assumptions, the predicted results should be considered the upper limit of model uncertainty for a scenario where the actual site impact is determined. Therefore, the actual predicted ground level concentrations would be expected to be lower than those reported in this assessment and, in some cases, significantly lower.

3. Assessment criteria

3.1 Relevant legislation and guidance

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; and*
>
> *c) on the carriageway of roads; and on the central reservation of roads except where there is normally pedestrian access to the central reservation."*

UK legislation

The Air Quality Standards Regulations 2010

The Air Quality Standards Regulations 2010 (the 'Regulations') came into force on the 11 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; and

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 exceedances, 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 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.

The Environment Act 1995

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.

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.

The H1 guidance note includes an additional EAL of relevance to this assessment, namely a limit of 75 µg m^{-3} on daily mean NO_x at ecological receptors. This is based on guidance from the World Health Organization (WHO, 2000), which says:

> *"Experimental evidence exists that the CLE [critical level] decreases from around 200 µg/m^3 to 75 µg/m^3 when in combination with O_3 or SO_2 at or above their critical levels. In the knowledge that short-term episodes of elevated NOx concentrations are generally combined with elevated concentrations of O_3 or SO_2, 75 µg/m^3 is proposed for the 24 h mean."*

3.2 Air quality impacts of the process

The atmospheric emissions of the following pollutants have been identified as requiring detailed dispersion modelling:

- Oxides of nitrogen (NO_x as NO_2); and
- Carbon monoxide (CO).

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

Table 3.1 Summary of the pollutants assessed

Pollutant	Description and effect on human health and the environment	Principal Sources
Oxides of Nitrogen (NO_x)	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%.
Carbon Monoxide (CO)	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.

3.3 Criteria appropriate to the assessment

Air Quality Standards, Objectives, Guidelines and Critical Levels

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/EAL	Averaging Period	Value (µg m^{-3})
NO_2	AQS	Annual mean	40
	AQS	1-hour mean, not to be exceeded more than 18 times a year (equivalent of 99.79 Percentile)	200
NO_x: Ecological Receptors	AQS	Annual mean	30
	EAL	Daily mean	75
CO	AQS	8-hour mean	10,000
	EAL	1-hour mean	30,000

Critical Loads relevant to the assessment

The Air Pollution Information Service (APIS) contains information on applicable critical loads for various habitats and species.

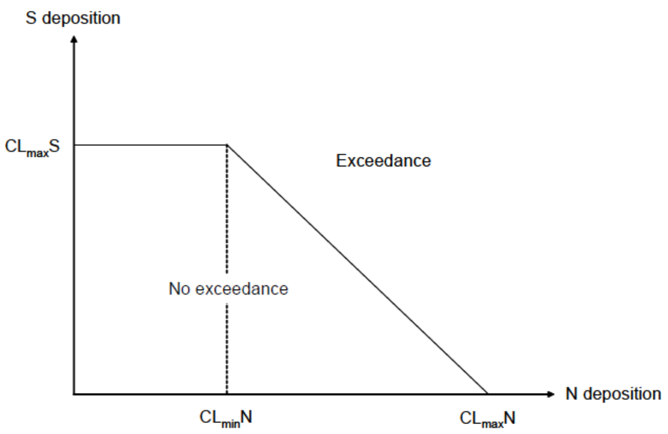
Eutrophication critical loads are given as a range and have units of kg N ha^{-1} y^{-1}. Generally, the lower end of the range should be used as a conservative assessment. The critical loads for acidification are more complicated, in that both the nitrogen and sulphur deposition fluxes must be considered at the same time. Therefore, a critical load function is specified for acidification, via the use of three critical load parameters:

- $CL_{max}S$ — the maximum critical load of sulphur, above which the deposition of sulphur alone would be considered to lead to an exceedance;
- $CL_{min}N$ — a measure of the ability of a system to "consume" deposited nitrogen (e.g. via immobilisation and uptake of the deposited nitrogen); and

- $CL_{max}N$ — the maximum critical load of acidifying nitrogen, above which the deposition of nitrogen alone would be considered to lead to an exceedance.

These three quantities define the critical load function shown in Figure 3.1.

Figure 3.1 Schematic Critical Load function for acidity



Source: Environment Agency (2011)

Information held on the APIS website has been reviewed in order to identify the main habitat/species features and their site relevant critical loads. Information is only available for the statutory designated sites (i.e. SACs, SSSIs etc.), not for Local Nature Reserves or ancient woodland with no other designation. Critical load data for these sites has been determined using the best available information on the primary habitat/species forming the sites. Table 3.3 summarises this information.

Table 3.3 Relevant Critical Load data for the assessment

Designated sites	Main notified habitat/species features in the assessment area	Minimum nutrient nitrogen deposition critical load (kg N ha^{-1} y^{-1})	CLmaxS (keq ha^{-1} y^{-1})	CLminN (keq ha^{-1} y^{-1})	CLmaxN (keq ha^{-1} y^{-1})
Carmarthen Bay and Estuaries SAC	Atlantic salt meadows; Salicornia and other annuals colonizing mud and sand; Estuaries	20	N/A	N/A	N/A
Crymlyn Bog	Transition mires and quaking bogs	5	0.342	0.321	0.661
Gower Ash Woods SAC	Tilio-Acerion forests of slopes, screes and ravines	15	0.322	0.142	0.666
Gower Commons SAC	Euphydryas aurinia - Marsh fritillary butterfly; European dry heaths; Northern Atlantic wet heaths with Erica tetralix; Coenagrion mercuriale - Southern damselfly; Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae) - Purple moor-grass meadows	10	0.160	0.223	0.526
Ancient woodland receptors and Cwmllwyd Wood LNR	Broadleaved, mixed and yew woodland	10	2.67	0.36	3.03

Public exposure

Guidance from the UK Government and Devolved Administrations makes clear that exceedances 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. As in Section 3.1, this also excludes workplaces. Table 3.4 provides an indication of those locations that may or may not be relevant for each averaging period.

Table 3.4 Examples of where the Air Quality Objectives should apply for human receptors

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.
8-hour mean	All locations where the annual mean objectives would apply, together with hotels. Gardens of residential properties[1].	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.

[1] For gardens, 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 against the assessment criteria detailed in Section 3. The predicted concentrations resulting from the process (i.e. the process contribution (PC)) are presented along with background concentrations and the percentage contribution that the predicted environmental concentrations (PEC) would make towards the relevant standard, objective or guideline value.

4.1 Meteorological data sensitivity analysis

As described in Section 2.3, results were calculated separately for five different years of meteorological data (‘met year’). For each of the specific receptors and for each pollutant measure, the met year giving the highest concentration was determined, and the corresponding concentration is the one presented here. In other words, each of the individual results are the worst case for that measure. For plotting the concentration isopleths, a single met year was chosen, namely the year producing the highest annual mean NO_2 concentration at any point in the model domain. This means that some results in the tables of specific receptors will not accord exactly with the contour bandings on the figure (they will be higher in the tables).

4.2 Human health effects

Nitrogen dioxide (NO_2)

Predicted concentrations of annual mean NO_2 are given in Table 4.1, and contours are shown in Figure 4.1 and Figure 4.2 for the near field and far field respectively.

The maximum annual mean NO_2 PEC at any relevant human receptor location is predicted as 22.6 µg m^{-3} or 56% of the AQS at Dores Acre. This receptor also experiences the greatest change in concentrations from baseline levels, namely 1.2 µg m^{-3}.

Table 4.1 Maximum PCs and PECs for annual mean NO_2

Receptor	Annual mean NO_2			
	AQS ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	PEC ($\mu g\ m^{-3}$)	% PEC of AQS
Keeper's Lodge Farm	40	0.96	20.76	51.9%
Properties 1	40	0.75	17.81	44.5%
Properties 2	40	0.39	13.50	33.7%
Westfield Road	40	0.30	12.13	30.3%
Tir Y Farchnad	40	0.19	10.56	26.4%
Fairwood Terrace	40	0.15	10.00	25.0%
Swansea Road	40	0.18	11.68	29.2%
Hospital	40	0.22	12.72	31.8%
Caer'r-bont	40	0.71	16.51	41.3%
Caenewydd Farm House	40	0.56	15.08	37.7%
Glasfryn Terrace	40	0.43	13.93	34.8%
Dores Acre	40	1.16	22.58	56.4%

Figure 4.1 NO_2 annual mean process contribution with 2011 meteorology — near field

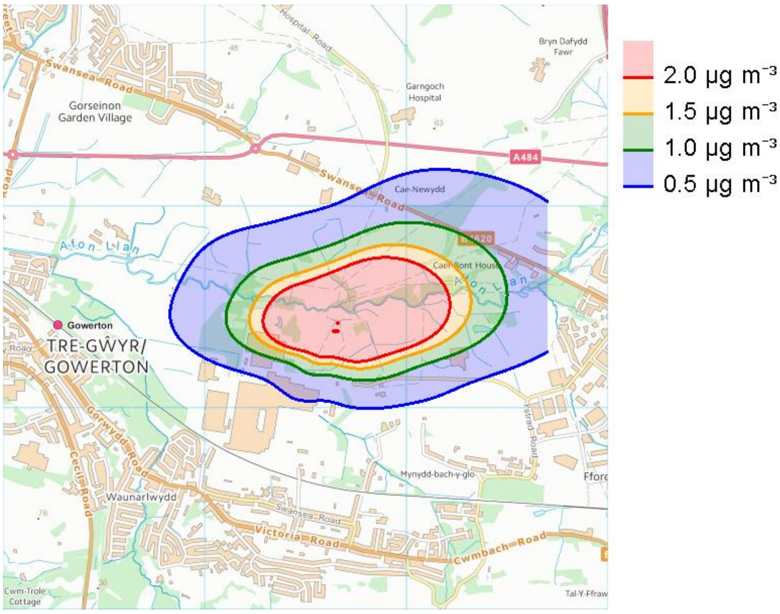


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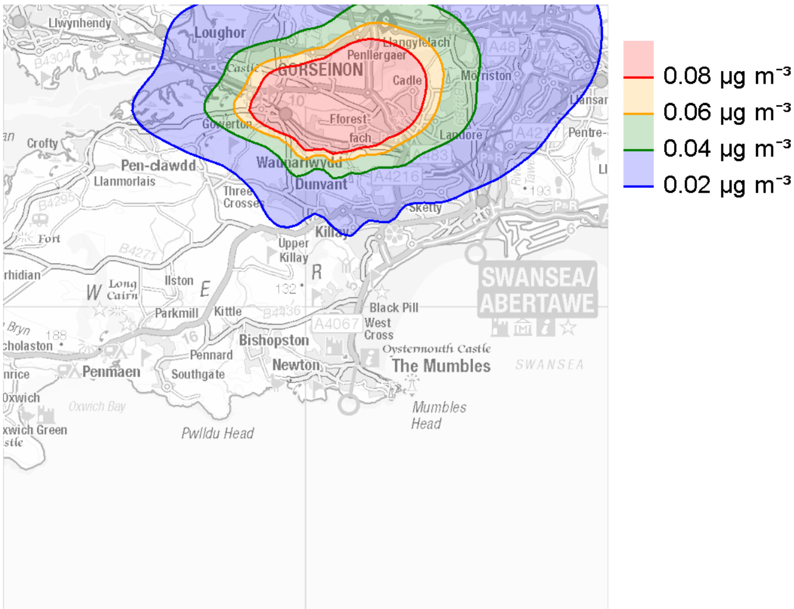
Figure 4.2 NO_2 annual mean process contribution with 2011 meteorology — far field



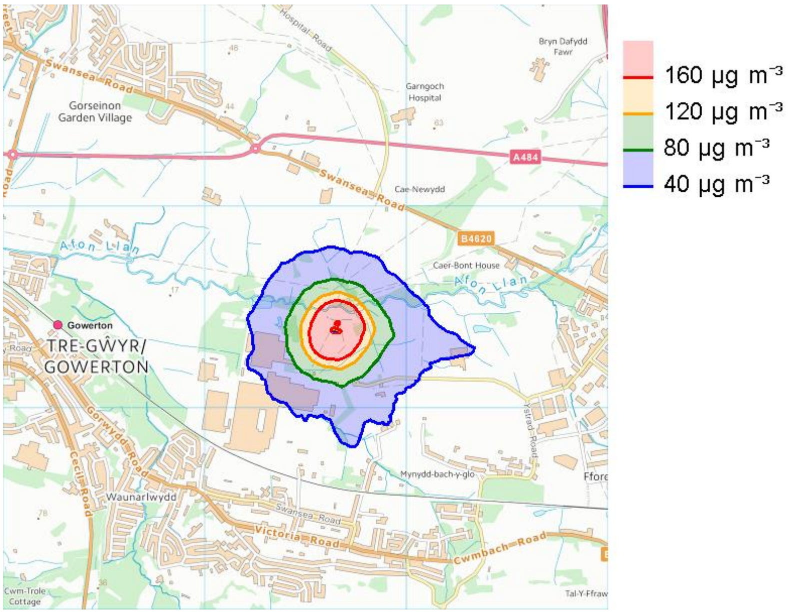
Predicted concentrations of the 99.79 percentile 1-hour mean NO_2 are given in Table 4.2, and contours are shown in Figure 4.3 (for the near field only, since it is not relevant for ecological receptors).

Table 4.2 Maximum PCs and PECs for 99.79th percentile 1-hour mean NO_2

Receptor	99.79 percentile 1-hour mean NO_2			
	AQS (µg m^{-3})	PC (µg m^{-3})	PEC (µg m^{-3})	% PEC of AQS
Keeper's Lodge Farm	200	43.28	563.56	281.8%
Properties 1	200	39.82	502.78	251.4%
Properties 2	200	20.49	279.44	139.7%
Westfield Road	200	17.94	263.74	131.9%
Tir Y Farchnad	200	10.37	154.79	77.4%
Fairwood Terrace	200	8.58	114.50	57.3%
Swansea Road	200	10.79	173.01	86.5%
Hospital	200	12.48	179.09	89.5%
Caer'r-bont	200	19.05	245.05	122.5%
Caenewydd Farm House	200	22.13	346.69	173.3%
Glasfryn Terrace	200	18.10	254.74	127.4%
Dores Acre	200	48.97	778.77	389.4%
Footpath 1	200	29.47	327.85	163.9%
Footpath 2	200	120.18	1392.37	696.2%

Receptor	99.79 percentile 1-hour mean NO_2			
	AQS ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	PEC ($\mu g\ m^{-3}$)	% PEC of AQS
Footpath 3	200	104.73	1494.04	747.0%

Figure 4.3 NO_2 99.79th percentile 1-hour mean process contribution with 2010 meteorology



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The maximum 99.79 percentile 1-hour mean NO_2 PEC at any relevant human receptor location is predicted as 1494 $\mu g\ m^{-3}$ or 747% of the AQS at the Footpath 2 receptor, with the PC at this receptor being 120.18 $\mu g\ m^{-3}$ or 60% of the AQS. The maximum 99.79 percentile 1-hour mean NO_2 PEC at any non-footpath receptor location is predicted as 779 $\mu g\ m^{-3}$ or 390% of the AQS at the Dores Acre receptor, with a PC of 49 $\mu g\ m^{-3}$ or 25% of the AQS.

As previously noted, these results are based on the pessimistic assumption that the plant is operating during those hours/weather conditions that give the highest concentrations, so the numbers are overestimated.

Additionally, for there to be relevant exposure, a member of the public would need to be present at that same location for a full hourly period in each instance and for a total number greater than 18 such occasions per year while the plant is operating, the wind is blowing towards the receptor and the other meteorological conditions are such as to produce unusually high concentrations there. Such events are not expected to coincide for footpath receptors, particularly given the transient nature of this type of receptor where members of the public are only likely to be present at that single location for a few minutes at a time, i.e. there would not be relevant exposure in relation to the averaging period of the AQS.

However, for residential receptors, there is the potential for relevant exposure in relation to the averaging period of the AQS. Additional probabilistic analysis has therefore been undertaken to quantify the likelihood of 1-hour mean NO_2 PECs exceeding 200 $\mu g\ m^{-3}$ on more than 18 occasions for the residential receptor predicted to experience the highest potential number of exceedences (Dores Acre).

The cumulative probability (*P*) of exceeding 200 $\mu g\ m^{-3}$ on more than 18 occasions in a single year can be calculated assuming a Poisson distribution to the exceedences (*E*):

$$P(E > 18) = 1 - P(E \leq 18)$$

Where:

$$P(E \leq 18) = \sum_{E=0}^{E=18} \frac{\mu^E e^{-\mu}}{E!}$$

And where:

$\mu = np$

n = actual number of events/operational hours per annum

p = probability of the PEC for any single event/hour exceeding 200 µg m^{-3}

In order to calculate p, the model is run with an exceedence threshold equating to a PEC of 200 µg m^{-3} entered in to the model output setup. However, as the model outputs NO_x concentrations (as opposed to NO_2) and does not consider other non-modelled background contributions (these are added in during the results post-processing), an equivalent exceedence threshold needs to be calculated such that the exceedence relates directly to NO_2 PECs as opposed to NO_x PCs. This is obtained as follows:

$$Exceedence\ threshold = \frac{200 - Background_{ST}}{0.35}$$

Here, 200 is the AQS concentration and 0.35 the short-term NO_x:NO_2 conversion factor. For each hour of met data that the model predicts a concentration above this threshold for a specific receptor, an increment of 1 is added to a running counter. For each year of met data, p is therefore calculated as:

$$p = \frac{1}{N_{met}} \cdot \sum_{i=1}^{N_{met}} \chi_i$$

Where:

N_{met} = modelled number of met lines where the plant could potentially be operating (in this case 5,110 hours per year)

χ = 1 if the modelled hourly mean concentration is above the exceedence threshold during the *i*th hour of met data, else χ = 0.

From analysis of the different source group contributions, it becomes evident that 1-hour mean PECs greater than 200 µg m^{-3} only occur when the Capacity Mechanism plant is operating in conjunction with the adjacent STOR plant. The limit on the maximum number of hours of the STOR plant operation in any year (as opposed to the Swansea Capacity Mechanism Power Plant maximum annual operating hours) therefore becomes the value of n in the equation above, since an exceedence cannot occur when the Capacity Mechanism plant is operational but the adjacent STOR plant is not.

Based on a maximum number of 100 simultaneous operational hours of both the Swansea Capacity Mechanism Power Plant and adjacent STOR plant (i.e. n = 100), the probability of the PEC exceeding 200 µg m^{-3} at the worst-case residential receptor location more than 18 times (and thus breaching the AQS) is predicted as 0.97%, equivalent to a 1 in 103 year event. The probability distribution function, which demonstrates the individual probability of experiencing a specific number of exceedences, is presented as Figure 4.4. This demonstrates the most likely number of PEC values exceeding 200 µg m^{-3} is 10 i.e. compliant with the AQS.

Furthermore, in the last 3 years during which the STOR plant has been operational, the average number of operational hours has been just 24 hours per annum. Based on this more realistic number, the probability of the PEC exceeding 200 µg m^{-3} more than 18 times at the worst-case residential receptor location reduces dramatically to 2.37x10^{-11}, equivalent to a 1 in 42 billion year event, and with the most likely number of exceedences, based on the probability distribution in Figure 4.5, being 2.

Additionally, there are a number of other qualitative factors which have not been part of the quantitative analysis and which would reduce the above probabilities even further:

- There is an inherent assumption in the analysis that the STOR plant will always operate in conjunction with the Capacity Mechanism plant. This will not necessarily be the case due to their respective energy production costs and the different manner/rationale upon which Capacity Mechanism and STOR plants are called upon by the National Grid;
- The majority of the average 24 hours per annum operation of the STOR plant in the last 3 years relates to routine testing of the plant to ensure the highest levels of reliability when the plant is eventually called. There has only been one 40-minute call from the National Grid in the last 2 years. This distinction is important, since the routine testing has generally been undertaken outside of peak periods, thereby further reducing the likely overlap between operation of the STOR plant and the Capacity Mechanism plant (the latter being assumed to operate at peak periods in the modelling); and
- When STOR plants are called, their typical call duration is less than 15 minutes. Therefore, one-hour mean contributions from the STOR plant have been over-estimated by this assessment, which assumes the STOR plant is operational for full hourly periods.

Based on all of the above factors, the probability of 1-hour mean NO_2 PECs exceeding 200 µg m^{-3} on more than 18 occasions in a calendar year, and thus breaching the AQS, is likely to be so low that it could not be considered a credible event.

It is also important to highlight that further analysis indicates that the probability distribution at the worst-case residential location receptor is not affected by operation of the Capacity Mechanism plant i.e. the probability of exceedence is constant between the existing baseline scenario and the scenario with the Capacity Mechanism plant in operation. This highlights that the exceedences are driven purely by operation of the STOR plant.

Figure 4.4 Probability distribution for the number of occasions NO_2 PECs exceed 200 µg m^{-3} based on 100 annual operational hours the STOR plant

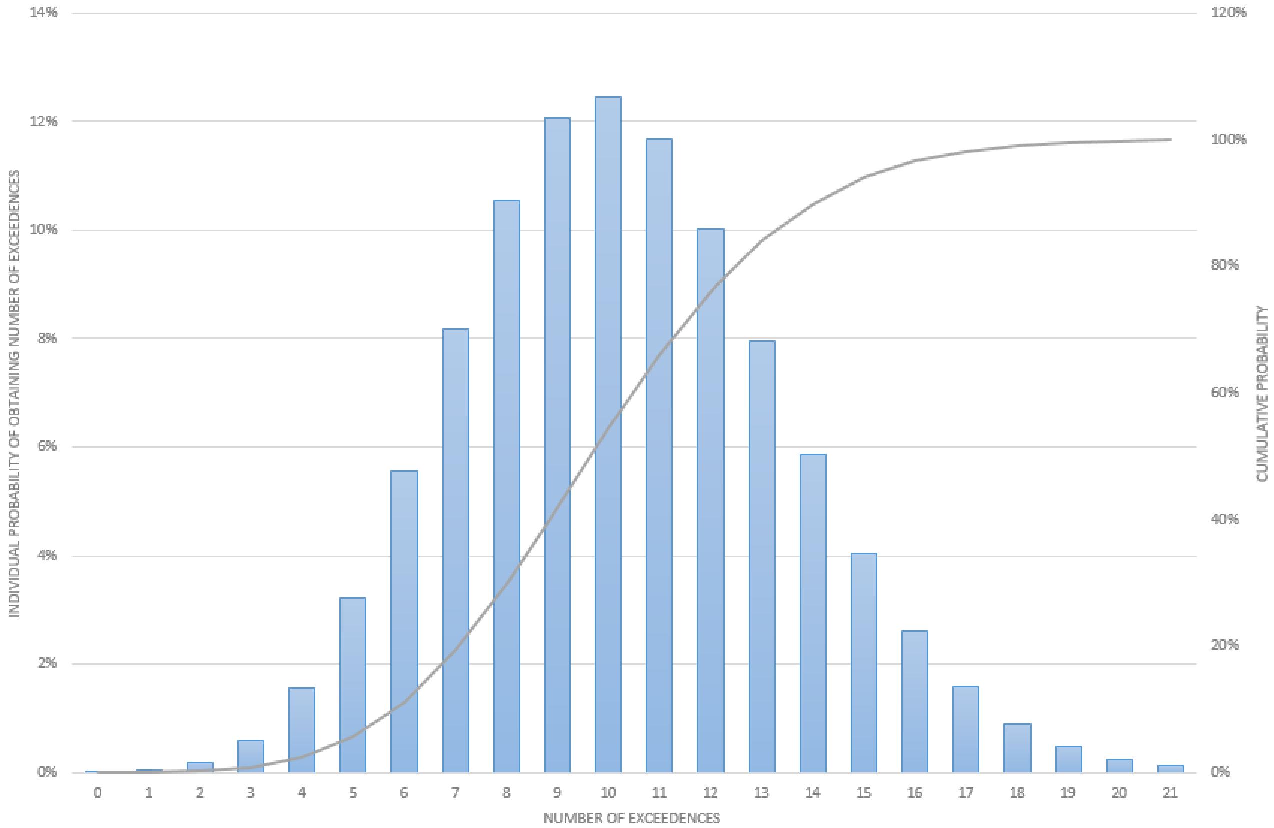
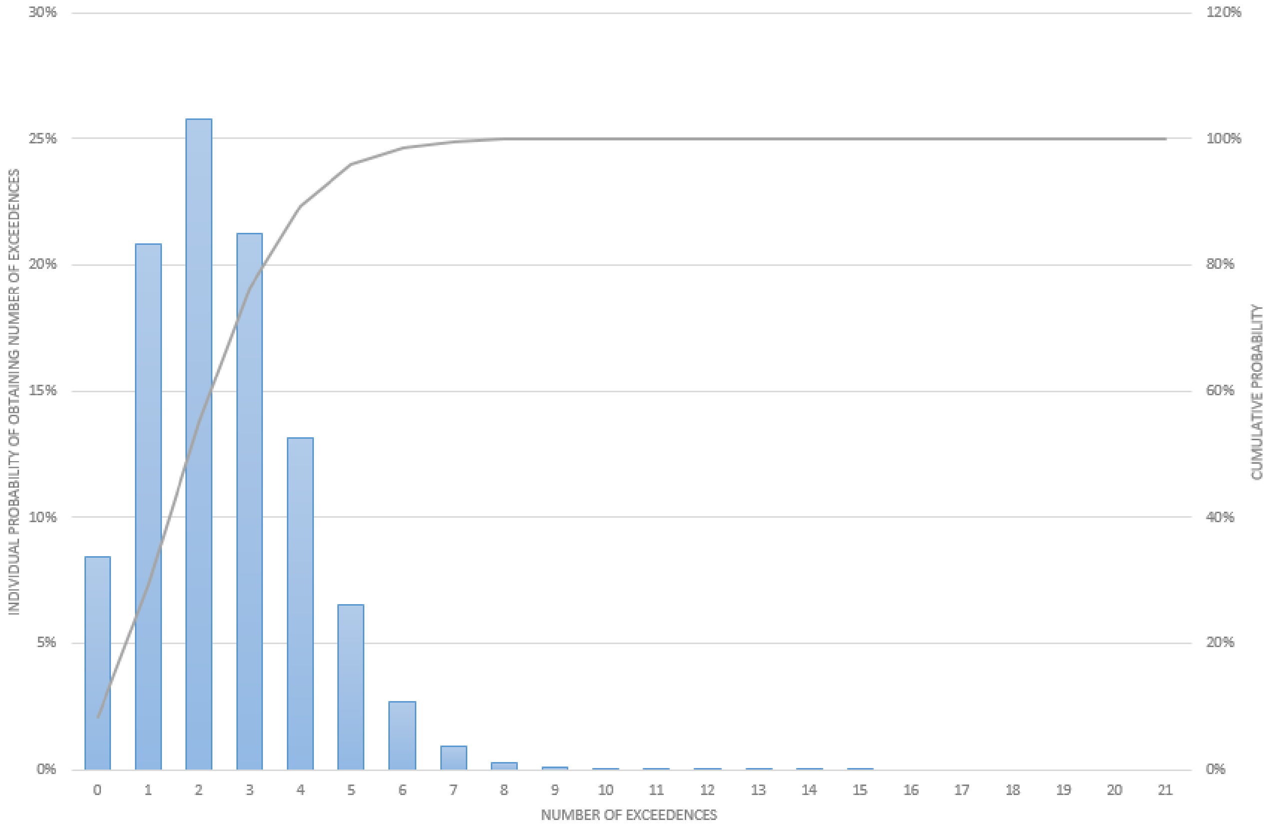


Figure 4.5 Probability distribution for the number of occasions NO_2 PECs exceed 200 µg m^{-3} based on 24 annual operational hours the STOR plant



Carbon monoxide (CO)

Predicted concentrations of annual mean CO and the maximum rolling 8-hour mean CO are given in Table 4.3.

The maximum 1-hour mean CO PEC at any relevant human receptor location is predicted as 2175 µg m^{-3} or 7% of the EAL at the Footpath 2 receptor. The maximum rolling 8-hour mean CO PEC at any relevant human receptor location is predicted as 800 µg m^{-3} or 8% of the AQS at the Properties 1 receptor. On this evidence, emissions of CO from the installation are likely to have a negligible impact on human health.

Table 4.3 Maximum PCs and PECs for CO

Receptor	Maximum 1-hour mean CO				Maximum rolling 8-hour mean CO			
	EAL ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	PEC ($\mu g\ m^{-3}$)	% PEC of AQS	AQS ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	PEC ($\mu g\ m^{-3}$)	% PEC of AQS
Keeper's Lodge Farm	30,000	639	1178	3.9%	10,000	247	732	7.3%
Properties 1	30,000	663	1178	3.9%	10,000	315	800	8.0%
Properties 2	30,000	487	957	3.2%	10,000	119	560	5.6%
Westfield Road	30,000	382	853	2.8%	10,000	90	527	5.3%
Tir Y Farchnad	30,000	269	711	2.4%	10,000	58	478	4.8%
Fairwood Terrace	30,000	190	633	2.1%	10,000	41	459	4.6%
Swansea Road	30,000	327	811	2.7%	10,000	61	508	5.1%
Hospital	30,000	488	988	3.3%	10,000	49	501	5.0%
Caer'r-bont	30,000	395	899	3.0%	10,000	90	538	5.4%
Caenewydd Farm House	30,000	723	1257	4.2%	10,000	106	557	5.6%
Glasfryn Terrace	30,000	717	1220	4.1%	10,000	94	546	5.5%
Dores Acre	30,000	689	1231	4.1%	10,000	293	764	7.6%
Footpath 1	30,000	494	991	3.3%	N/A	N/A	N/A	N/A
Footpath 2	30,000	1649	2175	7.2%	N/A	N/A	N/A	N/A
Footpath 3	30,000	1477	2134	7.1%	N/A	N/A	N/A	N/A

4.3 Ecological effects

Critical Levels

Table 4.4 and Table 4.5 present the assessment of predicted NO_x concentrations against established critical levels for the ecological receptors considered in this study.

Table 4.4 Critical Levels assessment of annual mean NO_x

Receptor	Annual mean NO_x			
	Critical Level ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	PEC ($\mu g\ m^{-3}$)	% PEC of Critical Level
Cadle Heath LNR	30	0.27	13.00	43.3%
Cwmllwyd Wood LNR	30	0.15	12.20	40.7%
AW1	30	0.10	11.90	39.7%
AW2	30	0.21	12.16	40.5%
AW3	30	0.78	12.24	40.8%
AW4	30	1.13	12.73	42.4%

Receptor	Annual mean NO_x			
	Critical Level ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	PEC ($\mu g\ m^{-3}$)	% PEC of Critical Level
AW5	30	4.48	18.67	62.2%
AW6	30	7.01	22.39	74.6%
AW7	30	27.26	44.38	147.9%
AW8	30	4.42	18.66	62.2%
AW9	30	3.38	17.56	58.5%
AW10	30	2.20	13.73	45.8%
AW11	30	1.84	13.55	45.2%
AW12	30	0.71	11.78	39.3%
AW13	30	0.48	11.39	38.0%
AW14	30	0.29	17.17	57.2%
AW15	30	0.27	10.82	36.1%
AW16	30	0.32	14.60	48.7%
AW17	30	0.29	13.42	44.7%
AW18	30	0.26	10.98	36.6%
AW19	30	0.15	10.82	36.1%
AW20	30	0.19	10.91	36.4%
AW21	30	0.39	11.47	38.2%
AW22	30	0.15	10.87	36.2%
AW23	30	0.14	10.85	36.2%
AW24	30	0.16	10.93	36.4%
AW25	30	0.16	12.91	43.0%
AW26	30	0.20	13.24	44.1%
AW27	30	0.14	12.93	43.1%
AW28	30	0.18	13.12	43.7%
AW29	30	0.13	14.24	47.5%
AW30	30	0.13	15.76	52.5%
AW31	30	0.11	15.60	52.0%
Carmarthen Bay and Estuaries SAC	30	0.08	15.28	50.9%
Crymlyn Bog	30	0.02	15.13	50.4%
Gower Ash Woods SAC 1	30	0.01	16.74	55.8%
Gower Ash Woods SAC 2	30	0.02	13.77	45.9%

Receptor	Annual mean NO_x			
	Critical Level ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	PEC ($\mu g\ m^{-3}$)	% PEC of Critical Level
Gower Ash Woods SAC 3	30	0.02	13.77	45.9%
Gower Ash Woods SAC 4	30	0.01	11.83	39.4%
Gower Commons SAC 1	30	0.01	11.81	39.4%
Gower Commons SAC 2	30	0.01	11.82	39.4%
Gower Commons SAC 3	30	0.01	10.26	34.2%
Gower Commons SAC 4	30	0.01	11.23	37.4%
Gower Commons SAC 5	30	0.04	9.86	32.9%
Killay Marsh LNR	30	0.05	11.34	37.8%
Priors Meadow LNR	30	0.03	11.29	37.6%

Table 4.5 Critical Levels assessment of daily mean NO_x

Receptor	Daily mean NO_x			
	Critical Level ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	PEC ($\mu g\ m^{-3}$)	% PEC of Critical Level
Cadle Heath LNR	75	10.56	178.43	237.9%
Cwmllwyd Wood LNR	75	13.36	269.06	358.7%
AW1	75	9.67	158.85	211.8%
AW2	75	15.78	255.62	340.8%
AW3	75	26.36	439.58	586.1%
AW4	75	30.56	491.44	655.2%
AW5	75	72.87	883.77	1178.4%
AW6	75	99.83	1267.23	1689.6%
AW7	75	262.86	3416.76	4555.7%
AW8	75	58.20	1069.10	1425.5%
AW9	75	35.81	677.17	902.9%
AW10	75	31.92	555.95	741.3%
AW11	75	27.97	486.44	648.6%
AW12	75	16.96	271.73	362.3%
AW13	75	16.85	317.24	423.0%
AW14	75	16.57	327.58	436.8%
AW15	75	13.66	255.47	340.6%

Receptor	Daily mean NO_x			
	Critical Level ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	PEC ($\mu g\ m^{-3}$)	% PEC of Critical Level
AW16	75	12.12	316.80	422.4%
AW17	75	10.35	306.53	408.7%
AW18	75	11.44	266.98	356.0%
AW19	75	11.47	177.78	237.0%
AW20	75	12.98	252.29	336.4%
AW21	75	20.17	382.18	509.6%
AW22	75	11.79	202.32	269.8%
AW23	75	11.20	184.54	246.0%
AW24	75	12.93	202.49	270.0%
AW25	75	14.12	282.52	376.7%
AW26	75	15.02	204.98	273.3%
AW27	75	10.22	185.44	247.2%
AW28	75	14.99	215.54	287.4%
AW29	75	15.87	289.42	385.9%
AW30	75	17.40	298.37	397.8%
AW31	75	18.03	287.97	384.0%
Carmarthen Bay and Estuaries SAC	75	5.58	80.52	107.4%
Crymlyn Bog	75	3.47	57.61	76.8%
Gower Ash Woods SAC 1	75	1.56	31.97	42.6%
Gower Ash Woods SAC 2	75	2.71	44.77	59.7%
Gower Ash Woods SAC 3	75	2.20	49.21	65.6%
Gower Ash Woods SAC 4	75	2.66	48.84	65.1%
Gower Commons SAC 1	75	2.32	38.86	51.8%
Gower Commons SAC 2	75	2.81	41.34	55.1%
Gower Commons SAC 3	75	3.62	53.65	71.5%
Gower Commons SAC 4	75	1.84	36.27	48.4%
Gower Commons SAC 5	75	5.53	96.79	129.1%
Killay Marsh LNR	75	4.97	105.40	140.5%
Priors Meadow LNR	75	6.52	84.19	112.3%

The maximum annual mean NO_x PEC at any relevant receptor location is predicted as 44.4 µg m^{-3} or 178% of the AQS at the ancient woodland AW7 receptor. For this receptor, the PC is 27.3 µg m^{-3} or 91% of the AQS. At all other receptors the annual mean NO_x is less than the AQS.

The maximum daily mean NO_x PEC at any relevant receptor location is predicted as 3417 µg m^{-3} or 4556% of the AQS at the AW7 receptor. This exceedence is primarily influenced by emissions from the adjacent Green Frog 214 STOR power plant. As noted in Section 3.1, this EAL is based on WHO guidance which assumes that O_3 or SO_2 are present at or above their critical levels, which is unlikely to be the case. In addition, as previously noted, the calculations of daily mean NO_x are based on the pessimistic assumption that both the application plant and the adjacent Green Frog 214 STOR power plant are operating during all those hours that give the highest concentrations, so the numbers in Table 4.5 are overestimated.

Critical Loads

Table 4.6 presents the assessment of nitrogen deposition at the ecological receptors. The maximum nutrient nitrogen deposition rate is predicted to be 5.5 kg N ha^{-1} y^{-1} at the AW7 receptor, or 55% of the lower critical load. At the statutory designated sites (i.e. SACs, SPAs, Ramsar and SSSIs), the maximum modelled deposition rate is less than or equal to 0.01 kg N ha^{-1} y^{-1} and is always less than 0.1% of the corresponding lower critical load.

Table 4.6 Critical Loads assessment of nitrogen deposition

Receptor	Minimum Critical Load (kg N ha^{-1} y^{-1})	PC (kg N ha^{-1} y^{-1})	PEC (kg N ha^{-1} y^{-1})	% PC of Critical Load	% PEC of Critical Load
Cadle Heath LNR	10	0.03	15.57	0.28%	155.68%
Cwmllwyd Wood LNR	10	0.03	13.19	0.30%	131.90%
AW1	10	0.02	13.74	0.19%	137.39%
AW2	10	0.04	15.58	0.43%	155.83%
AW3	10	0.16	15.70	1.58%	156.98%
AW4	10	0.23	15.77	2.28%	157.68%
AW5	10	0.90	16.44	9.04%	164.44%
AW6	10	1.41	16.95	14.14%	169.54%
AW7	10	5.50	21.04	54.96%	210.36%
AW8	10	0.89	16.43	8.90%	164.30%
AW9	10	0.68	16.22	6.81%	162.21%
AW10	10	0.44	15.98	4.43%	159.83%
AW11	10	0.37	15.91	3.71%	159.11%
AW12	10	0.14	15.68	1.43%	156.83%
AW13	10	0.10	15.64	0.98%	156.38%
AW14	10	0.06	15.60	0.58%	155.98%
AW15	10	0.06	15.60	0.55%	155.95%
AW16	10	0.06	15.60	0.64%	156.04%
AW17	10	0.06	15.60	0.59%	155.99%

Receptor	Minimum Critical Load (kg N ha^{-1} y^{-1})	PC (kg N ha^{-1} y^{-1})	PEC (kg N ha^{-1} y^{-1})	% PC of Critical Load	% PEC of Critical Load
AW18	10	0.05	15.59	0.52%	155.92%
AW19	10	0.03	15.57	0.29%	155.69%
AW20	10	0.04	15.58	0.39%	155.79%
AW21	10	0.08	15.62	0.78%	156.18%
AW22	10	0.03	13.19	0.30%	131.90%
AW23	10	0.03	13.19	0.28%	131.88%
AW24	10	0.03	13.19	0.32%	131.92%
AW25	10	0.03	13.19	0.32%	131.92%
AW26	10	0.04	13.76	0.41%	137.61%
AW27	10	0.03	12.77	0.29%	127.69%
AW28	10	0.04	13.76	0.36%	137.56%
AW29	10	0.03	13.75	0.25%	137.45%
AW30	10	0.03	13.75	0.26%	137.46%
AW31	10	0.02	13.74	0.22%	137.42%
Carmarthen Bay and Estuaries SAC	20	0.01	13.73	0.04%	68.64%
Crymlyn Bog	5	<0.01	11.34	0.05%	226.85%
Gower Ash Woods SAC 1	15	<0.01	15.12	0.01%	100.81%
Gower Ash Woods SAC 2	15	<0.01	21.14	0.02%	140.95%
Gower Ash Woods SAC 3	15	<0.01	18.48	0.02%	123.22%
Gower Ash Woods SAC 4	15	<0.01	18.48	0.02%	123.22%
Gower Commons SAC 1	10	<0.01	11.06	0.01%	110.61%
Gower Commons SAC 2	10	<0.01	11.06	0.01%	110.61%
Gower Commons SAC 3	10	<0.01	11.06	0.01%	110.61%
Gower Commons SAC 4	10	<0.01	11.20	0.01%	112.01%
Gower Commons SAC 5	10	<0.01	12.74	0.04%	127.44%
Killay Marsh LNR	10	<0.01	12.74	0.05%	127.45%
Priors Meadow LNR	10	<0.01	21.14	0.03%	211.43%

With respect to acid deposition, Table 4.7 provides an assessment of the predicted deposition rates of acidic equivalents at the statutory designated sites and Figure 4.6, Figure 4.7 and Figure 4.8 plot these values in relation to the acid deposition critical load function. At these receptors, the PC accounts for less than 0.1% of the critical load function with any exceedence driven by the existing background concentration.

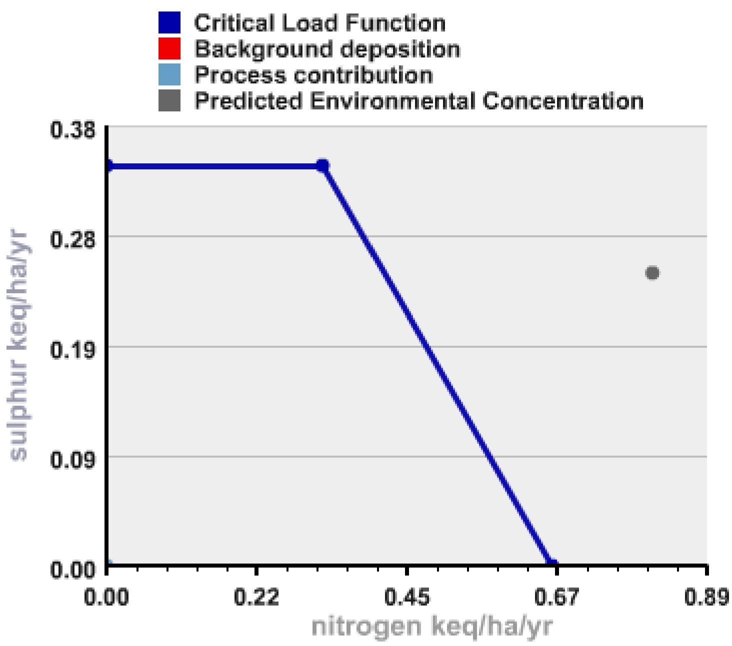
For the non-statutory sites, the maximum deposition rate of acidic equivalents occurs at the AW7 ancient woodland receptor. Here the PC is 12.7% of the critical load function but there is no PEC exceedence. For all other non-statutory sites, the PC is less than 1% of the critical load function.

Table 4.7 Critical Loads assessment of acid deposition

Receptor	Exceedance (keq ha^{-1} y^{-1})			% of CL function		
	PC	Back-ground	PEC	PC	Back-ground	PEC
Crymlyn Bog	no exceedance of CL function	0.4	0.4	<0.1%	160.4%	160.4%
Gower Ash Woods SAC 3	no exceedance of CL function	0.88	0.88	<0.1%	232.7%	232.7%
Gower Commons SAC 5	no exceedance of CL function	0.59	0.59	<0.1%	212.9%	212.9%

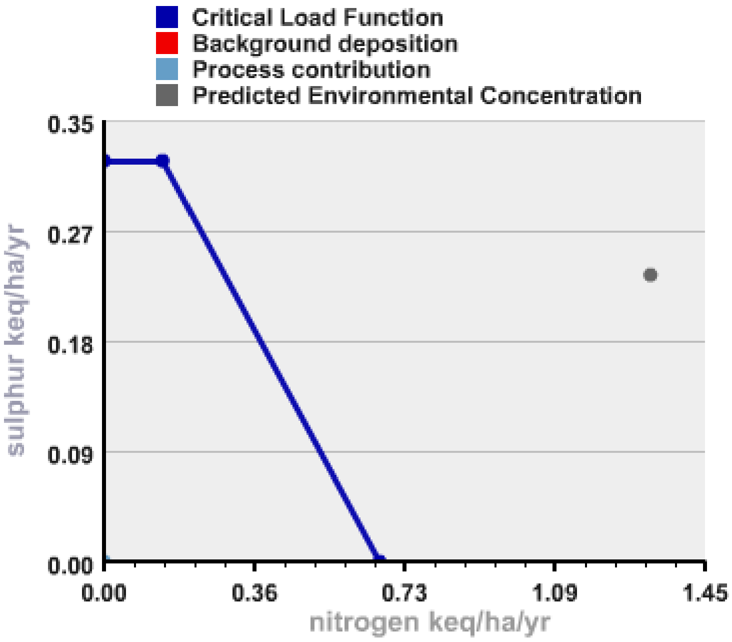
Source: http://www.apis.ac.uk/critical-load-function-tool

Figure 4.6 Assessment of acid deposition at the Crymlyn Bog receptor



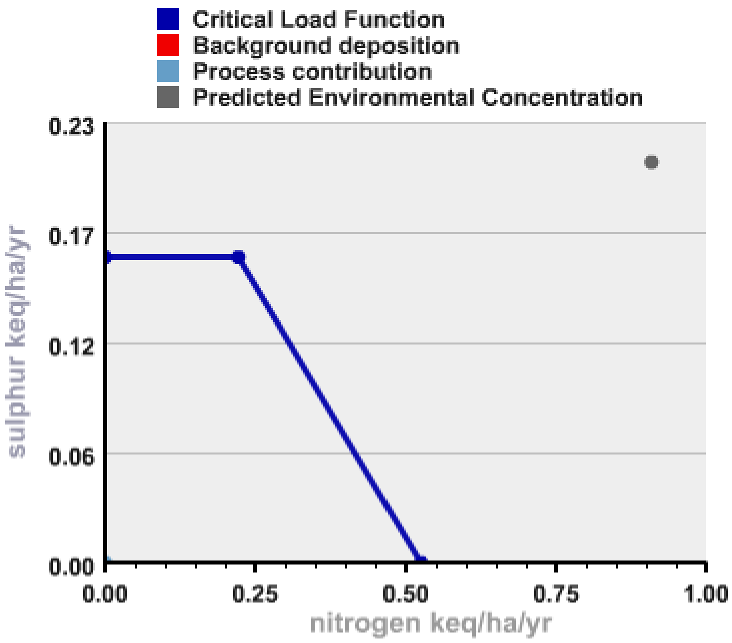
Source: http://www.apis.ac.uk/critical-load-function-tool

Figure 4.7 Assessment of acid deposition at the Gower Ash Woods SAC 3 receptor



Source: http://www.apis.ac.uk/critical-load-function-tool

Figure 4.8 Assessment of acid deposition at the Gower Commons SAC 5 receptor



Source: http://www.apis.ac.uk/critical-load-function-tool

5. Conclusions

This assessment has used detailed dispersion modelling to undertake an impact assessment of emissions to air from the proposed Viridis 178 embedded power plant. The pollutants covered by the assessment are:

- Oxides of nitrogen (NO_x as NO_2); and
- Carbon monoxide (CO).

The plant will generate power under the Capacity Mechanism. This assessment assumes the engines continuously operate for full, hourly periods during typical availability windows to predict both the long-term and short-term impacts of engine emissions. This approach ensures that those meteorological conditions conducive to producing elevated short-term ground level concentrations of pollutants are appropriately considered. However, given that the engines will only run for about 5 hours a day and a maximum of 1500 hours per year, additional post-processing of raw modelled output has been undertaken.

The impact assessment demonstrates that, under the anticipated operational profile of the plant, exceedances of any AQS, EAL, critical level or critical load are unlikely, or where exceedances are predicted, these are primarily due to the existing baseline concentration or deposition rate.

Although an exceedence of the 1-hour mean NO_2 AQS has been predicted by the assessment, this is solely a consequence of the necessary pessimistic assumptions inherent to any assessment where there is a random distribution to the operational profile and with the exceedence being influenced by the contribution from the adjacent STOR plant. Further probabilistic analysis indicates that the most likely probability of exceeding the 1-hour mean NO_2 AQS is equivalent to a 1 in 42 billion year event. Therefore, the probability of breaching the AQS is considered to be so low that it could not be considered a credible event.

6. References

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