A Dispersion Modelling Study of the Impact of Odour from the Existing and Proposed Free Range Egg Laying Chicken Houses at Cwm Farm, near Bwlch-y-ffridd in Powys

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Gail Lewis of Roger Parry & Partners LLP, on behalf of the applicant Mr Duncan Davies, to use computer modelling to assess the impact of odour emissions from the existing and proposed free range egg laying chicken houses at Cwm Farm, near Bwlch-y-ffridd in Powys. SY16 3JD.

Odour emission rates from the existing and proposed poultry houses have been assessed and quantified based upon an emissions model that takes into account the likely internal odour concentrations and ventilation rates of the poultry houses. The odour emission rates so obtained have then been used as inputs to an atmospheric dispersion model which calculates odour exposure levels in the surrounding area.

This report is arranged in the following manner:

- Section 2 provides relevant details of the site and potentially sensitive receptors in the area.

- Section 3 provides some general information on odour, details of the method used to estimate odour emissions from the poultry houses, relevant guidelines and legislation on exposure limits and where relevant, details of likely background levels of odour.

- Section 4 provides some information about ADMS, the dispersion model used for this study and details the modelling parameters and procedures.

- Section 5 contains the results of the modelling.

- Section 6 provides a discussion of the results and conclusions.

2. Background Details

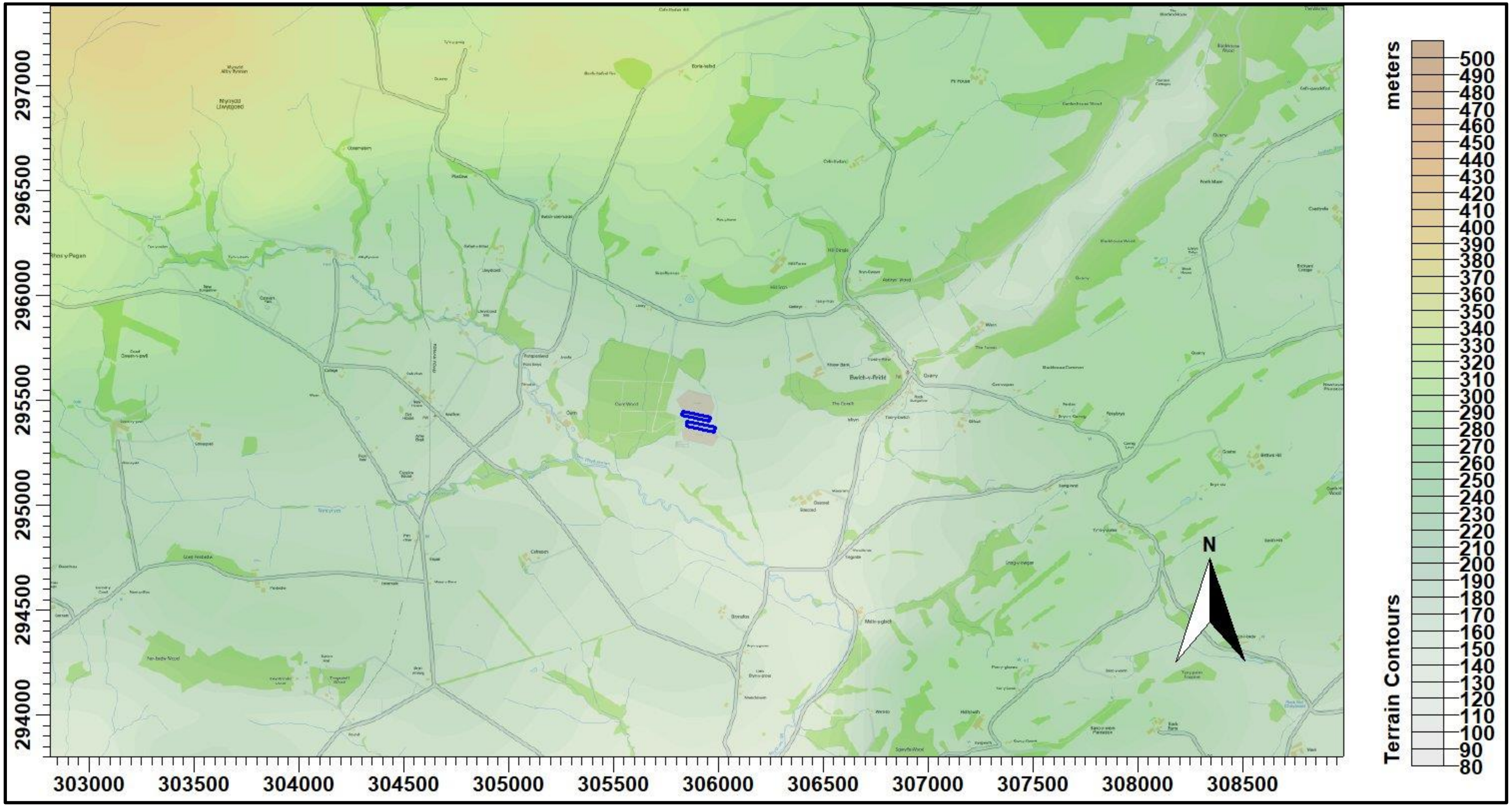
The site of the existing and proposed free range chicken houses at Cwm Farm is in a rural area, approximately 750 m to the east of the village of Bwlch-y-ffridd in Powys. The surrounding land is used largely for livestock farming and grazing, but there are also some wooded areas nearby. The site is at an altitude of around 190 m with the land rising towards hills and mountains to the north and north-west and falling towards the valley formed by the Nant Rhyd-ros-lan to the south.

There is currently one existing poultry house at Cwm Farm, which provides accommodation for up to 32,000 free range egg laying chickens. Under the proposal a new proposed building would be built to the south of the existing poultry house. The proposed poultry unit would provide accommodation for an additional 32,000 free range chickens. The existing and proposed poultry houses are/would be ventilated by high speed roof fans each with a short chimney.

There are some residences and commercial properties in the area surrounding Cwm Farm. The closest residential properties are: the residences to the east of Cwm Wood, approximately 480 m to the east; at Glascoed, approximately 500 m to the south-east and Rhiew Bank, approximately 520 m to the east-north-east of the existing and proposed poultry houses.

A map of the surrounding area is provided in Figure 1; in the figure, the positions of the existing and proposed poultry houses at Cwm Farm are outlined in blue.

Figure 1. The area surrounding the sites of the poultry houses at Cwm Farm



3. Odour, Emission Rates, Exposure Limits & Background Levels

3.1 Odour concentration, averaging times, percentiles and FIDOR

Odour concentration is expressed in terms of European Odour Units per metre cubed of air (ou_E/m^3). The following definitions and descriptions of how an odour might be perceived by a human with an average sense of smell may be useful, however, it should be noted that within a human population there is considerable variation in acuity of sense of smell.

- 1.0 ou_E/m^3 is defined as the limit of detection in laboratory conditions.

- At 2.0 – 3.0 ou_E/m^3, a particular odour might be detected against background odours in an open environment.

- When the concentration reaches around 5.0 ou_E/m^3, a particular odour will usually be recognisable, if known, but would usually be described as faint.

- At 10.0 ou_E/m^3, most would describe the intensity of the odour as moderate or strong and if persistent, it is likely that the odour would become intrusive.

The character, or hedonic tone, of an odour is also important; typically, odours are grouped into three categories.

Most offensive:

- Processes involving decaying animal or fish remains.
- Processes involving septic effluent or sludge.
- Biological landfill odours.

Moderately offensive:

- Intensive livestock rearing.
- Fat frying (food processing).
- Sugar beet processing.
- Well aerated green waste composting.

Less offensive:

- Brewery.
- Confectionery.
- Coffee roasting.
- Bakery.

Dispersion models usually calculate hourly mean odour concentrations and Environment Agency guidelines and findings from UK Water Industry Research (UKWIR) are also framed in terms of hourly mean odour concentration.

The Environment Agency guidelines and findings from UKWIR use the 98th percentile hourly mean; this is the hourly mean odour concentration that is equalled or exceeded for 2% of the time period considered, which is typically one year. The use of the 98th percentile statistic allows for some consideration of both frequency and intensity of the odours.

At some distance from a source, it would be unusual if odour concentration remained constant for an hour and in reality, due to air turbulence and changes in wind direction, short term fluctuations in concentration are observed. Therefore, although average exposure levels may be below the detection threshold, or a particular guideline, a population may be exposed to short term concentrations which are higher than the hourly average. It should be noted that a fluctuating odour is often more noticeable than a steady background odour at a low concentration. It is implicit that within the model's hourly averaging time and the Environment Agency guidelines and findings from UKWIR that there would be variation in the odour concentration around this mean, i.e. there would be short periods when odour concentration would be higher than the mean and lower than the mean.

The FIDOR acronym is a useful reminder of the factors that will determine the degree of odour pollution:

- **F**requency of detection.
- **I**ntensity as perceived.
- **D**uration of exposure.
- **O**ffensiveness.
- **R**eceptor sensitivity.

3.2 Environment Agency guidelines

In April 2011, the Environment Agency published H4 Odour Management guidance (H4). In Appendix 3 – Modelling Odour Exposure, benchmark exposure levels are provided. The benchmarks are based on the 98th percentile of hourly mean concentrations of odour modelled over a year at the site/installation boundary. The benchmarks are:

- 1.5 ou_E/m^3 for most offensive odours.
- 3.0 ou_E/m^3 for moderately offensive odours.
- 6.0 ou_E/m^3 for less offensive odours.

Any modelled results that project exposures above these benchmark levels, after taking uncertainty into account, indicates the likelihood of unacceptable odour pollution.

3.3 UK Water Industry Research findings

The main source of research into odour impacts in the UK has been the wastewater industry. An in-depth study of the correlation between modelled odour impacts and human response was published by UKWIR in 2001. This was based on a review of the correlation between reported odour complaints and modelled odour impacts in relation to nine wastewater treatment works in the UK with on-going odour complaints. The findings of this research and subsequent UKWIR research indicated the following, based on the modelled 98th percentile of hourly mean concentrations of odour:

- At below 5.0 ou_E/m^3, complaints are relatively rare at only 3% of the total registered.

- At between 5.0 ou_E/m^3 and 10.0 ou_E/m^3, a significant proportion of total registered complaints occur, 38% of the total.

- The majority of complaints occur in areas of modelled exposures of greater than 10.0 ou_E/m^3, 59% of the total.

3.4 Choice of odour benchmarks for this study

Odours from poultry rearing are usually placed in the moderately offensive category. Therefore, for this study, the Environment Agency's benchmark for moderately offensive odours, a 98th percentile hourly mean of 3.0 ou_E/m^3 over a one year period, is used to assess the impact of odour emissions from the proposed poultry unit at potentially sensitive receptors in the surrounding area. The UKWIR research is also considered.

3.5 Quantification of odour emissions

Odour emission rates from poultry houses depend on many factors and may be variable. When only minimum ventilation is required, the odour emission rate may be relatively small, but in hot weather, ventilation requirements and odour emission rates are greater. The main source of odour from the proposed new poultry house would be from the chimneys of the ridge or roof mounted fans. Some fugitive emissions from open pop holes would be possible, but because the house would normally be under negative pressure, these emissions would be minimal. In order to prevent odours building up within the house and provide negative pressure to prevent fugitive emissions, the modelling assumes that a minimum ventilation rate is maintained. The chickens would have access to ranging areas outside of the house and some odour would arise from the manure deposited on the ranging areas. The modelling assumes that good practices for farm cleanliness are followed and that other sources of odour may be considered negligible.

Peak odour emission rates are likely to occur when the housing is cleared of spent litter at the end of each production cycle. There is little available information on the magnitude of this peak emission, but it is likely to be greater than any emission that might occur when there are birds in the house. The time taken to perform the operation is usually around two to four hours and it is normal to maintain ventilation during this time. There are measures that can be taken to minimise odour production whilst the housing is being cleared of spent litter and there is usually some discretion as to when the operation is carried out; therefore, to avoid high odour levels at nearby sensitive receptors, it may be possible to time the operation to coincide with winds blowing in a favourable direction. As the proposed poultry house would operate a belt system that enables litter to be removed from the house twice weekly, it is assumed that these emissions would be significantly less than a more traditional house where the bird droppings are allowed to accumulate in the house throughout the crop.

To calculate an odour emission rate, it is necessary to know the internal odour concentration and ventilation rate of the poultry house. For the calculation, for egg laying chickens which are typically placed aged 18 to 20 weeks, the internal concentration is assumed to be constant at 750 ou_E/m^3; this figure is based upon a review of available literature and measured concentrations from similar free range egg laying chicken houses. Under high ventilation rates in layer chicken housing there may be a purging effect, that is, internal odour concentrations are reduced because the ventilation system removes odour faster than it is produced; this effect is not considered in the calculations, therefore, if anything, peak emission rates during hot weather may be overestimated. The housing is also assumed to be continuously occupied, but in reality, there would be periods between flocks when the housing is empty and clean and emitting little or no odour.

The ventilation rates used in the calculations are based on industry standard practices. For the calculations, the minimum ventilation rate is set at 1.0 m^3-air/bird/h and the maximum ventilation rate is 7.5 m^3-air/bird/h. If the external temperature is 13 Celsius, or lower, minimum ventilation only is assumed for the calculation. If the external temperature is 25 Celsius, or more, then the maximum ventilation rate is assumed. A transitional ventilation rate is calculated between these extremes.

Based upon these principles, an emission rate for each hour of the period modelled is calculated by multiplying the concentration by the ventilation rate. A summary of the emission rates used in this study are provided in Table 1. As additional information, the 98th percentile emission rate is approximately 0.90 ou_E/bird/s. As an example, a graph of the specific emission rate over the first year of the meteorological record is shown in Figure 2.

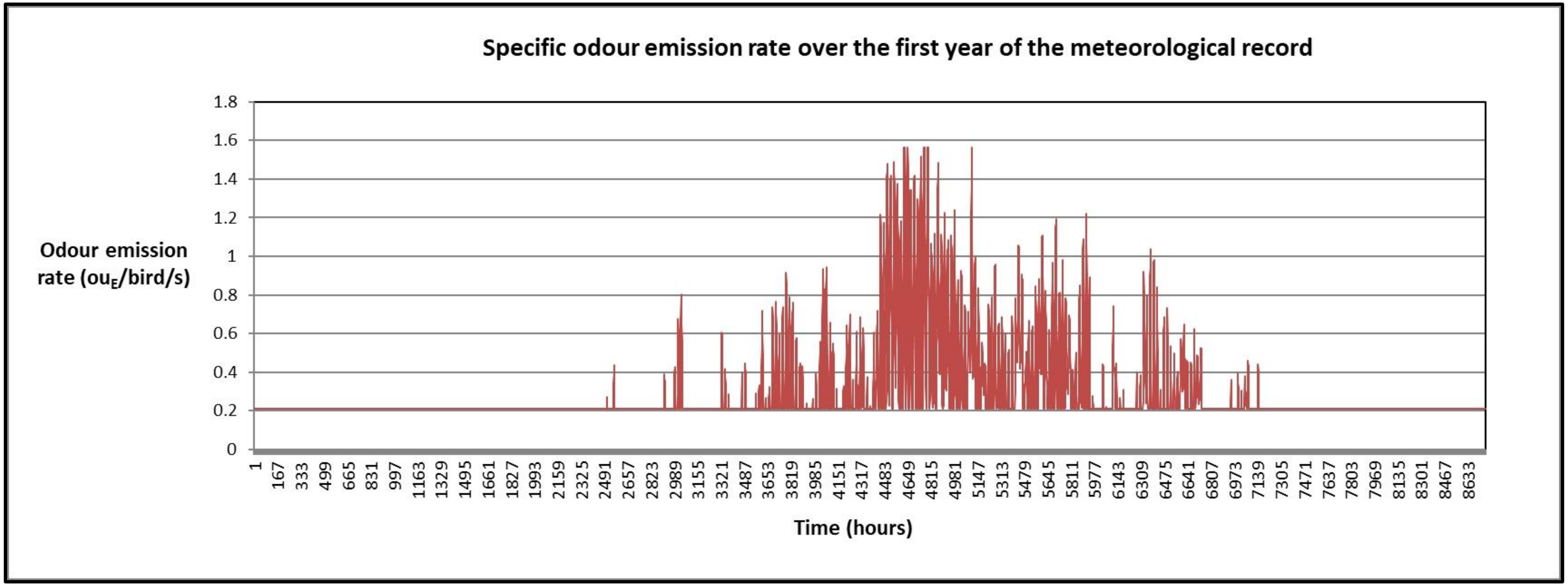
The chickens would have access to ranging areas. It is assumed that 20% of the droppings would be deposited on the ranging areas and an emission rate of 0.25 ou_E/bird/s is used to calculate the emission rate. This emission is assumed to be continuous with no diurnal, seasonal, or temperature dependent variations. N.B. This emission is additional to emissions from the housing, is probably quite precautionary and is also intended to account for any fugitive emissions from the pop holes, which might occur when ventilation rates are low.

Soiled hard-standings and farm equipment at the site are a source of odour, these sources are usually minor in comparison to other emissions from the housing; nevertheless, a strict cleansing regime and the avoidance of even temporary storage of manures in trailers or spreading equipment at the site will help to ameliorate potential odour issues.

Table 1. Summary of odour emission rates (average of all 3 cycles)

Emission rate (ou_E/s per bird as stocked during crop)				
Season	Average	Night-time Average	Day-time Average	Maximum
Winter	0.209	0.208	0.209	0.564
Spring	0.271	0.217	0.324	1.562
Summer	0.408	0.251	0.502	1.562
Autumn	0.220	0.212	0.229	0.678

Figure 2. Specific emission rate over the first year of the meteorological record



4. The Atmospheric Dispersion Modelling System (ADMS) and Model Parameters

The Atmospheric Dispersion Modelling System (ADMS) ADMS 5 is a new generation Gaussian plume air dispersion model, which means that the atmospheric boundary layer properties are characterised by two parameters; the boundary layer depth and the Monin-Obukhov length rather than in terms of the single parameter Pasquill-Gifford class.

Dispersion under convective meteorological conditions uses a skewed Gaussian concentration distribution (shown by validation studies to be a better representation than a symmetrical Gaussian expression).

ADMS has a number of model options including: dry and wet deposition; NO_x chemistry; impacts of hills, variable roughness, buildings and coastlines; puffs; fluctuations; odours; radioactivity decay (and γ-ray dose); condensed plume visibility; time varying sources and inclusion of background concentrations.

ADMS has an in-built meteorological pre-processor that allows flexible input of meteorological data both standard and more specialist. Hourly sequential and statistical data can be processed and all input and output meteorological variables are written to a file after processing.

The user defines the pollutant, the averaging time (which may be an annual average or a shorter period), which percentiles and exceedance values to calculate, whether a rolling average is required or not and the output units. The output options are designed to be flexible to cater for the variety of air quality limits, which can vary from country to country and are subject to revision.

4.1 Meteorological data

Computer modelling of dispersion requires hourly sequential meteorological data and to provide robust statistics the record should be of a suitable length; preferably four years or longer.

The meteorological data used in this study is obtained from assimilation and short term forecast fields of the Numerical Weather Prediction (NWP) system known as the Global Forecast System (GFS). Observational meteorological data from Trawscoed and Lake Vyrnwy are also considered.

The GFS is a spectral model and data are archived at a horizontal resolution of 0.25 degrees, which is approximately 25 km over the UK (formerly 0.5 degrees, or approximately 50 km). The GFS resolution adequately captures major topographical features and the broad-scale characteristics of the weather over the UK. Smaller scale topological features may be included in the dispersion modelling by using the flow field module of ADMS (FLOWSTAR). The use of NWP data has advantages over traditional meteorological records because:

- Calm periods in traditional observational records may be over represented, this is because the instrumentation used may not record wind speeds below approximately 0.5 m/s and start up wind speeds may be greater than 1.0 m/s. In NWP data, the wind speed is continuous down to 0.0 m/s, allowing the calms module of ADMS to function correctly.

- Traditional records may include very local deviations from the broad-scale wind flow that would not necessarily be representative of the site being modelled; these deviations are difficult to identify and remove from a meteorological record. Conversely, local effects at the site being modelled are relatively easy to impose on the broad-scale flow and provided horizontal resolution is not too great, the meteorological records from NWP data may be expected to represent well the broad-scale flow.

- Information on the state of the atmosphere above ground level which would otherwise be estimated by the meteorological pre-processor may be included explicitly.

The wind rose for the raw GFS data at the site of Cwm Farm is shown in Figure 3a.

Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and where terrain data is included in the modelling, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for the location at the existing and proposed poultry houses at Cwm Farm is shown in Figure 3b. Note that elsewhere in the modelling domain the modified wind roses may differ more, or less, markedly and that the resolution of the wind field is 100 m.

Data from the meteorological recording station at Lake Vyrnwy, the closest station to the site at Cwm Farm, and Trawscoed have also been considered. However, neither Lake Vyrnwy nor Trawscoed can be considered to have an aspect that in any way could be considered similar to that at Cwm Farm; therefore, it should be noted that the frequency of winds from a particular direction in the Trawscoed or Lake Vyrnwy data may be either high or low in comparison to what might occur at Cwm Farm, which means mean concentrations downwind may be either over or under predicted. Additionally, periods of light winds and calms cannot be properly modelled. Therefore, it is the opinion of AS Modelling & Data Ltd. that the results obtained using the GFS data, particularly when modified by using FLOWSTAR, are less likely to have gross errors than the results obtained using the observational data and should be given more weight when interpreting the results of the modelling. The wind roses for Trawscoed and Lake Vyrnwy are shown in Figure 3c and 3d, respectively.

Figure 3a. The wind rose. Raw GFS derived data, for 52.548 N, 3.388 W, 2013-2016

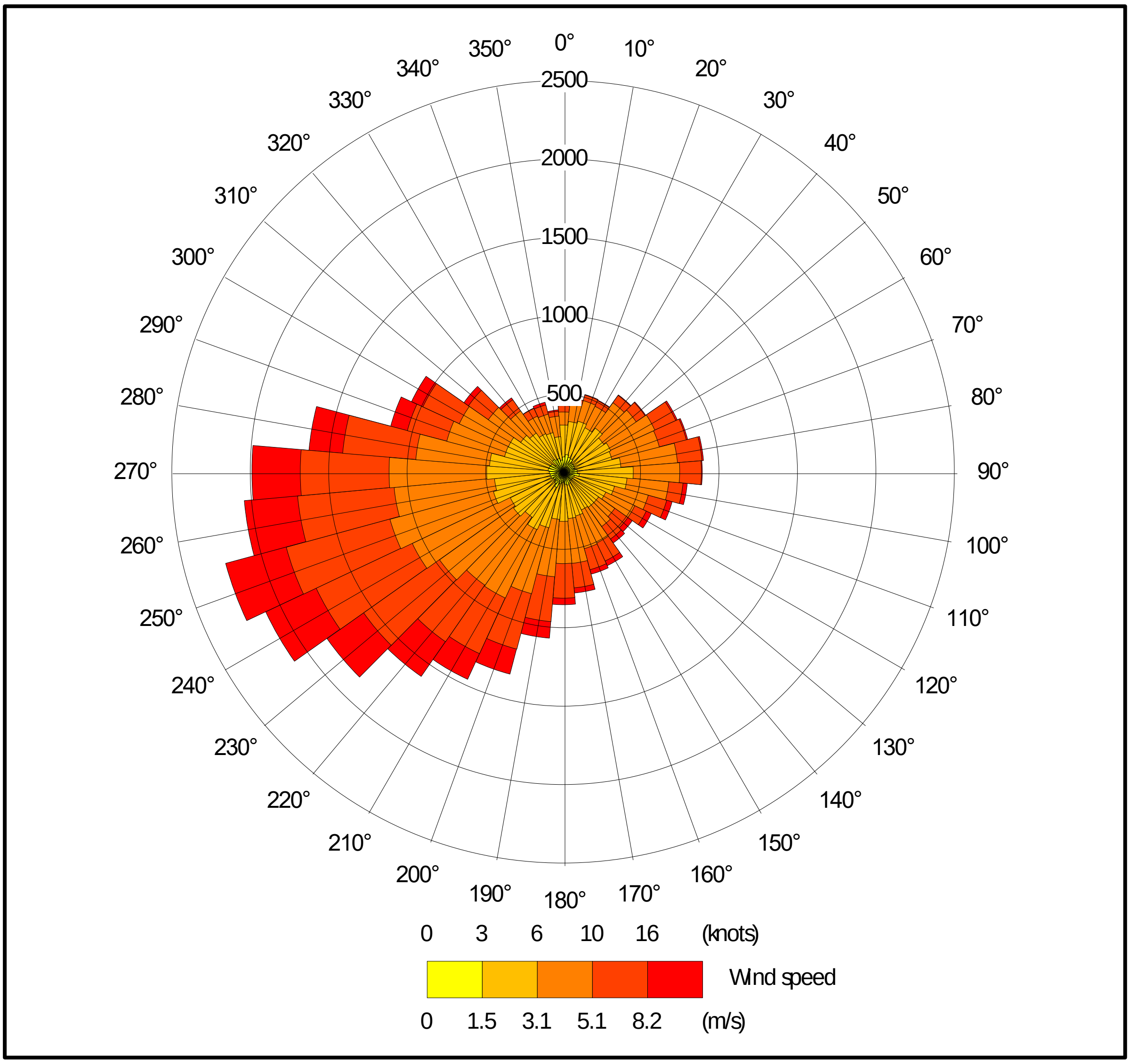


Figure 3b. The wind rose. FLOWSTAR modified GFS derived data for NGR 305900, 295400

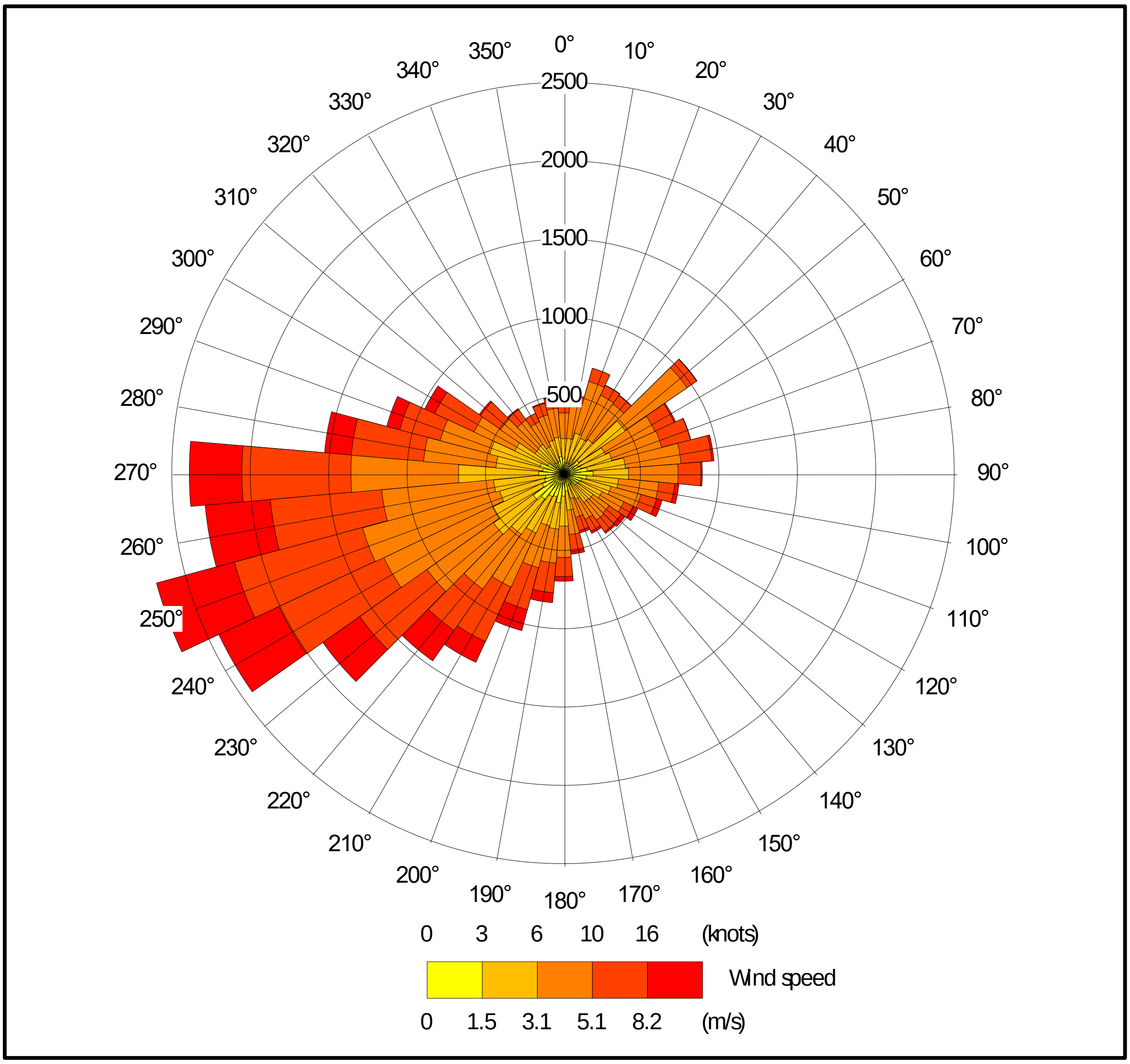


Figure 3c. The wind rose. Trawscoed, 2013 – 2016

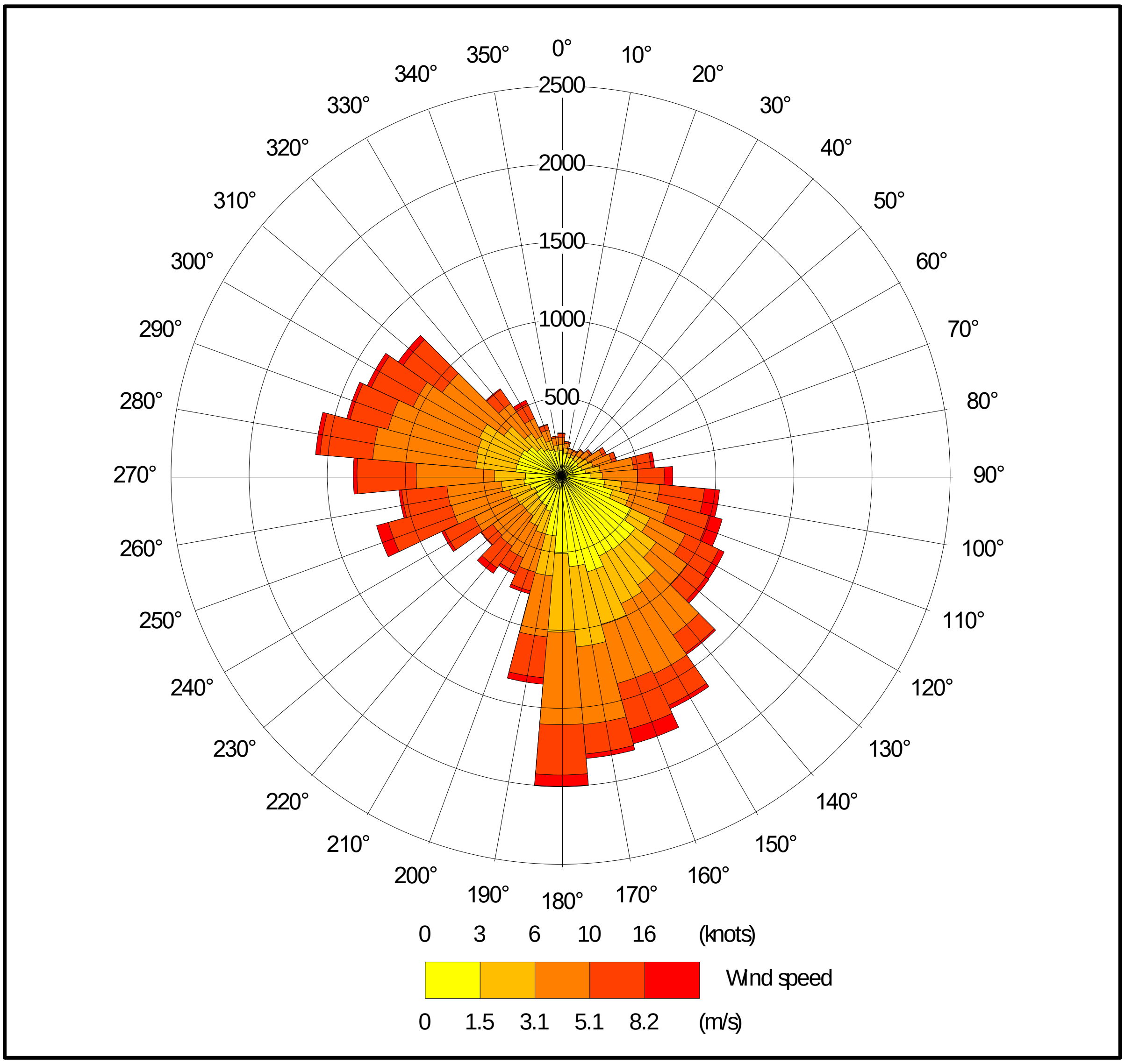
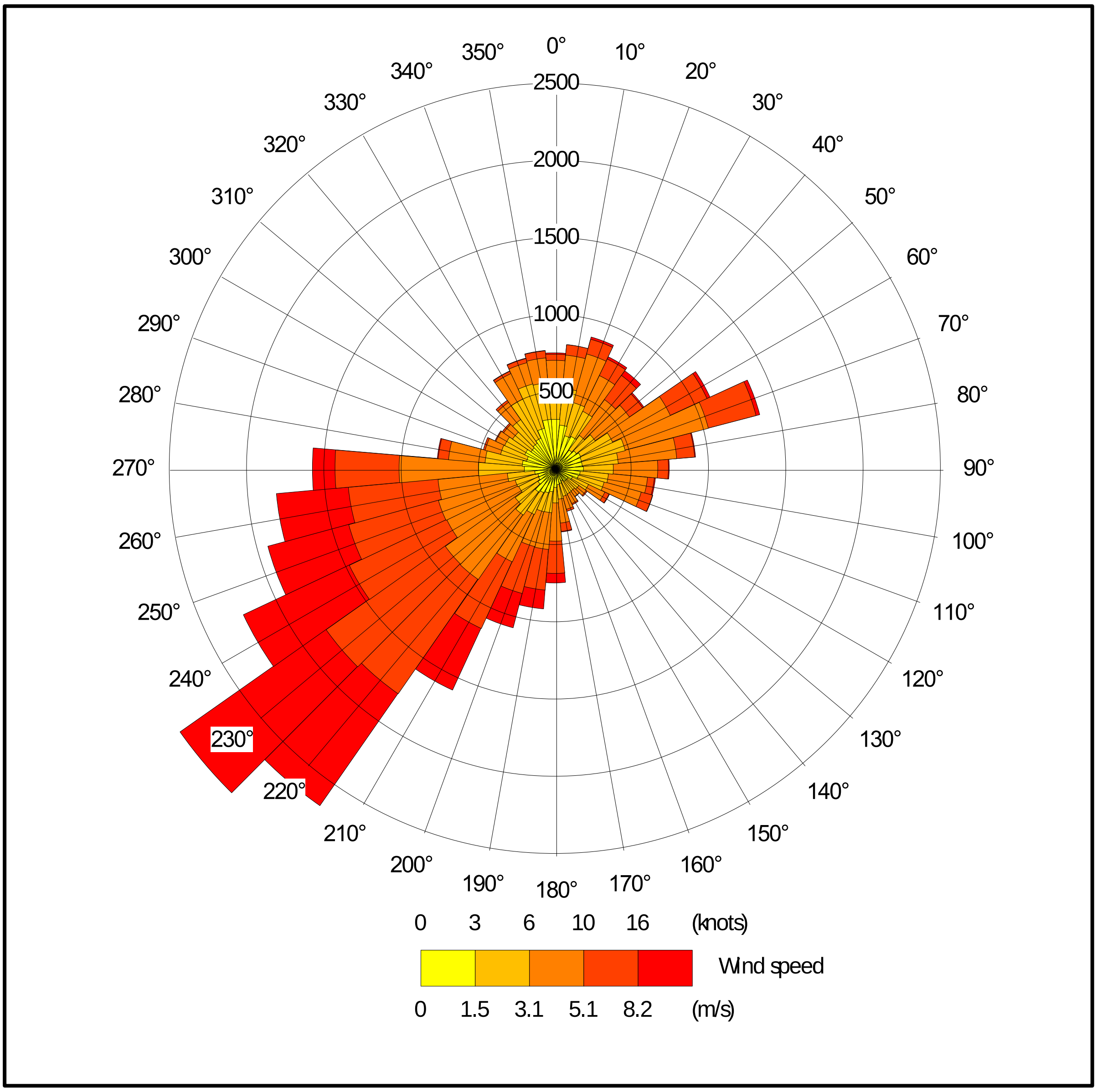


Figure 3c. The wind rose. Trawscoed, 2013 – 2016



4.2 Emission sources

Emissions from the high speed ridge/roof fans that are/would be used to ventilate the existing and proposed poultry houses are represented by three point sources per house within ADMS (EX1 a, b & c and PR1 a, b & c). Details of the point source parameters are shown in Table 2a. The positions of the point sources may be seen in Figure 4, where they are indicated by red star symbols.

Table 2a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source (ou_E/s)
EX1 a, b & c and PR1 a, b & c	6.0	0.8	11.0	Variable [1]	Variable [1]

1. Dependent on crop stage and ambient temperature.

The poultry houses have/would have ranging areas, which are represented by two area sources within ADMS (EX1_ran and PR1_ran). Note that the area sources cover the parts of the ranges most likely to be used frequently and not the whole ranging area.

Details of the area source parameters are provided in Table 2b. The position of the area sources are shown in Figure 4.

Table 2b. Area source parameters

Source ID	Area (m^2)	Base height (m)	Emission temperature (°C)	Emission rate (ou_E/s)
EX_ran	14756.10	0.0	Ambient	1600.0
PR_ran	10402.41	0.0	Ambient	1600.0

4.3 Modelled buildings

The structure of the existing and proposed poultry houses may affect the plumes from the point sources. Therefore, these buildings are modelled within ADMS. The positions of the modelled buildings may be seen in Figure 4, where they are marked by grey rectangles.

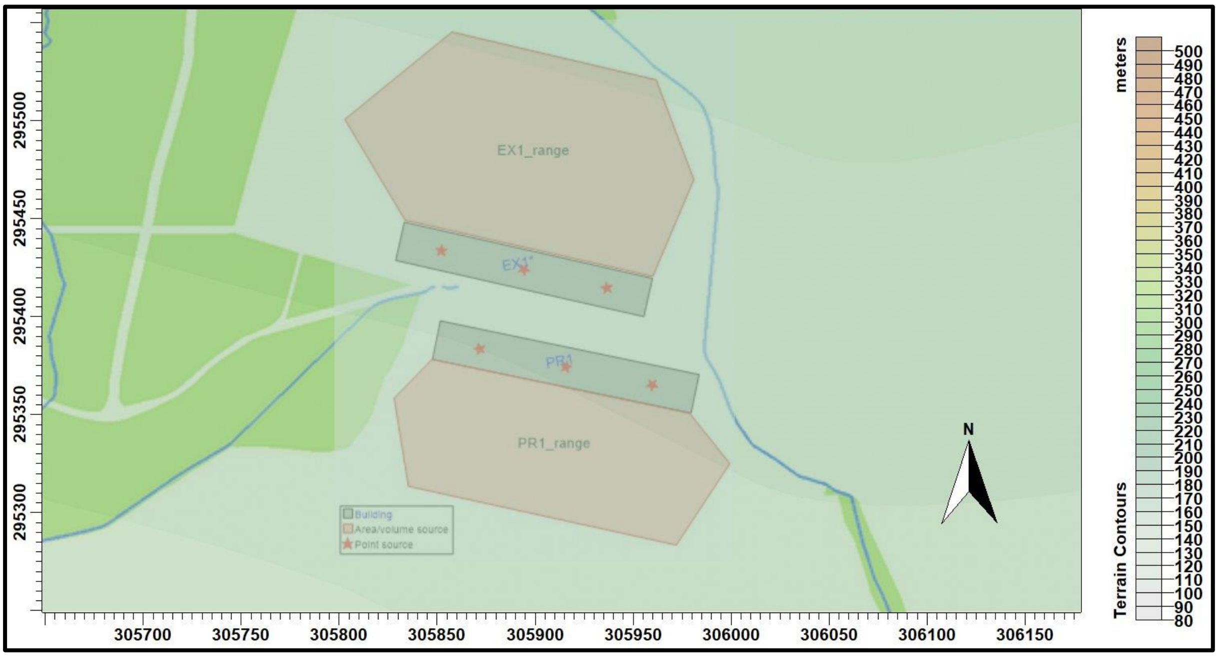
4.4 Discrete receptors

Twenty discrete receptors have been defined at a selection of nearby residences and commercial properties. The receptors are defined at 1.5 m above ground level within ADMS and their positions may be seen in Figure 5, where they are marked by enumerated pink rectangles.

4.5 Nested Cartesian grid

To produce the contour plots presented in Section 5 of this report, a nested Cartesian grid has been defined within ADMS. The grid receptors are defined at 1.5 m above ground level within ADMS. The positions of the grid receptors may be seen in Figure 5, where they are marked by green crosses.

Figure 4. The positions of modelled buildings & sources



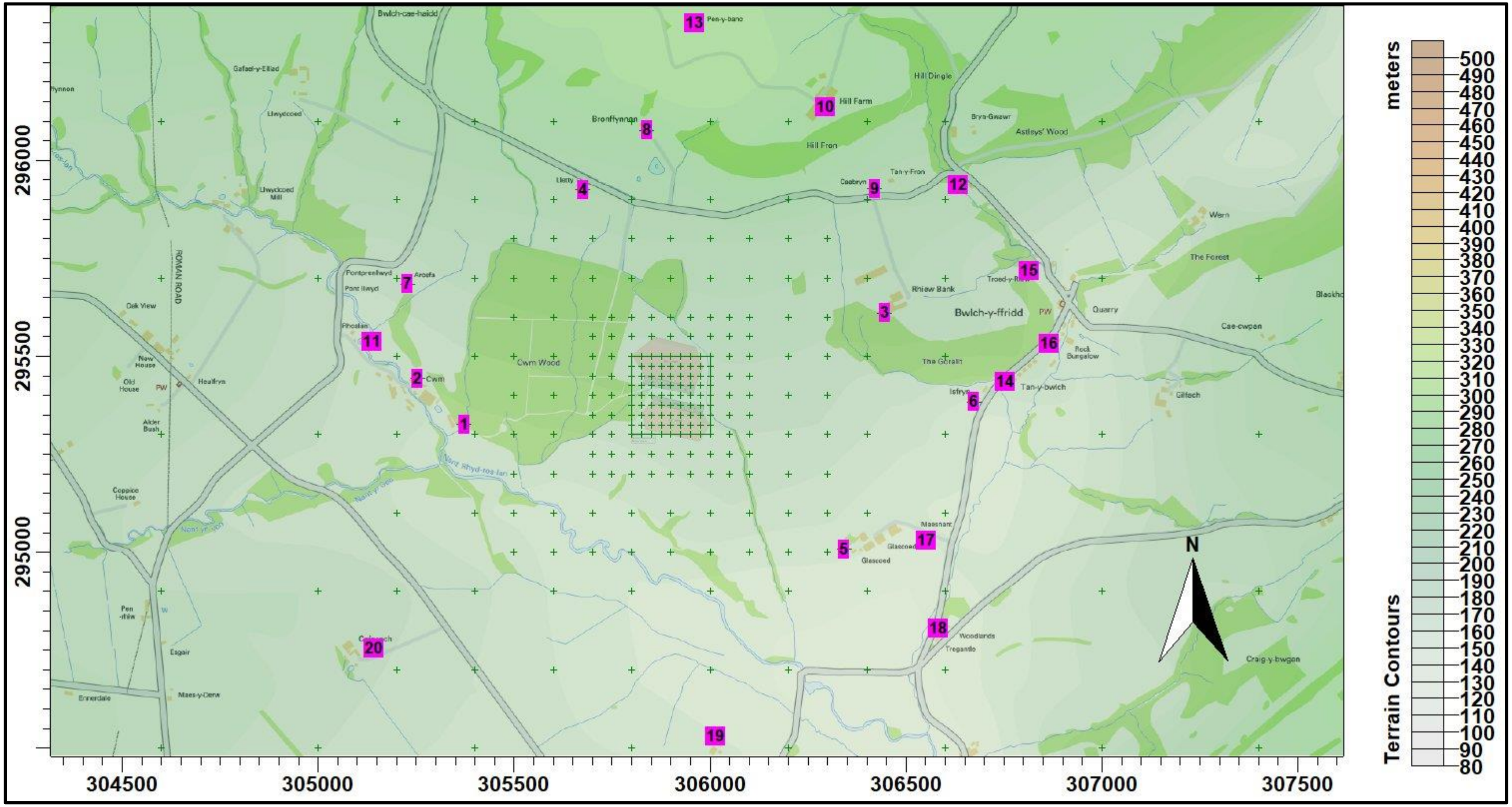
4.6 Terrain data

Terrain has been considered in the modelling. The terrain data are based upon the Ordnance Survey 50 m Digital Elevation Model. A 6.4 km x 6.4 km domain has been resampled at 50 m horizontal resolution for use within ADMS in the detailed modelling. N.B. The resolution of FLOWSTAR is 32 x 32 grid points; therefore, the effective resolution of the wind field is 200 m.

4.7 Other model parameters

A fixed surface roughness length of 0.375 m has been applied over the entire modelling domain. As a precautionary measure, the GFS meteorological data is assumed to have a roughness length of 0.350 m. The effect of the difference in roughness length is precautionary as it increases the frequency of low wind speeds and stability and therefore increases predicted ground level concentrations.

Figure 5. The discrete receptors and nested Cartesian grid receptors



5. Details of the Model Runs and Results

For this study, the model was run with the calms and terrain modules in ADMS four times; once for each year of the four year meteorological record. Statistics for the annual 98th percentile hourly mean odour concentration at each receptor were compiled for each of the four modelling runs.

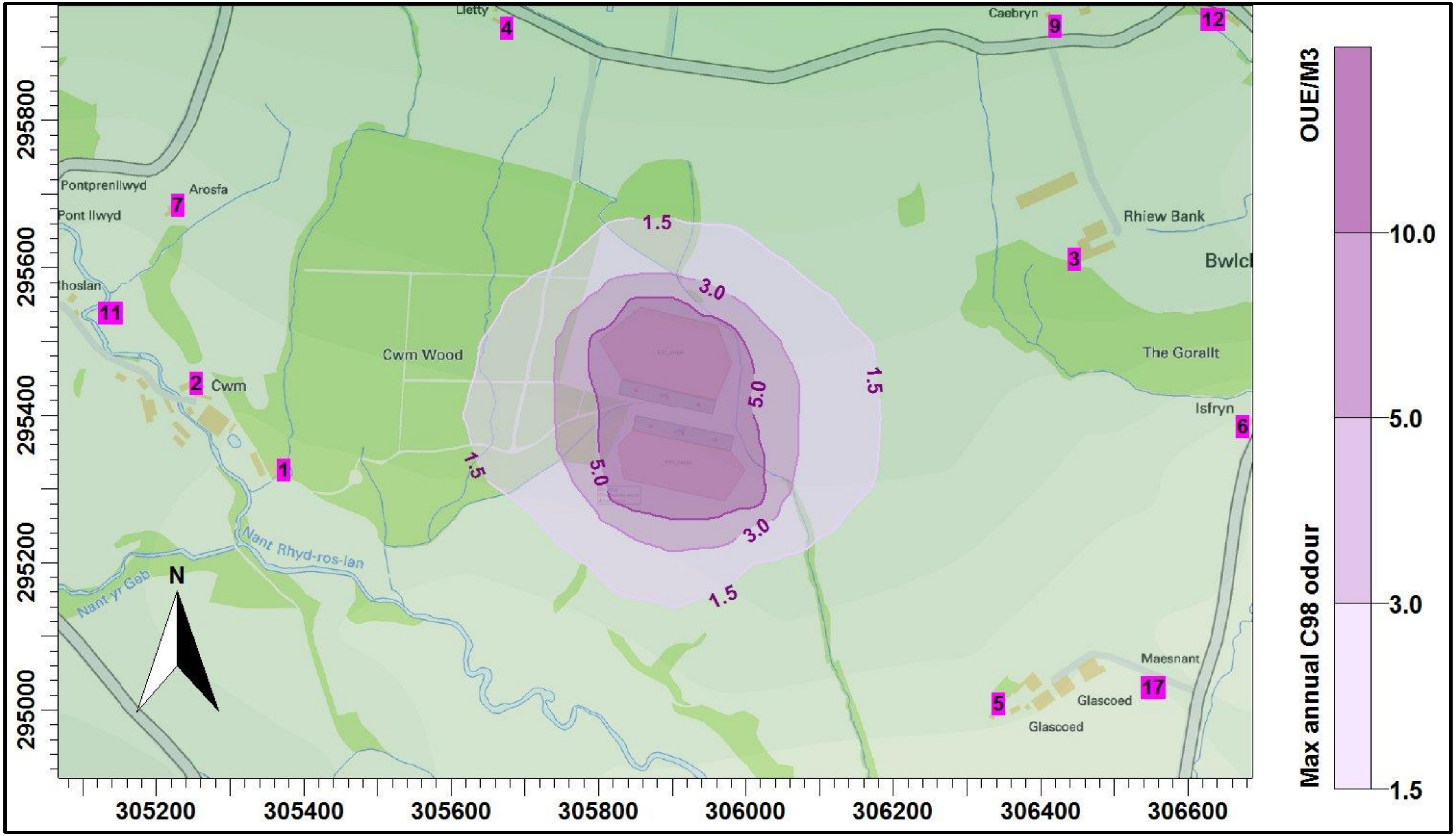
A summary of the results of these runs at the discrete receptors is provided in Table 3 where the maximum annual 98th percentile hourly mean odour concentration is shown. A contour plot of the maximum annual 98th percentile hourly mean odour concentrations is shown in Figure 6.

In Table 3, predicted odour exposures in excess of the Environment Agency's benchmark of 3.0 ou_E/m^3 as an annual 98th percentile hourly mean are coloured blue; those in the range that UKWIR research suggests gives rise to a significant proportion of complaints, 5.0 ou_E/m^3 to 10.0 ou_E/m^3 as an annual 98th percentile hourly mean, are coloured orange and predicted exposures likely to cause annoyance and complaint are coloured red.

Table 3. Predicted maximum annual 98th percentile hourly mean odour concentrations at the discrete receptors

Receptor number	X(m)	Y(m)	Maximum annual 98th percentile hourly mean odour concentration (ou_E/m^3)					
			GFS Calms Terrain		Trawscoed Calms Terrain		Lake Vyrnwy Calms Terrain	
			Existing	Proposed	Existing	Proposed	Existing	Proposed
1	305372	295326	0.25	0.55	0.14	0.33	0.25	0.52
2	305254	295443	0.20	0.41	0.14	0.30	0.19	0.37
3	306446	295611	0.22	0.43	0.18	0.37	0.23	0.45
4	305676	295925	0.16	0.30	0.58	1.02	0.08	0.15
5	306342	295008	0.18	0.42	0.18	0.42	0.20	0.43
6	306674	295384	0.23	0.48	0.20	0.40	0.24	0.53
7	305229	295684	0.13	0.25	0.16	0.40	0.11	0.20
8	305839	296077	0.10	0.18	0.43	0.74	0.07	0.12
9	306420	295927	0.12	0.23	0.10	0.19	0.13	0.27
10	306293	296136	0.08	0.15	0.09	0.16	0.09	0.15
11	305137	295538	0.14	0.28	0.11	0.23	0.13	0.24
12	306632	295936	0.11	0.20	0.09	0.17	0.10	0.21
13	305961	296351	0.05	0.10	0.17	0.34	0.05	0.09
14	306752	295434	0.23	0.46	0.16	0.35	0.25	0.54
15	306815	295718	0.14	0.27	0.11	0.21	0.12	0.24
16	306865	295532	0.20	0.40	0.13	0.26	0.23	0.47
17	306552	295030	0.17	0.39	0.18	0.40	0.14	0.36
18	306583	294806	0.10	0.21	0.09	0.20	0.12	0.23
19	306013	294530	0.06	0.13	0.04	0.08	0.15	0.35
20	305142	294753	0.07	0.16	0.03	0.05	0.08	0.18

Figure 6. Predicted maximum annual 98th percentile hourly mean odour concentration



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Gail Lewis of Roger Parry & Partners LLP, on behalf of the applicant Mr Duncan Davies, to use computer modelling to assess the impact of odour emissions from the existing and proposed free range egg laying chicken houses at Cwm Farm, near Bwlch-y-ffridd in Powys. SY16 3JD.

Odour emission rates from the existing and proposed poultry houses have been assessed and quantified based upon an emissions model that takes into account the likely internal odour concentrations and ventilation rates of the poultry houses. The odour emission rates so obtained have then been used as inputs to an atmospheric dispersion model which calculates odour exposure levels in the surrounding area.

The modelling predicts that odour exposures in the surrounding area would be below the Environment Agency's benchmark for moderately offensive odours, which is a maximum annual 98th percentile hourly mean concentration of 3.0 ou_E/m^3, at all residential receptors considered.

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