# A Dispersion Modelling Study of the Impact of Odour from the Proposed Broiler Chicken Rearing Houses at Cwmafan, Llanafan-Fawr, near to Builth Wells in Powys

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# 1. Introduction

AS Modelling & Data Ltd. has been instructed by Gerallt Davies, of Roger Parry & Partners LLP, on behalf of Lyndon Jones, to use computer modelling to assess the impact of odour emissions from the proposed broiler chicken rearing houses at Cwmafan, Lanafan-Fawr, near to Builth Wells, in Powys. LD2 3PF.

Odour emission rates from the 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

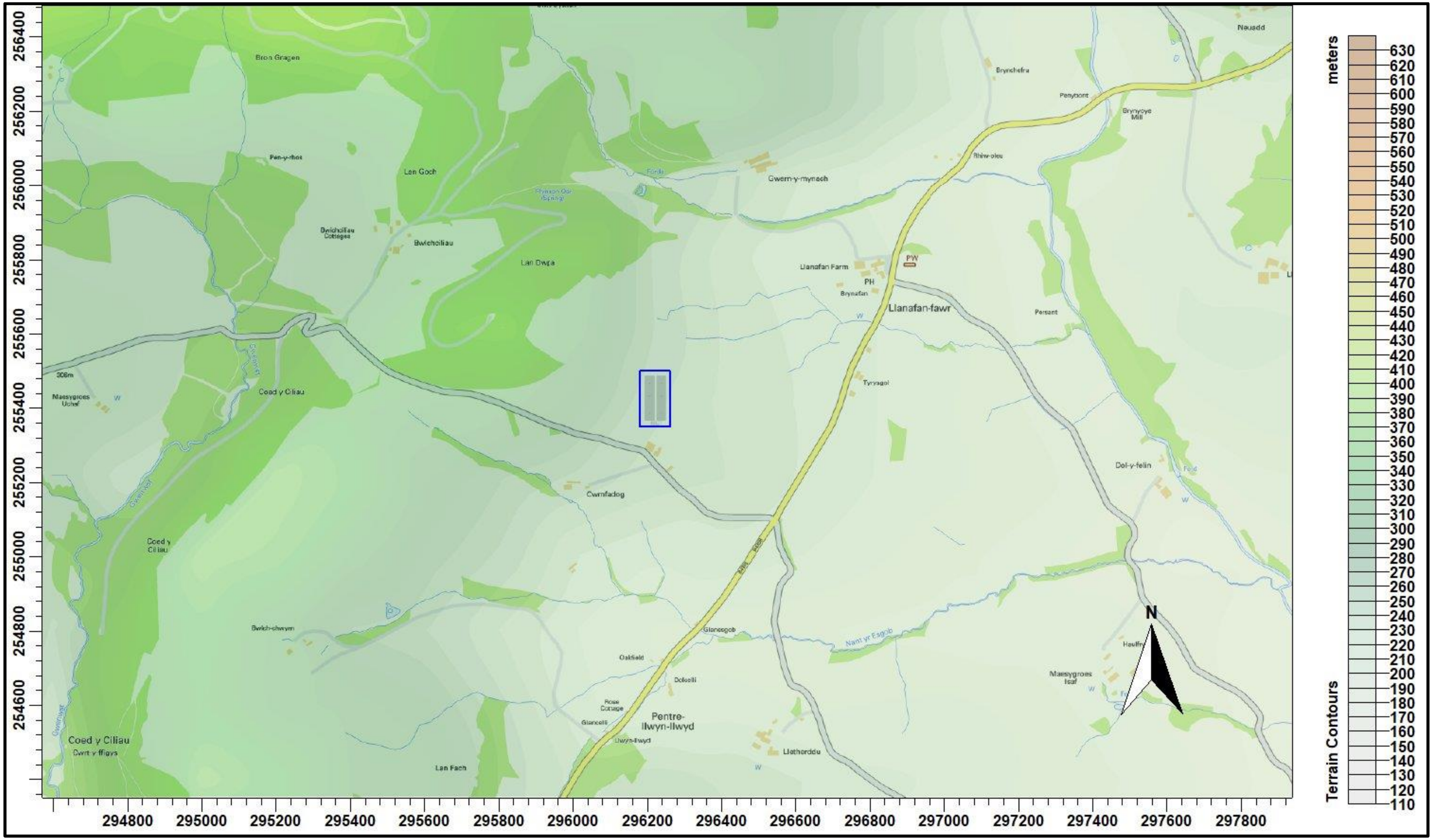
The farmstead at Cwmafan is in a rural area approximately 650 m to the south-west of the small village of Llanafan-Fawr, near to Builth Wells in Powys. The farm is at an elevation of approximately 260 m, with the land rising to Lan Dwpa at a height of 378 m to the north-west, above the Nant yr Esgob, which is to the south and flows eastward into the River Chwefri. The surrounding land is predominantly pasture and there are wooded areas nearby.

Under the proposal, two new poultry houses would be constructed on a green-field site to the north of the existing farm buildings at Cwmafan. These proposed poultry houses would provide accommodation for up to 100,000 broiler chickens and would be ventilated using uncapped high speed ridge mounted fans, each with a short chimney. The chickens would be reared from day old chicks to up to around 40 days old and there would be approximately 7 crops per year.

There are some residences and commercial properties in the area surrounding the site of the proposed poultry houses at Cwmafan. Excluding those at the farmstead at Cwmafan, the closest residences are at: Cwmfadog, which is approximately 230 m to the south-west; Brynafan, which is approximately 520 m to the north-east; Tyrysgol, which is approximately 490 m to the east and Glanesgob, which is approximately 540 m to the south of the proposed poultry houses.

A map of the surrounding area is provided in Figure 1; the positions of the proposed poultry rearing houses at Cwmafan are outlined in blue.

*Figure 1. The area surrounding the site of the proposed poultry houses at Cwmafan*



# 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 98$^{th}$ 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 98$^{th}$ 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 (Rebranded by Natural Resources Wales)

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 98$^{th}$ 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 98$^{th}$ 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 98$^{th}$ 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.

## 3.5 Quantification of odour emissions

Odour emission rates from broiler houses depend on many factors and are highly variable. At the beginning of a crop cycle, when chicks are small, litter is clean and only minimum ventilation is required, the odour emission rate may be small. Towards the end of the crop, odour production within the poultry housing increases rapidly and ventilation requirements are greater, particularly in hot weather, therefore emission rates are considerably greater than at the beginning of the crop.

Peak odour emission rates are likely to occur when the housing is cleared of spent litter at the end of each crop. 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 hours per shed 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.

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, the internal concentration is assumed to be a function of the age of the crop and the stocking density.

The internal concentrations used in the calculations increase exponentially from 300 $ou_E/m^3$ at day 1 of the crop, to approximately 700 $ou_E/m^3$ at day 16 of the crop, to approximately 1,750 $ou_E/m^3$ at day 30 of the crop and approximately 2,300 $ou_E/m^3$ at day 34 of the crop. These figures are obtained from a review of available literature and olfactometric measurements from similar broiler rearing houses that area available to AS Modelling & Data Ltd. and are based primarily on Robertson *et al.* (2002).

The ventilation rates used in the calculations are based on industry practices and standard bird growth factors. Minimum ventilation rates are as those of an operational poultry house and maximum ventilation rates are based on Defra guidelines. Target internal temperature is 33 Celsius at the beginning of the crop and is decreased to 22 Celsius by day 34 of the crop. If the external temperature is 7 Celsius, or more, lower than the target temperature, minimum ventilation only is assumed for the calculation. Above this, ventilation rates are increased in proportion to the difference between ambient temperature and target internal temperature. A maximum transitional ventilation rate (35% of the maximum possible ventilation rate) is reached when the ambient temperature is equal to the target temperature. A high ventilation rate (70% maximum possible ventilation rate) is reached when the temperature is 4 degrees above target and if external temperature is above 33 Celsius the maximum ventilation rate is assumed.

At high ventilation rates, it is likely that internal odour concentrations fall because odour is extracted much faster than it is created. Therefore, if the calculated ventilation rate exceeds that required to replace the volume of air in the house every 5 minutes, internal concentrations are reduced (by a factor of the square root of 7.5 times the shed volume divided by the ventilation rate as an hourly figure).

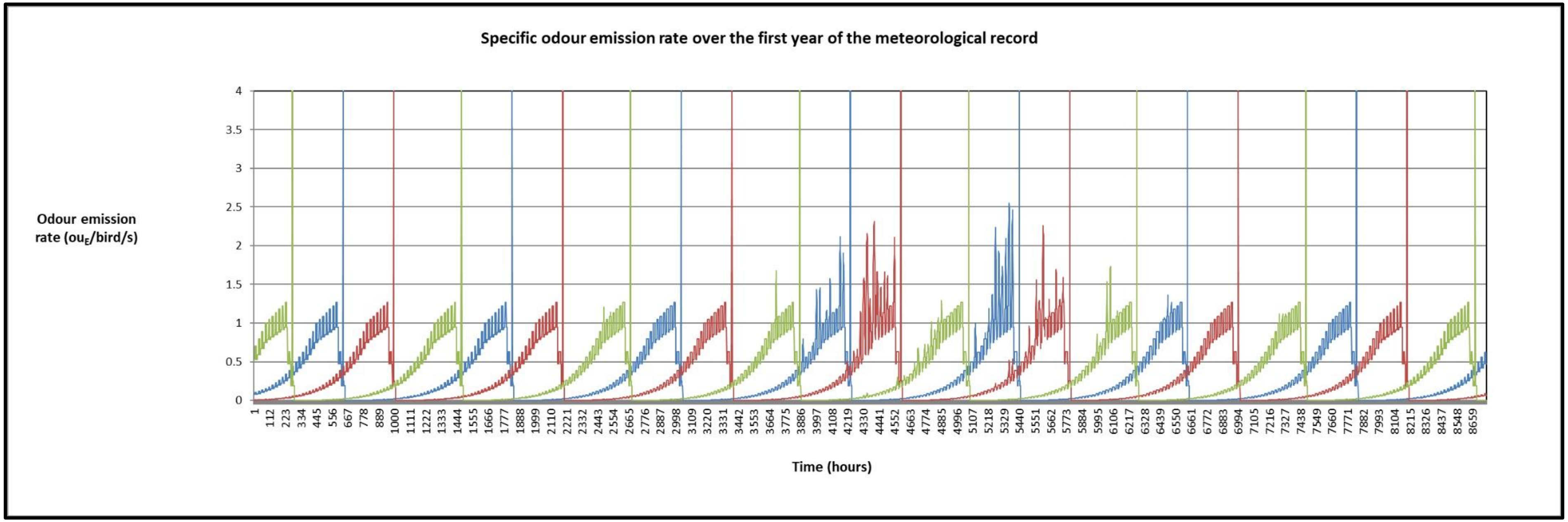
Based upon these principles, an emission rate for each hour of the period modelled is calculated by multiplying the concentration by the ventilation rate. Both the crop length and period the housing is empty can be varied. An estimation of the emission during the cleaning out process can also be included. In this case, it is assumed that the houses are cleared sequentially and each house takes 2 hours to clear.

In this case, it is assumed for the calculations that the crop length is 40 days with a 30% thin of the crop on day 32 and that there is an empty period of 10 days after each crop. To provide robust statistics, three sets of calculations were performed; the first with the first day of the meteorological record coinciding with day 1 of the crop cycle, the second coinciding with day 15 of the crop and the third coinciding with day 30 of the crop. A summary of the emission rates used in this study is provided in Table 1. It should be noted that the figures in this table refer to the whole of the crop length whilst most figures quoted in literature are figures obtained from the latter stages of the crop cycle and therefore should not be compared directly to these AS Modelling & Data Ltd. figures. The specific odour emission rate used for the clearing process is approximately 4.00 $ou_E$/bird/s and the 98$^{th}$ percentile emission rate is approximately 1.25 $ou_E$/bird/s. As an example, a graph of the specific emission rate over the first year of the meteorological record for each of the three crop cycles is shown in Figure 2.

*Table 1. Summary of odour emission rates (average/maxima 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 | 0.322 | 0.290 | 0.387 | 1.264 |
| Spring | 0.355 | 0.289 | 0.421 | 2.746 |
| Summer | 0.387 | 0.290 | 0.445 | 2.679 |
| Autumn | 0.335 | 0.287 | 0.383 | 1.444 |

*Figure 2. Specific emission rate over the first year (2015) of each of the three crop cycles*



# 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 that include: 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). There are no nearby traditional observation meteorological datasets that could be considered representative of the area around Cwnafan, or that could be considered as suitable for use as driving data for modelling terrain flow; however, data from the observational meteorological station at Sennybridge have been considered, primarily to demonstrate that the use of GFS data provides similar results to traditional observational meteorological data.

The GFS is a spectral model: the physics/dynamics model has an equivalent resolution of approximately 13 km; terrain is understood to be resolved at a resolution of approximately 2 km (with sub-13 km terrain effects parameterised) and data are archived at a resolution of 0.25 degrees (site specific data may be extrapolated from nearby archive grid points or a most representative grid point chosen). 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 is shown in Figure 3a. Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and because terrain data is included in the modelling, wind speeds and directions will be modified. The terrain and roughness length modified wind rose is shown in Figure 3b. Note that, elsewhere in the modelling domain the modified wind roses may differ markedly, reflecting the local flow in that part of the domain. The resolution of the wind field in terrain runs is 100 m. Please also note that FLOWSTAR is used to obtain a local flow field, not to explicitly model dispersion in complex terrain as defined in the ADMS User Guide; therefore, the ADMS default value for minimum turbulence length has been amended.

Data from the meteorological recording station at Sennybridge have also been considered. However, Sennybridge does not have an aspect that in any way could be considered similar to Cwmafan; therefore, it should be noted that the frequency of winds from a particular direction in the Sennybridge data may be either high or low in comparison to what might occur at Cwmafan, 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, should be given more weight when interpreting the results of the modelling.

The wind rose for Sennybridge is shown in Figure 3c.

*Figure 3a. The wind rose. Raw GFS derived data for 52.187 N, 3.518 W, 2015 – 2018*

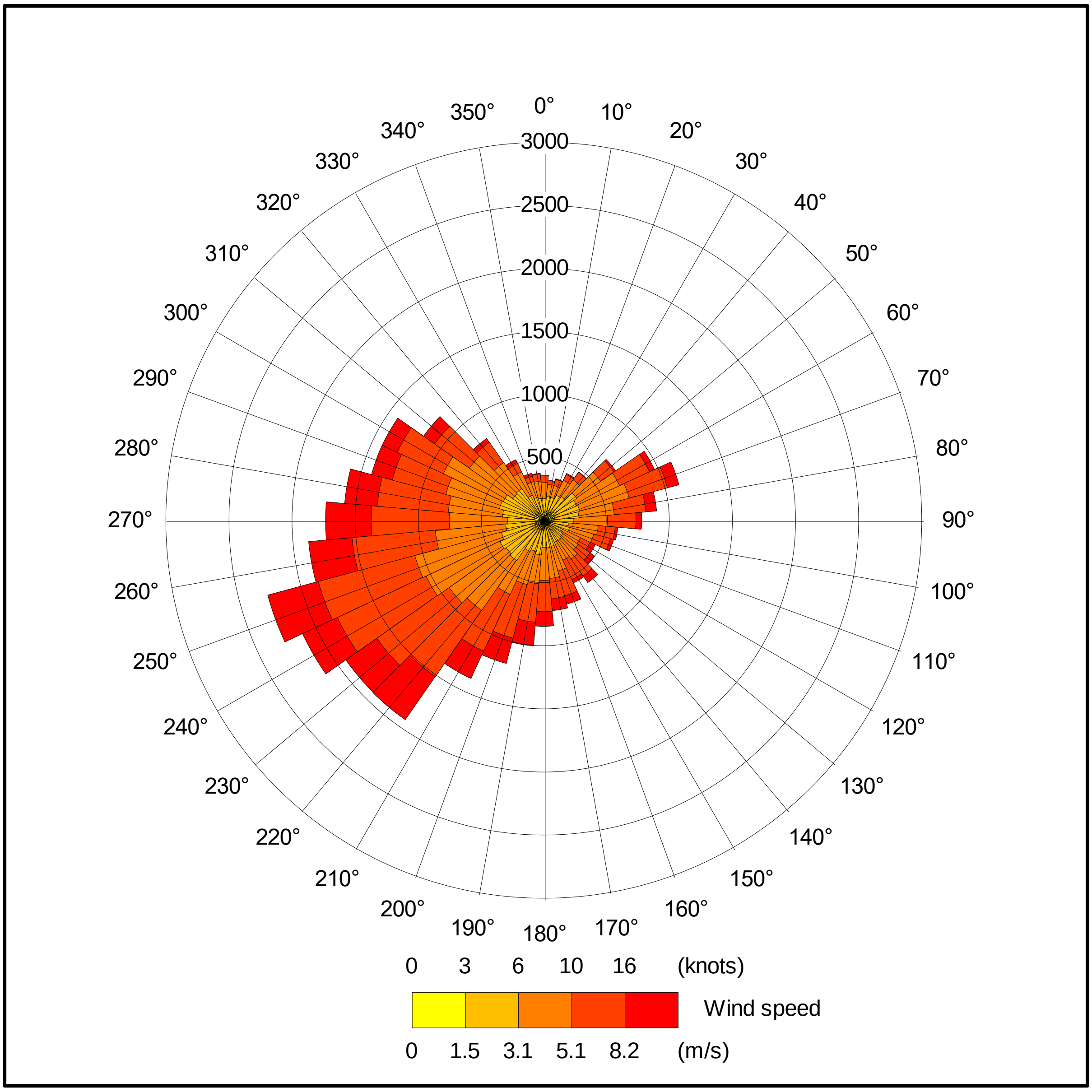


*Figure 3b. The wind rose. FLOWSTAR derived data for NGR 296200, 255400, 2015-2018*

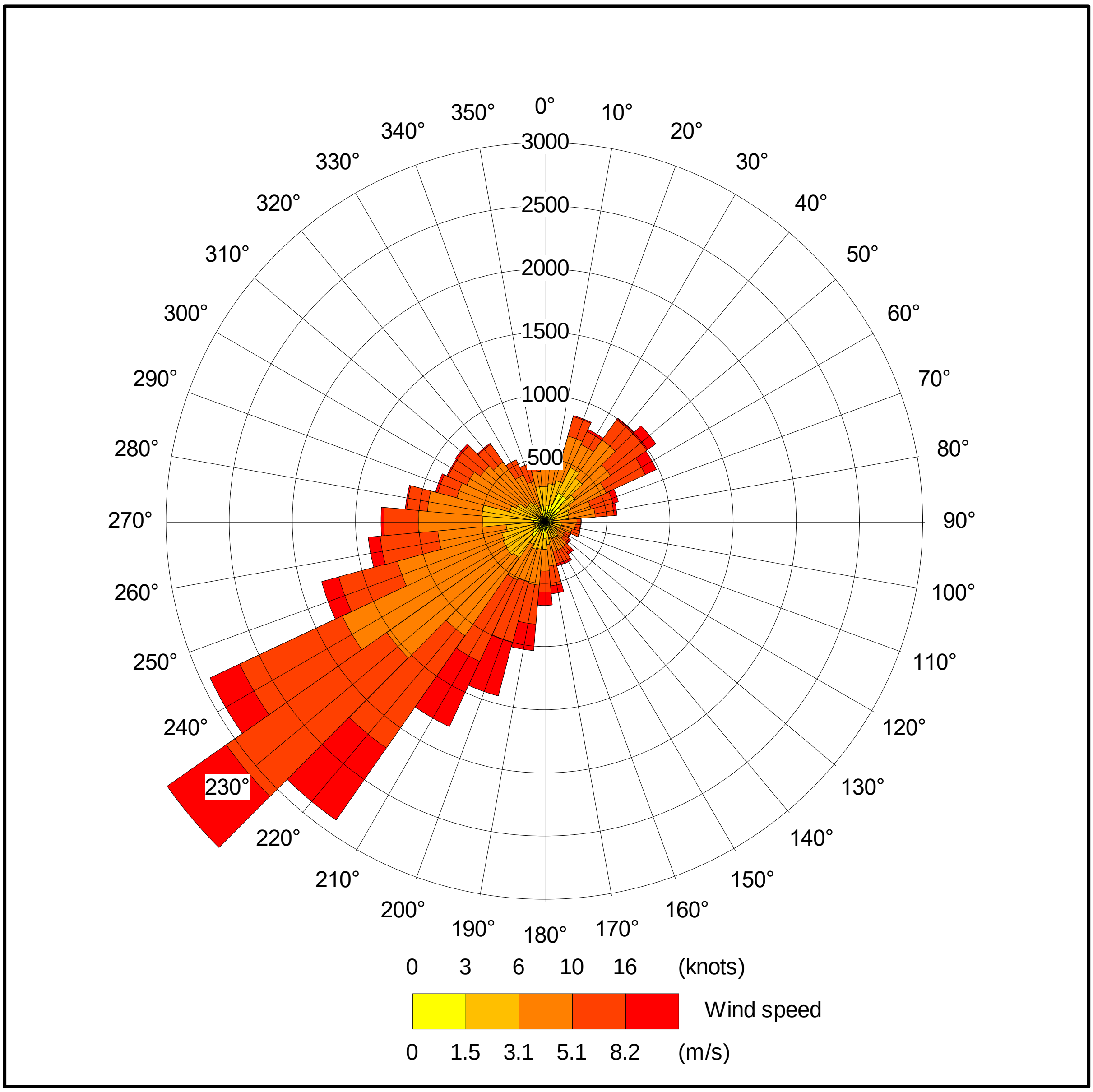
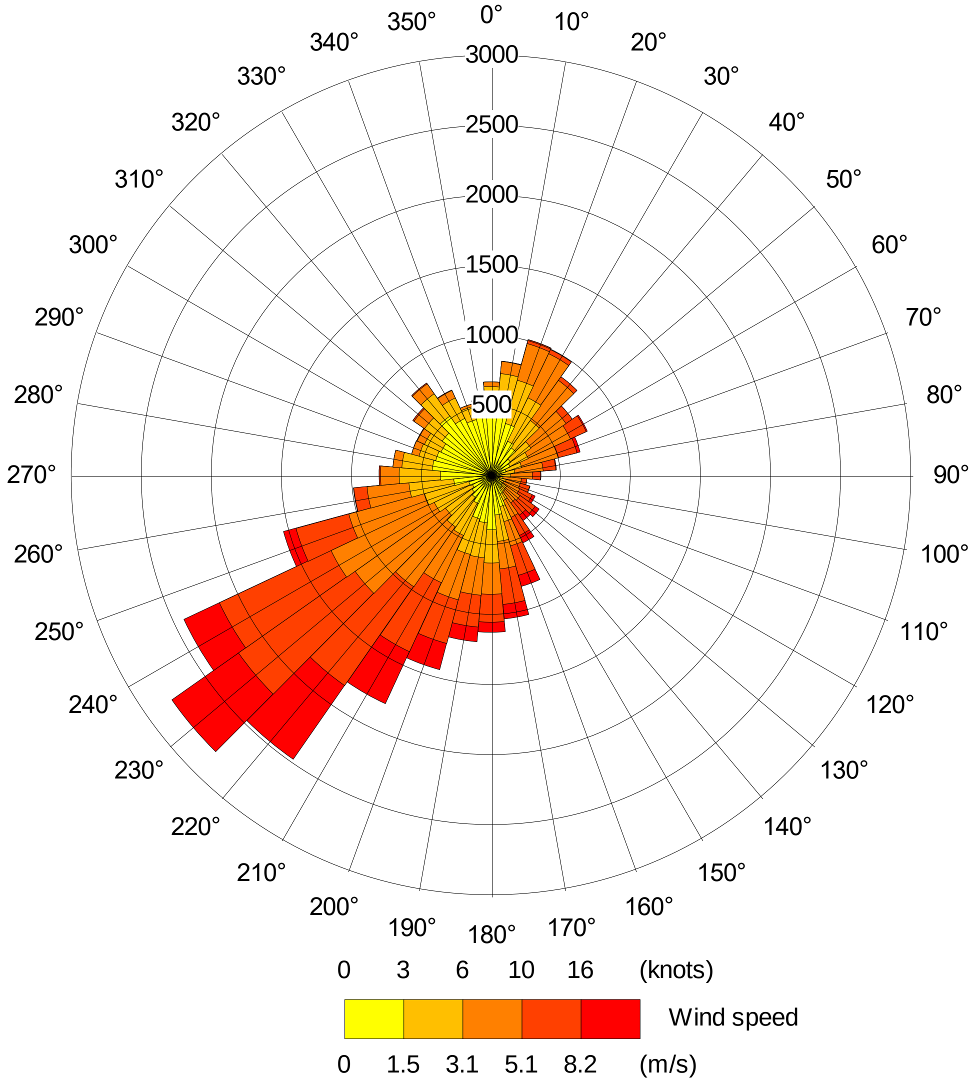


*Figure 3c. The wind rose for Sennybridge, 2015 -2018*



## 4.2 Emission sources

Emissions from the chimneys of the high speed ridge fans that would be used to ventilate the proposed poultry houses are represented by three point sources per house within ADMS (PR1 and PR2; a, b & c).

Details of the point source parameters are shown in Table 2. The positions of the sources used are shown in Figure 4.

*Table 2. Point source parameters*

| Source ID | Height (m) | Diameter (m) | Efflux velocity (m/s) | Emission temperature (˚C) | Emission rate per source ($ou_E$/s) |
|---|---|---|---|---|---|
| PR1 & PR2; a, b & c | 5.5 | 0.92 | 12.0 | Variable [1] | Variable [1] |

1. Dependent on crop stage and ambient temperature.

## 4.3 Modelled buildings

The structure of the proposed poultry houses may affect the odour plumes from the point sources. Therefore, the 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

Ten 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.

## 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. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field for the terrain runs is 100 m.

## 4.7 Other model parameters

A fixed surface roughness length of 0.35 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 0.325 m. The effect of the difference in roughness length is precautionary as it increases the frequency of low wind speeds and the stability and therefore increases predicted ground level concentrations.

*Figure 4. The positions of modelled buildings and sources*

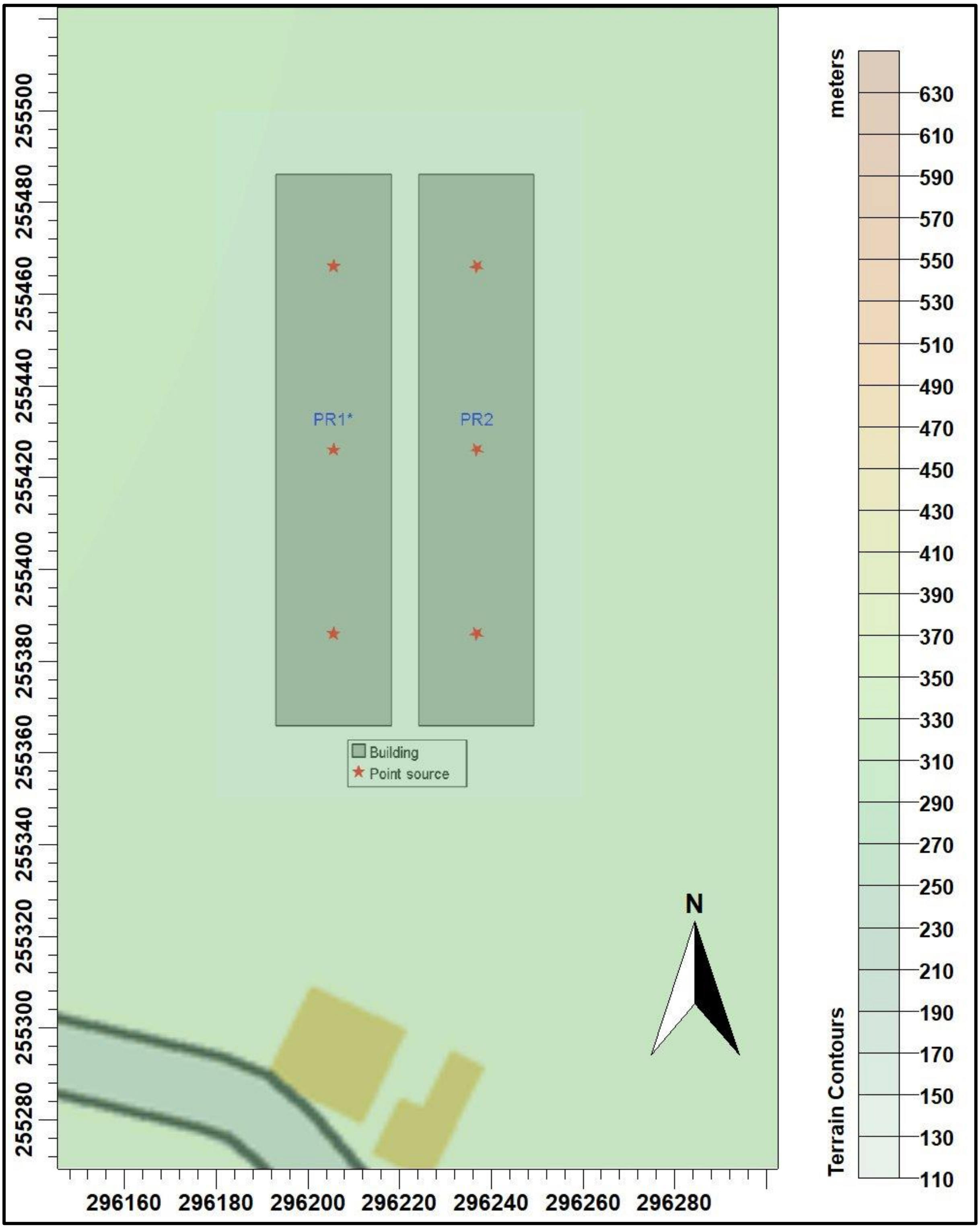
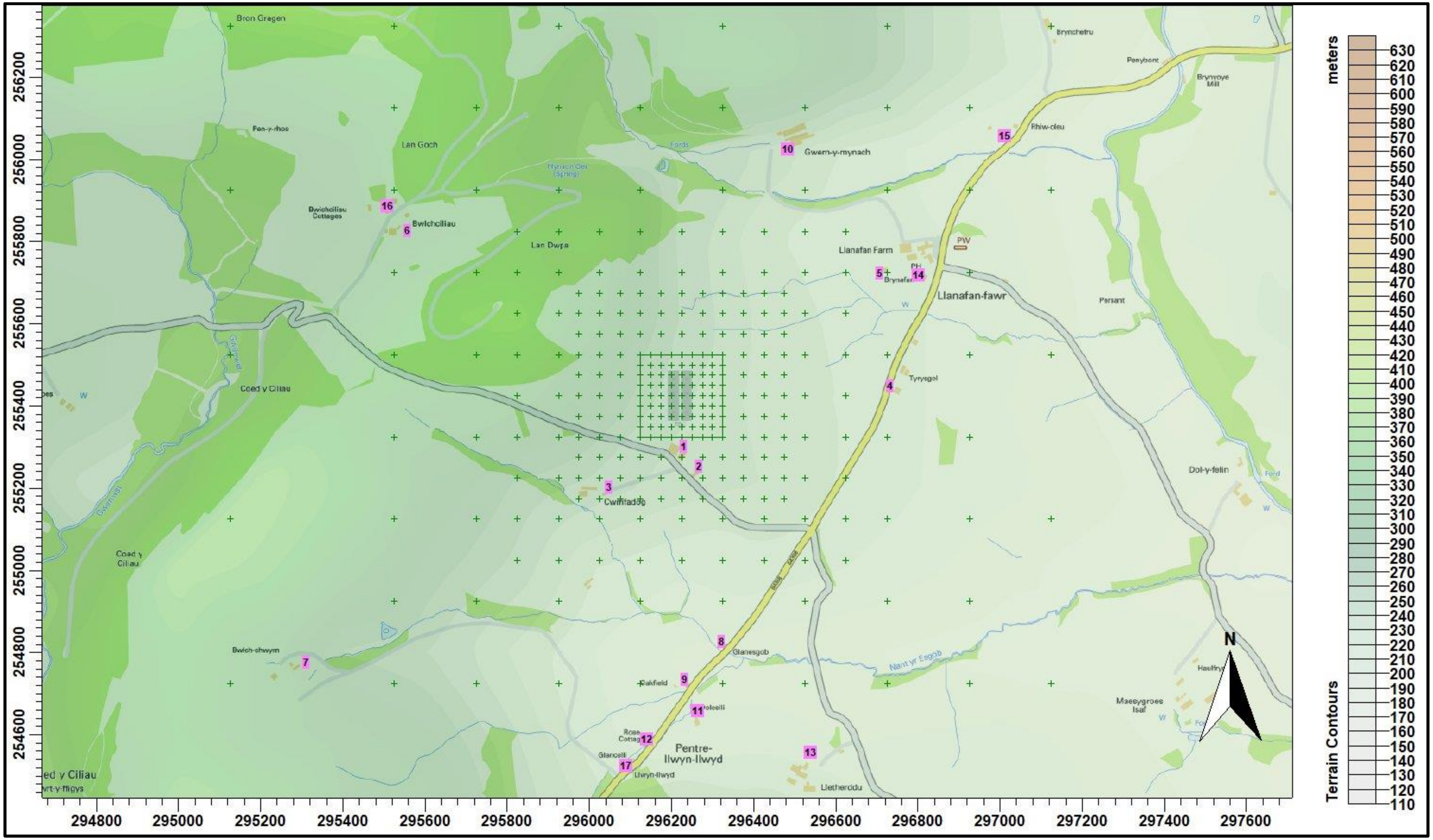


*Figure 5. The discrete receptors and nested Cartesian grid receptors*



# 5. Details of the Model Runs and Results

ADMS was effectively run twenty-four times with terrain and the calms module of ADMS: once for each year of the four year meteorological record and for each of the three crop cycles, using both the GFS meteorological data and the Sennybridge meteorological data. Statistics for the annual 98$^{th}$ percentile hourly mean odour concentration at each receptor were compiled for each of the runs.

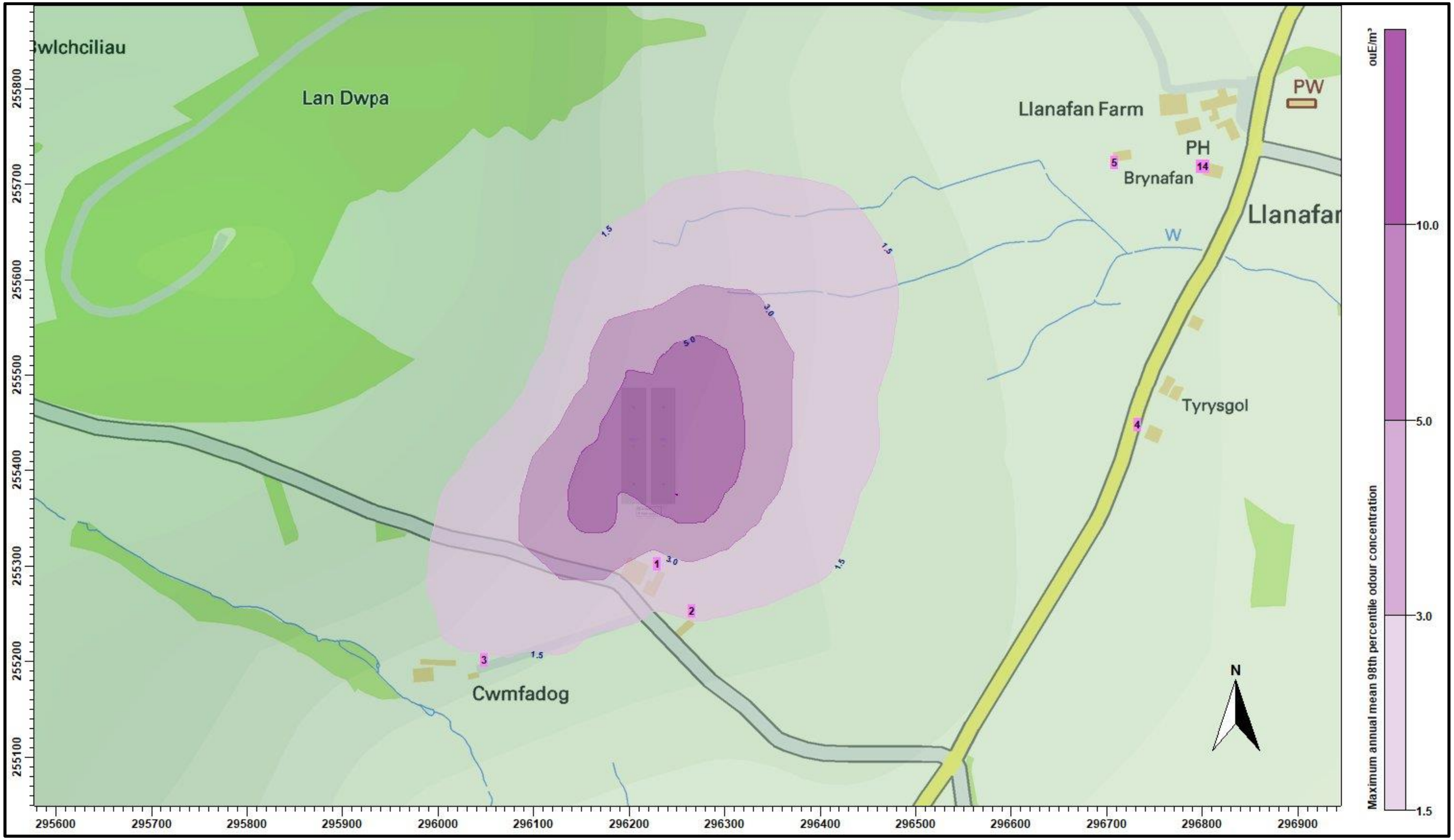
A summary of the results obtained at the discrete receptors is provided in Table 3, where the maximum annual 98$^{th}$ percentile hourly mean odour concentration is shown. A contour plot of the maximum annual 98$^{th}$ percentile hourly mean odour concentrations obtained using the GFS data is shown in 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 98$^{th}$ 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 98$^{th}$ 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) | Site | Maximum annual 98th percentile hourly mean odour concentration ($ou_E/m^3$) | |
|---|---|---|---|---|---|
| | | | | GFS Calms Terrain | Sennybridge Calms Terrain |
| 1 | 296229 | 255302 | Cwmafan | 2.47 | 2.15 |
| 2 | 296266 | 255253 | Cwmafan farmstead | 1.64 | 1.10 |
| 3 | 296049 | 255201 | Cwmfadog | 1.43 | 1.64 |
| 4 | 296732 | 255448 | Tyrysgol | 0.47 | 0.38 |
| 5 | 296708 | 255722 | Brynafan | 0.62 | 0.69 |
| 6 | 295558 | 255827 | Bwlchciliau | 0.17 | 0.12 |
| 7 | 295311 | 254775 | Bwlch-chwyrn | 0.16 | 0.15 |
| 8 | 296322 | 254827 | Glanesgob | 0.18 | 0.14 |
| 9 | 296231 | 254734 | Oakfield | 0.13 | 0.15 |
| 10 | 296482 | 256024 | Gwern-y-mynach | 0.27 | 0.28 |
| 11 | 296265 | 254658 | Dolcelli | 0.11 | 0.12 |
| 12 | 296141 | 254590 | Rose Cottage | 0.06 | 0.13 |
| 13 | 296539 | 254557 | Lletherddu | 0.09 | 0.09 |
| 14 | 296801 | 255718 | Llanafan-fawr | 0.49 | 0.53 |
| 15 | 297012 | 256057 | Rhiw-oleu | 0.25 | 0.31 |
| 16 | 295508 | 255887 | Bwlchciliau Cottages | 0.16 | 0.11 |
| 17 | 296089 | 254524 | Glancelli | 0.05 | 0.13 |

*Figure 6. Predicted maximum annual 98th percentile hourly mean odour concentration – GFS data*



# 6. Summary and Conclusions

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Odour emission rates from the 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, should the proposed poultry houses be constructed at Cwmafan, the odour exposure would be below the benchmark for moderately offensive odours, which is a maximum annual 98$^{th}$ percentile hourly mean concentration of 3.0 $ou_E/m^3$, at all residential receptors considered.

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