

**A Dispersion Modelling Study of the Impact of Odour from the
Proposed Pullet Rearing Houses at Gaufron Farm, Howey,
Llandrindod Wells, Powys**

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Steve Raasch, on behalf of the applicant Sun Valley Foods Ltd. to use computer modelling to assess the impact of odour emissions from the proposed pullet rearing houses at Gaufron Farm, Howey, Llandrindod Wells, Powys. LD1 5RG.

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 methods used to estimate odour emissions from the proposed 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.
- And Section 6 provides a discussion of the results and conclusions.

2. Background Details

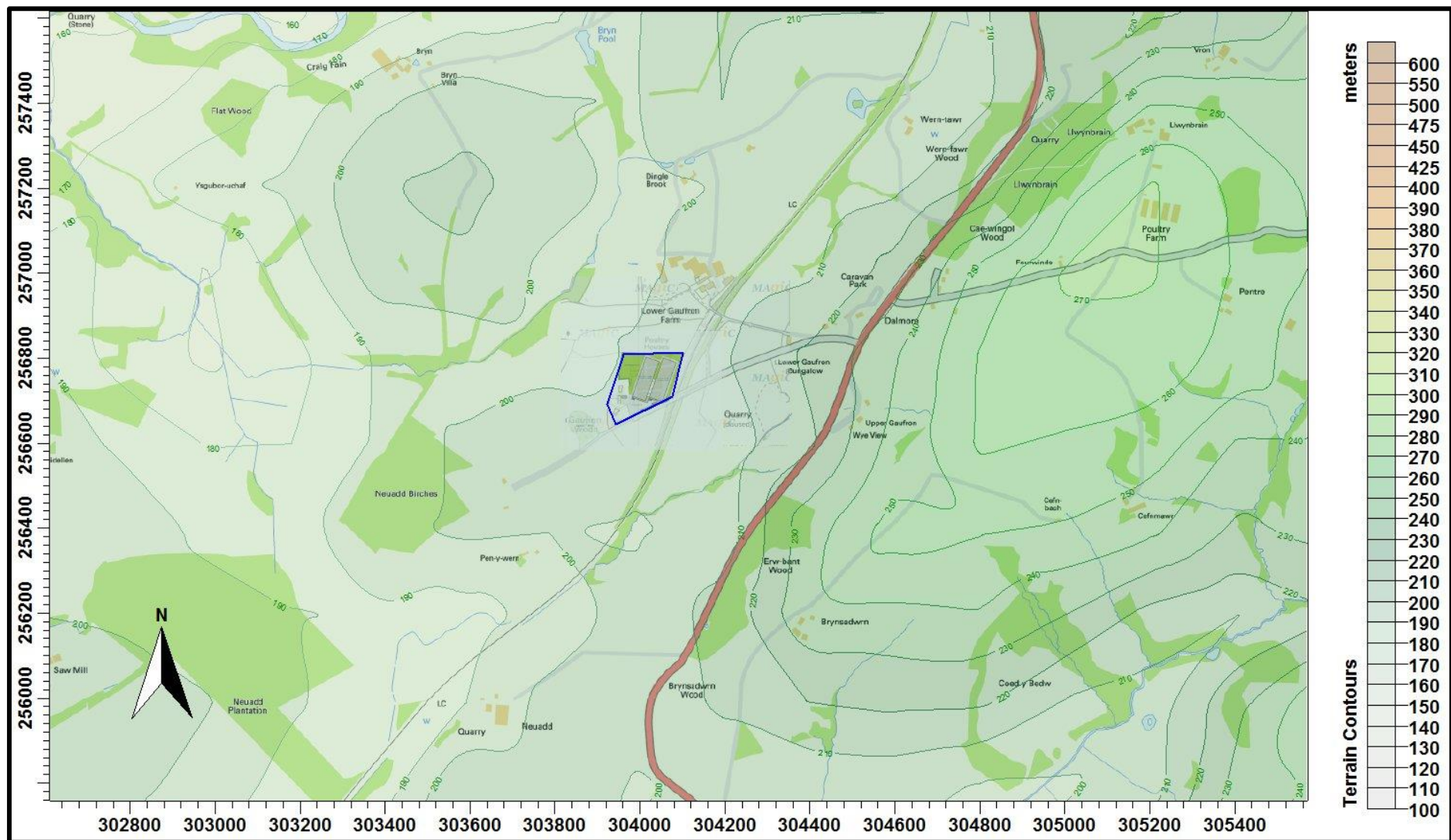
The site of the proposed poultry houses at Gaufron Farm is in a rural area. The surrounding land is used primarily as pasture for livestock farming although there are also some arable fields and some wooded areas. The site is at an altitude of around 202 m with the land falling towards the River Ithon Valley to the west and rising towards hills and mountains to the east.

It is proposed that two new chicken rearing houses be constructed at Gaufron Farm; these houses would replace the five existing poultry houses. The new houses would provide accommodation for up to 56,000 pullets, which would be reared from day old chicks up to the age of around 18 weeks old, prior to transfer to egg laying units elsewhere. The new houses would be ventilated by uncapped high speed ridge mounted fans, each with a short chimney.

There are some residences and commercial properties in the area surrounding the site of the proposed poultry houses at Gaufron Farm. Excluding the workers' residences at the farm, the closest residences are at; the farmhouse at Lower Gaufron Farm, which is approximately 175 m to the north-east of the site of the proposed poultry houses; Lower Gaufron Bungalow, approximately 260 m to the east-north-east; Wye View and Upper Gaufron, approximately 440 m to the east-south-east and residences near Pen-y-wern, between approximately 380 m and 420 m to the south-west. There is also a caravan park approximately 420 m to the east-north-east.

A map of the surrounding area is provided in Figure 1; the site of the proposed poultry houses at Gaufron Farm is outlined in blue.

Figure 1. The area surrounding the site of the poultry unit at Gaufron Farm



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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.

- $1.0 \text{ ou}_E/\text{m}^3$ is defined as the limit of detection in laboratory conditions.
- At $2.0 - 3.0 \text{ ou}_E/\text{m}^3$, a particular odour might be detected against background odours in an open environment.
- When the concentration reaches around $5.0 \text{ ou}_E/\text{m}^3$, a particular odour will usually be recognisable, if known, but would usually be described as faint.
- At $10.0 \text{ ou}_E/\text{m}^3$, 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 models 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/m³ for most offensive odours.
- 3.0 ou_E/m³ for moderately offensive odours.
- 6.0 ou_E/m³ 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/m³, complaints are relatively rare at only 3% of the total registered.
- At between 5.0 ou_E/m³ and 10.0 ou_E/m³, 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/m³, 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/m³ 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 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 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 house. Note that 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.

For the calculation for pullet rearing houses, 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/m³ at day 1 of the crop, to a maximum of 2,000 ou_E/m³ at day 49 of the crop.

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 32 Celsius at the beginning of the crop and is decreased to 21 Celsius by day 91 of the cycle. 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 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).

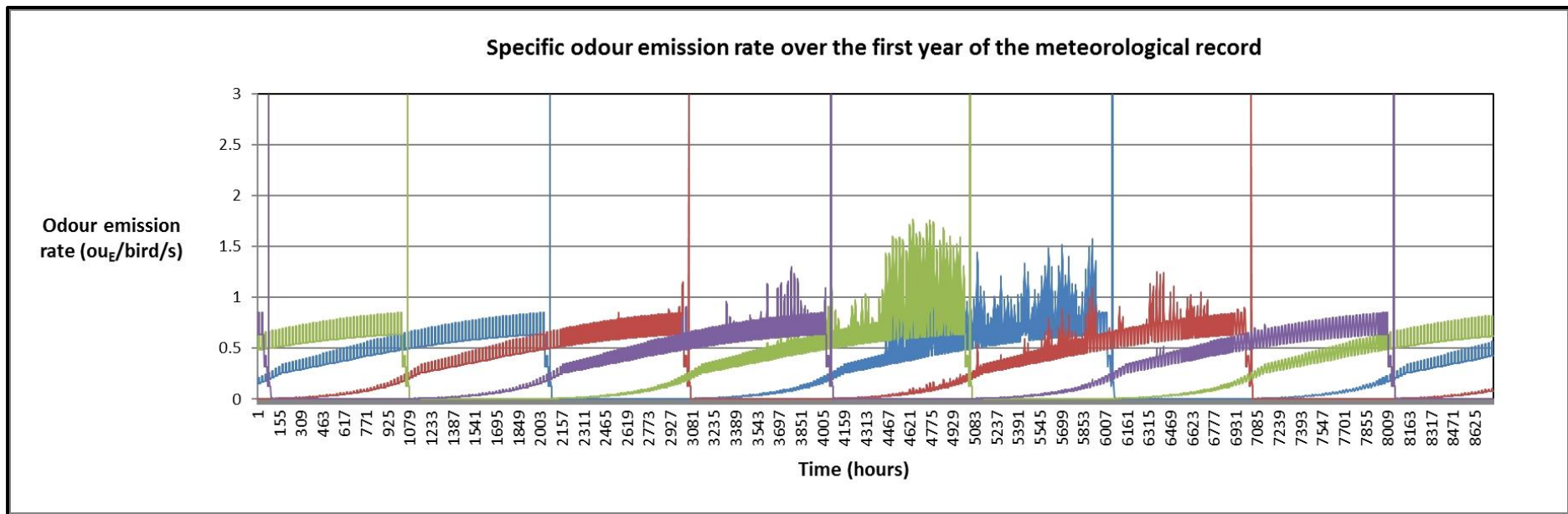
Based upon these principles, an emission rate for each hour of the period modelled is calculated by multiplying the concentration by the ventilation rate. Both the crop length and period the housing is empty can be varied. An estimate of the emission during the cleaning out process can also be included. 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 126 days and that there is an empty period of 40 days after each crop. To provide robust statistics, four 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 41 of the crop, the third coinciding with day 83 of the crop and the fourth coinciding with day 124 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 the AS Modelling & Data Ltd. figures in the table. The specific odour emission rate used for the clearing process is approximately 2.95 ou_E/bird/s and the 98th percentile emission rate is approximately 0.95 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 four crop cycles is shown in Figure 2.

Table 1. Summary of odour emission rates (average/maximum of all 4 cycles)

Emission rate (ou _E /s per bird as stocked, during crop)				
Season	Average	Night-time Average	Day-time Average	Maximum
Winter	0.358	0.322	0.430	1.007
Spring	0.389	0.325	0.454	1.760
Summer	0.436	0.327	0.501	1.842
Autumn	0.378	0.324	0.433	1.097

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



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). Traditional observational meteorological datasets from Sennybridge and Shobdon, which are the two closest recording stations. Have also been 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 the poultry unit 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 modified wind roses may differ more markedly and that the resolution of the wind field in terrain runs is 200 m.

Gaufron Farm is approximately central to the meteorological recording stations at Sennybridge and Shobdon. However, neither Sennybridge nor Shobdon has an aspect that in any way could be considered similar to Gaufron Farm. Therefore, it should be noted that the frequency of winds from a particular direction in the Sennybridge or Shobdon data may be either high or low in comparison to what might occur at Gaufron Farm, which means mean concentrations downwind may be either over or under predicted. In particular, note that Shobdon is a station that is located in a valley bottom and as such is likely to have a considerable greater frequency of light or calm winds than a hillside location such as Gaufron Farm. 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 considerably more weight when interpreting the results of the modelling and furthermore that results obtained using Sennybridge and Shobdon meteorological data are rather more likely to be subject to gross errors than are the GFS/FLOWSTAR results.

The wind roses for Sennybridge and Shobdon are provided in Figures 3c and 3d and should serve to demonstrate how different the wind regime from relatively close observing sites in complex terrain can be and how unlikely it is that a remote observational dataset could in any way be representative of the wind regime around Gaufron Farm.

Figure 3a. The wind rose. GFS derived data for 52.200 N, 3.405 W 2013 – 2016

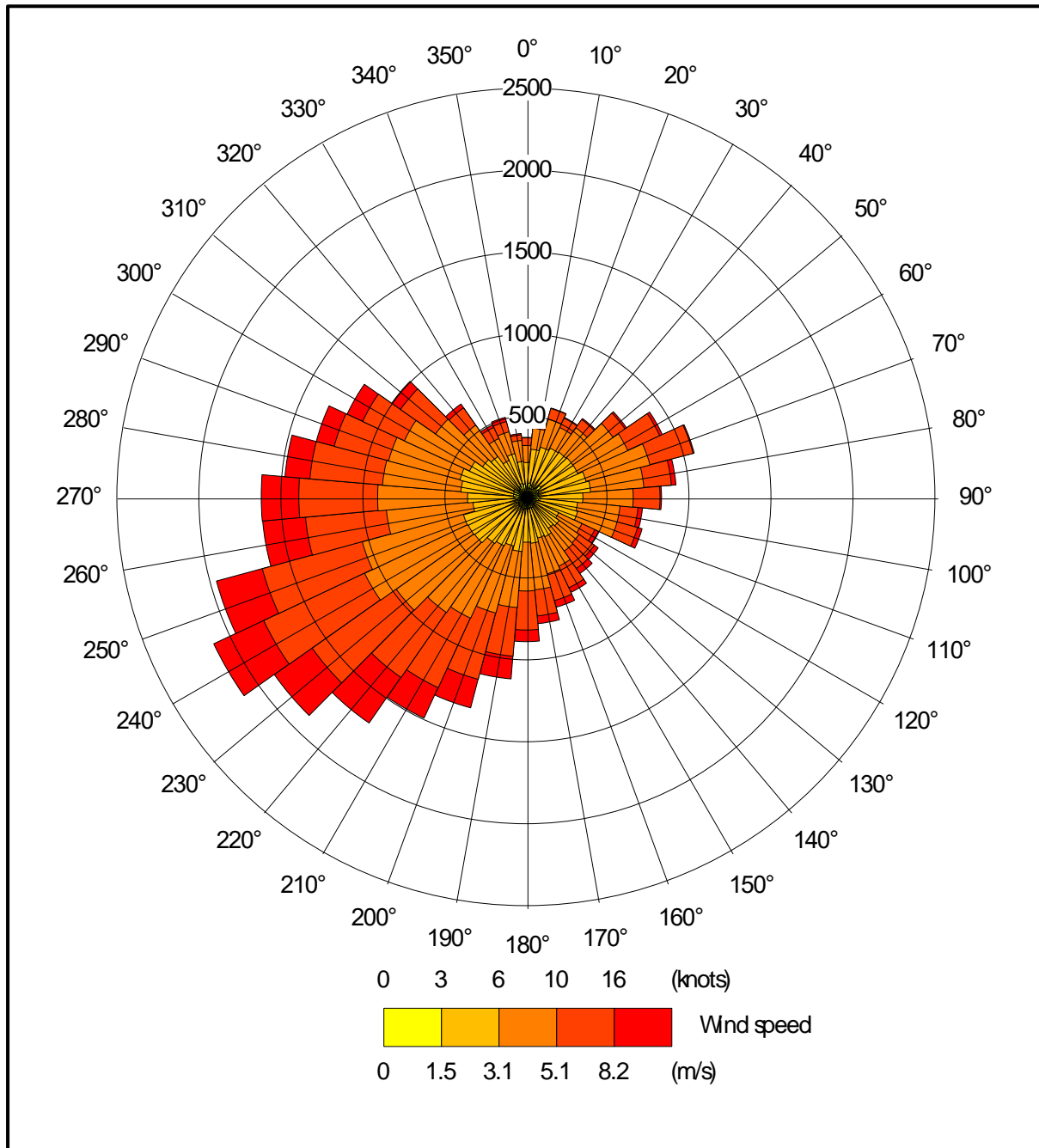


Figure 3b. The wind rose. FLOWSTAR modified GFS data for the site of the poultry unit NGR 304000, 256750)

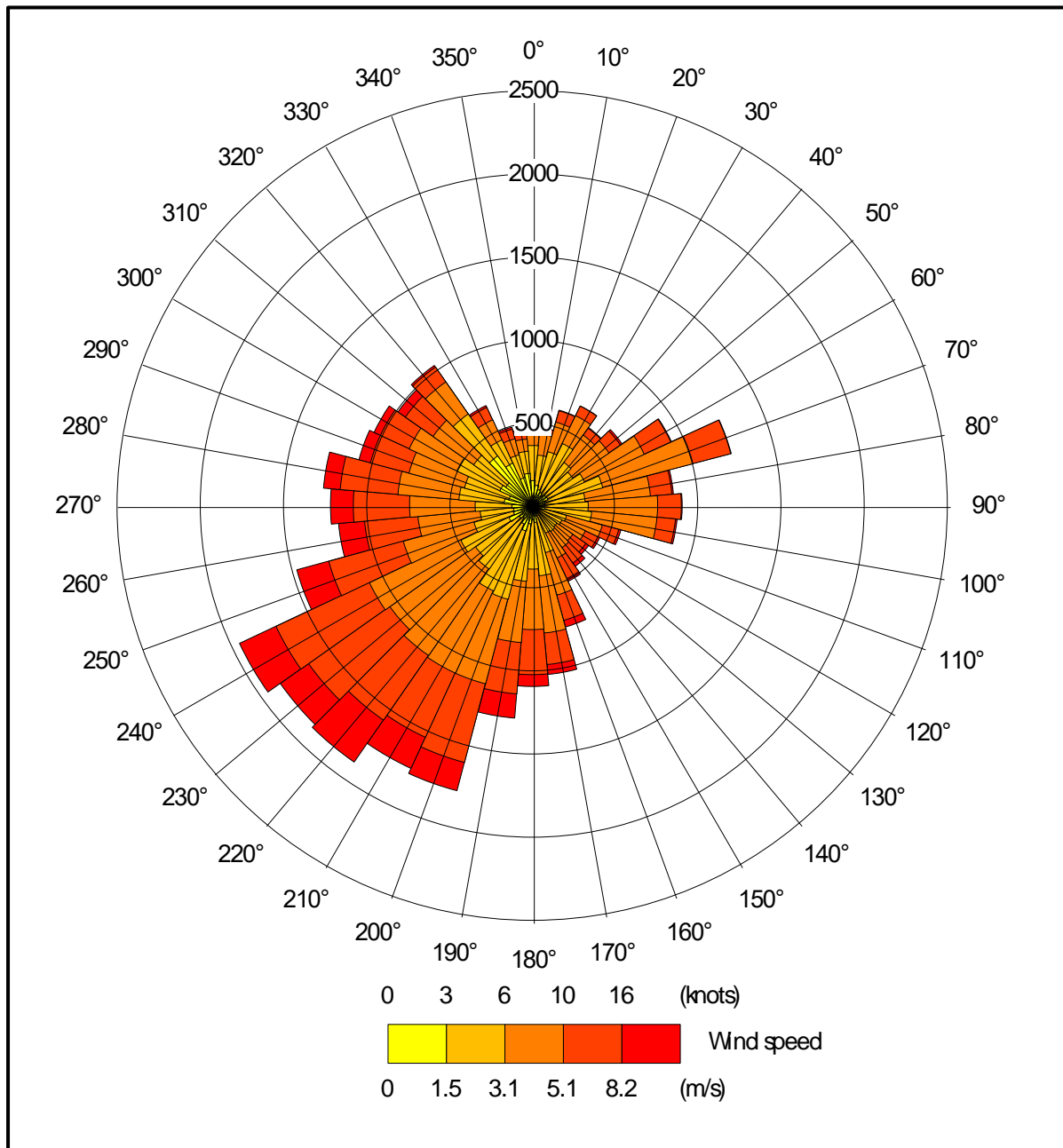


Figure 3c. The wind rose. Sennybridge data 2013 – 2016

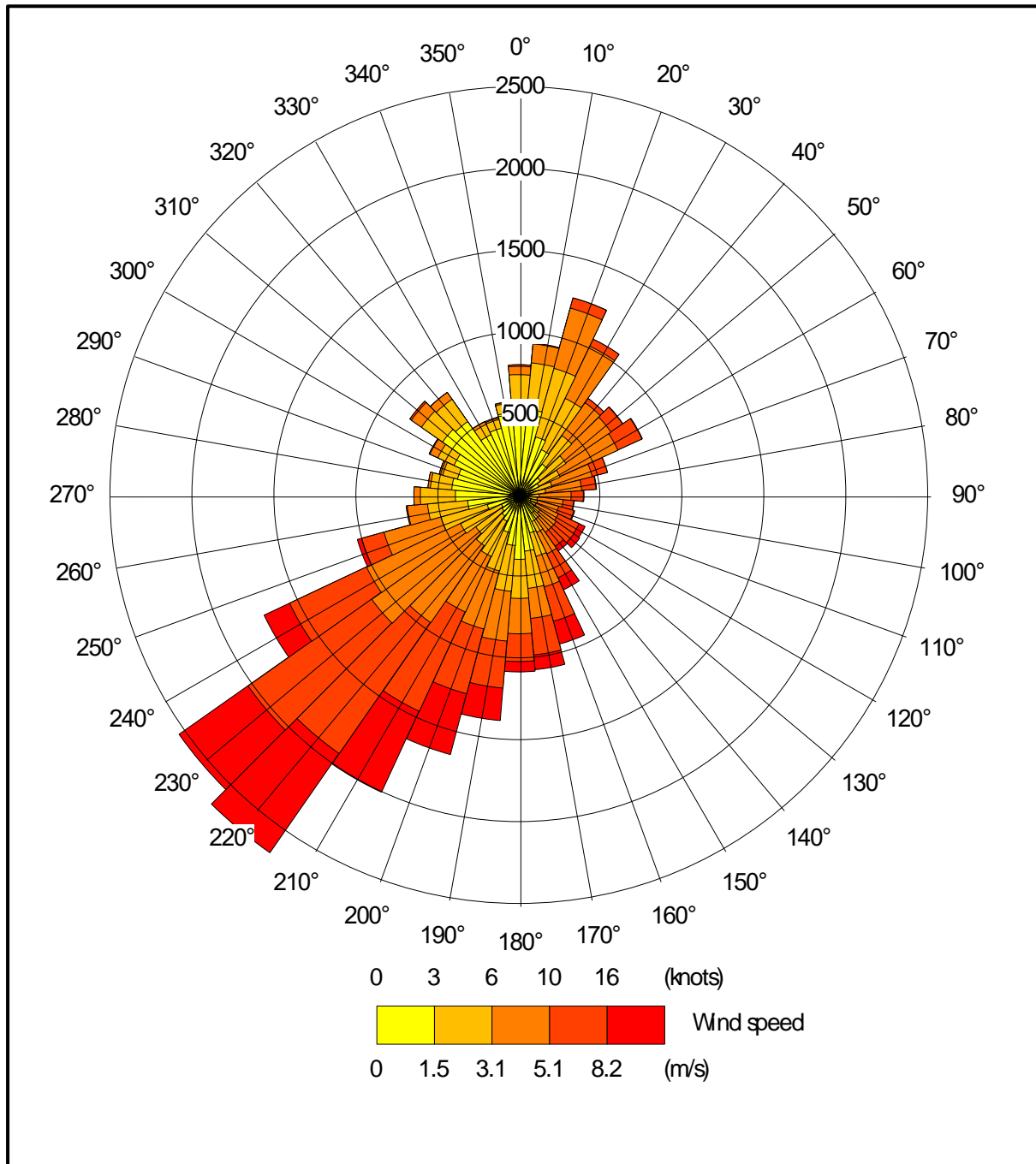
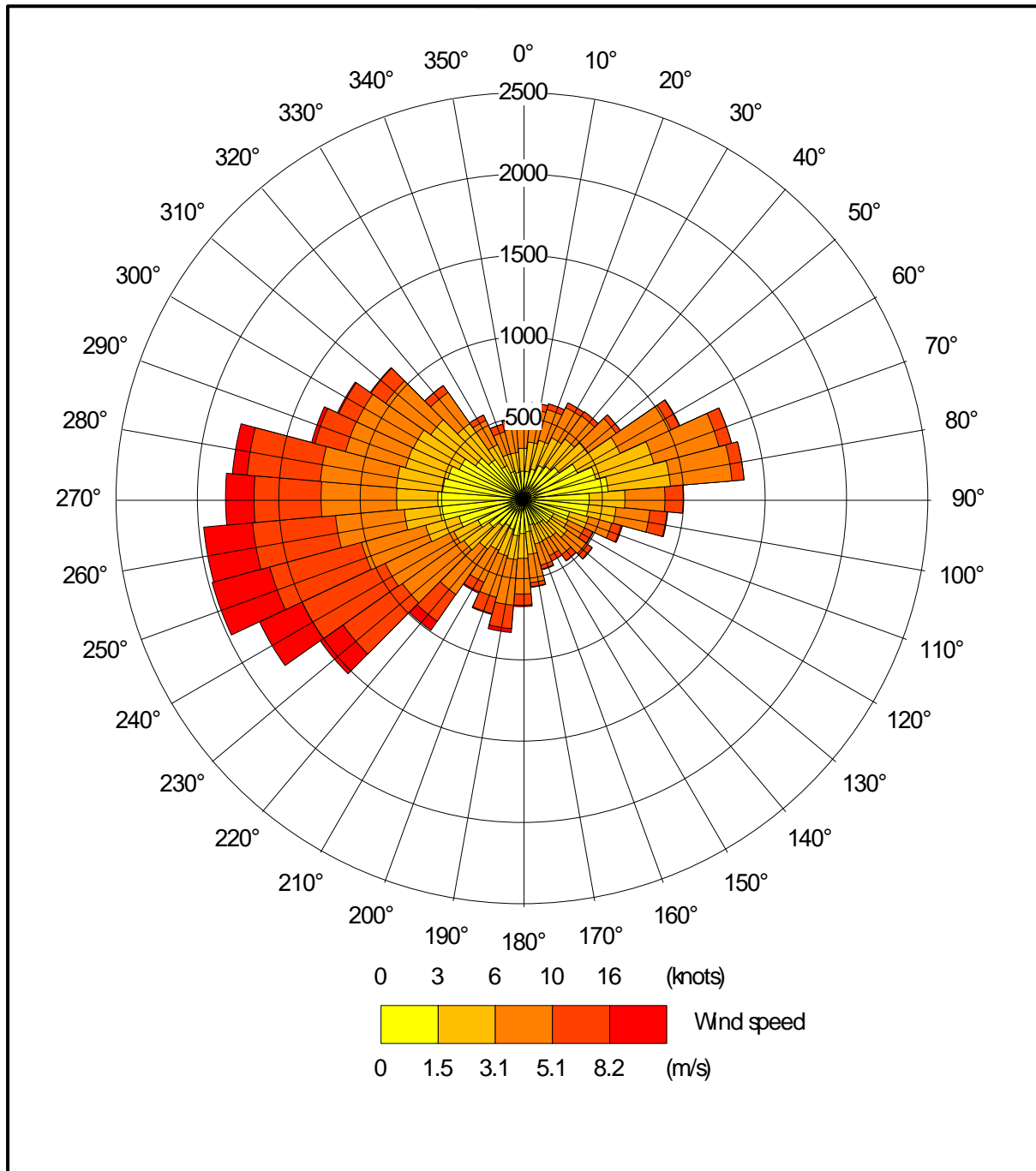


Figure 3d. The wind rose. Shobdon data 2013 – 2016



4.2 Emission sources

Emissions from the chimneys of the uncapped high speed ridge mounted fans on the proposed poultry houses are represented by three point sources per house within ADMS (PR1 a, b & c and PR2 a, b & c). Details of the point source parameters are shown in Table 2. The positions of the point sources may be seen 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 a, b & c	6.5	0.8	11.0	Variable ¹	Variable ¹
PR2 a, b & c	6.5	0.8	11.0	Variable ¹	Variable ¹

1. Dependent on crop stage and ambient temperature.

4.3 Modelled buildings

The structure of the proposed poultry houses and other farm buildings 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.

Figure 4. The positions of modelled buildings & sources



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4.4 Discrete receptors

Twenty-two 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 receptors may be seen in Figure 5 where they are marked by grey lines.

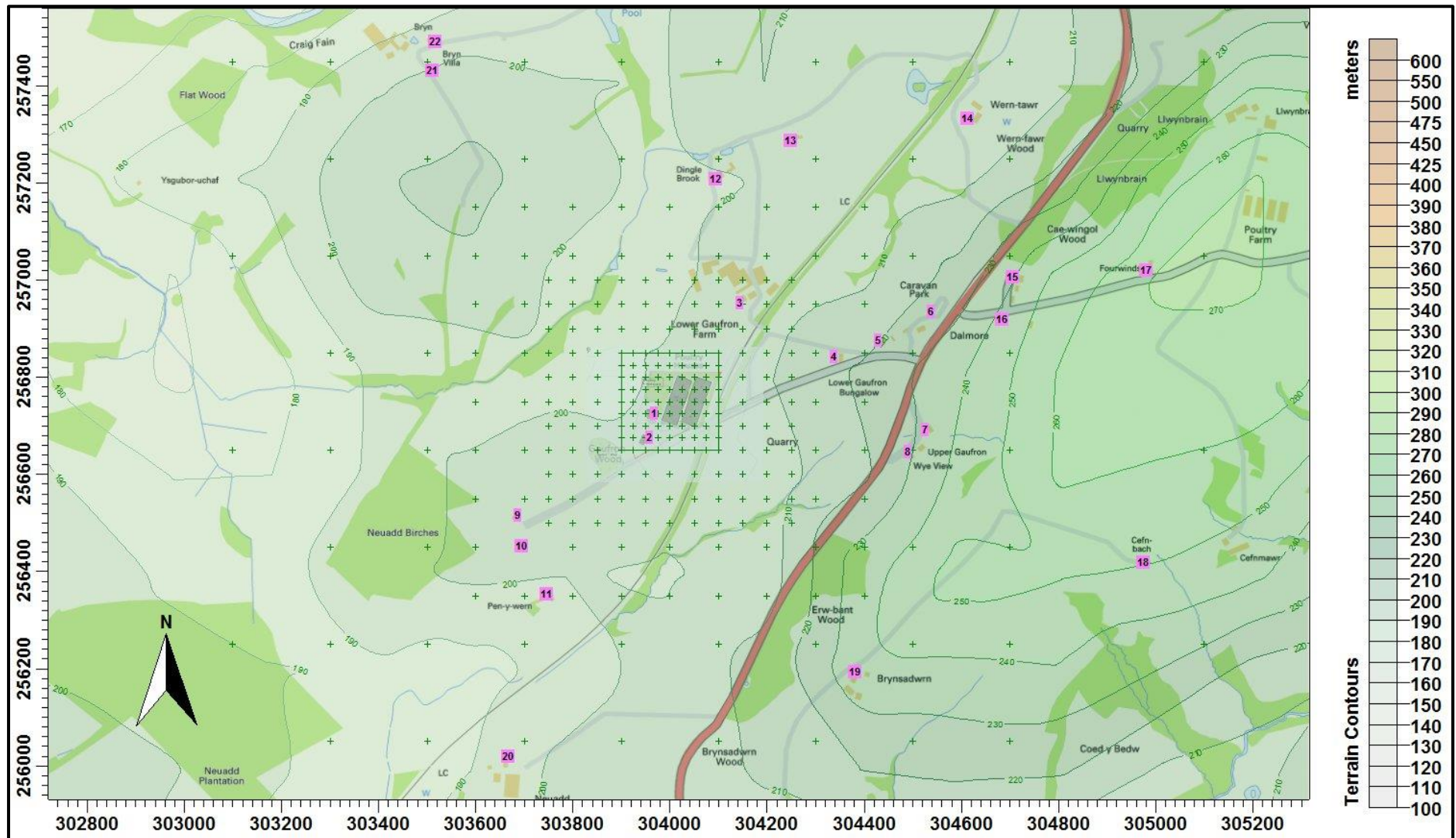
4.6 Terrain data

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 32 x 32 grid points; therefore, the effective resolution of the wind field for the terrain runs is 200 m.

4.7 Other model parameters

A fixed surface roughness length of 0.30 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 0.275 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 5. The discrete receptors and nested Cartesian grid receptors



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5. Details of the Model Runs and Results

For this study, ADMS was run with calms module of ADMS and with terrain. ADMS was run a total of sixteen times, once for each year of the four year meteorological record in the following three modes:

- With calms and with terrain – GFS data
- With calms and with terrain – Sennybridge data
- With calms and with terrain – Shobdon data

Statistics for the annual 98th percentile hourly mean odour concentration at each receptor were compiled for each of the twenty runs.

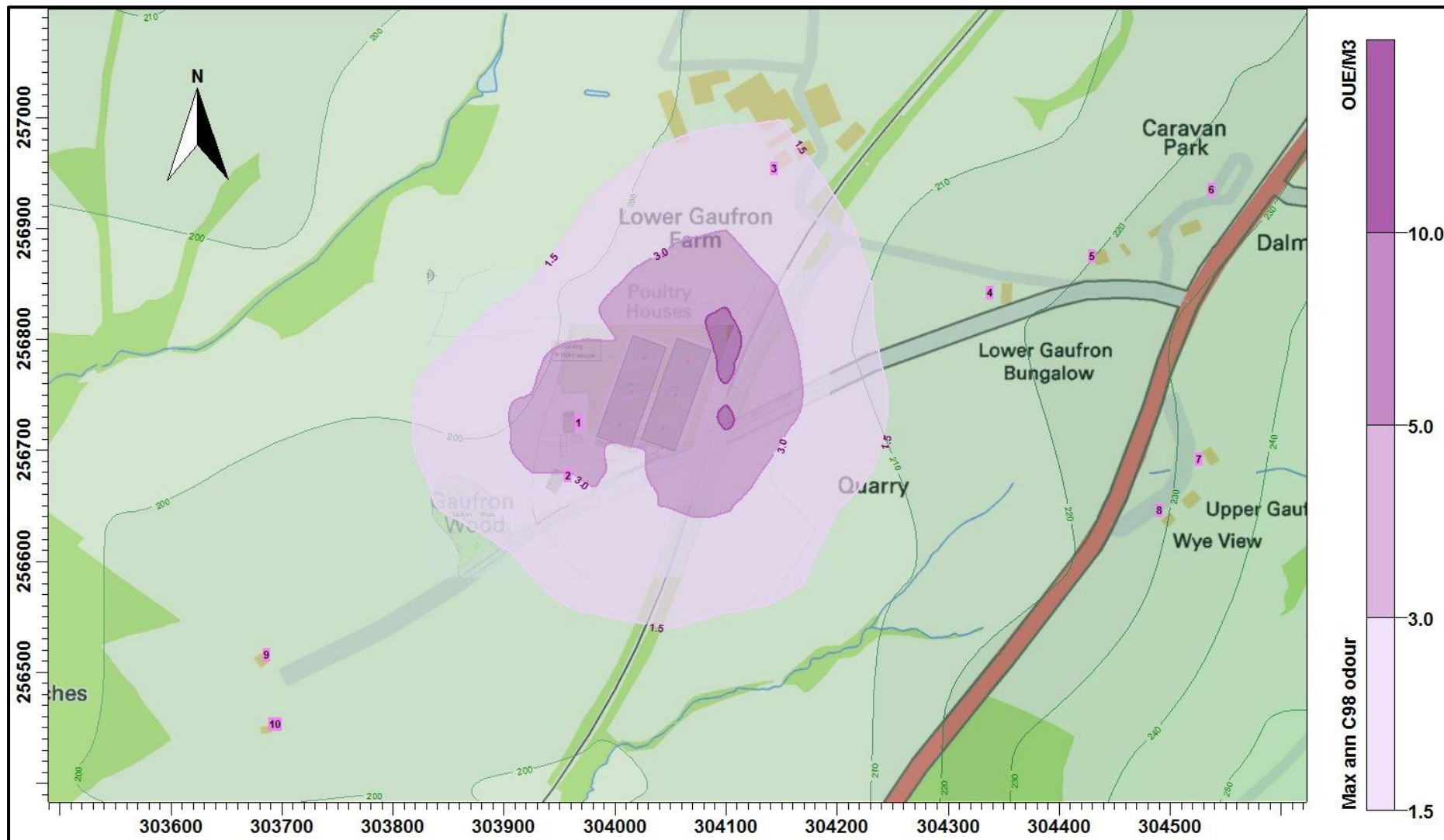
A summary of the results at the discrete receptors is shown in Table 3 where the maximum annual 98th percentile hourly mean odour for each mode is shown. A contour plot of the maximum annual 98th percentile hourly mean odour concentration obtained, using GFS data with calms and terrain modelled, is shown in Figure 6.

In Table 3, predicted odour exposures in excess of the Environment Agency's benchmark of 3.0 ou_E/m³ 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/m³ to 10.0 ou_E/m³ as an annual 98th percentile hourly mean, are coloured orange and predicted exposures likely to cause annoyance and complaint, those in excess of 10.0 ou_E/m³ as an annual 98th percentile hourly mean, 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 98 th percentile hourly mean odour concentration (ouE/m ³)		
			GFS Calms Terrain	Sennybridge Calms Terrain	Shobdon Calms Terrain
1	303967	256725	4.00	3.34	4.10
2	303957	256677	2.88	3.02	2.98
3	304144	256954	1.87	1.62	1.46
4	304338	256841	0.76	0.58	0.75
5	304429	256875	0.49	0.37	0.49
6	304537	256934	0.34	0.27	0.34
7	304526	256692	0.34	0.20	0.35
8	304490	256645	0.37	0.21	0.37
9	303686	256515	0.50	0.47	0.52
10	303694	256453	0.35	0.35	0.35
11	303747	256353	0.40	0.33	0.31
12	304094	257207	0.54	0.45	0.37
13	304248	257286	0.44	0.38	0.32
14	304612	257333	0.24	0.22	0.21
15	304705	257007	0.20	0.16	0.21
16	304683	256919	0.20	0.14	0.20
17	304980	257021	0.11	0.08	0.11
18	304974	256419	0.11	0.06	0.15
19	304380	256193	0.23	0.14	0.21
20	303666	256020	0.19	0.23	0.13
21	303511	257432	0.08	0.06	0.09
22	303516	257490	0.08	0.06	0.08

Figure 6. Predicted maximum annual 98th percentile hourly mean odour concentration GFS data – Calms & Terrain modelled



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6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Steve Raasch, on behalf of the applicant Sun Valley Foods Ltd. to use computer modelling to assess the impact of odour emissions from the proposed pullet rearing houses at Gaufron Farm, Howey, Llandrindod Wells, Powys. LD1 5RG.

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 results of the modelling indicate that, should the proposed development of the poultry unit at Gaufron Farm proceed, at all receptors un-associated with the farm, the 98th percentile hourly mean odour concentration would be below the Environment Agency's benchmark for moderately offensive odours, a 98th percentile hourly mean of 3.0 ou_E/m³ over a one year period.

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