A Dispersion Modelling Study of the Impact of Odour from the Proposed Poultry Houses at Coombe Farm, Llanvair Discoed, near Chepstow in Monmouthshire

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29th May 2015

1. Introduction

AS Modelling & Data Ltd. has been instructed by Gareth Adams to use computer modelling to assess the impact of odour emissions from the proposed broiler rearing houses at Coombe Farm, , Llanvair Discoed, near Chepstow in Monmouthshire. NP16 6LN.

Odour emission rates from the proposed poultry houses have been assessed and quantified based upon an emissions model that takes into account the 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 proposed poultry unit, 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

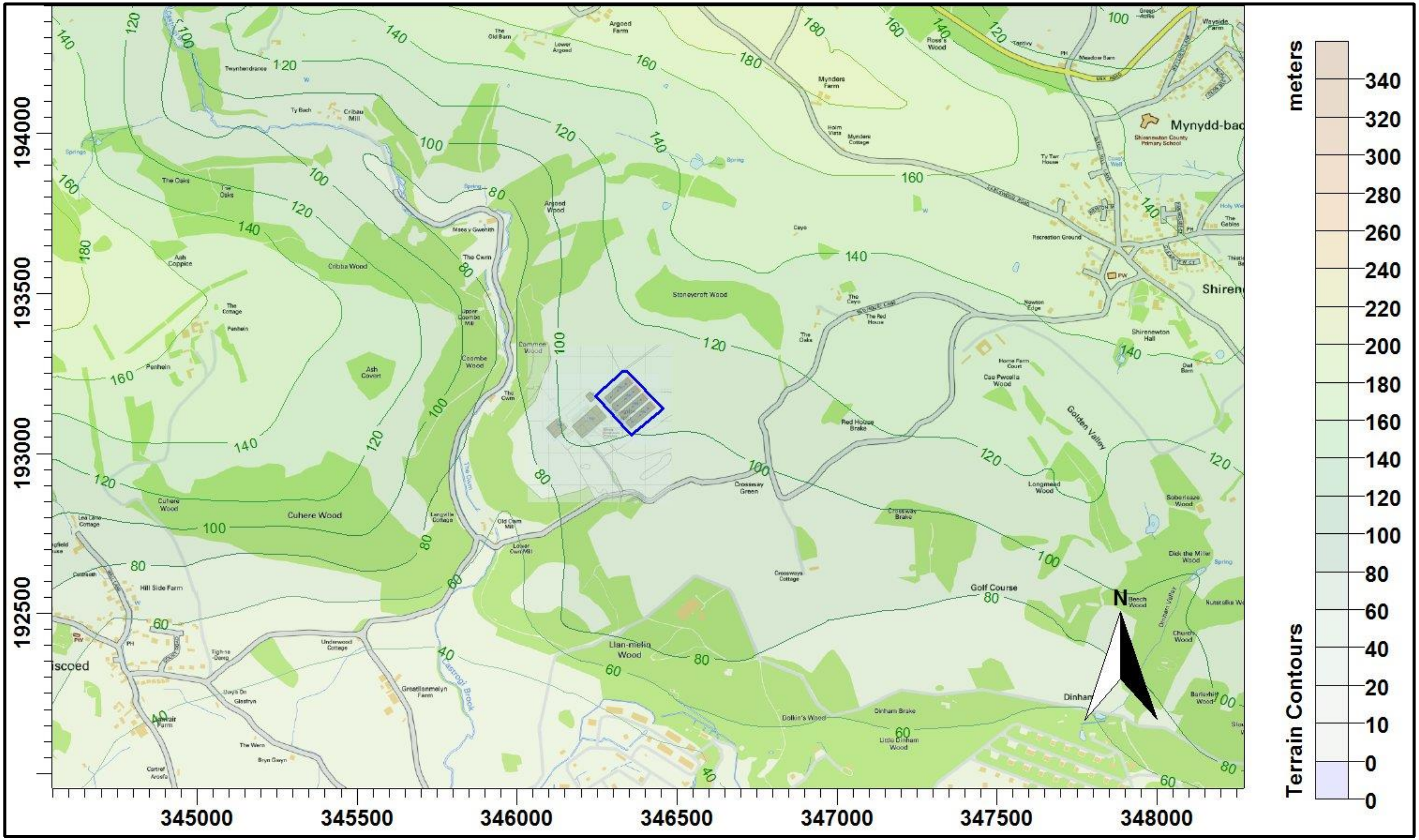
The site of the proposed broiler rearing unit at Coombe Farm is in an isolated rural area approximately 1.5 km to the north-east of the village of Llanvair Discoed in Monmouthshire. The surrounding land is used primarily for arable and livestock farming, although there are some semi-natural wooded areas. The site is at an altitude of around 105 m with the land rising towards hills and mountains to the north and falling towards the coastal plain of the River Severn Estuary to the south.

It is proposed that four poultry rearing houses be constructed on land to the north-east of the existing farm buildings at Coombe Farm. The new poultry houses would be used to provide accommodation for up to 200,000 broiler chickens. The chickens would be raised from day old chicks to up to 35 days old and there would be approximately 8.5 flocks per year. The poultry houses would be ventilated primarily by high speed ridge mounted fans, each with a short chimney, but there would also be gable end fans to provide supplementary ventilation in hot weather conditions.

There are some residences/commercial properties within 1.0 km the site of the proposed poultry unit at Coombe Farm. Excluding the farmhouse at Coombe Farm, the closest residences are at: The Cwm, approximately 340 m to the west; Old Cwm Mill, approximately 520 m to the south-west; Upper Coombe Mill, approximately 470 m to the north-west and The Oaks, approximately 550 m to the west-north-west.

A map of the surrounding area is provided in Figure 1, in the figure the proposed poultry houses are outlined in blue.

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

And 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/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 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 1,800 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 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 32 Celsius at the beginning of the crop and is decreased to 21 Celsius by day 32 of the crop. If the external temperature is 4 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 (30% of the maximum possible ventilation rate) is reached when the temperature is 1 degree above the target temperature. A high ventilation rate (60% 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 12 times the shed volume/divided by the ventilation rate as an hourly figure).

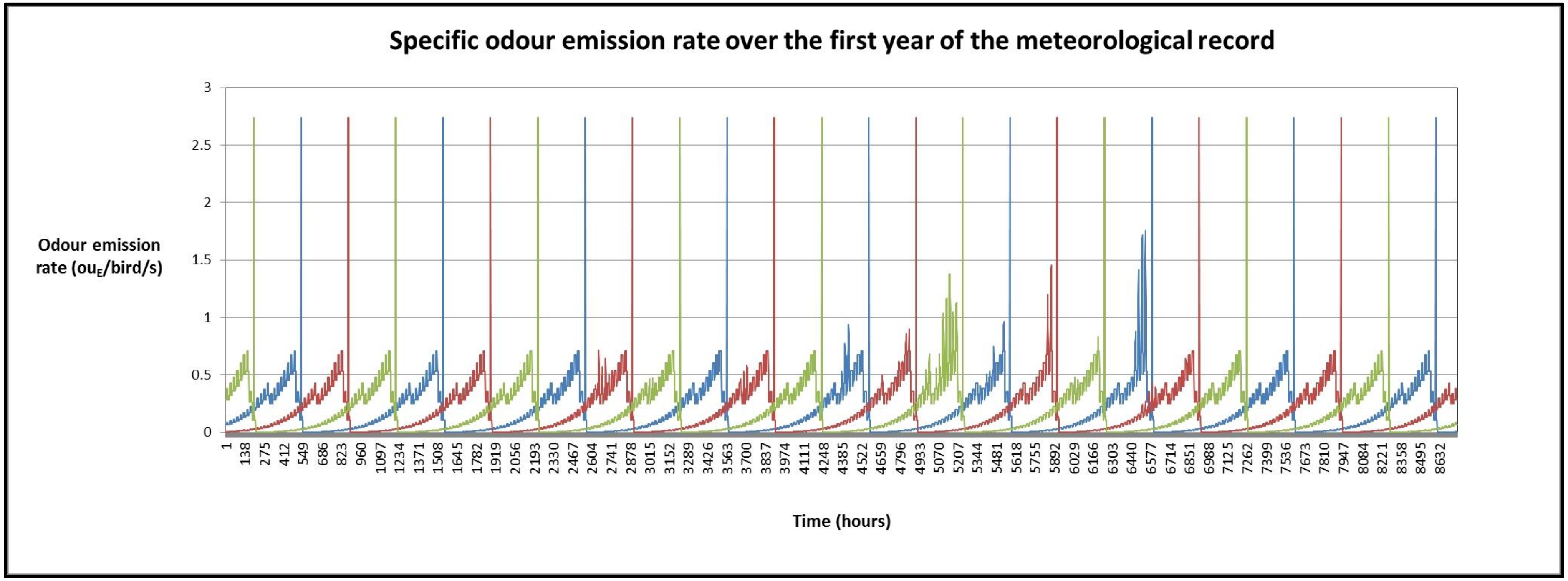
Based upon these principles, an emission rate for each hour of the period modelled is calculated by multiplying the concentration by the ventilation rate. Both the crop length and period the housing is empty can be varied. An estimation of the emission during the cleaning out process can also be included. 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 35 days, with 30% thinning of the birds at day 28 and that there is an empty period of 7 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 14 of the crop and the third coinciding with day 28 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 and are based upon the initial number of birds stocked. Most figures quoted in literature are figures obtained from the latter stages of the crop cycle and are based on actual bird numbers at the time and therefore should not be compared directly to the AS Modelling & Data Ltd. figures in the table. It should also be noted that the short crop length and early thinning means that emissions may be quite low in comparison hoses with longer crops and greater stocking density. The specific odour emission rate used for the clearing process is approximately 2.70 ou_E/bird/s (as stocked) and the 98th percentile emission rate is approximately 0.70 ou_E/bird/s (as stocked). 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/maximum 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	0.178	0.160	0.213	0.707
Spring	0.188	0.158	0.218	1.687
Summer	0.216	0.161	0.249	1.970
Autumn	0.184	0.158	0.211	0.707

Figure 2. Specific emission rate over the first year 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 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) and data from the meteorological recording station at Filton, several kilometres to the south-east of Coombe Farm.

The GFS is a spectral model and data are archived at a horizontal resolution of 0.5 degrees (approximately 50 km over the UK). 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 records may be over represented, this is because the instrumentation used may not record wind speed 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 meteorological recording station at Filton is a considerable distance from Combe Farm and is on the opposite side of the Severn Estuary, as such, it is rather unlikely to be fully representative of the weather conditions around Coombe Farm. However, there are no observational meteorological stations that fully record the variables required for dispersion modelling nearby and other alternatives are in coastal or mountainous areas and are even less likely to be representative of the weather conditions around Coombe Farm. The results of the modelling using meteorological data from Filton are included solely to demonstrate that the use of GFS data does not lead to results that would be greatly different from those that would be obtained were a representative traditional observational data set available.

Therefore, it should be noted that the frequency of winds from a particular direction in the Filton data are likely to be high or low in comparison to what might occur at Coombe Farm, which means mean concentrations downwind may be either over or under predicted. The GFS data provides a more rounded dataset, in which local effects are not included, but can be included using terrain data and FLOWSTAR. Therefore, it is the opinion of AS Modelling & Data Ltd. that the results obtained using the GFS data will provide results less likely to have gross errors due to inclusion of local effect at the meteorological recording site which are not present at the application site and that they should be given more weight when interpreting the results of the modelling.

Wind roses for Filton and the raw GFS data at the site of the proposed poultry unit at Coombe Farm are shown in Figures 3a and 3b.

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 Coombe Farm is shown in Figure 3c. Note that elsewhere in the modelling domain, modified wind roses may differ markedly and that the resolution of the wind field in terrain runs is 200 m.

The wind rose for the FLOWSTAR modified GFS data at the site of the proposed poultry unit at Coombe is shown in Figure 3c.

Figure 3a. The wind rose. Filton data, 2011 – 2014

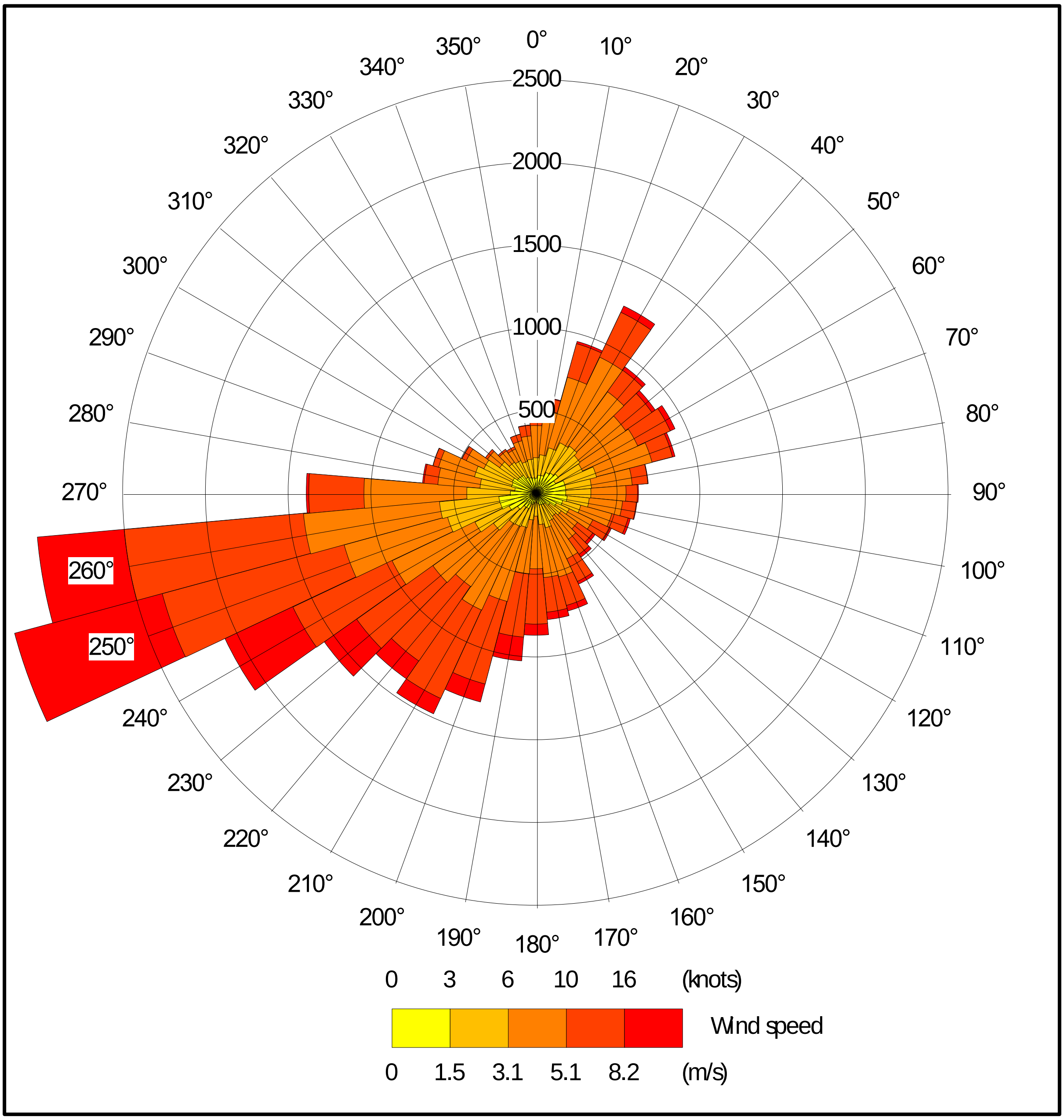


Figure 3b. The wind rose. Raw GFS derived data, for 51.634 N, 2.775 W, 2011 – 2014

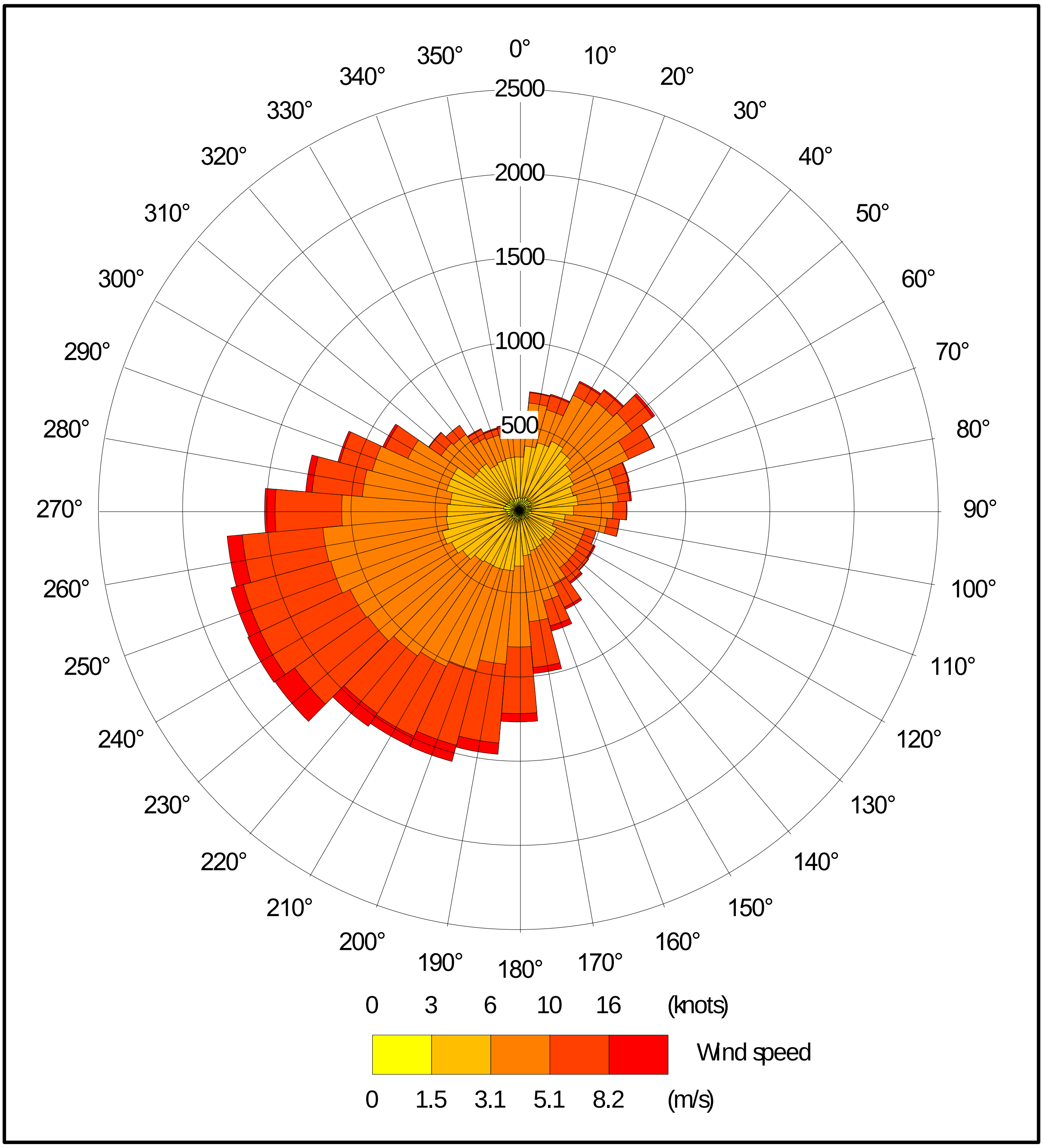
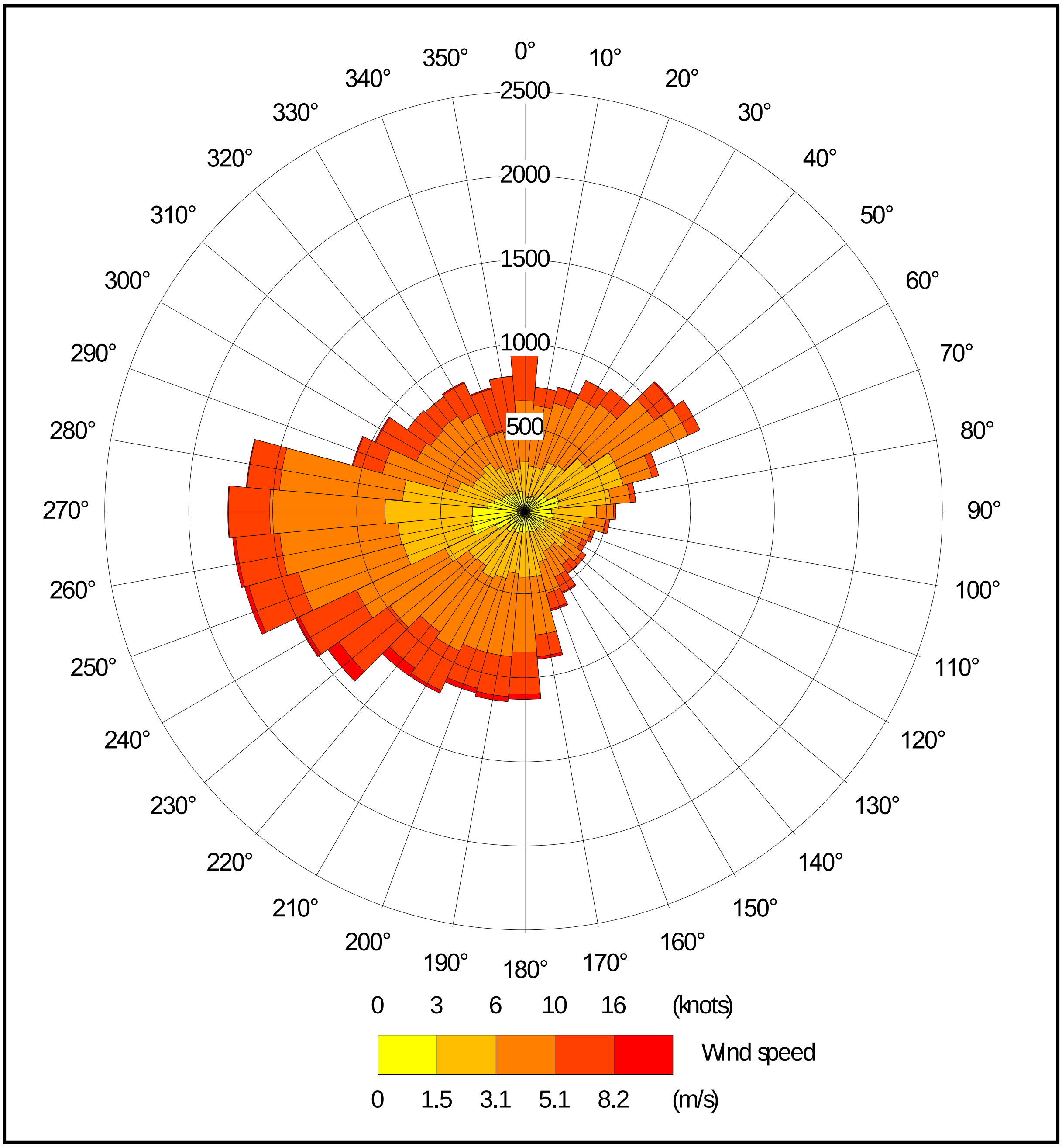


Figure 3c. The wind rose. FLOWSTAR modified GFS derived data, for 51.634 N, 2.775 W, 2011 – 2014



4.2 Emission sources

Emissions from the chimneys of the uncapped high speed ridge fans that would be used to ventilate the poultry houses are represented by three point sources per house within ADMS. 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 marked by red star symbols.

The poultry houses at Coombe Farm would also be fitted with gable end fans which would be used to provide supplementary ventilation in hot weather. Emissions from the gable end fans are represented by a single volume source per house within ADMS. The volume sources are assumed to emit 50% of the total emission only when the ambient temperature equals, or exceeds, 21 Celsius. When the volume sources are emitting, the emissions from the point sources are reduced by 50%. Details of the volume source parameters are shown in Table 2b. The position of these volume sources may also be seen in Figure 4.

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)
PR1 to PR4 a, b & c	6.8	0.8	11.3	Variable [1]	Variable [1 & 2]

1. Dependent on crop stage and ambient temperature
2. Reduced by 50% when ambient temperature equals or exceeds 20 Celsius.

Table 2b. Volume source parameters

Source ID	Length Y (m)	Width X (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (ou_E/s)
PR1_gab to PR4_gab	25.0	5.0	3.0	0.0	Ambient	Variable [3]

3. 50% of total emission only emitted when ambient temperature equals or exceeds 20 Celsius.

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

Eleven discrete receptors have been defined at a selection of nearby residences and commercial properties that are within approximately 1,000 m of the proposed poultry houses. 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 green crosses.

4.6 Terrain data

There are some slopes and hills that might affect wind flow and dispersion of odour in the area around Coombe Farm; therefore, terrain has been considered in the modelling. The terrain data used are derived from the Ordnance Survey 50 m Digital Elevation Model. These data are resampled at a 100 m horizontal resolution for use within ADMS. The terrain domain is 6,4 km by 6,4 km and FLOWSTAR is run at a resolution of 32 x 32 points; therefore, the effective model resolution is 200 m.

4.7 Other model parameters

A fixed surface roughness length of 0.5 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 0.25 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 & sources

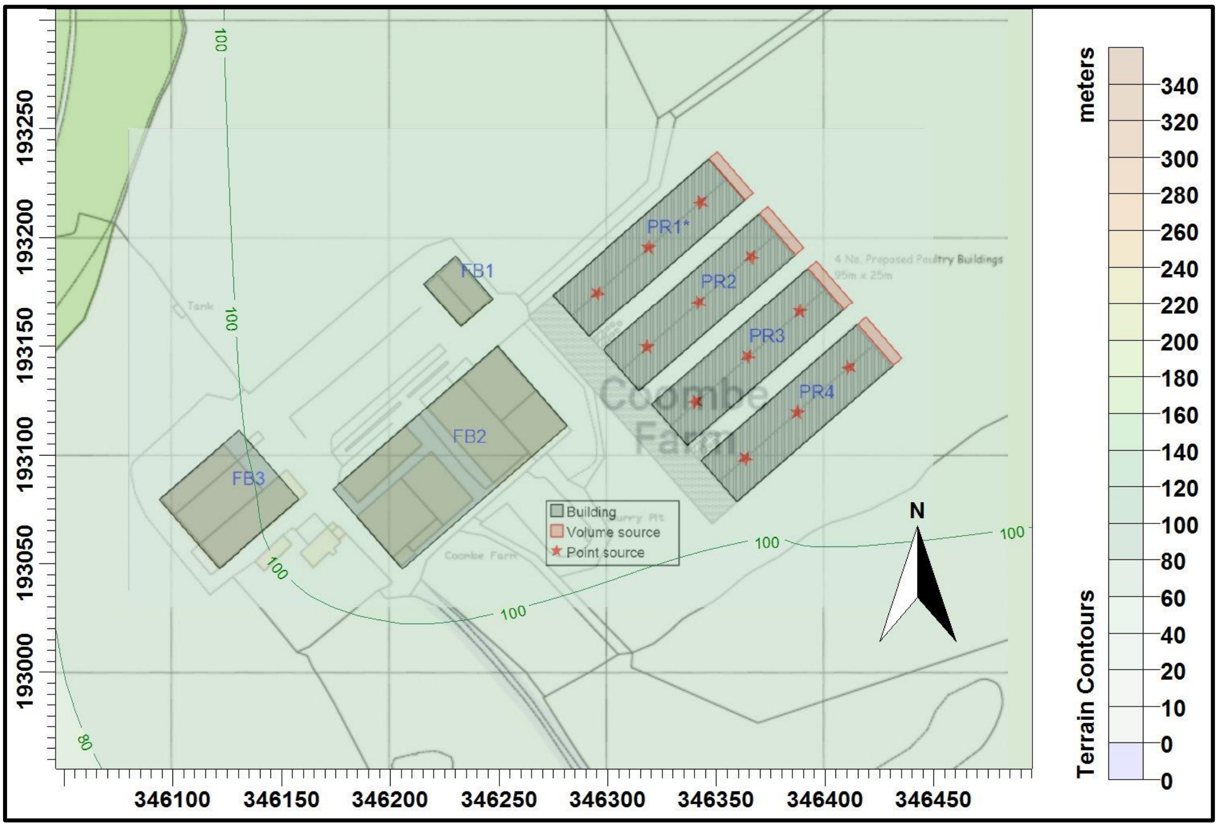
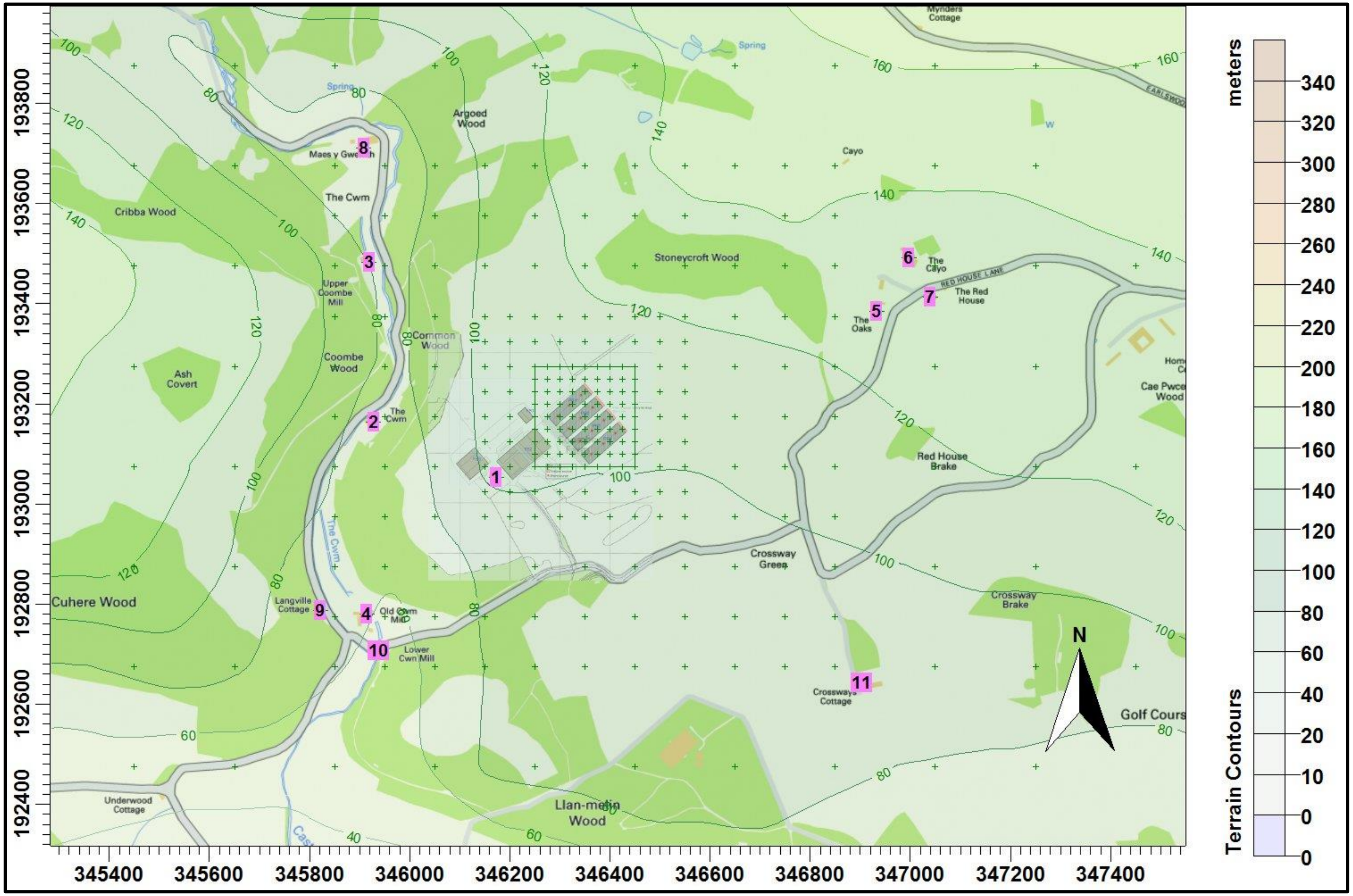


Figure 5. The discrete receptors and nested Cartesian grid receptors.



5. Details of the Model Runs and Results

For this study ADMS was run in three modes:

- With neither calms, nor terrain – GFS data.
- With calms and without terrain – GFS data.
- Without calms and with terrain – GFS data.
- In basic mode without calms, or terrain – Filton data.

To provide robust statistics, three emission files were created and three sets of runs were performed for each mode: the first with the first day of the meteorological record coinciding with day 1 of the crop cycle; the second coinciding with day 14 of the crop and the third coinciding with day 28 of the crop cycle. This is to ensure that there is a reasonable chance that higher emission rates that occur towards the end of each crop occur in all weather conditions.

ADMS was effectively run a total of thirty-two times (for each year of the four year meteorological record, in each of the four modes and for each of the three crop cycles). Statistics for the annual 98^{th} percentile hourly mean odour concentration at each receptor were compiled for each of the thirty-two runs.

A summary of the results of these thirty-two runs at the discrete receptors is shown in Table 3a where the maximum annual mean for each mode is shown. A contour plot of the maximum annual 98^{th} percentile hourly mean odour concentration is shown in Figure 6.

In Table 3a, 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.

Odours that arise during the clearing out process although short in duration can be quite intense. AS Modelling & Data Ltd. do include a peak in emissions when modelling broiler rearing (See Section 3.5); however, as the duration of the emission is short, this has little effect on the predicted 98^{th} percentile statistics, on which guidance on the acceptability or not of odour is based.

To address this, 99.5^{th} and 99.8^{th} percentile statistics, upon which the cleaning out process will have a more significant effect than it does on the 98^{th} percentile statistics, have also been compiled. N.B. the 99.5^{th} percentile is the value equalled or exceeded for 0.5% of the time and the 99.8^{th} percentile is the value equalled or exceeded 0.2% of the time. The results are presented in Table 3b. No comment on the significance/acceptability is made as there is no guidance available; however, the descriptions in Section 3.1 of the main report may be useful when interpreting the results.

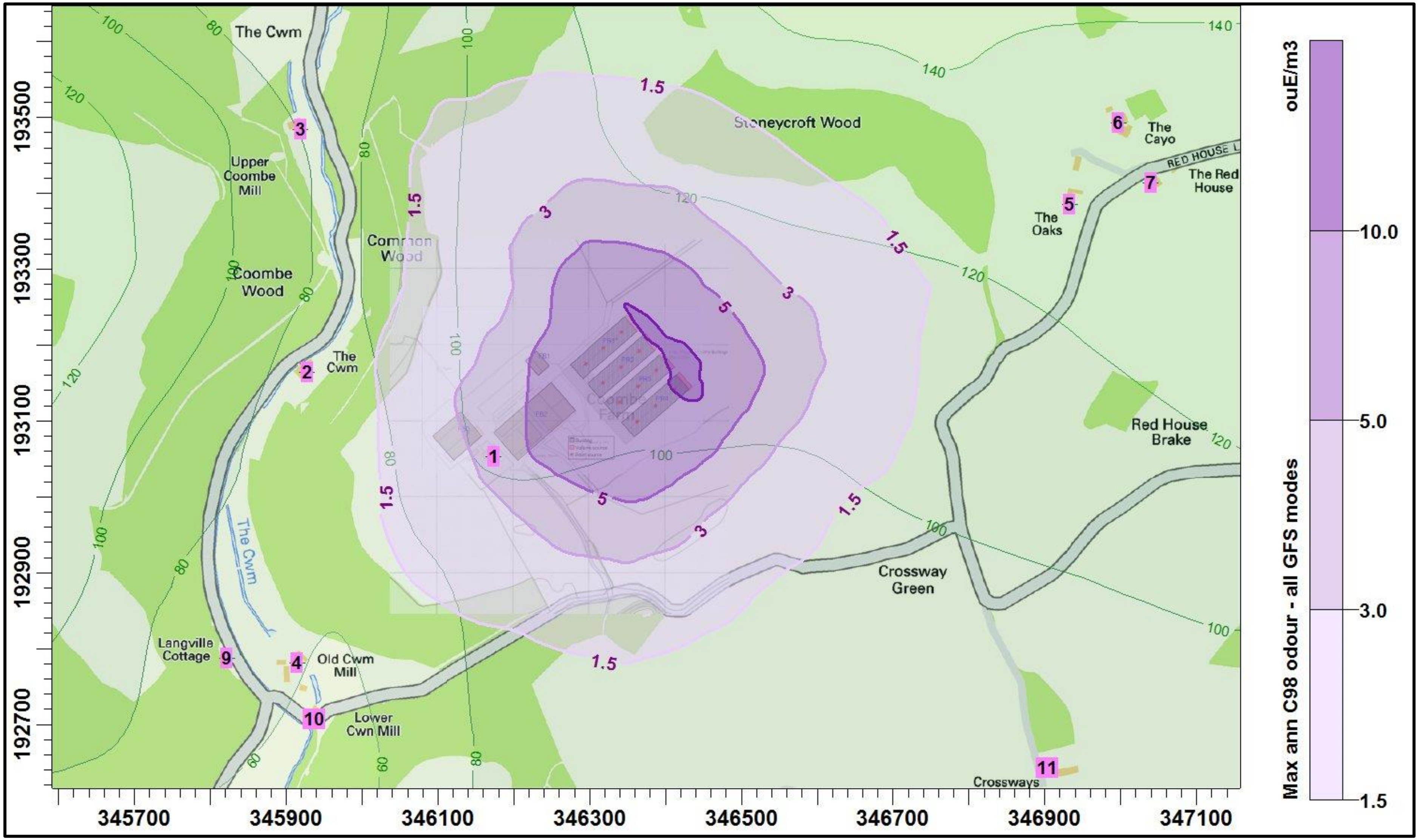
Table 3a. Predicted maximum annual 98th percentile hourly mean odour concentrations at the discrete receptors

Receptor number	X(m)	Y(m)	Maximum annual 98th percentile hourly mean odour concentration (ou_E/m^3)			
			GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	Filton No Calms No Terrain
1	346173	193053	**3.46**	**3.37**	2.59	**3.13**
2	345927	193165	0.91	0.87	0.74	0.74
3	345919	193484	0.56	0.56	0.69	0.41
4	345914	192781	0.85	0.84	0.80	0.72
5	346933	193386	0.71	0.70	0.86	0.78
6	346997	193492	0.60	0.59	0.80	0.57
7	347040	193413	0.56	0.55	0.65	0.61
8	345908	193712	0.35	0.35	0.70	0.29
9	345822	192787	0.69	0.68	0.54	0.57
10	345938	192706	0.71	0.70	0.77	0.70
11	346904	192642	0.35	0.35	0.38	0.21

Table 3b. Predicted maximum annual 98th, 99.5th and 99.8th percentile hourly mean odour concentrations at the discrete receptors (maximum of all modes)

Receptor number	X(m)	Y(m)	Maximum annual hourly mean odour concentration (ou_E/m^3)		
			98th percentile	99.5th percentile	99.8th percentile
1	346173	193053	**3.46**	6.61	10.25
2	345927	193165	0.91	2.48	4.03
3	345919	193484	0.69	1.68	2.58
4	345914	192781	0.85	1.91	2.99
5	346933	193386	0.86	1.63	2.31
6	346997	193492	0.80	1.44	2.34
7	347040	193413	0.65	1.39	2.01
8	345908	193712	0.70	2.06	2.91
9	345822	192787	0.69	1.49	2.30
10	345938	192706	0.77	1.63	2.81
11	346904	192642	0.38	1.12	1.75

Figure 6. Predicted maximum annual 98th percentile hourly mean odour concentration (maximum of the three GFS modes)



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Gareth Adams to use computer modelling to assess the impact of odour emissions from the proposed broiler rearing houses at Coombe Farm, , Llanvair Discoed, near Chepstow in Monmouthshire. NP16 6LN.

Odour emission rates from the proposed poultry houses have been assessed and quantified based upon an emissions model that takes into account the 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 Coombe Farm proceed, the 98th percentile hourly mean odour concentration at nearby residences that are not associated with the farm would be below 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.

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