A Dispersion Modelling Study of the Impact of Odour from the Proposed Free Range Egg Laying Chicken House at Barrow Farm, near Bearwood in Herefordshire

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Claire Harness of BowlerEnergy, on behalf of the applicant, to use computer modelling to assess the impact of odour emissions from a proposed free range egg laying chicken house at Barrow Farm, near Bearwood in Herefordshire. HR6 9EQ.

Odour emission rates from the proposed poultry house 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 house. 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

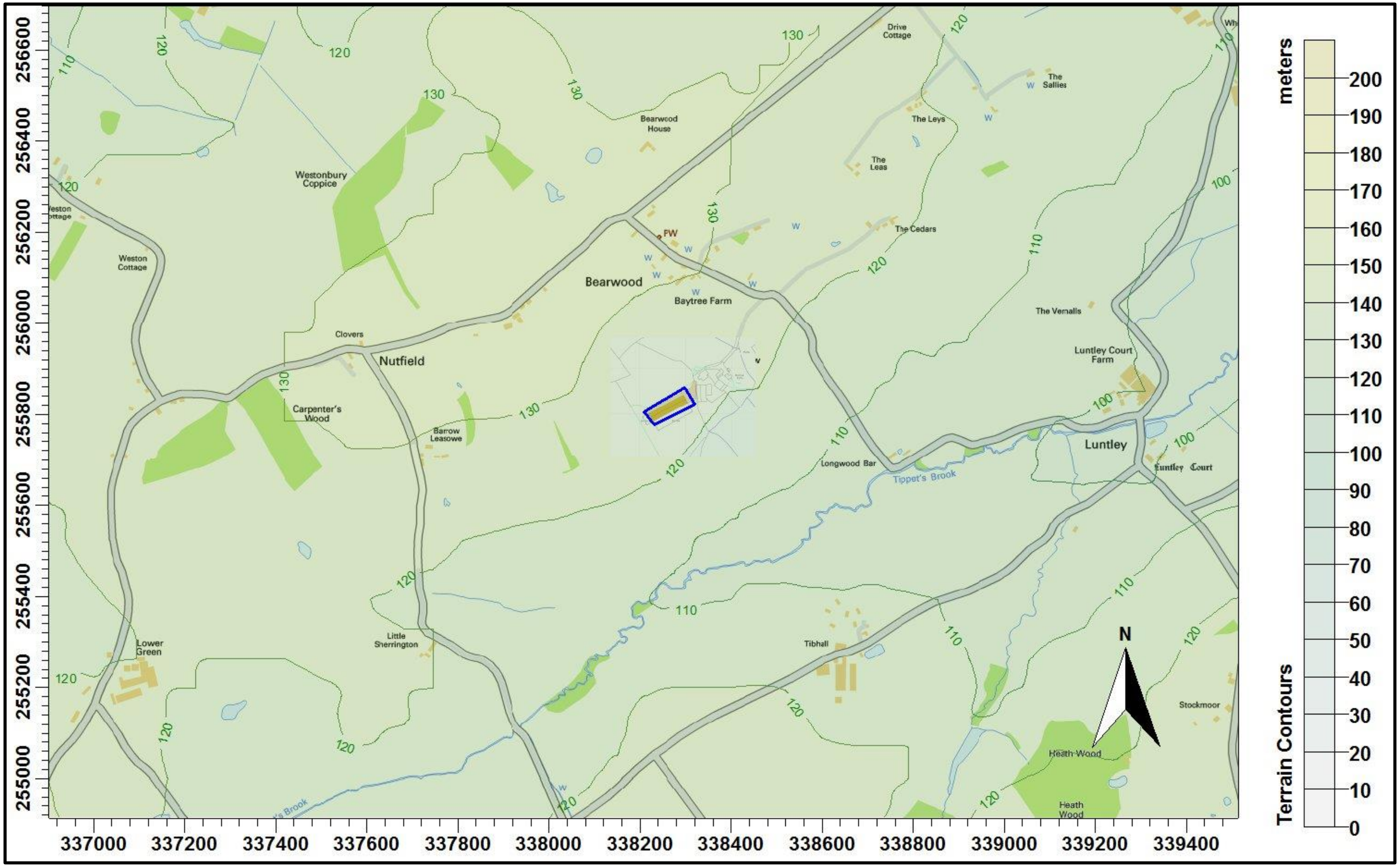
The site of the proposed free range egg laying chicken house at Barrow Farm is in a rural area approximately 250 m to the south of the village of Bearwood in Herefordshire. The site is at an elevation of approximately 123 m with the land rising towards hill tops to the north-west and falling towards Tippet's Brook to the south-east.

It is proposed that a single poultry house, with capacity for up to 16,000 egg laying chickens, be constructed at the site. The new building would have pop holes which would provide the birds with daytime access to outside ranging areas. The new poultry house would be ventilated primarily by high velocity ridge/roof mounted fans each with a short chimney and there would be gable end fans to provide supplementary ventilation in warm weather conditions. The bird's droppings would be removed by a belt collection system and stored temporarily in a sealed skip prior to removal from the site on a twice weekly basis.

There are some residences and commercial properties in the area surrounding the site of the proposed poultry unit at Barrow Farm. The closest residences are at: the farmhouse at Barrow Farm, which is approximately 95 m to east-north-east; Baytree Farm, approximately 250 m to the north; Lower House, approximately 280 m to the north-east; residences in Bearwood, the closest of which are approximately 280 m to the north; residences at and near Bearwood Training and Livery, approximately 340 m to the north-west; Barrow Leasowe, approximately 440 m to the west and Longwood Bar, approximately 440 m to the south-east.

A map of the surrounding area is provided in Figure 1, where the site of the proposed poultry house is outlined in blue.

Figure 1. The area surrounding the site of the proposed poultry house at Barrow 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.

And Less offensive:
- Brewery.
- Confectionery.
- Coffee roasting.
- Bakery.

Dispersion models usually calculate hourly mean odour concentrations; 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 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 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, indicate 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 ongoing odour complaints. The findings of this research and subsequent UKWIR research indicate 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 housing 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.

3.5 Quantification of Odour Emissions

Odour emission rates from poultry houses depend on many factors and are highly 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 primary source of odour would be from the chimneys of the ridge 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. The chickens would have access to ranging areas to the north and south of the houses and some odour would arise from the manure deposited on the ranging areas.

In traditional egg laying houses, peak odour emission rates occur when the housing is cleared of spent litter and manure at the end of each crop. Emissions at this time may be several times greater than normal emissions from the housing. However, although the poultry house at Barrow Farm would be cleaned between flocks (approximately one per year), because the manure would be collected and removed throughout the flock cycle, the magnitude of odours during cleaning would be much lower than from more traditional houses in which manure collects within the house.

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 constant at 750 ou_E/m^3; this figure is based upon a review of available literature. 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 16 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.

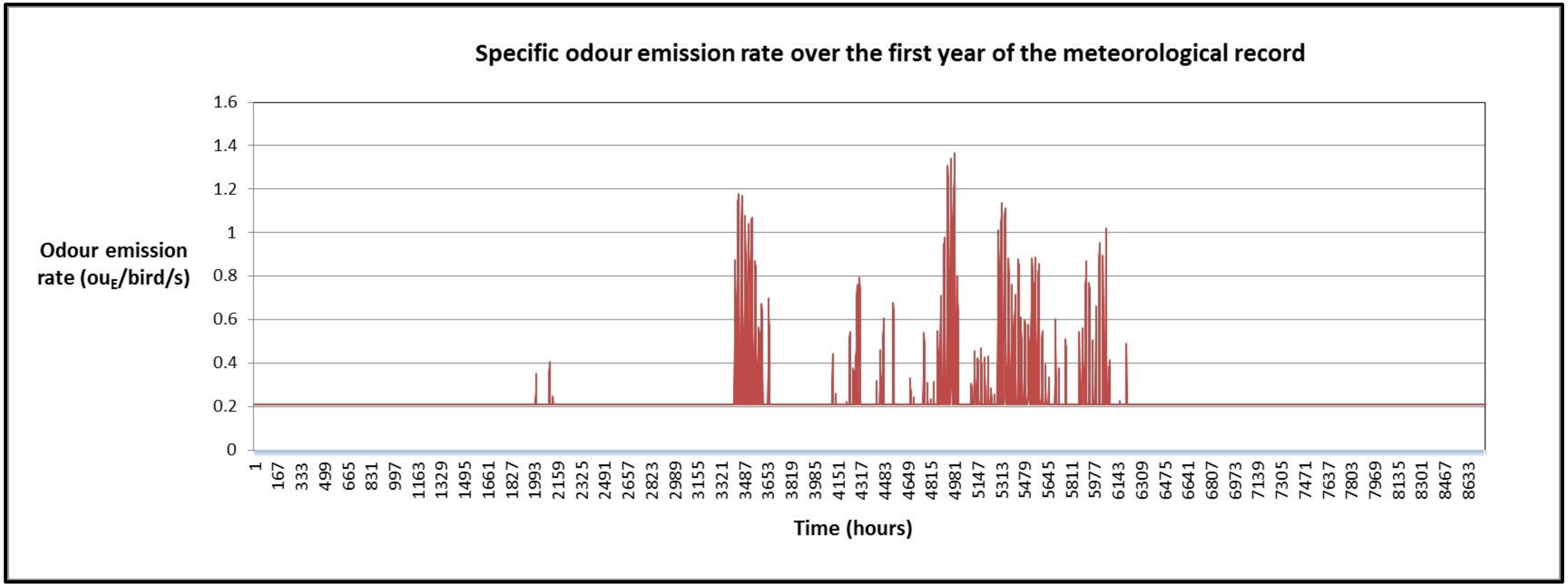
Based upon these principles, an emission rate for each hour of the period modelled is calculated by multiplying the concentration by the ventilation rate. A summary of the emission rates used in this study is provided in Table 1. As additional information, the 98th percentile emission rate is approximately 0.85 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.

Table 1. Summary of odour emission rates from the proposed poultry house

Emission rate (ou_E/bird/s)				
Season	Average	Night-time Average	Day-time Average	Maximum
Winter	0.208	0.208	0.209	0.405
Spring	0.240	0.211	0.269	1.562
Summer	0.331	0.212	0.403	1.562
Autumn	0.210	0.208	0.211	0.503

The chickens would have access to ranging areas. It is assumed that 20% of the droppings are deposited on the ranging area and an emission rate of 0.25 ou_E/bird/s is used to calculate the emission rate. The 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.

Figure 2. Specific emission rate over the first year of the meteorological record (2012)



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). 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 records may be over represented 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.

A wind rose showing the distribution of wind speeds and directions in the GFS derived 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 for the site of the proposed poultry house 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 the terrain runs is 200 m.

Figure 3a. The wind rose. GFS derived data, for 52.197 N, 2.903 W, 2012 – 2015

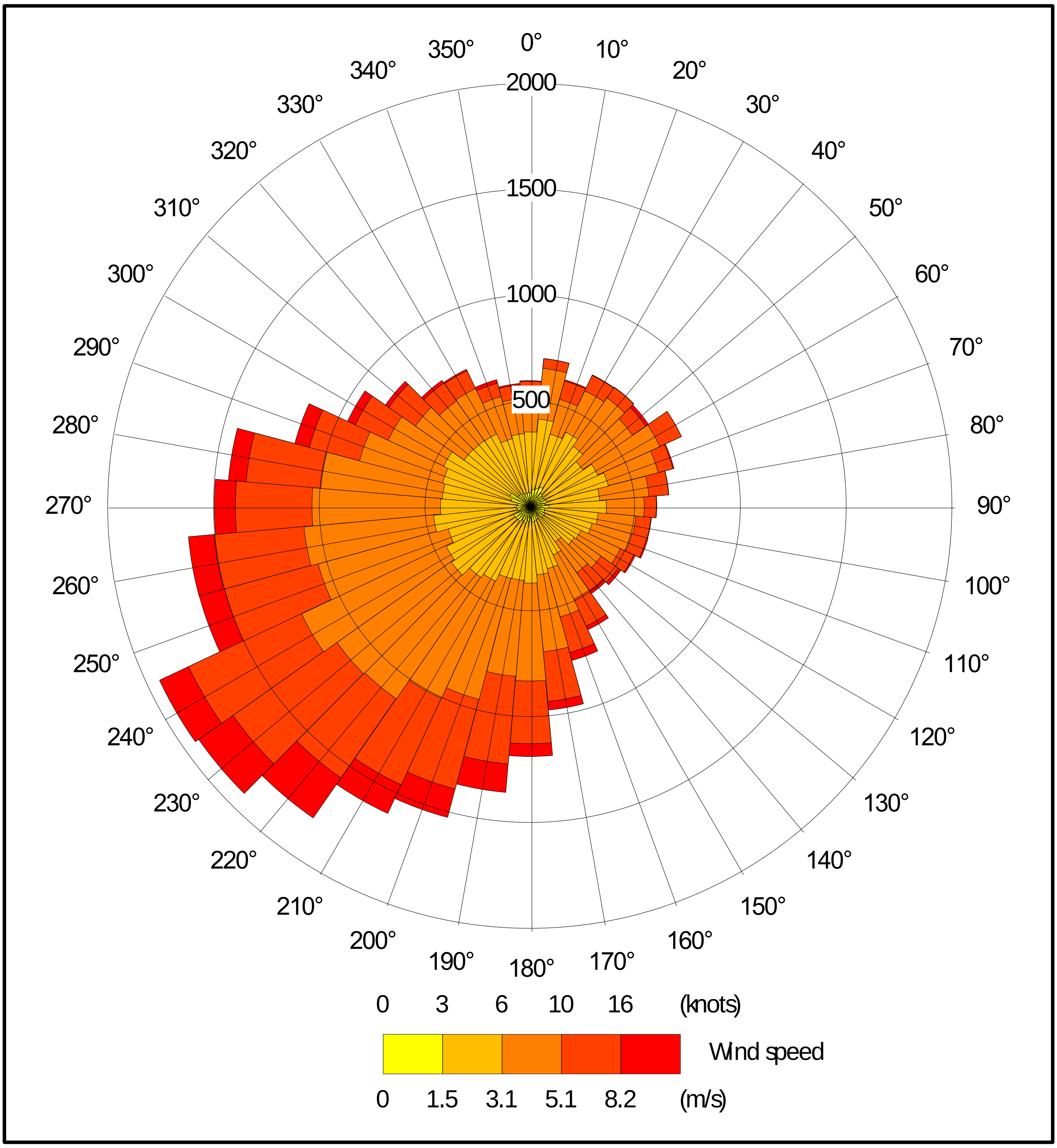
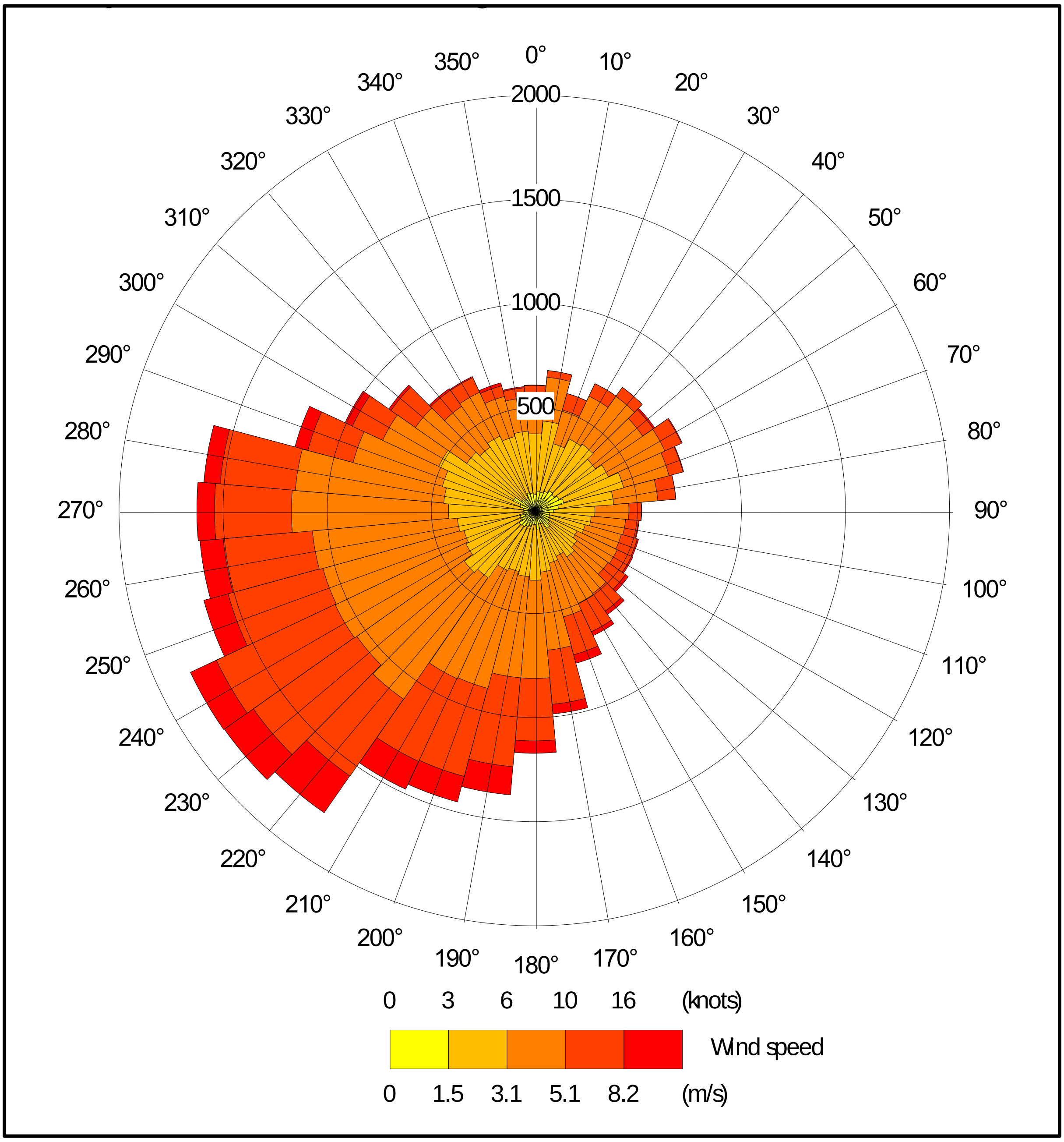


Figure 3b. The wind rose for the site of the poultry unit derived from FLOWSTAR output.



4.2 Emission Sources

Emissions from the chimneys of uncapped high speed ridge/roof fans that would be used to ventilate the proposed poultry house are represented by three point sources within ADMS (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.

The proposed poultry house would also be fitted with gable end fans which would be used to provide supplementary ventilation in warm weather conditions. The emissions from these gable end fans are represented by a single volume source within ADMS (PR1_gab). Details of the volume source parameters are shown in Table 2b. The position of the volume source may be seen in Figure 4.

Emissions from the ranging area are represented by a single area source within ADMS. N.B. The area source covers the parts of the range most likely to be used frequently, not the whole of the ranging area. Details of the area source parameters are shown in Table 2c. The position of the area source may 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 a, b & c	6.3	0.8	11.0	Variable [1]	Variable [2]

1. 19 Celsius, or ambient temperature, if greater than 19 Celsius.
2. Dependent on ambient temperature and reduced by 50% when the ambient temperature equals or exceeds 19 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	20	5.0	3.0	0.5	Ambient	Variable [3]

3. 50% of the total emission emitted only when the ambient temperature equals or exceeds 19 Celsius.

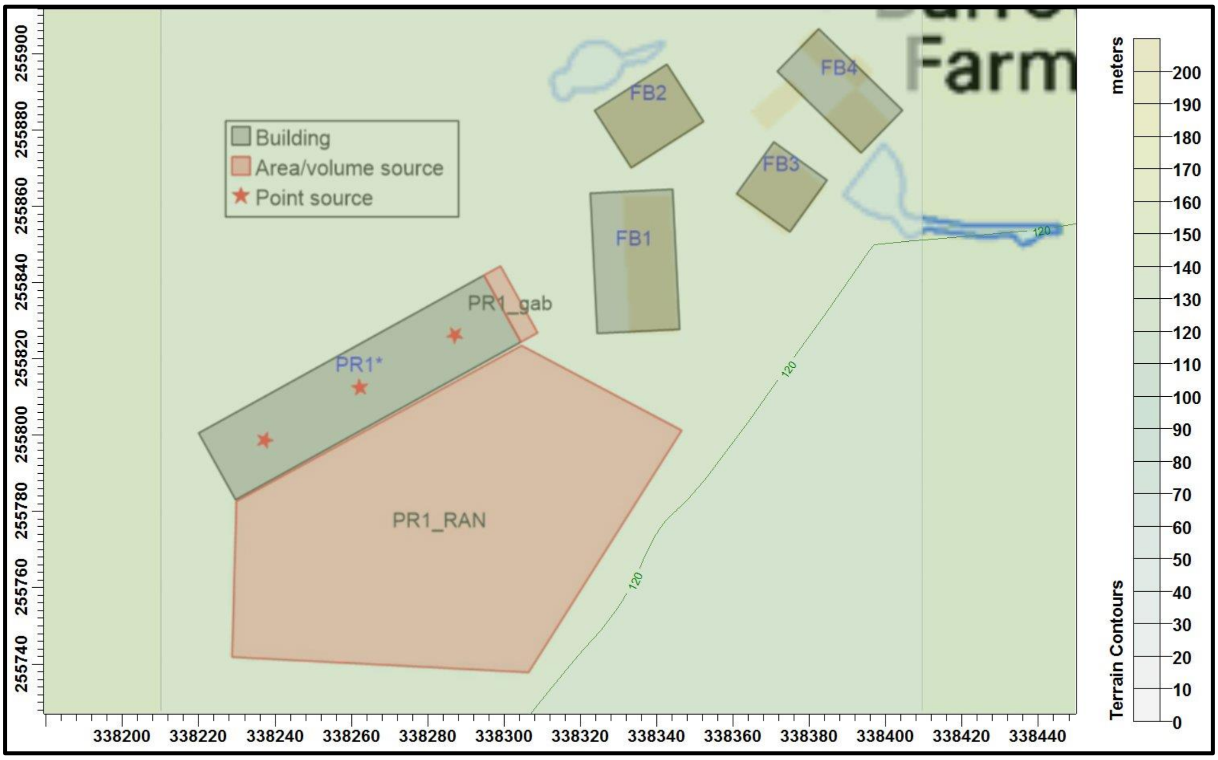
Table 2c. Area source parameters

Source ID	Base Height (m)	Emission temperature (°C)	Area (m^3)	Emission rate (ou_E/s)
PR1_ran	0.0	Ambient	6604.7	800.0

4.3 Modelled Buildings

The structures of the proposed poultry house and other existing farm buildings may affect the plumes from the point sources and therefore, the buildings are modelled within ADMS. The position of the modelled buildings may be seen in Figure 4, where they are marked by grey rectangles.

Figure 4. The positions of modelled buildings and sources



4.4 Discrete Receptors

Twenty-nine 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 green crosses, with the modelling domain defined by a green outlined rectangle.

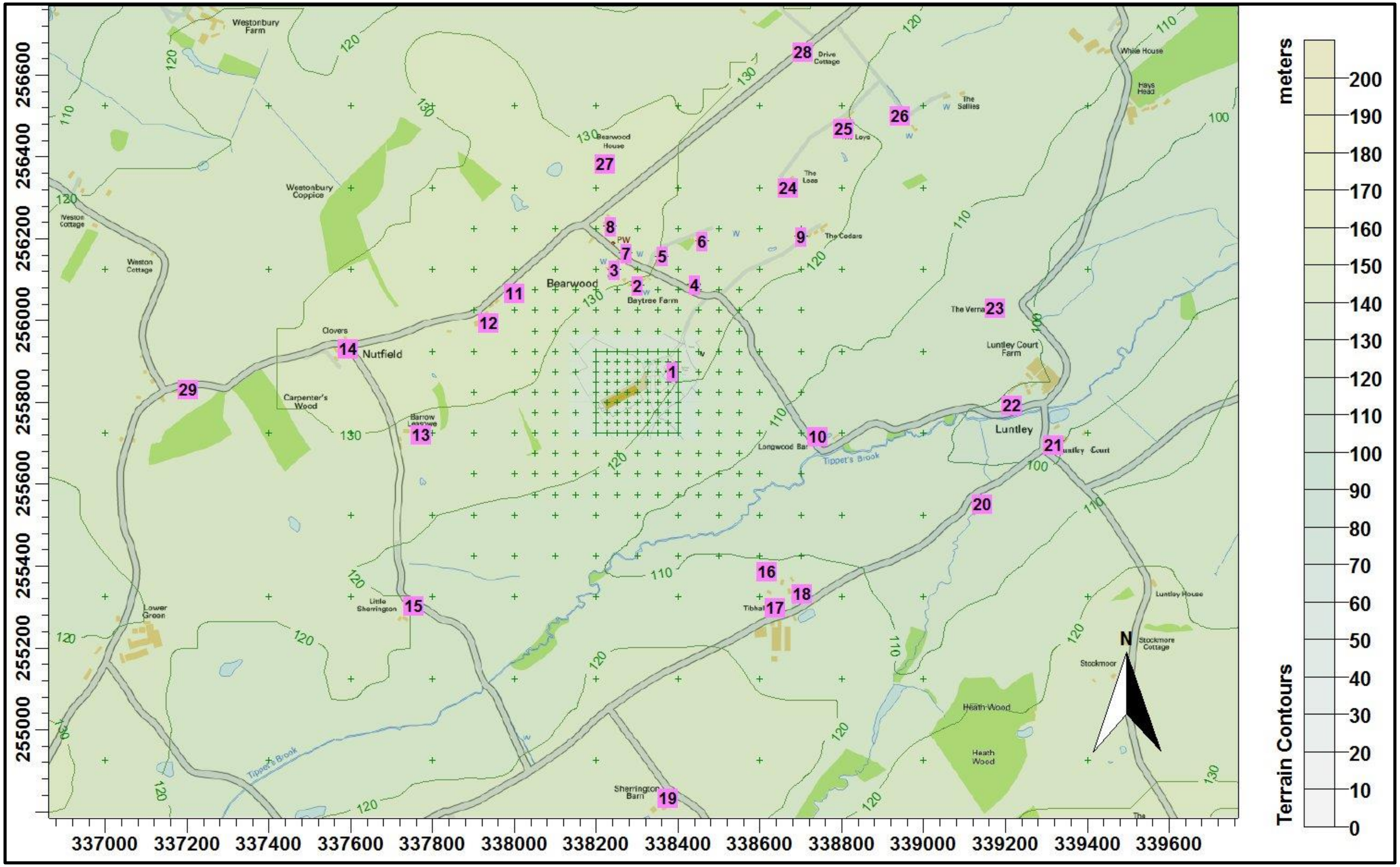
4.6 Terrain data

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



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 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 these runs.

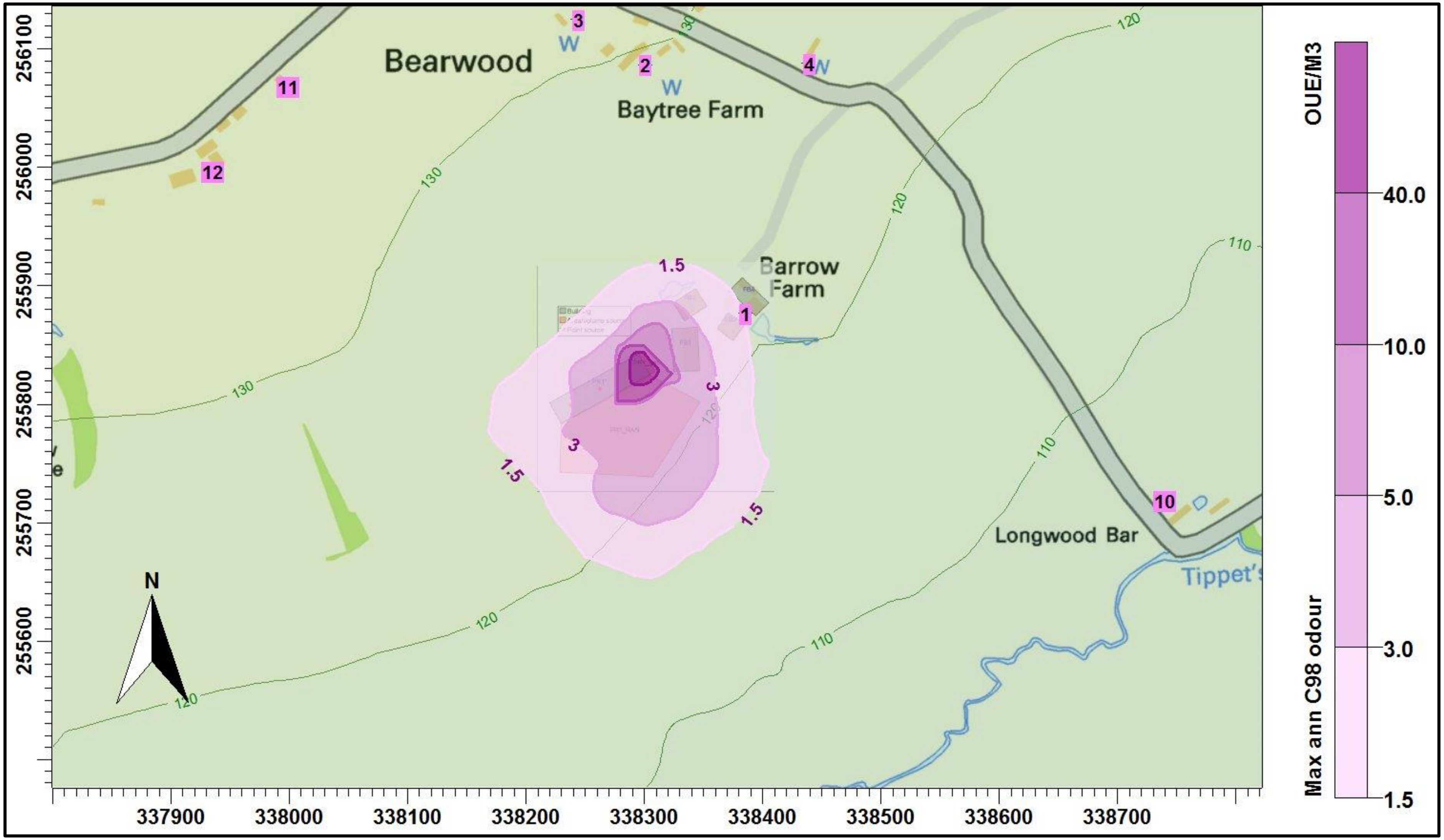
A summary of the results at the discrete receptors is shown in Table 3 where the maximum annual 98th percentile hourly mean odour for each mode is shown. A contour plot of the maximum annual 98th percentile hourly mean odour concentration is shown in Figure 6.

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, those in excess of 10.0 ou_E/m^e as an annual 98th percentile hourly mean, are coloured red.

Table 3. 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
1	338385	255877	1.44
2	338300	256087	0.29
3	338244	256125	0.23
4	338439	256088	0.22
5	338360	256157	0.19
6	338458	256195	0.14
7	338271	256165	0.20
8	338233	256231	0.15
9	338700	256206	0.10
10	338738	255719	0.18
11	337998	256068	0.13
12	337934	255997	0.12
13	337769	255723	0.10
14	337592	255933	0.05
15	337751	255303	0.07
16	338615	255387	0.11
17	338635	255299	0.09
18	338702	255334	0.08
19	338372	254834	0.03
20	339142	255553	0.07
21	339315	255697	0.06
22	339215	255795	0.06
23	339173	256032	0.05
24	338666	256326	0.08
25	338802	256470	0.05
26	338940	256501	0.05
27	338220	256385	0.10
28	338704	256657	0.04
29	337200	255833	0.03
30	338200	255725	1.06

Figure 6. Predicted maximum annual 98th percentile hourly mean odour concentration in the area surrounding the site of proposed poultry unit



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Odour emission rates from the proposed poultry house 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 house. 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 at all of the discrete receptors considered, the odour exposure 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.

7. References

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