A Dispersion Modelling Study of the Impact of Odour from the Existing and Proposed Free Range Egg-Laying Chicken Houses at Poplar Farm, Keal Cotes, near Spilsby in Lincolnshire

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Mr. Oliver Grundy of JHG Planning Consultancy Ltd., on behalf of Mr. David Wright, to use computer modelling to assess the impact of odour emissions from the existing and proposed free range egg-laying chicken houses at Poplar Farm, Hagnaby Lane, Keal Cotes, near to Spilsby in Lincolnshire. PE23 4AL.

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

This report is arranged in the following manner:

- Section 2 provides relevant details of the site and potentially sensitive receptors in the area.
- Section 3 provides some general information on odour, details of the method used to estimate odour emissions from the proposed poultry house and range, 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 poultry unit at Poplar Farm is in a rural area approximately 1 km to the west-north-west of the village of Keal Cotes, near to Spilsby in Lincolnshire. The site is at an elevation of around 10 m; this low-lying area is very gently undulating; the land, which is predominantly used for arable cultivation on loamy and clayey soils, benefits from a network of drainage channels.

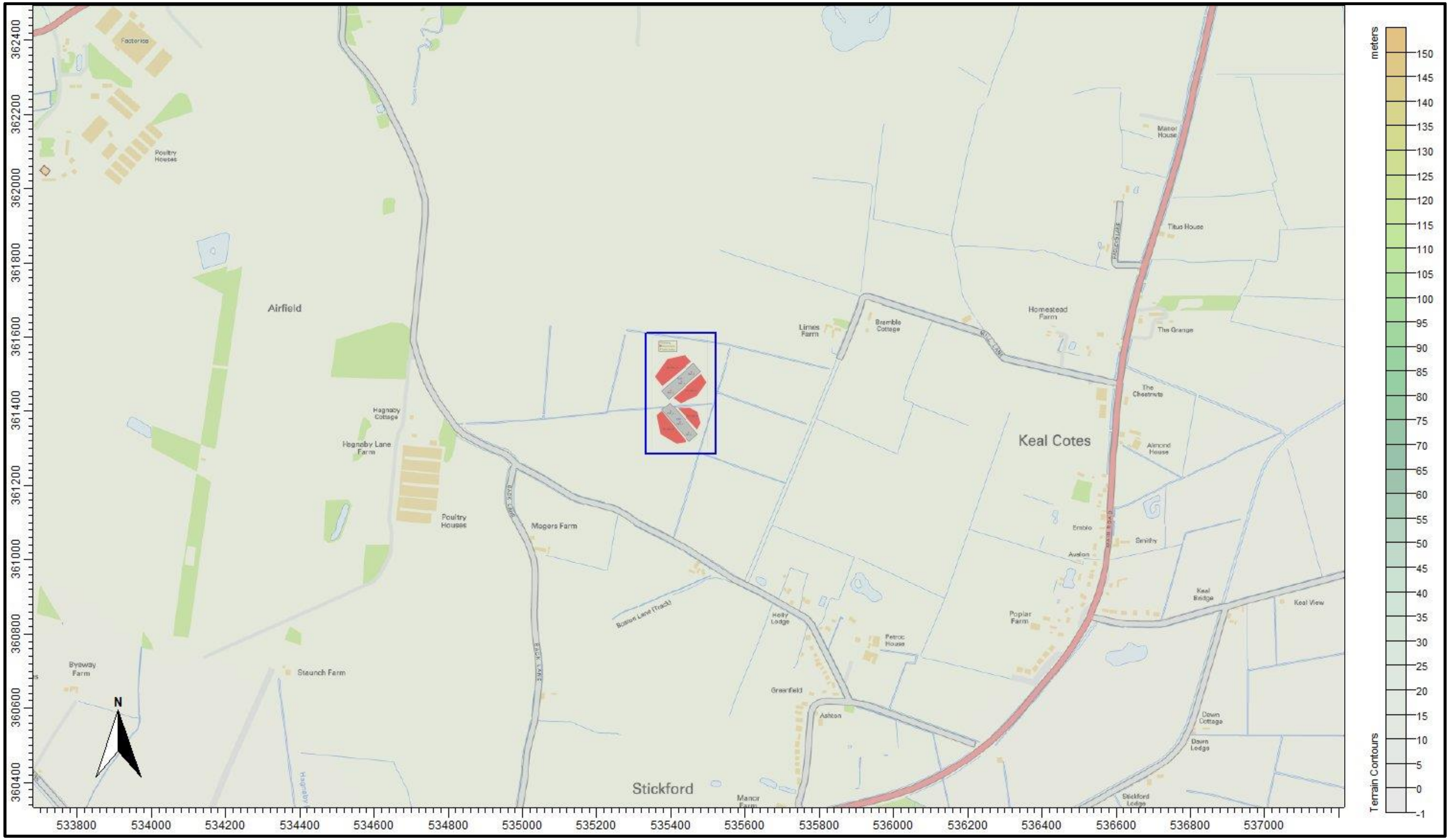
There is currently one poultry house at Poplar Farm, which provides accommodation for up to 32,000 free range egg laying chickens. This poultry house is ventilated by uncapped high speed ridge fans, each with a short chimney and manure is removed from the poultry house using a belt system twice weekly and removed from the site on covered trailers. The chickens have daytime access to outside ranging areas via a series of pop holes in the sides of the poultry house.

It is proposed that a second poultry house be constructed to the south of the existing poultry house. The proposed poultry house would provide accommodation for a further 32,000 free range egg laying chickens. The proposed poultry house would be ventilated by uncapped high speed ridge fans, each with a short chimney. Manure would be removed from the proposed poultry house using a belt system twice weekly and removed from the site on covered trailers. The chickens would have daytime access to outside ranging areas via a series of pop holes in the sides of the houses.

There are residences in the area surrounding the site of the existing and proposed poultry houses at Poplar Farm. The closest residence to the existing poultry house is at Limes Farm, which is approximately 350 m to the east-north-east. To the south, there are further residences along Hagnaby Lane, the closest being Willoughby House, which is approximately 315 m to the south-south-east and there are residences at Holly Lodge, which is approximately 475 m to the south-east and Hagnaby Cottage, which is approximately 620 m to the west, of the proposed poultry house. There are further residences and farmsteads in the countryside around the existing and proposed poultry houses at Poplar Farm.

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

Figure 1. The area surrounding the site of the existing and proposed poultry houses at Poplar Farm



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

3.1 Odour concentration, averaging times, percentiles and FIDOR

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

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

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

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

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

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

Most offensive:

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

Moderately offensive:

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

Less offensive:

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

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

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

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

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

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

3.2 Environment Agency guidelines

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

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

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

3.3 UK Water Industry Research findings

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

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

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

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

3.4 Choice of odour benchmarks for this study

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

3.5 Quantification of odour emissions

3.5.1 Housing odour emissions

Odour emission rates from poultry houses depend on many factors and may be variable. When only minimum ventilation is required, the odour emission rate may be relatively small, but in hot weather, ventilation requirements and odour emission rates are greater.

The main source of odours from the existing and proposed houses would be from the chimneys of the uncapped high speed ridge fans. Some fugitive emissions from open pop holes are/would be possible, but because the houses would be under negative pressure, these emissions would be expected to be minimal. In order to prevent odours building up within the proposed houses and provide negative pressure to prevent fugitive emissions, the modelling assumes that a minimum ventilation rate is maintained. The chickens would have access to daytime ranging areas outside of the houses and some odours would arise from the manure deposited on these ranging areas. The modelling assumes that good practices for farm cleanliness are followed and that other sources of odour may be considered negligible.

Peak odour emission rates are likely to occur when the housing would be cleaned and cleared of spent litter at the end of each production period, approximately once per annum. 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 whilst the birds are in the housing. As the proposed poultry houses would operate a belt system that enables litter to be removed from the house twice weekly, it is assumed that these emissions would be significantly less than from a more traditional house where the droppings accumulate in the house throughout the crop.

For the calculation of the emission rates from the proposed poultry houses, the internal odour concentration is assumed to be a constant 750 ou_E/m^3. These figures are based upon a review of available literature and measured concentrations from similar poultry houses that are available to AS Modelling & Data Ltd.

The ventilation rates used in the calculations are based on industry standard practices. For the calculations, the minimum ventilation rate is set at 1.0 m^3-air/bird/h and the maximum ventilation rate is 7.5 m^3-air/bird/h. If the external temperature is 13 Celsius, or lower, minimum ventilation only is assumed for the calculation. If the external temperature is 23 Celsius, or more, then the maximum ventilation rate is assumed. A transitional ventilation rate is calculated between these extremes.

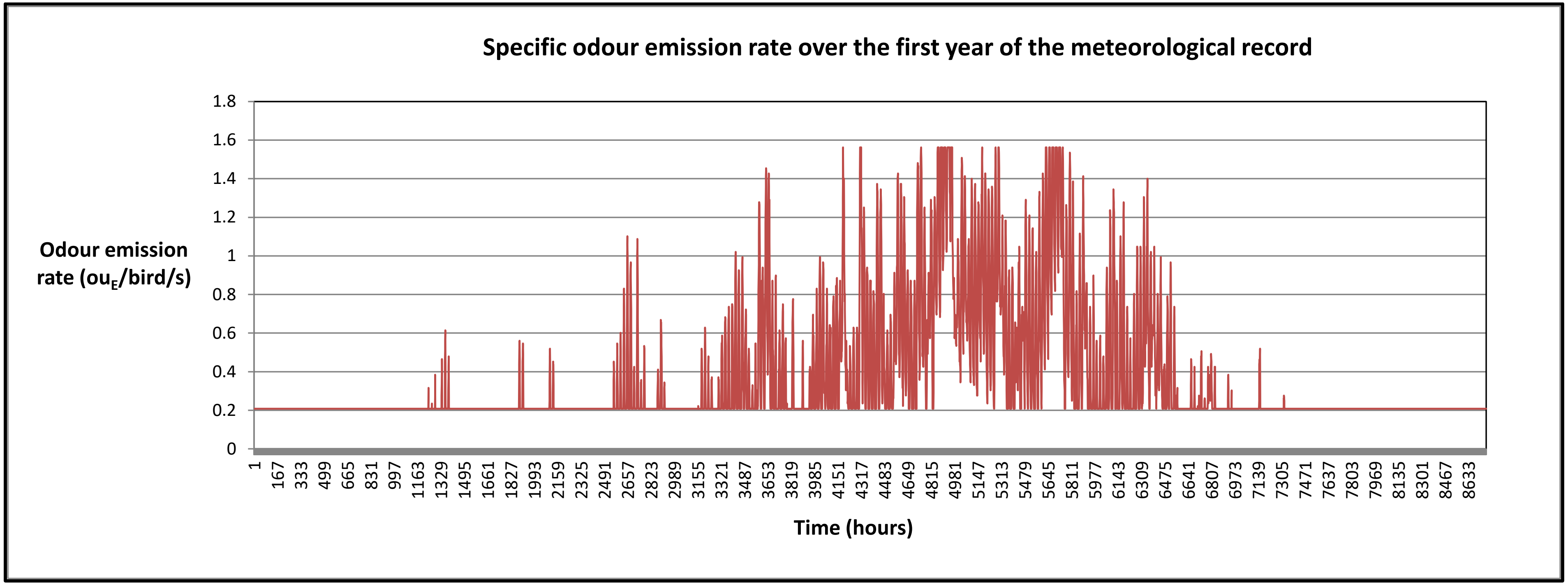
Based upon these principles, an emission rate for each hour of the period modelled is calculated by multiplying the concentration by the ventilation rate. As an example, a graph of the specific emission rates over the first year of the meteorological record is shown in Figure 2 for the existing poultry house.

3.5.2 Ranging area odour emissions

The chickens that are housed in the existing poultry houses and those that would be housed in the proposed poultry houses would have access to ranging areas. It is assumed that 20%[1] 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 the housing emissions, 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.

1. It should be noted that this figure is probably based primarily upon the widely accepted figure of 80% of droppings occurring at night when birds are housed and a single report; however, because, even under optimal conditions, not all of the birds go outside (50% is considered a high percentage), this does not imply that 20% of droppings occur outside the house (realistically, for free range broiler chickens the figure is probably less than 5%).

Figure 2. Odour specific emission rate over the first year from the existing house



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)[1].

Prior to April 2019 the GFS was a spectral model, post April 2019 the physics are discrete. The physics/dynamics model has a resolution or had an equivalent resolution of approximately 7 km over the UK; terrain is understood to be resolved at a resolution of approximately 2 km, with sub-7 km terrain effects parameterised. 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[2]). 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, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for the location of the existing and proposed poultry houses at Poplar Farm is shown in Figure 3b. Although, as might be expected, there is very little modification in this case, elsewhere in the modelling domain, the modified wind roses may differ more markedly. The resolution of the wind field is 100 m. Please also note that FLOWSTAR[2] 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[3].

1. The GFS data used is derived from the high resolution operational GFS datasets, the data is not obtained from the lower resolution (0.5 degree) long-term archive.
2. Note that FLOWSTAR requirements are for meteorological data representative of the upwind flow over the modelling domain and that single site meteorological data (observational or from high resolution modelled

data) that is representative of the application site is not generally suitable (personal correspondence: CERC 2019 and UK Met O 2015). If data are deemed representative of a particular application site, either wholly or partially, then these data cannot also be representative of the upstream flow over the modelling domain. Furthermore, it would be extremely poor practice to use such data as the boundary conditions for a flow-solver, such as FLOWSTAR.

3. When modelling complex terrain with ADMS, by default, the minimum turbulence length has 0.1 m added to the flat terrain value (calculated from the Monin-Obukhov length). Whilst this might be appropriate over hill/mountain tops in terrain with slopes > 1:10 (and quite possibly only in certain wind directions) in lesser terrain it introduces model behaviour that is not desirable where FLOWSTAR is simply being used to modify the upwind flow. Specifically, the parameter sigma z of the Gaussian plume model is overly constrained, which for elevated point sources emissions, may on occasion cause over prediction of ground level concentrations in stable weather conditions and light winds (Steven R. Hanna & Biswanath Chowdhury, 2013), conversely for low level emission sources, this will cause gross under prediction. Note that this becomes particularly important overnight and if calm and light wind conditions are not being ignored, as they often are when using traditional observational meteorological datasets. To reduce this behaviour, where terrain is modelled, AS Modelling & Data Ltd. have set a minimum turbulence length of 0.025 m in ADMS. This approximates the normal behaviour of ADMS with flat terrain.

Figure 3a. The wind rose. GFS derived data, for 53.132 N, 0.024 E, 2019-2022

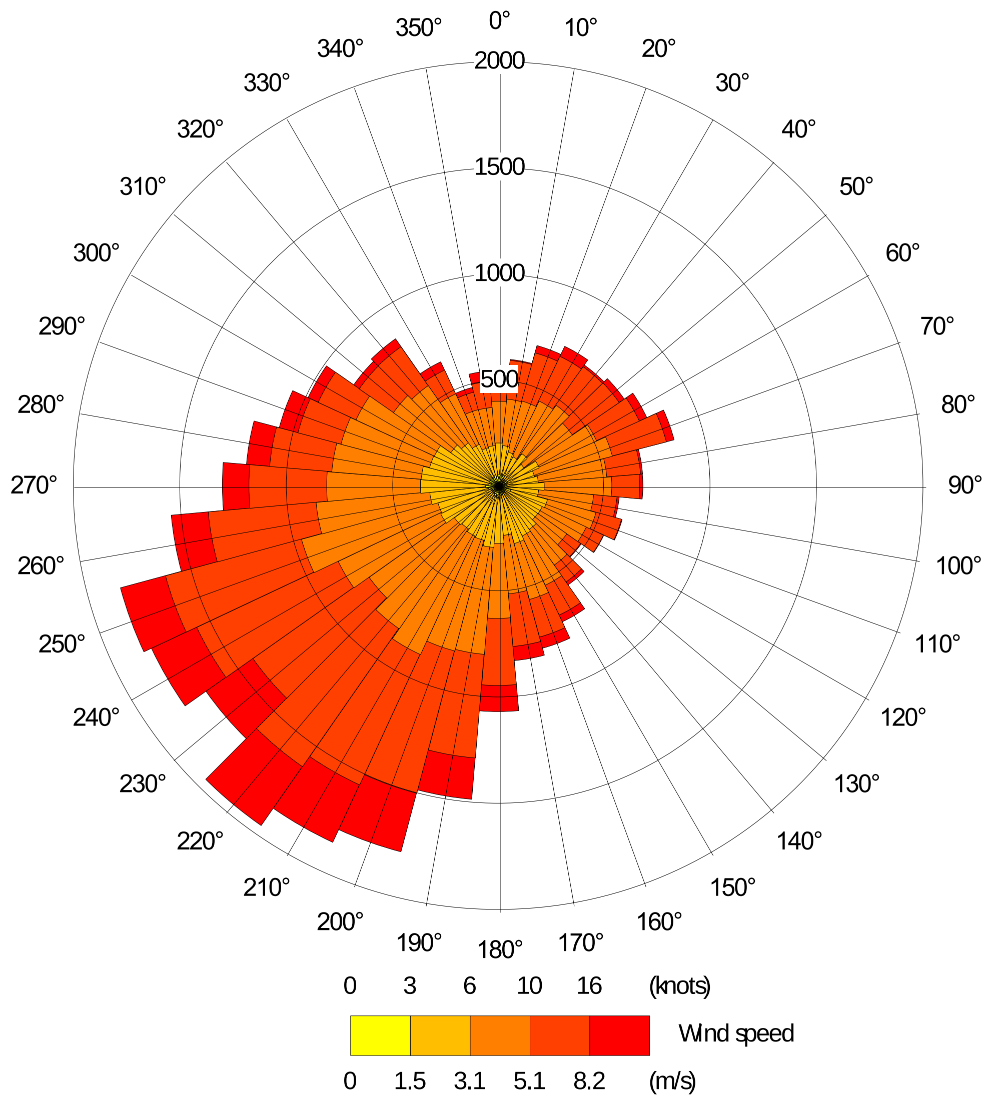
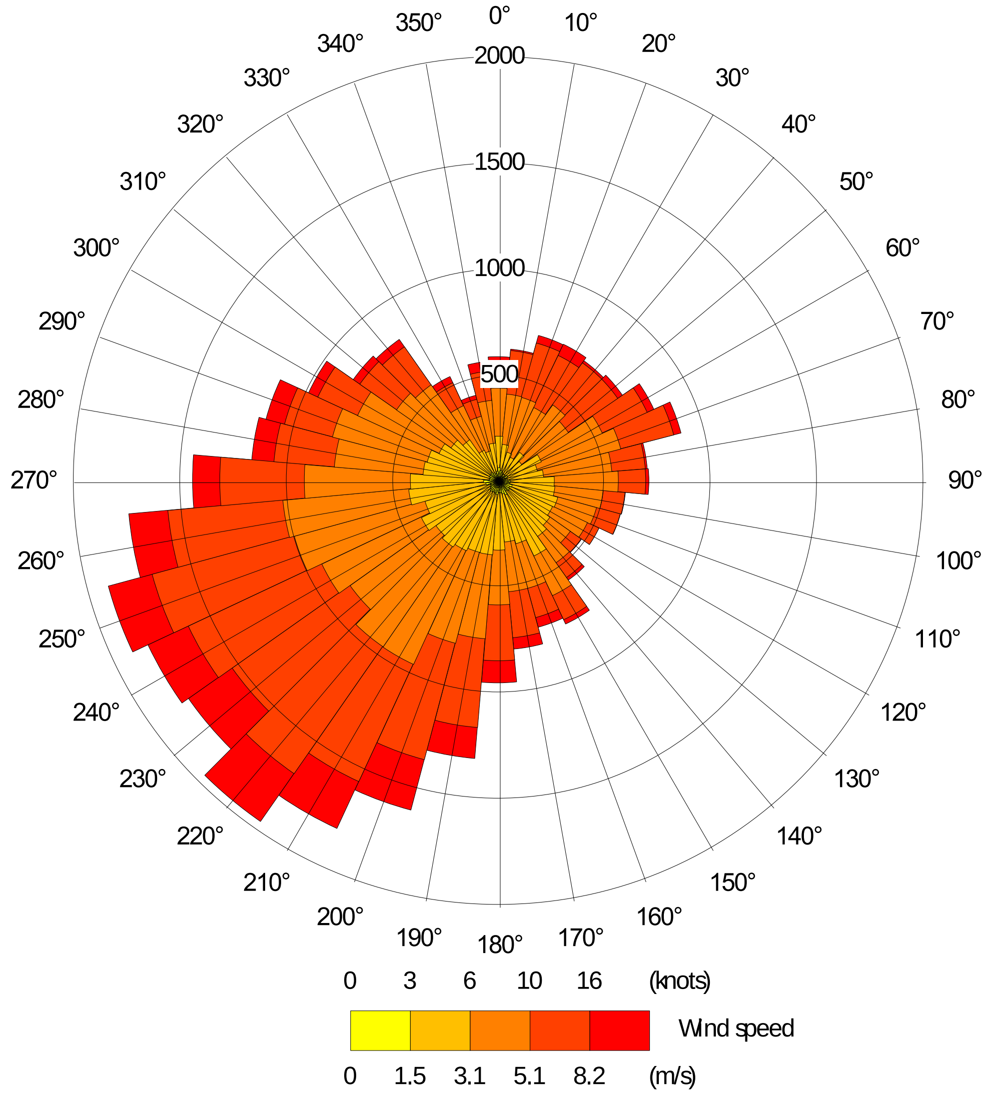


Figure 3b. The wind rose. FLOWSTAR derived data for NGR 535400, 361420, 2019-2022



4.2 Emission sources

Emissions from the chimneys of the uncapped high speed fans that are, or would be, used for the ventilation of the existing and proposed poultry houses are represented by three point sources per house within ADMS (EX1 and PR1; 1, 2 and 3). Details of the point source parameters are shown in Table 1a. The positions of the point sources may be seen in Figures 4, marked by red stars.

The existing and proposed poultry houses have/would have ranging areas, which are represented by three area sources within ADMS (EX_RAN_E, EX_RAN_W, PR_RAN_E and PR_RAN_W). Note that the area sources cover the parts of the ranges most likely to be used frequently and not the whole of the ranging areas. Details of the area source parameters are provided in Table 1b. The positions of the area sources are shown in Figures 4 (red shaded polygons).

Table 1a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source (ou_E/s)
EX1 and PR1; 1, 2 & 3	5.5	0.8	11.0	Variable [1]	Variable [1]

1. Dependent on crop stage and ambient temperature.

Table 1b. Area source parameters

Source ID	Base Height (m)	Emission temperature (°C)	Area (m^2)	Emission rate (ou_E/s)
EX_RAN_E	0.0	Ambient	2,753	800.0
EX_RAN_W	0.0	Ambient	3,555	800.0
PR_RAN_E	0.0	Ambient	1,584	800.0
PR_RAN_W	0.0	Ambient	2,905	800.0

4.3 Modelled buildings

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

4.4 Discrete receptors

Sixteen discrete receptors have been defined at a selection of nearby residences. The receptors are defined at 1.5 m above ground level within ADMS and their positions may be seen in Figure 5 (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 (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 22.0 km by 22.0 km domain has been resampled at 50 m horizontal resolution for use within ADMS. The resolution of FLOWSTAR is 64 by 64 grid points; therefore, the effective resolution of the wind field for the terrain runs is approximately 340 m.

4.7 Other model parameters

In this case, a spatially varying roughness length file has been defined, this is based upon the Defra Living Landscapes land use database. The GFS meteorological data is assumed to have a roughness length of 0.126 m (the average over the modelling domain). The sample of the central area of the spatially varying roughness length field is shown in Figure 6.

Figure 4. The positions of the modelled buildings and sources – existing and proposed poultry houses

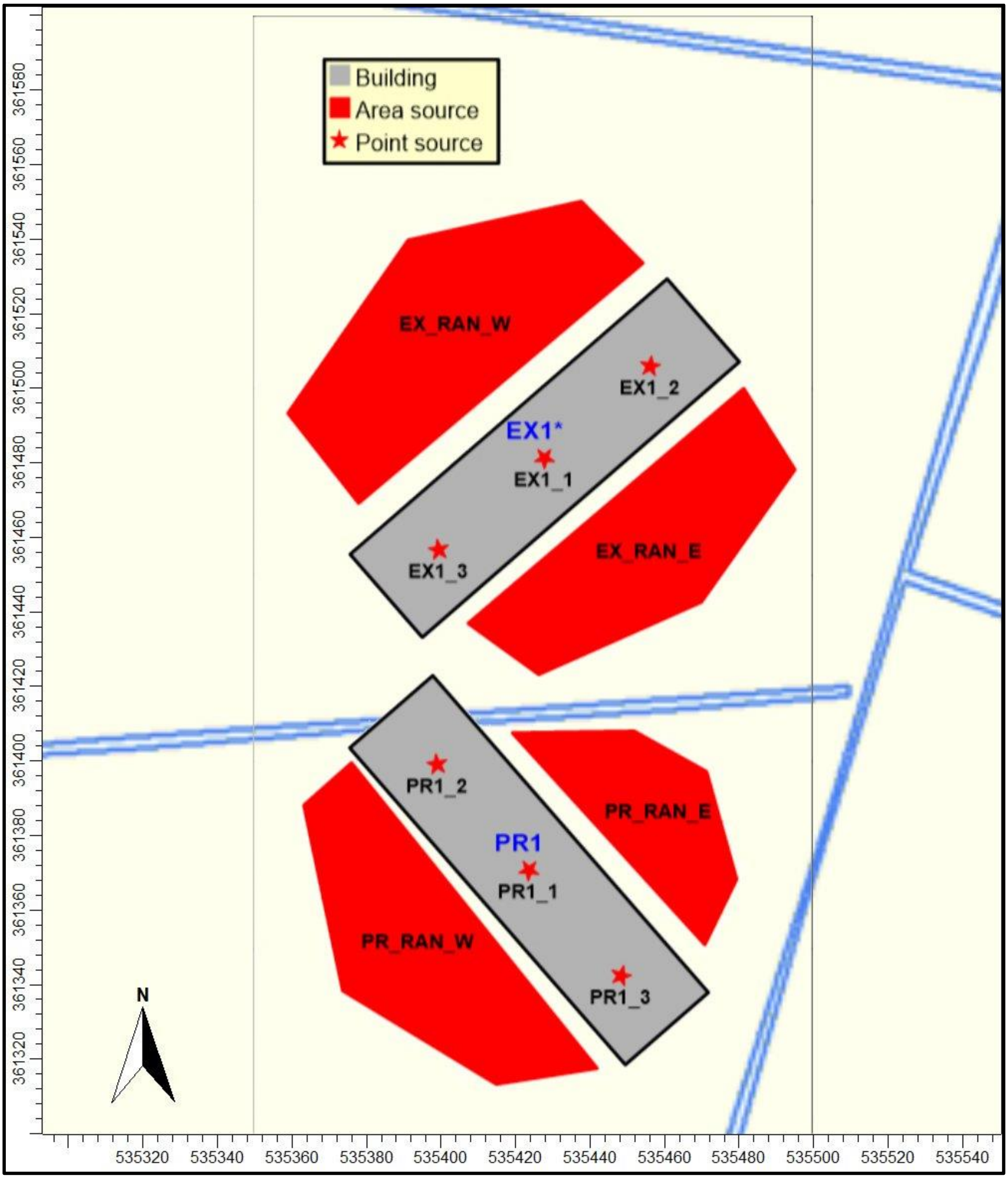


Figure 5. The discrete receptors and nested Cartesian grid receptors

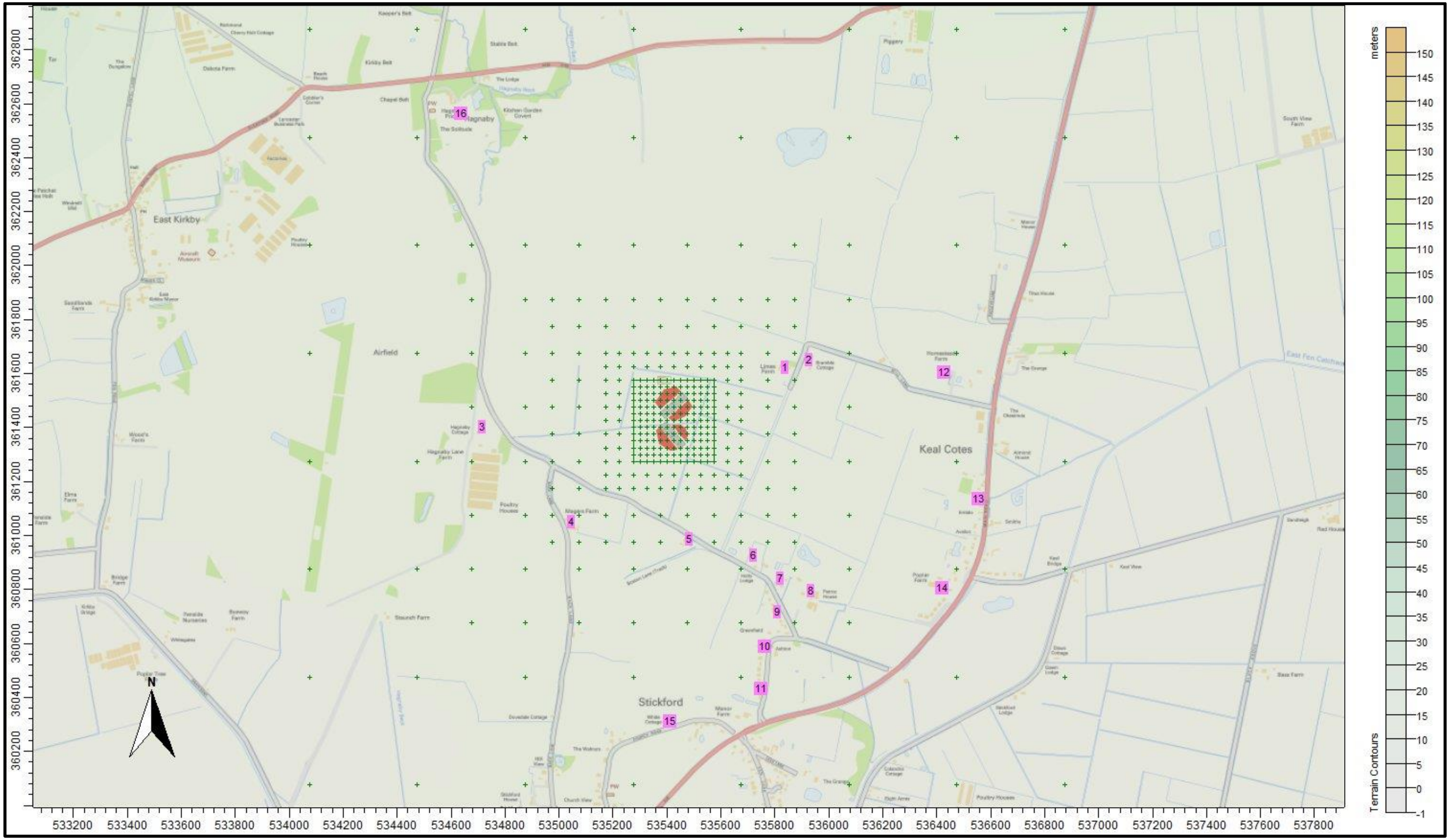
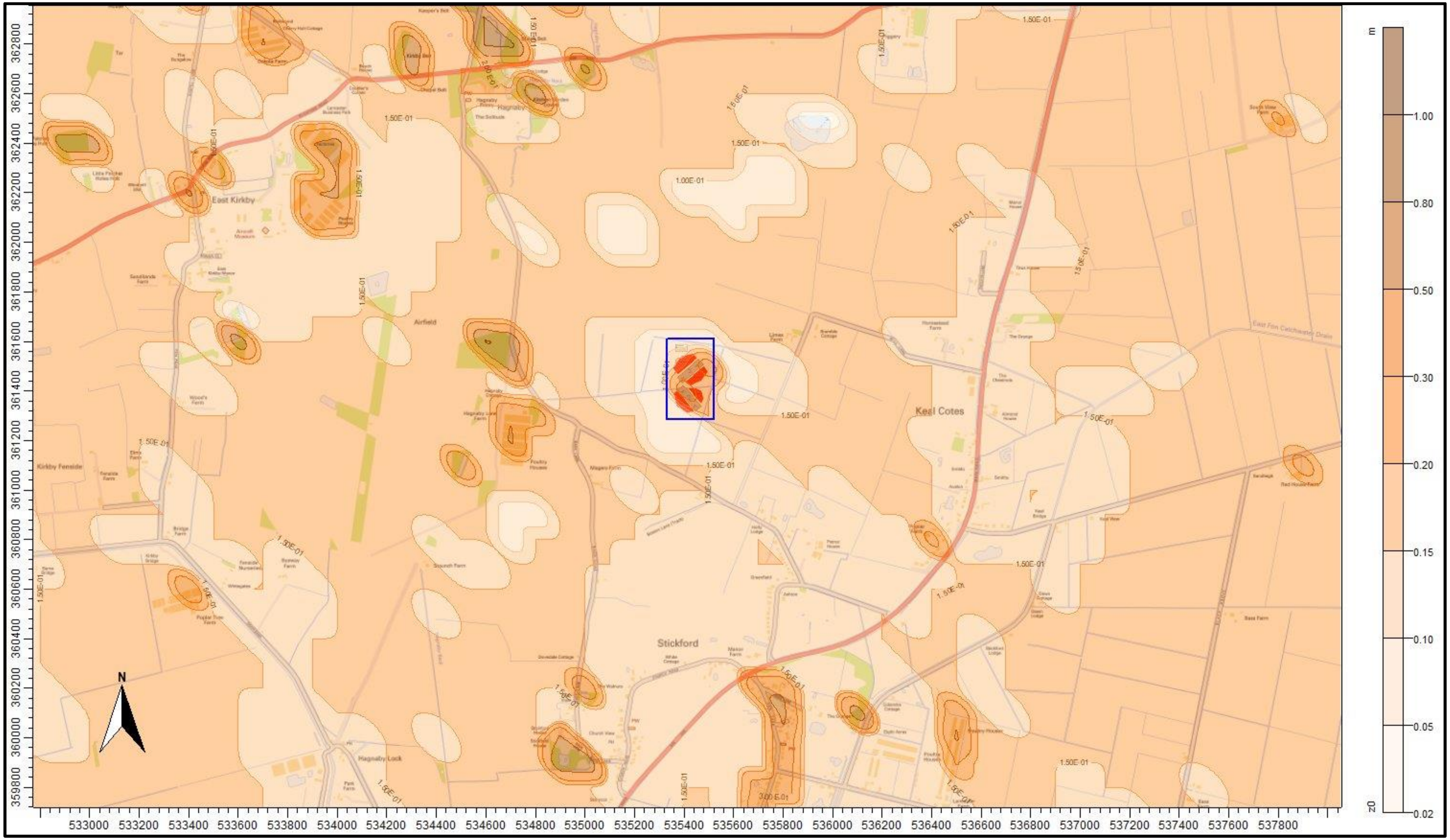


Figure 6. The spatially varying surface roughness field (central area)



5. Details of the Model Runs and Results

For this study, ADMS was run with the calms and terrain modules of ADMS, using GFS meteorological data. ADMS was run four times; once for each of the four year meteorological record.

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

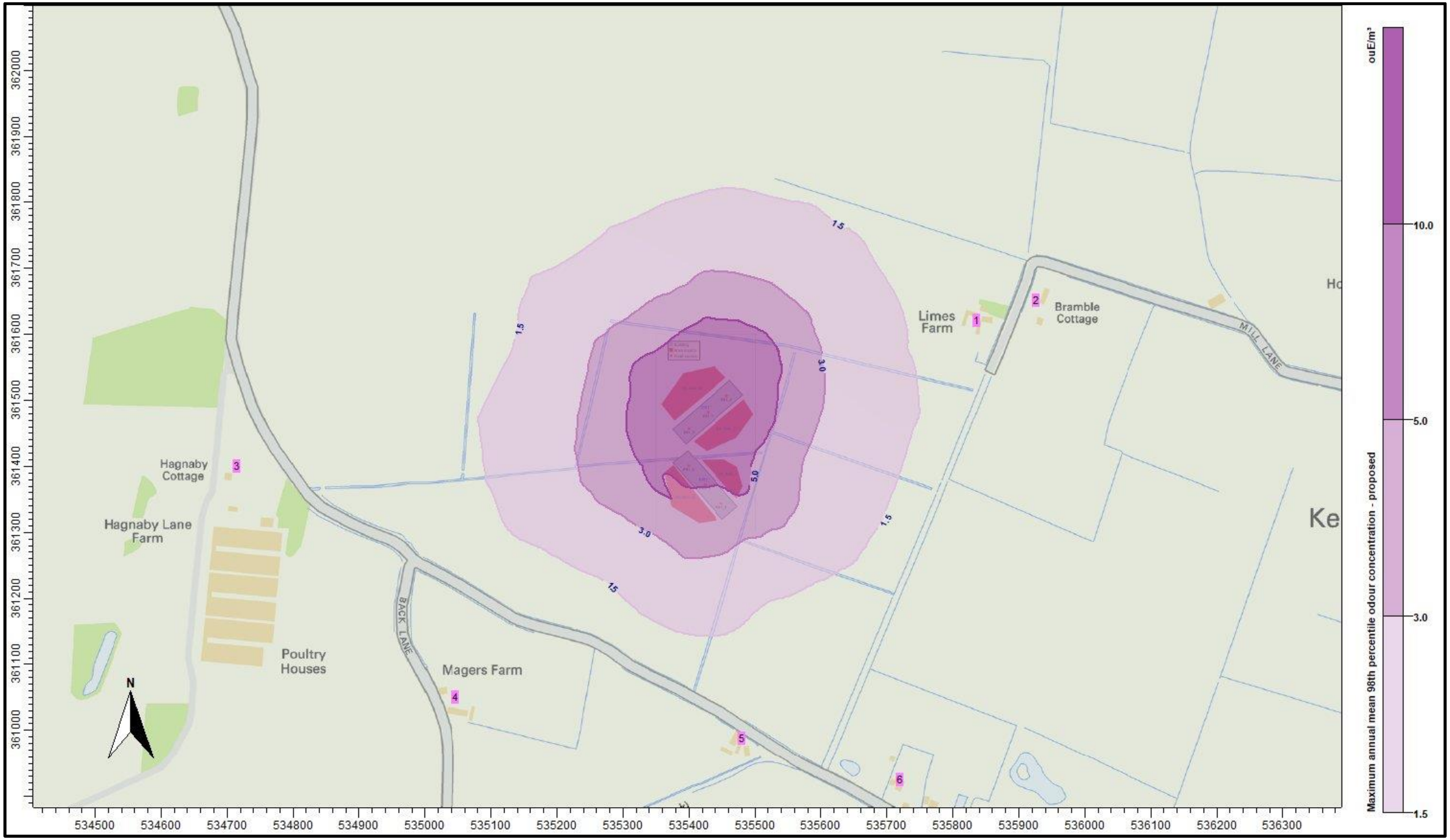
A summary of the results of these modelling runs at the discrete receptors is provided in Table 2, where the predicted maximum annual 98th percentile hourly mean odour concentration is shown for each of the discrete receptors. A contour plot of the maximum annual 98th percentile hourly mean odour concentrations are shown in Figure 7.

In Table 2, 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 concentration 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^3, are coloured red.

Table 2. 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
1	535836	361621	Limes Farm	0.94
2	535926	361652	Bramble Cottage	0.70
3	534715	361400	Hagnaby Cottage	0.47
4	535046	361051	Magers Farnm	0.45
5	535481	360987	Willoughby House	0.76
6	535720	360925	Holly Lodge	0.42
7	535821	360840	Residence, Hagnaby Lane	0.29
8	535935	360795	Petroc House	0.25
9	535810	360714	Residence, Hagnaby Lane	0.21
10	535763	360589	Greenfield	0.17
11	535748	360431	Residence, Hagnaby Road	0.14
12	536427	361603	Homestead Farm	0.26
13	536554	361133	Emblo Main Road	0.19
14	536420	360805	Poplar Farm	0.17
15	535413	360310	White Cottage	0.16
16	534639	362562	Hagnaby Priory	0.14

Figure 7. Predicted maximum annual 98th percentile hourly mean odour concentration



6. Summary and Conclusions

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The modelling predicts that:

- At all of the discrete receptors, the predicted odour concentrations would be well below the Environment Agency benchmark for moderately offensive odours, which is an annual 98th percentile hourly mean of 3.0 ou_E/m^3.

7. References

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