

An Odour Dispersion Modelling Study of the Impact of the Existing and Proposed Turkey Rearing Units at Greenway Farm near Llanhamiach in Powys

Prepared by Steve Smith

AS Modelling & Data Ltd.

Email: steve@asmodata.co.uk

Telephone: 01952 462500

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1. Introduction

AS Modelling & Data Ltd. has been instructed by P B Williams & Son to use computer modelling to assess the impact of odour emissions from the existing and proposed turkey rearing units at Greenway Farm, near Llanhamlach in Powys. LD3 7YA.

Odour emission rates from the existing and proposed turkey rearing units 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 existing and proposed poultry units; 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

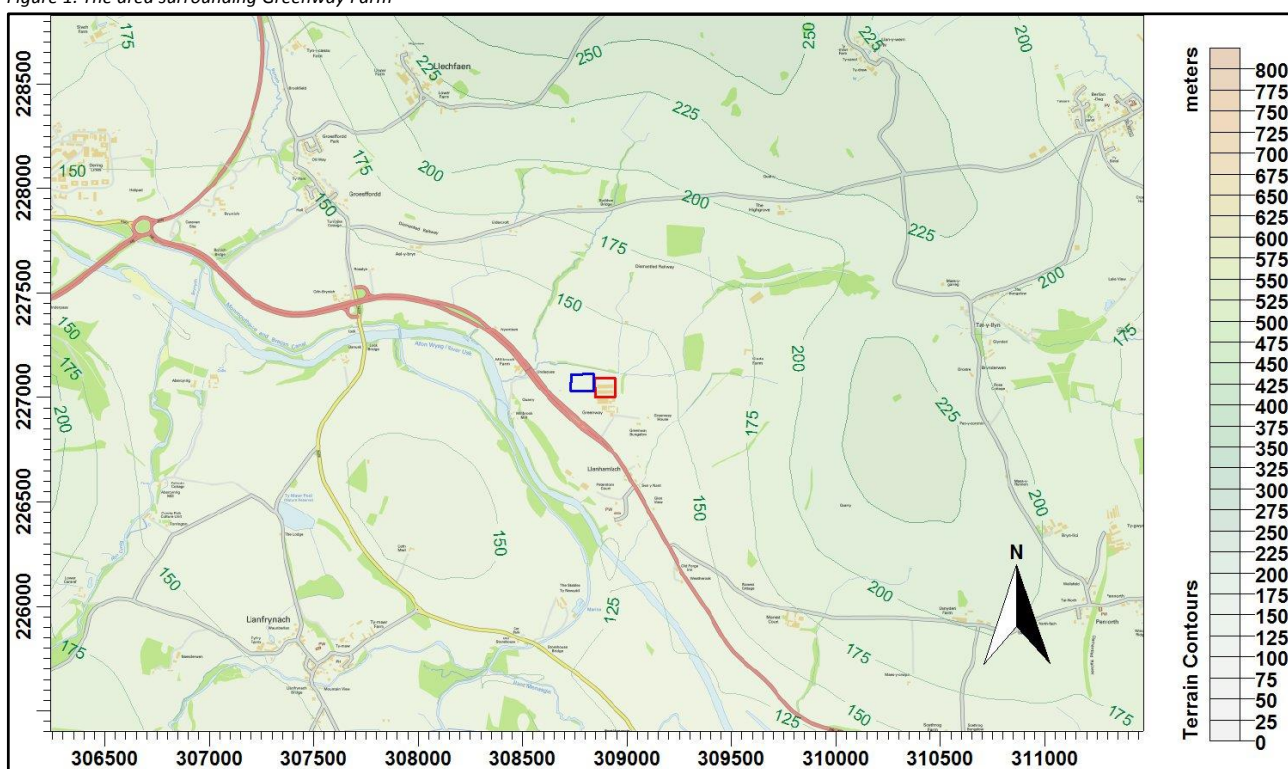
Greenway Farm is in a rural area approximately 200 m to the north-north west of the village of Llanhamiach in Powys. The surrounding land is used primarily for arable farming although there are some meadows and wooded areas. The site is at an altitude of around 141 m; the surrounding land rises towards hills to the north east and falls towards the River Usk Valley to the south-west.

There are three existing turkey rearing houses at Greenway Farm, these houses are used to accommodate up to 13,320 turkeys and are currently ventilated via side mounted fans. It is proposed that three new poultry house to accommodate an additional 14,400 turkeys be constructed on land to the west of existing poultry houses. The new houses would be ventilated by uncapped ridge mounted fans, each with a short chimney. To mitigate against the anticipated increase in odour production at the site the ventilation system of the three existing houses would be modified. The modification would involve the addition of gable end fans each being served by a chimney and being capable of providing 75% of the required maximum ventilation; some of the side ventilation fans would be retained, this is deemed necessary to maintain adequate circulation of air within the houses when maximum ventilation is required in hot weather conditions.

There are isolated residences in the area surrounding the site of the poultry unit at Greenway Farm. Excluding the farmhouse at Greenway Farm, the closest residences are; Greenway Bungalow and Greenway House, which are approximately 170 m and 185 m, respectively, to the east-south-east of the existing turkey rearing houses; residences at Llanhamiach, approximately 340 m to the south-south-east; at Millbrook Farm approximately 350 m to the west-north-west; at Millbrook Mill approximately 400 m to the west-south-west; and at Peterstone Court, approximately 425 m to the south.

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

Figure 1. The area surrounding Greenway 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

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.

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.

3.5 Quantification of Odour Emissions

Odour emission rates from turkey rearing houses depend on many factors and are highly variable. At the beginning of a crop cycle, when birds are smaller, litter is clean and only minimum ventilation is normally 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. There are measures that can be taken to minimise odour production whilst the housing is being cleared of spent litter. The time taken to perform the operation is usually around an hour or two per shed 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. It should be noted that it is normal to maintain ventilation during clearing out.

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 linearly from 300 ou_E/m³ at day 1 of the crop, to approximately 1,000 ou_E/m³ at day 15 of the crop. These figures are obtained from a review of available literature.

The ventilation rates used in the calculations are based on industry standard practices and bird growth factors and where available site specific practices. Target internal temperature is 18 Celsius at the beginning of the crop and is decreased to 14 Celsius by day 82 of the crop. If the external temperature is 6 Celsius, or more, lower than the target temperature then minimum ventilation only is assumed for the calculation. If the external temperature is 3 Celsius, or more, greater than the target temperature then the maximum ventilation rate is assumed. A transitional ventilation rate is calculated between these extremes.

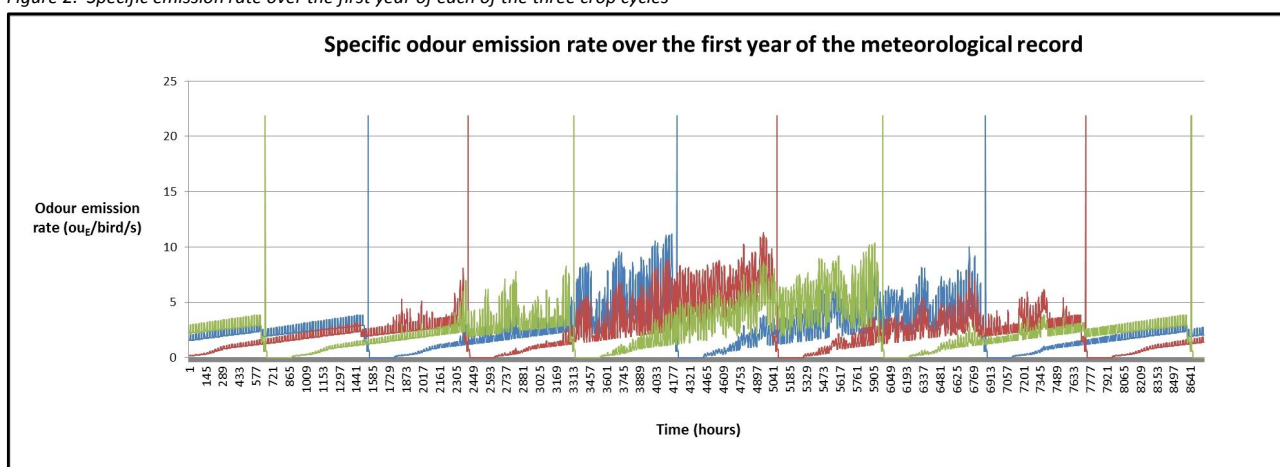
Based upon these principles, an emission rate for each hour of the period modelled is calculated by multiplying the concentration by the ventilation rate. Both the crop length and period the housing is empty can be varied. An estimation of the emission during the cleaning out process can also be included.

In this case a crop length of 100 days and an empty period of 11 days after each crop is assumed for the calculations. N.B. At Greenway Farm, the turkeys are around 36 days old when brought to the farm for the start of the cycle. 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 38 of the crop and the third coinciding with day 76 of the crop. A summary of the emission rates used in this study is provided in Table 1. The specific odour emission rate used for the clearing process is approximately 21.85 ou_E/bird/s (as stocked) and the 98th percentile emission rate is approximately 8.25 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 or maximum of all three cycles)

Emission rate (ou _E /s per bird as stocked during crop)				
Season	Average	Night-time Average	Day-time Average	Maximum
Winter	1.936	1.720	2.366	7.781
Spring	2.772	1.973	3.571	11.893
Summer	3.654	2.350	4.437	12.601
Autumn	2.437	1.968	2.905	10.034

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, averaging time (which may be an annual average or a shorter period), which percentiles and exceedence 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

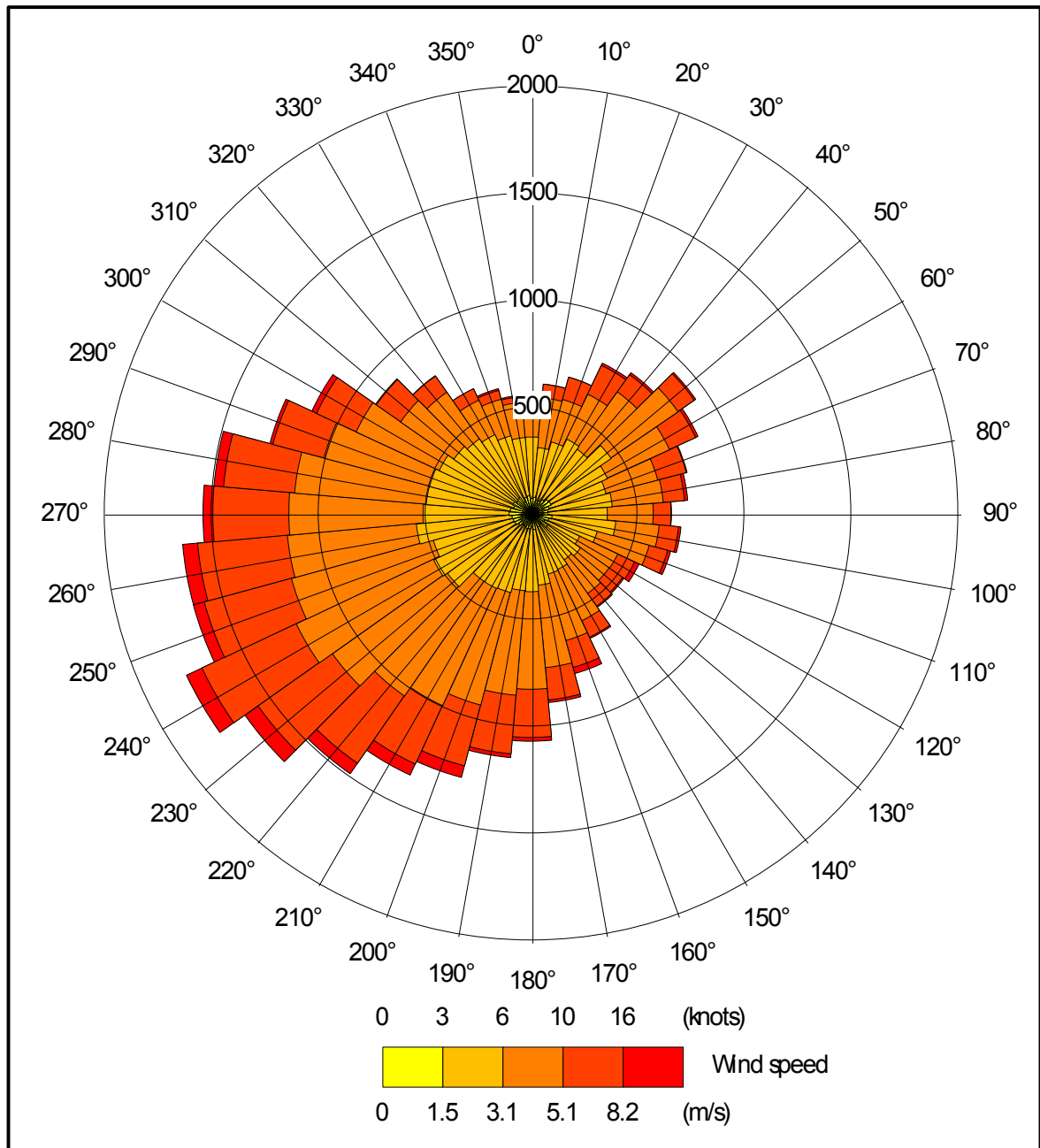
Computer modelling of dispersion requires hourly sequential meteorological data and to provide robust statistics the record should be of a suitable length; preferably four years or longer.

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 0.5 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.

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 3. N.B where terrain data is included in the modelling these wind speeds and directions will be modified. These data are derived for latitude 51.934 degrees North, longitude 3.326 degrees West.

Figure 3. The wind rose. GFS derived data, for 51.934 N, 3.326 W, 2010 - 2013



4.2 Emission sources

Emissions from the side fans of the three existing poultry houses in the existing scenario are represented by a single volume source per house within ADMS (EX1_v to EX3_v). Details of the volume sources parameters are shown in Table 2a. The position of the volume sources may be seen in Figure 4.

Emissions from the retained side fans of the three existing poultry houses in the proposed scenario are represented by a single volume source per house within ADMS (EX1_v_pr to EX3_v_pr). Details of the volume sources parameters are shown in Table 3a. The position of the volume sources may be seen in Figure 4.

Emissions from the uncapped chimneys serving the gable end fans on the existing houses in the proposed scenario are represented by three point sources per house within ADMS (EX1 to EX3 a, b & c). Details of the point source parameters are shown in Table 2b. The positions of the point sources may be seen in Figure 4.

Emissions from the uncapped high speed ridge fans that would be used on the three new houses in the proposed scenario are represented by three point sources per house within ADMS (PR1 to PR3 a, b & c). Details of the point source parameters are shown in Table 2b. The positions of the point sources may be seen in Figure 4.

Table 2a. Volume source parameters

Source ID	Length Y (m)	Width X (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate per source (ou _E /s)
EX1_v to EX4_v	18.29	73.15	3.0	0.0	Ambient	Variable ²
EX1_v_pr to EX4_v_pr	18.29	18.29	3.0	0.0	Ambient	Variable ^{1&2}

Table 2b. Point source parameters

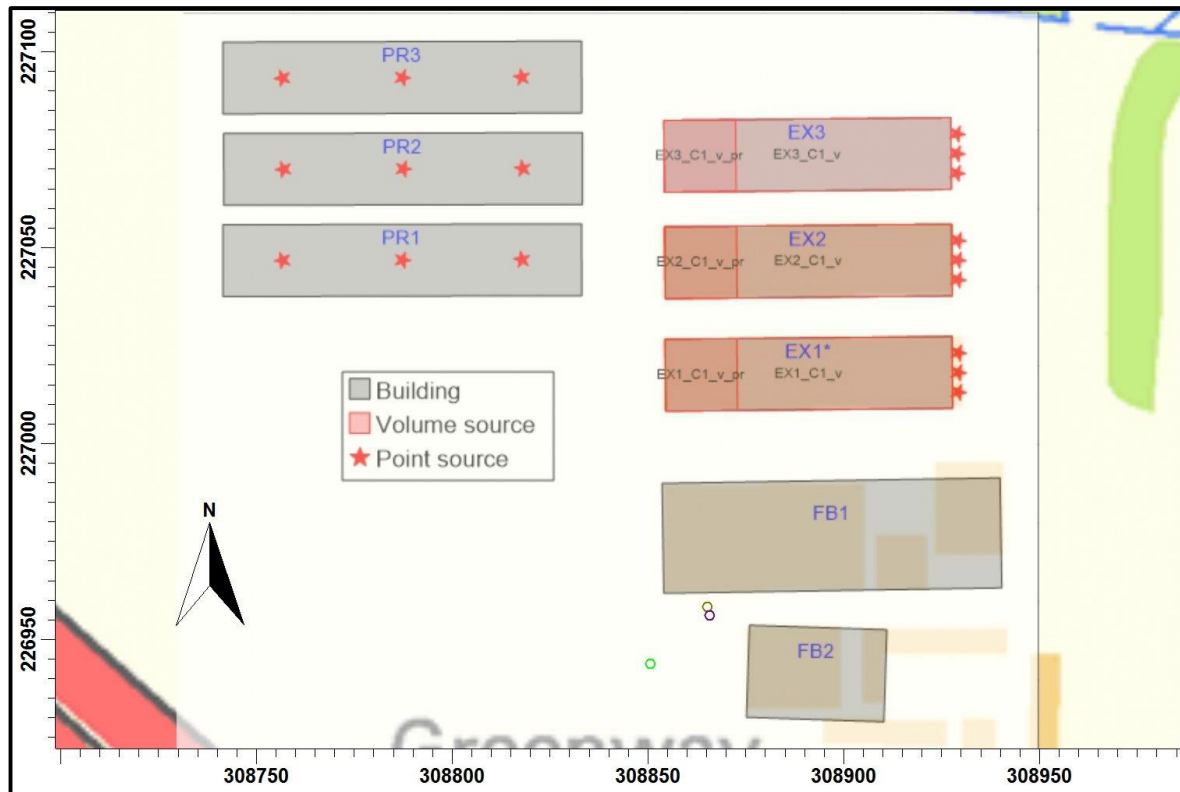
Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (°C)	Emission rate per source (ou _E /s)
EX1 to EX3 a, b & c	5.5	0.8	11	Variable ²	Variable ²
PR1 to PR3 a, b & c	5.5	0.8	11	Variable ²	Variable ^{2&3}

1. 25% of total is emitted only when ambient temperature equals or exceeds 18 Celsius.
2. Dependent on ambient temperature and target temperature.
3. Reduced by 25% when ambient temperature equals or exceeds 18 Celsius.

4.3 Modelled buildings

The structure of the poultry houses and other buildings at the farm may affect the odour plumes from the point sources in the proposed scenario. Therefore, the existing and proposed buildings and other farm 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 and sources



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4.4 Discrete receptors

Twenty-two 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, 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.

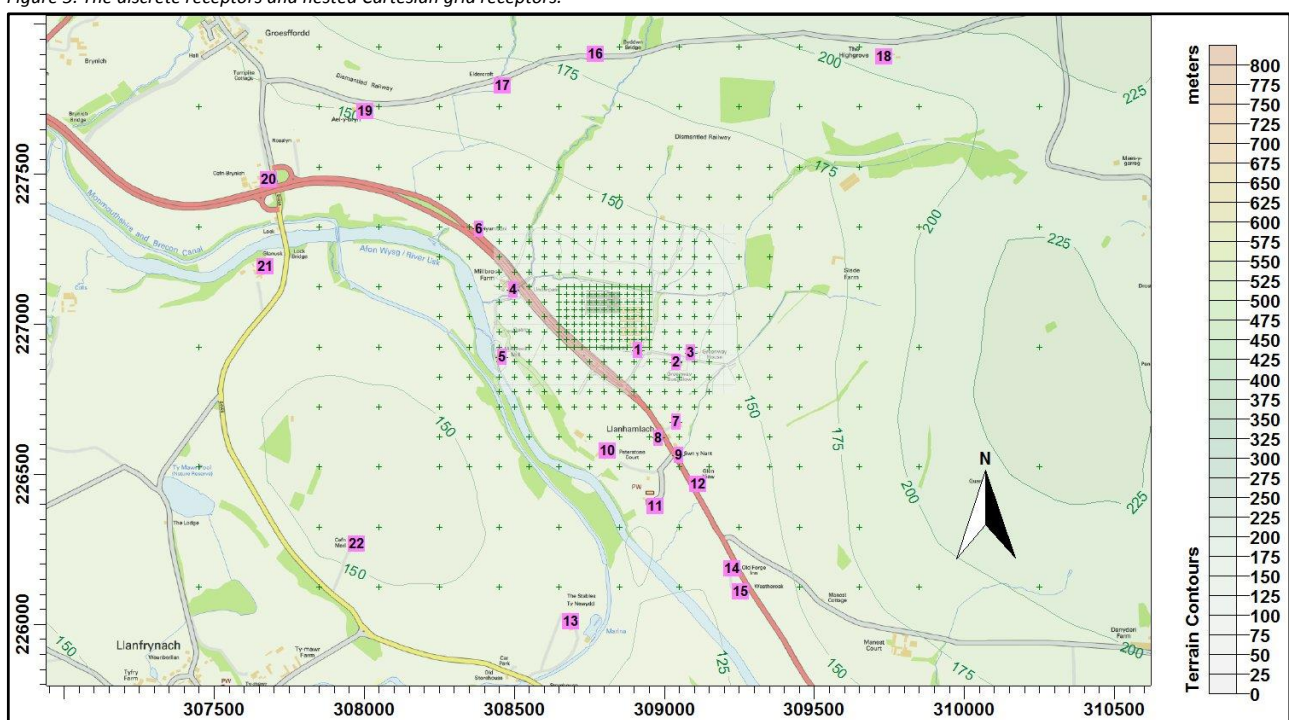
4.6 Terrain data

The area around Greenway Farm is hilly, therefore, terrain data has been considered in the modelling. The terrain data used is derived from the Ordnance Survey 50 m Digital Elevation Model (DEM). The 50 m DEM data has been resampled at 200 m for use within ADMS.

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 0.1 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 in three modes;

- In basic mode without calms, or terrain.
- With calms and without terrain.
- Without calms and with terrain.

ADMS was effectively run a total of seventy-two times (once for each year of the four year meteorological record, for each of the three modes, for the existing and proposed scenarios and for each of the three crop cycle). Statistics for the annual 98th percentile hourly mean odour concentration at each receptor were compiled for each of the seventy-two runs.

A summary of the results of these seventy-two runs at the discrete receptors is shown in Table 3 where the maximum annual 98th percentile hourly mean odour for each mode is shown for the existing and proposed scenarios. Contour plots of the maximum annual 98th percentile hourly mean odour concentration from all modes and all cycles is shown in Figure 6a (existing) and 6b (proposed).

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 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 (ou _E /m ³)					
			Existing			Proposed		
			No Calms No Terrain	Calms No Terrain	No Calms Terrain	No Calms No Terrain	Calms No Terrain	No Calms Terrain
1	418328	339076	23.41	35.13	17.70	5.96	5.87	6.44
2	418542	339176	10.91	14.87	9.32	4.60	4.55	5.52
3	418340	338810	10.62	14.19	10.62	4.39	4.34	6.31
4	418371	338763	2.74	3.99	2.07	2.59	2.56	3.05
5	418108	338690	1.90	3.18	1.00	1.92	1.91	1.58
6	418606	338553	1.28	1.98	1.30	1.31	1.28	2.44
7	418795	338628	3.80	5.00	2.42	2.09	2.08	2.06
8	418730	338449	2.42	4.48	2.06	1.68	1.63	1.67
9	418886	338918	2.18	3.45	1.59	1.45	1.43	1.45
10	418975	338638	1.80	2.90	1.75	1.43	1.43	1.31
11	418486	339547	1.06	2.05	1.11	0.92	0.91	0.91
12	418901	339468	1.75	2.42	1.25	1.18	1.16	1.19
13	418390	339721	0.46	0.73	0.49	0.52	0.52	0.47
14	418450	339840	0.89	1.20	0.71	0.73	0.72	0.79
15	417884	339512	0.77	1.04	0.64	0.66	0.65	0.71
16	417338	339410	0.76	1.37	0.46	0.87	0.86	0.51
17	418100	338950	0.64	1.12	0.51	0.92	0.91	0.81
18	418125	338950	0.55	0.73	0.43	0.59	0.58	0.40
19	418150	338950	0.27	0.63	0.37	0.42	0.42	0.74
20	418175	338950	0.33	0.52	0.32	0.43	0.42	0.71
21	418200	338950	0.38	0.58	0.31	0.45	0.44	0.56
22	418225	338950	0.50	0.71	0.24	0.50	0.50	0.49

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6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by P B Williams & Son to use computer modelling to assess the impact of odour emissions from the existing and proposed turkey rearing units at Greenway Farm, near Llanhamiach in Powys. LD3 7YA.

Odour emission rates from the existing and proposed turkey rearing units 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.

Existing Scenario

The results of the modelling indicate that, odour exposure levels at several nearby residences are currently above 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. At some of the residences, the predicted odour exposures are at levels where UKWIR research would suggest that some complaints may arise (receptors 1 to 3 and 7), or are likely (receptors 1 to 3). The predictions are highest when calm periods are considered and this is what would normally be expected with low level emission points such as the side fans on the existing turkey rearing houses.

Proposed Scenario

At all receptors considered, the maximum predicted 98th percentile hourly mean odour concentrations are reduced from those predicted under the existing scenario, particularly when calm periods are considered. At receptors 1 to 4 the maximum predicted odour exposure level remain above 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 and at receptors 1 to 3 are in the lower end of the range where UKWIR research would suggest that some complaints may arise. At other receptors they are below the Environment Agency's benchmark for moderately offensive odours.

The improvement in air quality around the poultry unit would be due to the adoption of high speed fans on the proposed houses and the adaption of the existing ventilation system, both of which would improve dispersion, particularly in periods of light or calm winds, or when dispersion conditions are otherwise poor. It is likely that the improvement would be more marked at higher percentiles.

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