Mr D Langford

Proposed Poultry Unit Expansion at The Gaer, Meifod, Powys

Odour Impact Assessment

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RSK GENERAL NOTES

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This work has been undertaken in accordance with the quality management system of RSK Group plc.

Summary

RSK Environment Ltd has been commissioned by Mr David Langford, to conduct a study to assess the potential impact of odour emissions from a proposed expansion of the poultry unit at The Gaer, Meifod, Powys. The aim of the study is to focus on how odour emissions from the proposed expansion may affect residential receptors in the surrounding area.

Odour emissions from the existing and proposed poultry houses have been assessed and quantified based on a review of available literature including research work by Hayes et. al. (2006) and Robertson et. al. (2002) and odour emission measurement work undertaken by ADAS at other poultry units as part of commercial consultancy. The emission figures obtained were then used in atmospheric dispersion modelling to assess the likely impact of odour in the area around the site of the poultry unit.

Guideline values and benchmarks

The Environment Agency published guidelines on odour regulation, assessment and control (H4: Odour management), in March 2011, which have been adopted by Natural Resources Wales. Odour from livestock housing is normally placed in the moderately offensive category. The target impact level suggested in H4 for moderately offensive odours is an hourly mean odour concentration of 3.0 European Odour Units per cubic metre of air (ou_E/m^3) at the 98^{th} percentile, as a guideline to indicate the likelihood of unacceptable odour pollution. Predicted odour exposures have also been compared to 5.0 ou_E/m^3 at the annual 98^{th} percentile, which is the level above which ADAS has generally found that the likelihood of off-site impact increases, and which is consistent with UK Water Industry Research organisation studies. The five year mean annual 98^{th} percentile hourly average odour concentrations have been compared to these benchmarks.

Dispersion modelling methodology

The choice of model for this study is UK Atmospheric Dispersion Modelling System (ADMS) Version 5.2. A five year weather file from the meteorological station at Shawbury for the years 2011 – 2015 has been used.

Emissions from high velocity ridge mounted fans on the existing and proposed poultry houses have been represented by six point sources per house within the model. Emissions from gable end fans, used to augment the ridge mounted fans during hot weather have also been modelled and have been represented by a single volume source at the eastern end of each of the poultry houses. Emissions from the volume sources representing the gable end fans are assumed to occur when the ambient temperature equals or exceeds 22°C. When these conditions occur, the gable end fans are assumed to account for 50% of the total emission and whilst they are emitting, emissions from the point sources, representing the high velocity ridge extraction fans, are reduced by 50%. Three scenarios were modelled to account for crop cycles starting at different times of the year.

Findings

The modelling predicts that for all scenarios modelled, the predicted annual mean 98th percentile hourly mean odour concentrations are within the benchmark range of 3.0 to 5.0 ou_E/m^3 at all identified discrete receptor points, representing nearby residential and commercial properties. At receptor 1, which is connected to the Gaer Farm, the predicted annual 98th percentile hourly mean odour concentration is slightly above the 3.0 ou_E/m^3 benchmark for the 2014 meteorological file run for scenario 1 and the 2015 meteorological file run for scenario 3. However, for all other years modelled the annual 98th percentile hourly mean odour concentrations at this receptor are well below the 3.0 ou_E/m^3 benchmark. At all receptors not connected with the poultry farm, the predicted annual 98th percentile hourly mean odour concentrations are below the 3.0 ou_E/m^3 EA benchmark for all years modelled.

It is therefore concluded that the proposed expansion at the poultry unit would not result in any significant loss of local residential amenity.

Abbreviations

ADMS	Atmospheric Dispersion Modelling System
CERC	Cambridge Environmental Research Consultants
CIWEM	Chartered Institute of Water and Environmental Management
Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency
EPR	Environmental Permitting Regulations
IAQM	Institute of Air Quality Management
NRW	Natural Resources Wales
ou_E/m^3	European Odour Units per cubic metre of air
UKWIR	UK Water industry Research

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1 INTRODUCTION

1.1 Background

RSK Environment Ltd has been commissioned by Mr David Langford, to conduct a study to assess the potential impact of odour emissions from a proposed expansion of the poultry unit at The Gaer, Meifod, Powys. The aim of the study is to focus on how odour emissions from the proposed expansion may affect residential receptors in the surrounding area.

Odour emissions from the two existing and two proposed additional poultry houses have been assessed and quantified based on a review of available literature including research work by Hayes et al (2006) and Robertson et al. (2002), and odour measurement work undertaken by ADAS at other poultry units as part of commercial consultancy. The emission figures obtained were then used in atmospheric dispersion modelling to assess the likely impact of odour in the area around the site of the poultry unit.

1.2 Proposed Development

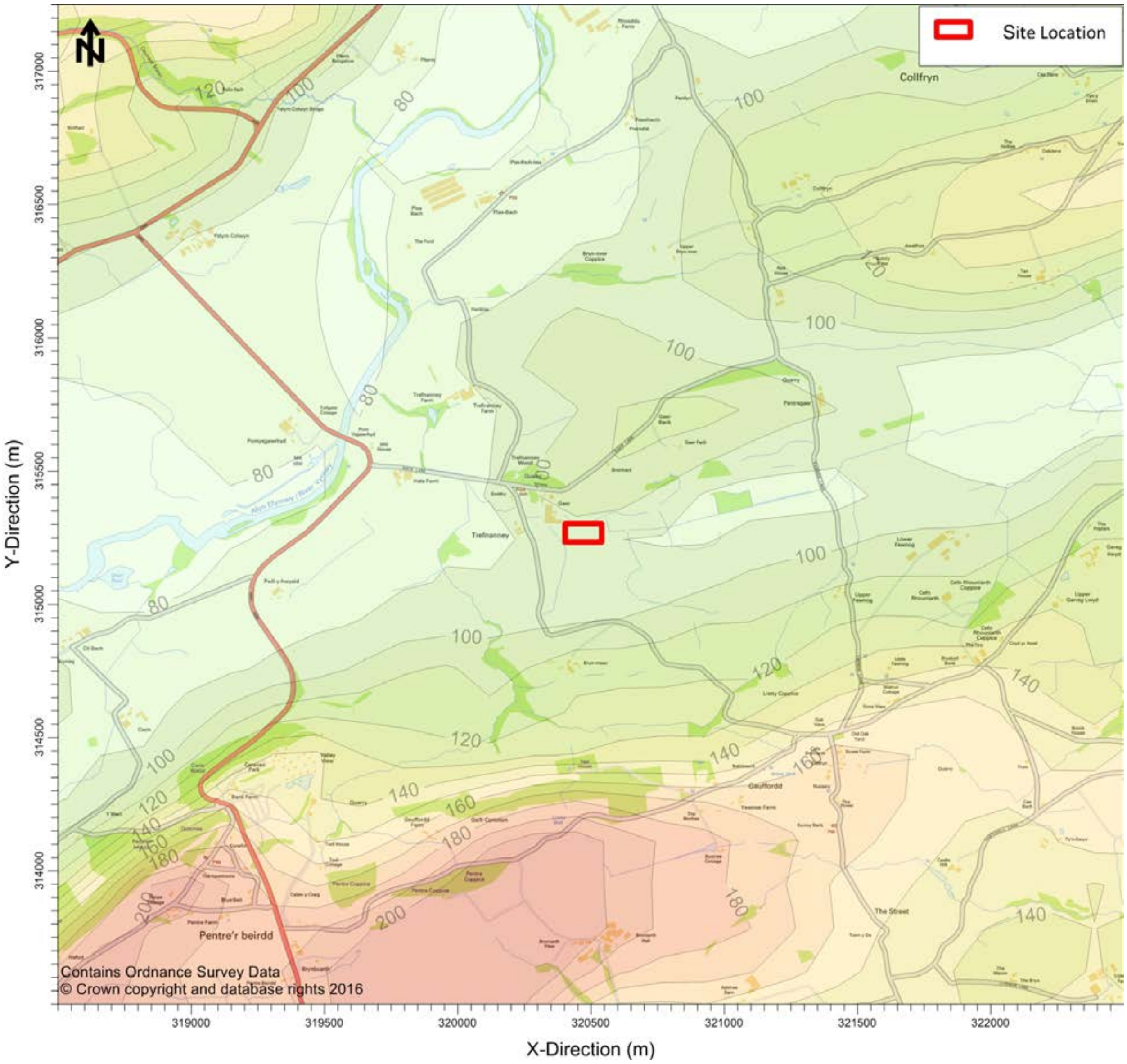
The proposed poultry unit at the Gaer is located in a rural setting on the outskirts of the hamlet of Trefanney, approximately 5 km to the north east of Meifod. The site of the proposed development is currently laid to pasture and is at an elevation of approximately 90 m. There are several isolated farmhouses and residences in the area around application site. The closest residence is The Gaer Farmhouse, which is owned and occupied by the Applicant. The closest residential property not associated with the proposed development is located in Trefanney, approximately 200 m to the west of the application site. More densely populated areas include the village of Geufford, which is located approximately 1.1 km to the south east and Sarnau, at around 2.8 km to the east. A map of the surrounding area is presented in Figure 1. The site of the proposed poultry unit is outlined in red.

Under the proposal, two new poultry houses of modern design would be constructed on land to the south of two existing poultry houses at The Gaer, situated to the south-east of existing agricultural buildings. Each poultry house would measure 128 m x 18.5 m and would provide accommodation for approximately 50,000 broiler chickens. The expanded poultry unit would therefore provide accommodation for a total of 200,000 broiler chickens.

The birds would be reared from 1 day old chicks to an age of 37 days, with approximately 50% of each flock thinned at 30 days. The proposed poultry unit would operate 7 to 7.5 flock cycles per year, which includes an allowance of approximately 12 days between each flock to clean out the houses and to prepare them for re-stocking.

The proposed new poultry houses would be primarily ventilated by uncapped high velocity ridge mounted extraction fans, with additional ventilation provided by gable end wall extract fans during hot weather, as with the two existing poultry buildings.

Figure 1.1: Site Location



2 LEGISLATION AND POLICY CONTEXT

2.1 Legislation

The Environmental Protection Act 1990 is used to regulate potential ‘statutory nuisance’, including odours, dust and nuisances derived from poor air quality. Section 3 requires local authorities to issue abatement notices where a nuisance “*unreasonably and substantially interfere[s] with the use or enjoyment of a home or other premises*” or where it could “*injure health or be likely to injure health*”.

The Environmental Permitting (England and Wales) Regulations (EPR) 2016 consolidate the previous amending instruments and provide the process for applying, regulating and measuring compliance with environmental permitting. Under the regulations the rearing of over 40,000 poultry in an intensive installation requires a permit to operate.

2.2 Planning Policy

The land use planning process is a key means of improving air quality, particularly in the long term, through the strategic location and design of new developments. Any air quality concern that relates to land use and its development can, depending on the details of the proposed development, be a material consideration in the determination of planning applications.

2.2.1 National Planning Policy

Planning Policy Wales (PPW) outlines the Welsh Government’s land use planning policies (2016). Although odour is not mentioned specifically, PPW requires consideration of the effects on amenity. In terms of promoting development in the rural economy, PPW states that “*The expansion of existing businesses located in the open countryside should be supported provided there are no unacceptable impacts on local amenity*.”

2.2.2 Local Planning Policy

The Powys Local Development Plan 2011 - 2016 was adopted in April 2018. Policy DM13 Design and Resources relates to development and requires that development proposals have regard to the qualities and amenity of the surrounding area. In particular the policy states that “*The amenities enjoyed by the occupants or users of nearby or proposed properties shall not be unacceptably affected by levels of noise, dust, air pollution, litter, odour, hours of operation, overlooking or any other planning matter*”.

2.3 Guidance

2.3.1 Environment Agency Guidance H4 Odour Management

The Environment Agency (EA) published guidelines on odour regulation, assessment and control in March 2011. This guidance document is aimed at operators of installation regulated by the EA under the Environmental Permitting Regulations (EPR), which require the control of pollution including odour. Natural Resources Wales (NRW) rebranded the guidance to NRW in 2014 although this did not include the appendices.

2.3.2 Guidance on the Assessment of Odour for Planning

The Institute of Air Quality Management (IAQM) (Bull et. al., 2014) provides a comprehensive review of approaches to the assessment of odour impacts and dispersion modelling.

2.4 Assessment Criteria

Odour emission rates are expressed as European Odour Units per second (ou_E/s) and odour concentration as European Odour Units per cubic metre of air (ou_E/m^3). The following descriptions of how odour of certain concentrations may be helpful:

- 1.0 ou_E/m^3 – This is defined as the detection limit in the controlled, odour free, conditions of an odour laboratory;
- 2.0 - 3.0 ou_E/m^3 – A particular odour may become just detectable against normal background odour;
- 3.0 - 5.0 ou_E/m^3 – Odour may be detectable and identifiable, but most observers would only describe it as faint;
- 5.0 - 10.0 ou_E/m^3 – Odour levels in this range may start to become annoying, if persistent and/or if unpleasant; and
- >10 ou_E/m^3 – Most observers would describe the odour intensity of unwanted odours as moderate or strong.

It is noted that humans readily occupy and tolerate living spaces with "background", from odour sources such as furniture, carpets, cosmetics, pets, food and cleaning products/polishes at odour concentrations well in excess of these levels.

Since the early 1990s the technique of odour dispersion modelling has become well established as a means of assessing the off-site odour impact of a very wide range of odorous activities and particularly sewage/wastewater and intensive livestock farming (poultry and pigs). Odour impact benchmark levels have been developed as a matter of "custom and practice", of which the best established is the so-called "Newbiggin" standard.

The widely accepted convention in the UK is that odour impacts are expressed as 98th percentile hourly means, and these standards have been based on "dose-response" relationships which take account of normal temporal and metrological variations in downwind/off-site odour impacts. Various impact standards have been derived and applied in planning and impact assessments, as set out below.

2.4.1 The Newbiggin Standard

This empirical standard, of 5.0 ou/m^3 at the 98th percentile, has been widely used in the intensive livestock and wastewater (sewage) sectors in the UK and elsewhere, to assess the likelihood of community annoyance.

This standard was derived from an early 1990s planning appeal decision relating to an appeal by Northumberland Water for the construction of a wastewater (sewage) treatment facility at Newbiggin-by-the-Sea in Northumberland in which evidence on potential off-site odour impacts was presented using odour dispersion modelling. The decision in this appeal case was the origin of the now well-established "Newbiggin" criterion that has been used, and is still used to this day, for odour impact assessments.

2.4.2 UKWIR Research

In 2001 the UK Water industry Research (UKWIR) organisation undertook research into correlations between (dispersion) modelled odour impact and the distribution of odour complaints around wastewater (sewage) treatment works. The findings of this work were concisely summarised in a more recent Chartered Institute of Water and Environmental Management (CIWEM) document:

"The main source of research into odour impacts in the UK has been the wastewater industry and the most in-depth study published study in the UK of the correlation between of modelled odour impacts and human response (dose-effect) was published by UK Water industry Research (UKWIR) in 2001. This was based on a review of the correlation between reported odour complaints and modelled odour impacts in relation to 9 wastewater treatment works in the UK with ongoing odour complaints. The findings of this research (and subsequent UKWIR research) indicated the following:

- *At modelled exposures of below C98, 1-hour 5ou_E/m^3, complaints are relatively rare, at only 3% of the total registered;*
- *At modelled exposures between C98, 1-hour 5ou_E/m^3 and C98, 1-hour 10ouE/m3, a significant proportion of total registered complaints occur; 38% of the total;*
- *The majority of complaints occur in areas of modelled exposure greater than C98, 1-hour 10ou_E/m^3, 59% of the total."* (CIWEM, 2012)

In effect these findings demonstrated that with appropriate modelling, potential odour impact and annoyance is effectively controlled at 98th percentile hourly mean odour impacts of 5 ou_E/m^3 or less. These findings are consistent with the Newbiggin standard.

2.4.3 H4 Odour Guidance

Odour detection thresholds and consideration of whether or not an odour is offensive are discussed in Appendix 2 of the H4 guidance document. In Appendix 3 (of H4), modelled odour concentration benchmark levels are presented for odours of varying degrees of offensiveness. A threshold value of 6.0 ou_E/m^3 is suggested in H4 as being appropriate for the least offensive odours, expressed as a 98th percentile of the hourly mean odour concentrations over a one year period. This effectively means that a situation should be acceptable, provided that the value of 6.0 ou_E/m^3 is not exceeded on more than 2% of occasions. For moderately offensive odours and highly offensive odours, the equivalent Environment Agency threshold values are 3.0 ou_E/m^3 and 1.5 ou_E/m^3 respectively.

Odours from livestock housing are specifically placed in the moderately offensive category in the H4 guidance and the target suggested in H4 for moderately offensive odours is an hourly mean odour concentration of 3.0 ou_E/m^3 at the 98th percentile.

The H4 guidance only recognises 98th percentile guideline values and this document provides the most relevant and authoritative guidance on the use of percentile values.

2.4.4 Suggested Odour Benchmarks

A range of odours, including those from livestock housing, are unlikely to cause unacceptable off-site impacts with annual 98th percentile odour concentrations of less than 5.0 ou_E/m^3. However, as exposure exceeds 5.0 ou_E/m^3 at the annual 98th percentile, there is an increasing risk of annoyance, and above 10.0 ou_E/m^3, some adverse impact might be expected. These observations are consistent with an empirical standard of 5.0 ou_E/m^3 at the annual 98th percentile, used in the landfill and wastewater industries in the UK and elsewhere, to assess the likelihood of community annoyance.

When assessing the impact of odours it is important to take account of the nature of receptors in the area. For example, it has been accepted by the Courts that industrial areas are less “sensitive” to odours than residential areas (e.g. Hirose Electrical vs Peak Ingredients). It is therefore suggested that taking account of the Newbiggin standard, the UKWIR research findings and the H4, it is reasonable to assess odour impacts against benchmarks of 3.0 ou_E/m^3 to 5.0 ou_E/m^3 in predominantly agricultural areas.

It should be noted that the prediction that any particular property lies above the guideline concentration does not necessarily imply that a loss of residential amenity (or a nuisance) will follow. However, it is suggested that the probability of such an occurrence is increased in proportion to the exceedance of the guideline.

2.4.5 IAQM Assessment of Significance

In accordance with IAQM guidance on the assessment of odour, the significance of the odour impact can be assessed in relation to the magnitude of the modelled impact and the sensitivity of the receptor. The magnitude scale that has been developed is based on the suggested odour benchmarks above for odours in the moderately offensive category. The magnitude is combined with the receptor sensitivity to determine the significance of the impact using the matrix shown in Table 2.1. It is important to note however that there is limited evidence of the dose related odour impact in the community and therefore assigning significance is not as straightforward as simply following the matrix in Table 2.1. Although the matrix acts as a guide, professional judgement still needs to be used to take into account various factors such as a community’s existing tolerance of odours.

Table 2.1: Matrix for Assessing the Significance of Effects Predicted by Modelling

Odour Exposure, 98th Percenile of Hourly OU_E/m^2	Recepotor Sensitivity		
	Low	Medium	High
≥10	Moderate	Substantial	Substantial
5-<10	Slight	Moderate	Moderate
3-<5	Slight	Slight	Moderate
1.5-<3	Negligible	Slight	Slight
0.5-<1.5	Negligible	Negligible	Negligible
<0.5	Negligible	Negligible	Negligible

3 METHODOLOGY

3.1 Overall Approach

The overall approach taken for assessing the potential odour impacts of the proposed development is summarised as follows:

- review of the proposed development and its operation;
- estimation of odour emission rates;
- identification of receptors;
- detailed dispersion modelling assessment;
- recommendation of mitigation measures, where appropriate, to ensure any adverse effects are minimised; and
- identification of residual effects resulting from the proposed development.

3.2 Estimation of Odour Emission Rates

Odour emission rates from poultry houses such as those proposed at The Gaer depend on odour concentration within the houses/emitted air and the rate of extract ventilation emitted to the outside atmosphere. Internal odour concentrations depend upon many factors including the number and weight of the birds housed, building design and litter management, and the methods of provision of feed and drinking water. The minimisation of odour production is addressed by Defra in Section 4 of its Code of Good Agricultural Practice (Defra, 2009) in which paragraphs 229 and 319 to 328 are especially relevant.

3.2.1 Sources of Odour from the Proposed Poultry Unit

As with the existing houses, the proposed poultry houses at The Gaer would be ventilated via uncapped high velocity ridge mounted extraction fans, which will be the primary source of odour from these buildings. Since the outflow from the high velocity ridge fans would not be obstructed by any caps or any other obstacles, this arrangement will optimise dispersion of odours from the proposed poultry houses, especially under low wind speed conditions. However, to provide additional ventilation during hot weather, gable end wall fans would also be fitted and therefore, some lower level emissions are also expected.

Modern, well-insulated poultry houses such as those proposed will help to minimise odour production at source through good temperature control and good internal temperature distribution which facilitates good litter management and dry litter conditions. Drinking water would be supplied through low spillage nipple drinkers which have been shown to maintain low poultry litter moisture levels and, as a consequence, reduce odour emission rates.

No spent litter or manure would be stored on the site as this would be taken away off-site immediately following the poultry house clear out and stored in field stockpiles before being spread onto agricultural land as organic manure.

3.2.2 Estimation of Odour Emission Rates

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, then the odour emission rates are very low. Towards the end of each crop, odour production within the poultry housing increases more rapidly and ventilation requirements are greater, particularly in hot weather, therefore emission rates are considerably greater than at the beginning of the crop cycle.

To calculate odour emissions rate it is necessary to know the internal odour concentration and ventilation rate of the poultry houses. For the calculation of emission rates, the internal concentration is assumed to be a function of the age of the crop and the stocking density.

The internal odour concentrations used in the calculations increase progressively with increases in bird weight 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 to approximately 2,300 ou_E/m^3 at day 34 and for the rest 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 of emission rates 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 1^0C above the target temperature. A high ventilation rate (60% maximum possible ventilation rate) is reached when the temperature is 4^0C above target and if external temperature is above 33^0C the maximum ventilation rate is assumed.

At high ventilation rates, it is likely that internal odour concentrations decrease because odour is diluted by the higher air flows. Therefore, if the calculated ventilation rate exceeds that required to replace the volume of air in the house every 5 minutes, then 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 modelling period is calculated by multiplying the internal building odour concentration by the ventilation rate. In this case it is assumed for the calculations that the crop length is 37 days and that there is an empty period of 12 days after each crop. To provide more robust statistics three sets of modelling calculations were performed; the first (Scenario 1) with the first day of the meteorological record coinciding with day 1 of the crop cycle, the second scenario (Scenario 2) coinciding with the bird cycle starting on day 16 of the weather file and the third (Scenario 3) coinciding with a crop start at day 33 of the weather file. A summary of the emission rates used in this study is provided in Table 3.1.

Table 3.1: Summary of Odour Emission Rates (Average/Maximum of all 3 Cycles)

Season	Emission Rate (ou_E/s per bird as stocked during crop)			
	Average	Night-time average	Day-time average	Maximum
Winter	0.176	0.159	0.212	0.547
Spring	0.191	0.160	0.223	1.524
Summer	0.219	0.160	0.255	1.704
Autumn	0.186	0.159	0.214	1.455

3.2.3 Peak Odour Emissions

Odour emissions can increase during the period when the poultry houses are being cleared of spent floor litter, unless good management practices are deployed. Emissions rates are dependent upon management of litter throughout the bird growth cycle. Litter which has low odour potential when it is cleaned out (e.g. because of good litter management leading to dry litter which is inherently less odorous than high moisture content litter) combined with careful management of the cleaning operation result in lower emissions during cleaning out. Typical controls include restricting cleaning out to one poultry house at a time, and using only sufficient ridge fan extract ventilation on that house to draw air in through the open doorway so that fan extracted emissions are dispersed to atmosphere at high level, rather than escaping at low level through the doorway (see Appendix A for odour mitigation options).

Little factual information exists on the magnitude of odour emission rates during clearing out, and because of the short term duration of these activities it is not feasible to model them and relate the results to accepted odour impact standards. The emissions are transitory and infrequent in nature, and therefore the output of modelling could not be assessed against conventional 98th percentile impact benchmarks and guidance. For these reasons, it has been concluded that it is not feasible to model odour emissions during the cleaning out of poultry houses. This approach is supported by planning appeals, in particular the Mapleton Farm appeal (at Horsington in Lincolnshire), where the Planning Inspector considered that modelling emissions during cleaning out was not appropriate. We have seen no guidance or scientific evidence that suggests that the planning and assessment criteria have changed since this planning appeal decision.

Emissions rates are dependent upon management of litter throughout the bird growth cycle so that the litter has low odour potential when it is cleaned out, because good litter management means dry litter which is inherently less odorous than high moisture content litter, and careful management of the cleaning out operation. Typical controls include restricting cleaning out to one poultry house at a time, and using only sufficient ridge fan extract ventilation on that house to draw air inwards through the open doorway so that emissions are dispersed to atmosphere at high level, rather than escaping at low level through the doorway. Some odour emission rate measurements carried out by ADAS on a farm in Worcestershire demonstrated that if these measures are adopted, then emissions will be lower than from the unit as a whole than when it is fully stocked.

Under the proposal, the poultry houses will be cleared of manure once at the completion of each flock cycle. It is assumed that the houses will be cleared sequentially two days after depopulation and each house will take approximately three hours to clear. The odour emission rates used to represent emissions from clear out operations are based on odour measurements undertaken by ADAS as part of commercial consultancy, which suggest that with a building ventilation rate equivalent to 50% of the rated extraction capacity, internal odour concentrations during clear out are around 10,000 ou_E/m^3. Based on maintaining a building ventilation rate equivalent to 50% of the rated extraction capacity for each building at the Gaer during clear out, the gross emission rate per building is estimated to be 120,637 ou_E/s.

In addition, as a sensitivity analysis, the odour model was also run with one extra day added to the crop cycle to represent clear out rather than the above emission rate. This is based on odour emission rate measurements carried out by ADAS on the farm in Worcestershire in June 2014 which demonstrated that with controlled extraction of the building which is being cleaned out, odour emissions were comparable with those from a single fully stocked poultry building, and certainly no higher than from two fully stocked building.

3.3 Dispersion Modelling Assessment

3.3.1 Modelling Software

The choice of model used in this study is UK Atmospheric Dispersion Modelling System (ADMS) Version 5.2. ADMS is a steady-state atmospheric dispersion model that is based on modern atmospheric physics. It can include treatment of both surface and elevated sources and both simple and complex terrain. ADMS is one of the few models capable of simulating all the important atmospheric processes. The model calculates downwind pollutant concentrations in the surrounding area for each hour of the day and night over an appropriate period. Statistics on the frequency and concentration of pollutants at the receptor sites are based upon the hourly calculations. A grid referencing system within the computer model allows the location of both sources and receptors to be specified to an accuracy of within 1 m. If necessary, the model also incorporates the effects of buildings on the pollutant plume, known as building downwash.

ADMS has been chosen because it is "fitted for the purpose of the modelling procedure" as defined by the guidelines published by the Royal Meteorological Society (Britter et al, 1995 and Ireland et al, 2006). The group that leads the development of ADMS is Cambridge Environmental Research Consultants (CERC), but the UK Met Office and others have made additional contributions. The model has been extensively validated against site measurements. Details of these validation studies and the formulation of the ADMS are available on the CERC website.

Published studies have shown that atmospheric dispersion models are reliable at predicting the pattern of downwind pollutant concentrations and deposition rates (as statistical distributions) over a period of time (H.R. Olesen, 1997). The modelling study reported here is based on calculations made over a period of 43,800 hours (5 years) and represents a suitably long period for such a statistical study

3.3.2 Modelling Period

The EA, in the H4 guidance, recommends that a minimum of three years, and preferably five years, should be used to calculate the 98th percentile of the hourly mean odour concentrations, in order to represent conditions for an "average year". The IAQM guidance also recommends that five years of data should be used and that individual years should be modelled. Comparisons of single yearly statistics will show the range, or sensitivity, of the modelled 98th percentile odour concentrations to meteorological data. For example, a particular year may have a number of periods where dispersion conditions are very poor, leading to higher annual 98th percentile values. The mean 98th percentile of the hourly mean odour concentrations over a five year period is used to provide statistically robust results, smoothing out inter-annual variations, as set out in the H4 guidance.

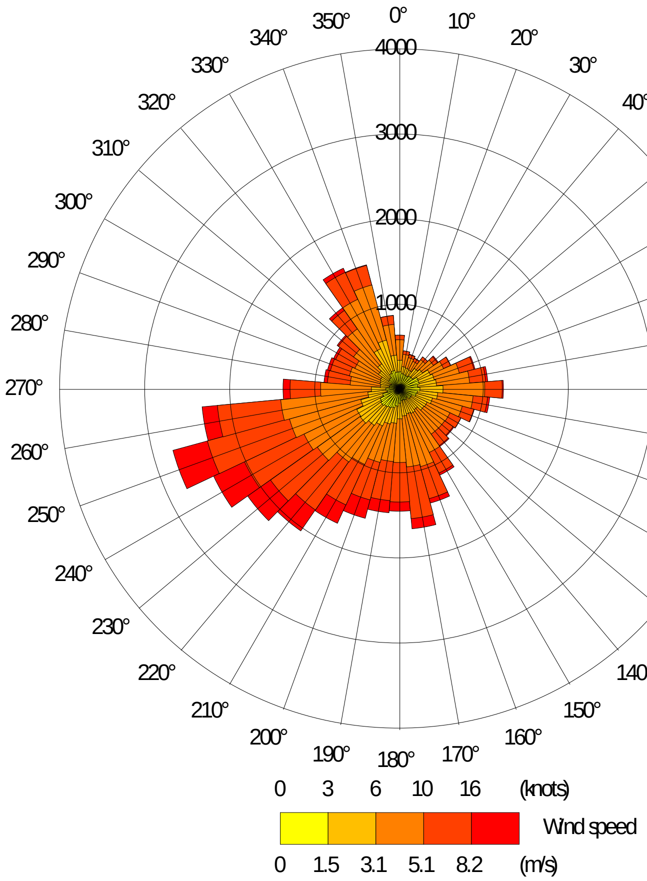
3.3.3 Meteorology

The closest meteorological station to the proposed development that regularly records all the elements required for dispersion modelling to a suitable standard is at Lake Vrynwy, approximately 20 km to the north west of the application site. However, this station is at an elevation of 360 m, which is significantly higher than the proposed site and therefore is not considered to be wholly representative of meteorological conditions in the area around the application site.

The next closest meteorological station that regularly records all the elements required for dispersion modelling and with similar exposure to the poultry unit is at Shawbury, approximately 34 km to the north east of the application site at an elevation of 72 m.

The wind rose for the weather file, derived from data from Shawbury (2011 - 2015), is shown in Figure 2. This shows the direction FROM which winds blows and illustrates the relative frequency of wind directions and wind speeds used in the modelling study.

Figure 3.1: Wind Rose, derived from Data from Shawbury (2011 - 2015)



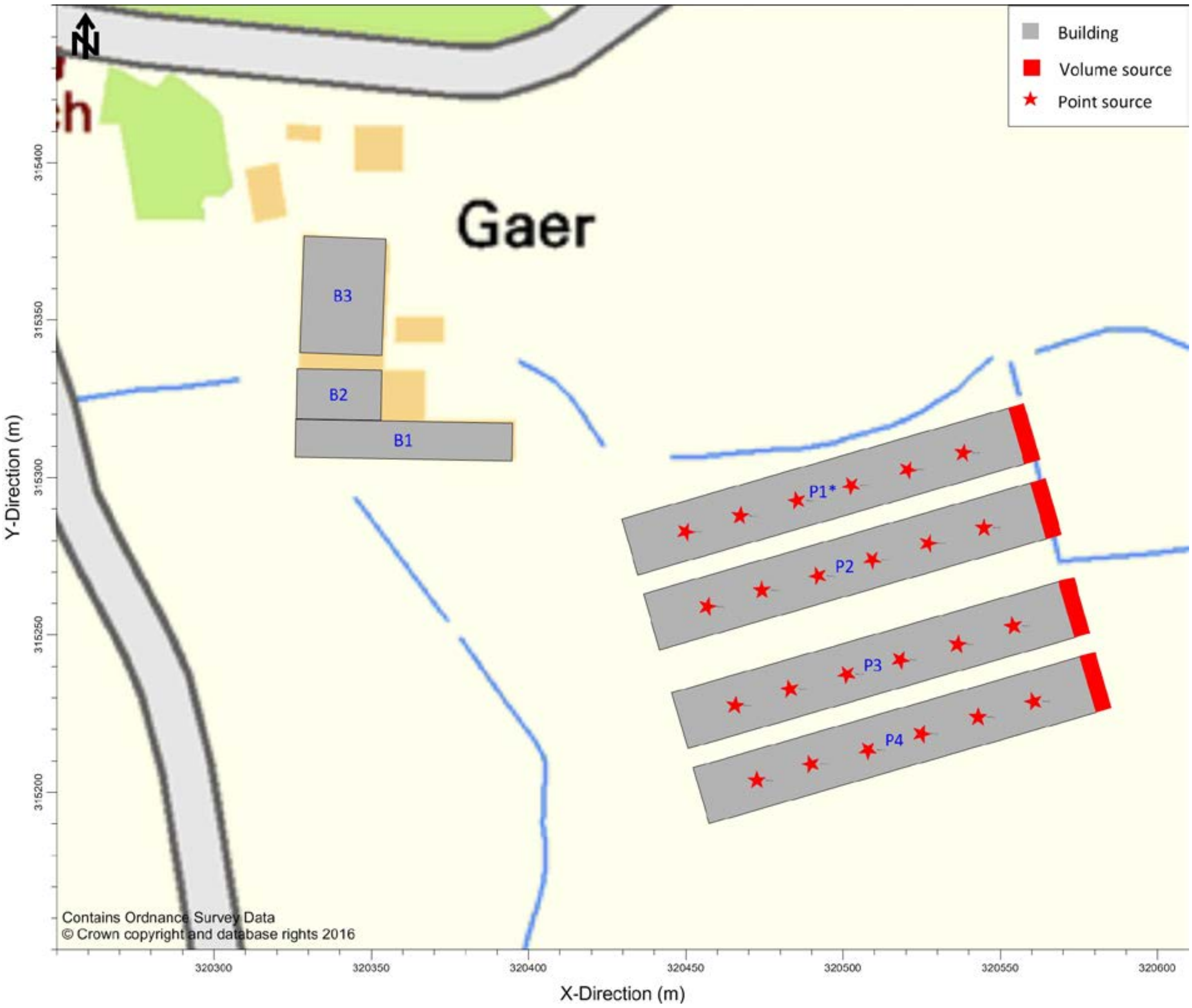
3.3.4 Emission Sources

Emissions from the high velocity ridge mounted fans on all four houses are represented by six point sources per house within ADMS. Emissions from the gable end fans, used to augment the high velocity ridge fans during periods of hot weather are represented by one volume source per house, at the eastern end of the proposed poultry houses.

Emissions from the volume sources representing the gable end fans are assumed to occur when the ambient temperature equals or exceeds 22°C. When these conditions do occur, the gable end fans are assumed to account for 50% of the total emission and whilst they are emitting, emissions from the point sources, representing the high velocity roof fans, are reduced by 50%.

Further details of the point source and volume source parameters are provided in Appendix B. The positions of the modelled sources are shown in Figure 3.2.

Figure 3.2: Modelled Sources and Buildings



3.3.5 Buildings

The structure of the poultry houses and other farm buildings nearby will have some effect on the behaviour of the odour plumes from the point sources representing the high velocity roof extraction fans on the proposed poultry houses. Therefore, the poultry houses and other nearby buildings are modelled as rectangular blocks within ADMS. The locations and heights of these buildings/structures are listed in Table 5.2. The position of the modelled buildings are shown in Figure 3.2, where they are marked by grey rectangles.

Table 3.2: Buildings Details included in the Model

ID	Building	Grid Ref, X	Grid Ref, Y	Height, m
P1	Poultry house 1 (existing)	320493.7	315295.6	5
P2	Poultry house 2 (existing)	320500.6	315271.8	5
P3	Poultry house 3 (proposed)	320509.6	315240.4	5
P4	Poultry house 4 (proposed)	320516.4	315216.6	5
B1	Farm building	320360.3	315311.9	6
B2	Farm building	320339.7	315326.4	9
B3	Farm building	320341.0	315357.8	7

3.3.6 Terrain and Roughness Length

The land in the vicinity of the proposed expanded poultry unit contains some slopes and topographical features that may affect wind flow and the dispersion of odours. Therefore, terrain data have been used within ADMS. This data is based on Ordnance Survey Land-Form PANORAMA. A fixed roughness length of 0.25 m is used over the entire modelling domain.

3.3.7 Monin-Obukhov Length

The Monin-Obukhov length provides a measure of the stability of the atmosphere. The CERC guidance advises that in "*in very stable conditions in a rural areas its value would typically be 2 to 20 m*". A minimum Monin-Obukhov length of 10 m was used in the dispersion modelling study.

3.3.8 Receptor Locations and Model Domain

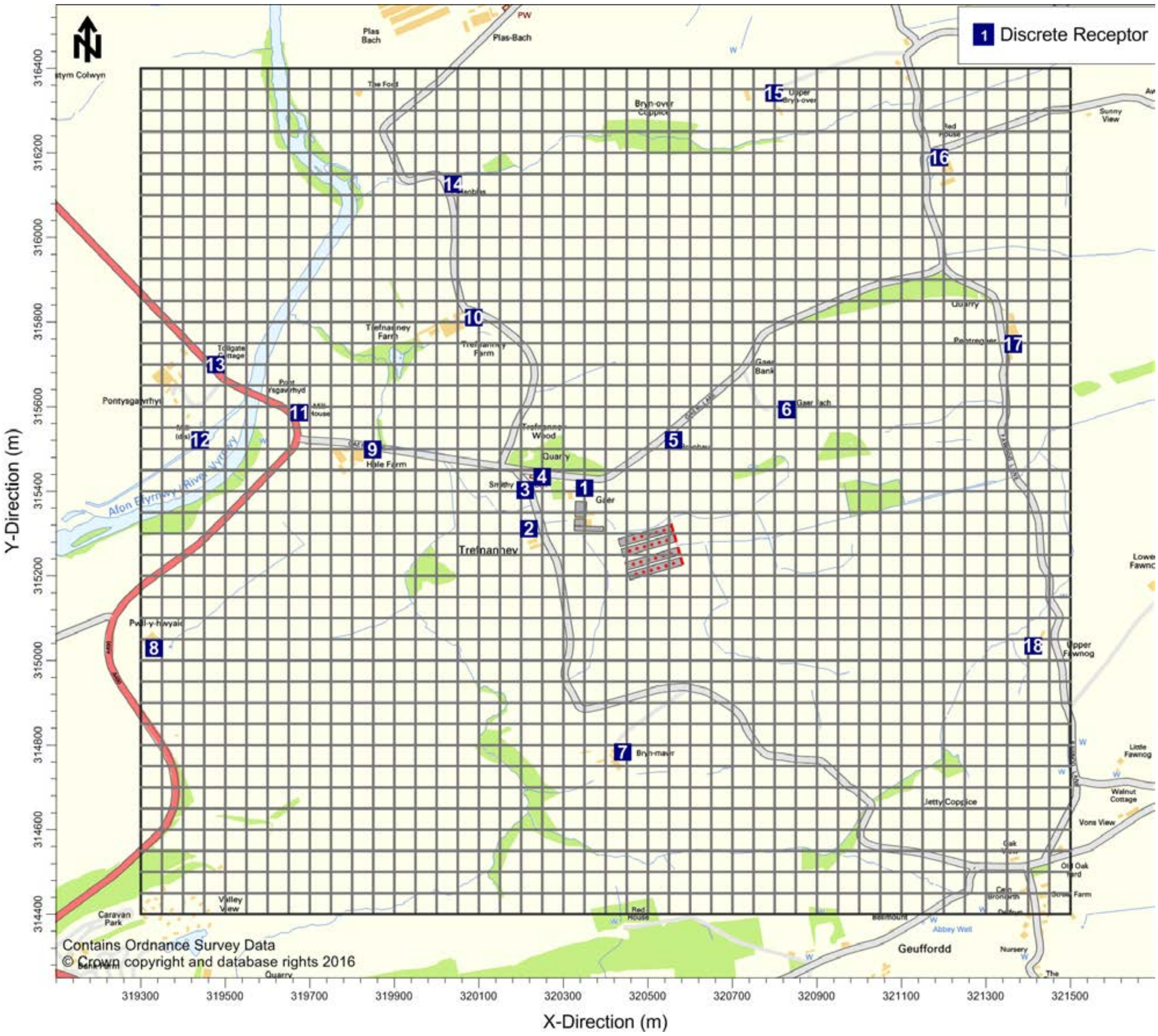
Eighteen discrete receptor points have been defined within the model to represent a selection of nearby residential and commercial properties. These discrete receptors are defined at 1.5 m above ground level. The discrete receptors are listed in Table 3.3 below, and shown in Figure 3.3.

A 2.2 km by 2 km regular Cartesian grid at 50 m resolution has been used to produce the contour map presented in the results of this study. The grid points are defined at a height of 1.5 m above ground level within ADMS.

Table 3.3: Discrete Receptors in the Dispersion Modelling

Receptor ID	Receptor Location	Grid reference	
		X	Y
1	Gaer	320350	315407
2	Trefnanney	320219	315311
3	Smithy	320210	315403
4	School	320250	315434
5	Bronhaul	320561	315521
6	Gaer Fach	320829	315593
7	Bryn-mawr	320441	314783
8	Pwll-y-hwyaid	319332	315029
9	Hale Farm	319849	315498
10	Trefnanney Farm	320088	315811
11	Mill House	319676	315586
12	Pontysgawrhyd	319441	315521
13	Tollgate Cottage	319477	315699
14	Henblas	320040	316126
15	Upper Bryn-over	320799	316341
16	Red House	321190	316189
17	Pentregaer	321365	315748
18	Upper Fawnog	321412	315035

Figure 3.3: The Discrete Receptors and the Regular Cartesian Grid used in ADMS



3.4 Uncertainties and Assumptions

The following uncertainties and assumptions have been made in the odour assessment:

- There will be uncertainties introduced because the modelling has simplified real-world processes into a series of algorithms. For example, it has been assumed that wind conditions measured at Shawbury weather station in 2011 - 2015 were representative of wind conditions at the site. Furthermore, it has been assumed that the subsequent dispersion of odour will conform to a Gaussian distribution in order to simplify the real-world dilution and dispersion conditions; and,
- There is an element of uncertainty in all measured and modelled data. All values presented in this report are best possible estimates.

4 DISPERSION MODELLING RESULTS

4.1 Modelling Results

ADMS calculates hourly mean odour concentrations at the regular Cartesian grid points and the discrete receptor points for each hour over a five-year period. From these calculations, statistics have been produced of the predicted 98th percentile hourly mean odour concentrations. That is, the odour hourly mean concentration which is exceeded for only 2% of all hours (around 14 hours per month on average).

For each of the three scenarios modelled, five runs, one for each year in the meteorological record (2011 – 2015) were performed. For each scenario the annual mean predicted 98th percentile hourly mean odour concentrations at identified discrete receptors for each year in the meteorological file are shown in Table 4.1, Table 4.2 and Table 4.3. A contour plot of the predicted five year mean 98th percentile concentrations for Scenario 3, the scenario with generally the highest mean concentrations, in the area surrounding the farm is shown in Figure 4.1.

4.1.1 Scenario 1 (Day 1 of crop cycle on day 1 of meteorological file)

The modelling predicts that the five year mean annual 98th percentile hourly mean odour concentrations are below the EA's H4 benchmark of 3.0 ou_E/m^3 and considerably lower than the higher benchmark of 5.0 ou_E/m^3 at all modelled receptors. At receptor 1, which is connected to the Gaer Farm, the predicted annual 98th percentile hourly mean odour concentration is slightly above the 3.0 ou_E/m^3 EA H4 benchmark for the 2014 meteorological file run, however impacts at this receptor are below the 3.0 ou_E/m^3 benchmark for all other years modelled.

4.1.2 Scenario 2 (Day 16 of crop cycle on day 1 of meteorological file)

The modelling predicts that the five year mean annual 98th percentile hourly mean odour concentrations are below the EA's H4 benchmark of 3.0 ou_E/m^3 and considerably lower than the higher benchmark of 5.0 ou_E/m^3 at all modelled receptors. The modelling predicts that odour exposure levels at all identified discrete receptor points are below the EA's benchmark of 3.0 ou_E/m^3 for all years modelled.

4.1.3 Scenario 3 (Day 33 of crop cycle on day 1 of meteorological file)

The modelling predicts that the five year mean annual 98th percentile hourly mean odour concentrations are below the EA's H4 benchmark of 3.0 ou_E/m^3 and considerably lower than the higher benchmark of 5.0 ou_E/m^3 at all modelled receptors. At receptor 1, which is connected to the Gaer Farm, the predicted annual 98th percentile hourly mean odour concentration is slightly above the 3.0 ou_E/m^3 EA H4 benchmark for the 2015 meteorological file run, however impacts at this receptor are below the 3.0 ou_E/m^3 H4 benchmark for all other years modelled.

Table 4.1: Scenario 1 (Start Day 1) 98th Percentile Hourly Mean Odour Concentration at the Discrete Receptors

Receptor ID	X (m)	y (m)	98th Percentile Hourly Mean Odour Concentration (ou_E/m^3)					
			2011	2012	2013	2014	2015	Mean
1	320350	315407	2.78	1.91	1.24	3.29	2.11	2.26
2	320219	315311	1.88	1.81	2.02	2.62	1.32	1.93
3	320210	315403	1.73	1.57	1.24	1.71	0.81	1.41
4	320250	315434	1.72	1.43	0.91	1.82	0.86	1.35
5	320561	315521	2.02	1.99	1.47	1.88	1.80	1.83
6	320829	315593	0.91	1.26	0.69	0.94	0.90	0.94
7	320441	314783	0.24	0.29	0.27	0.47	0.55	0.36
8	319332	315029	0.15	0.15	0.19	0.33	0.12	0.19
9	319849	315498	0.48	0.52	0.42	0.51	0.22	0.43
10	320088	315811	0.53	0.27	0.19	0.60	0.38	0.39
11	319676	315586	0.30	0.35	0.27	0.31	0.14	0.27
12	319441	315521	0.23	0.26	0.23	0.29	0.11	0.22
13	319477	315699	0.20	0.22	0.16	0.19	0.08	0.17
14	320040	316126	0.39	0.22	0.14	0.41	0.27	0.29
15	320799	316341	0.18	0.26	0.15	0.22	0.17	0.19
16	321190	316189	0.19	0.28	0.14	0.19	0.19	0.20
17	321365	315748	0.48	0.60	0.49	0.51	0.45	0.51
18	321412	315035	0.20	0.28	0.29	0.16	0.22	0.23

Table 4.2: Scenario 2 (Start Day 16) 98th Percentile Hourly Mean Odour Concentration at the Discrete Receptors

Receptor ID	X (m)	y (m)	98th Percentile Hourly Mean Odour Concentration (ou_E/m^3)					
			2011	2012	2013	2014	2015	Mean
1	320350	315407	2.69	2.24	2.69	2.31	2.23	2.43
2	320219	315311	2.14	2.09	2.66	2.43	1.44	2.15
3	320210	315403	1.48	1.37	1.66	1.48	1.10	1.42
4	320250	315434	1.48	1.33	1.45	1.28	1.18	1.34
5	320561	315521	1.76	1.02	2.12	1.78	1.85	1.70
6	320829	315593	0.94	0.77	1.04	1.00	0.89	0.93
7	320441	314783	0.43	0.31	0.24	0.31	0.25	0.31
8	319332	315029	0.20	0.25	0.22	0.20	0.19	0.21
9	319849	315498	0.45	0.53	0.62	0.50	0.33	0.48
10	320088	315811	0.49	0.42	0.46	0.36	0.43	0.43
11	319676	315586	0.27	0.34	0.41	0.29	0.20	0.30
12	319441	315521	0.23	0.28	0.32	0.27	0.19	0.26
13	319477	315699	0.17	0.21	0.24	0.17	0.13	0.19
14	320040	316126	0.38	0.34	0.39	0.27	0.30	0.34
15	320799	316341	0.20	0.11	0.24	0.19	0.21	0.19
16	321190	316189	0.20	0.14	0.25	0.20	0.19	0.20

Receptor ID	X (m)	y (m)	98th Percentile Hourly Mean Odour Concentration (ou_E/m^3)					
			2011	2012	2013	2014	2015	Mean
17	321365	315748	0.48	0.56	0.53	0.47	0.50	0.51
18	321412	315035	0.22	0.25	0.25	0.17	0.14	0.21

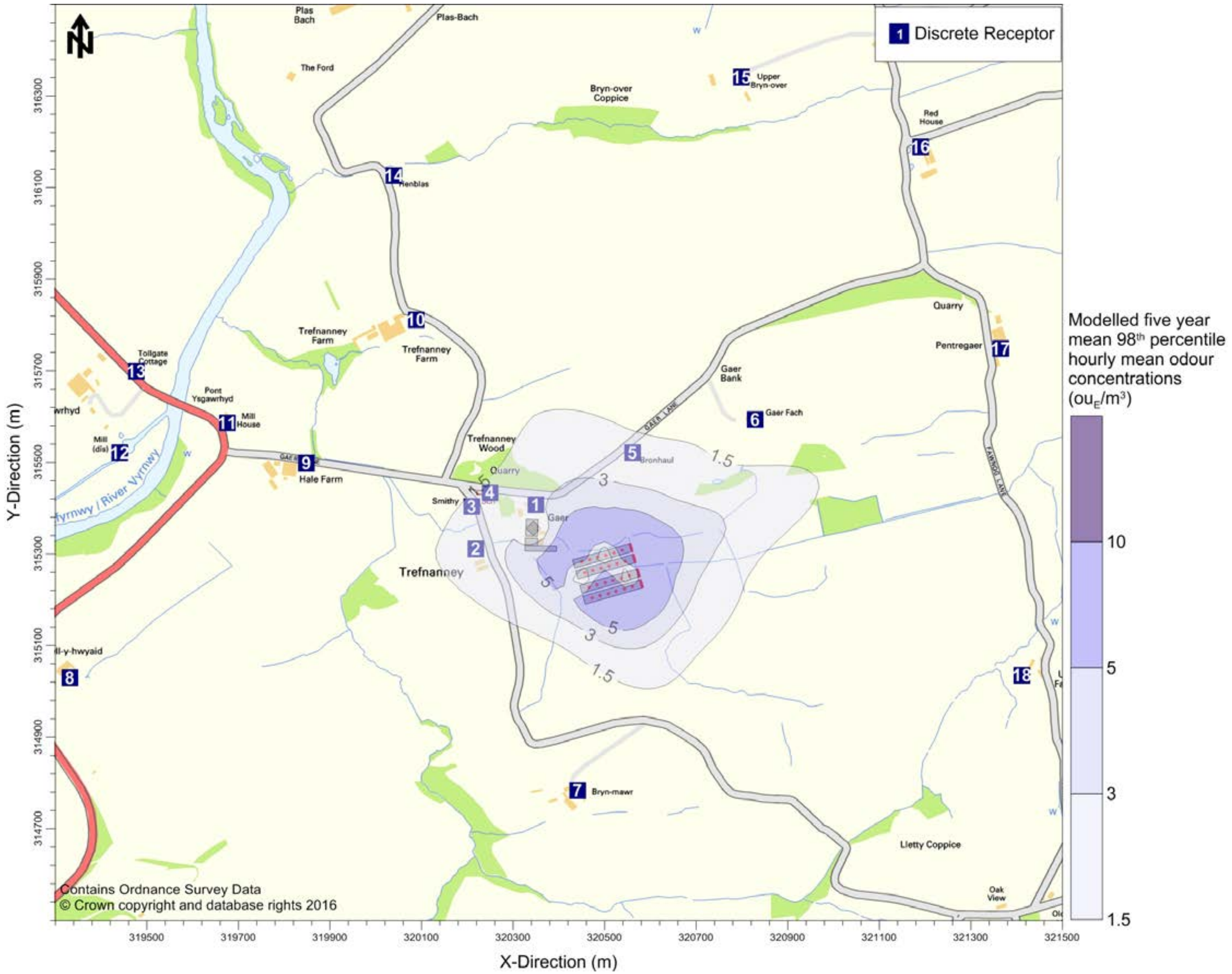
Table 4.3: Scenario 3 (Start Day 33) 98th Percentile Hourly Mean Odour Concentration at the Discrete Receptors

Receptor ID	X (m)	y (m)	98th Percentile Hourly Mean Odour Concentration (ou_E/m^3)					
			2011	2012	2013	2014	2015	Mean
1	320350	315407	2.85	2.52	2.50	2.77	3.07	2.74
2	320219	315311	1.55	2.13	2.30	2.31	2.28	2.11
3	320210	315403	1.61	1.50	1.52	1.54	2.10	1.65
4	320250	315434	1.72	1.51	1.47	1.54	2.15	1.68
5	320561	315521	1.98	2.07	2.08	1.54	1.75	1.88
6	320829	315593	0.93	1.03	0.95	0.90	0.94	0.95
7	320441	314783	0.17	0.24	0.43	0.42	0.29	0.31
8	319332	315029	0.07	0.22	0.23	0.21	0.16	0.18
9	319849	315498	0.43	0.48	0.51	0.52	0.62	0.51
10	320088	315811	0.47	0.55	0.46	0.49	0.51	0.49
11	319676	315586	0.28	0.32	0.32	0.33	0.40	0.33
12	319441	315521	0.21	0.28	0.27	0.29	0.28	0.27
13	319477	315699	0.19	0.21	0.21	0.20	0.26	0.21
14	320040	316126	0.33	0.38	0.35	0.33	0.35	0.35
15	320799	316341	0.21	0.24	0.20	0.15	0.18	0.20
16	321190	316189	0.20	0.24	0.21	0.21	0.19	0.21
17	321365	315748	0.53	0.54	0.48	0.47	0.50	0.50
18	321412	315035	0.18	0.17	0.23	0.18	0.19	0.19

4.1.4 Sensitivity Analysis

The results of the sensitivity analysis, based on running the odour model with one extra day added to the crop cycle to represent emissions during cleaning out are provided in Appendix C. Similar to the results above, the modelling predicts that the five year mean annual 98th percentile hourly mean odour concentrations are below the EA's H4 benchmark of 3.0 ou_E/m^3 and considerably lower than the higher benchmark of 5.0 ou_E/m^3 at all modelled receptors. Slight exceedance of the 3.0 ou_E/m^3 benchmark are predicted for the 2014 and 2015 meteorological file runs for scenario 1 and 3 at receptor 1, which is connected to the Gaer Farm.

Figure 4.1: Scenario 3 - The Modelled Five Year mean Annual 98th Percentile Hourly Mean Odour Concentration (2011-2015)



4.2 IAQM Assessment of Significance

The assessment of the significance of effects at each receptor using the IAQM adapted criterion is assessed below in Table 7. All potential residential receptors have been classed as high sensitivity, apart from receptor 1, the farmhouse at the Gaer as it is within the applicant's ownership.

A slight adverse or negligible to slight adverse significance of effect is predicted at the five closest receptors. At all other receptors, the significance of the effects is assessed as negligible.

Table 4.4: Significance of Predicted Odour Impacts at Surrounding Receptors

Receptor ID	Sensitivity	Mean Annual 98th Percentile Hourly Mean Odour Concentration (ou_E/m^3)						Significance
		Scenario 1		Scenario 2		Scenario 3		
		Mean	Max	Mean	Max	Mean	Max	
1	Medium	2.26	3.29	2.43	2.69	2.74	3.07	Slight
2	High	1.93	2.62	2.15	2.66	2.11	2.31	Slight
3	High	1.41	1.73	1.42	1.66	1.65	2.10	Slight
4	High	1.35	1.82	1.34	1.48	1.68	2.15	Negligible to slight
5	High	1.83	2.02	1.70	2.12	1.88	2.08	Slight
6	High	0.94	1.26	0.93	1.04	0.95	1.03	Negligible
7	High	0.36	0.55	0.31	0.43	0.31	0.43	Negligible
8	High	0.19	0.33	0.21	0.25	0.18	0.23	Negligible
9	High	0.43	0.52	0.48	0.62	0.51	0.62	Negligible
10	High	0.39	0.60	0.43	0.49	0.49	0.55	Negligible
11	High	0.27	0.35	0.30	0.41	0.33	0.40	Negligible
12	High	0.22	0.29	0.26	0.32	0.27	0.29	Negligible
13	High	0.17	0.22	0.19	0.24	0.21	0.26	Negligible
14	High	0.29	0.41	0.34	0.39	0.35	0.38	Negligible
15	High	0.19	0.26	0.19	0.24	0.20	0.24	Negligible
16	High	0.20	0.28	0.20	0.25	0.21	0.24	Negligible
17	High	0.51	0.60	0.51	0.56	0.50	0.54	Negligible
18	High	0.23	0.29	0.21	0.25	0.19	0.23	Negligible

5 CONCLUSIONS

An odour impact assessment has been carried out of odour emissions from a proposed expansion of the poultry unit at The Gaer, Meifod, Powys. The aim was to focus on how odour emissions from the proposed expansion may affect the surrounding area.

Odour emissions from the existing and proposed poultry houses have been assessed and quantified based on a review of available literature including research work by Hayes et al (2006) and Robertson et al. (2002) and odour measurement work undertaken by ADAS at other poultry units as part of commercial consultancy. The emission figures obtained were then used in atmospheric dispersion modelling to assess the likely impact of odour in the area around the site of the poultry unit.

The modelling predicts that for all scenarios modelled, the predicted five year mean annual 98th percentile hourly mean odour concentrations are below the benchmark range of 3.0 to 5.0 ou_E/m^3 at all identified discrete receptor points, representing nearby properties.

At receptor 1, which is connected to the Gaer Farm, the predicted annual 98th percentile hourly mean odour concentration is slightly above the 3.0 ou_E/m^3 EA benchmark for the 2014 meteorological file run for scenario 1 (the bird production cycle starting on day 1 of the weather file) and the 2015 meteorological file run for scenario 3 (the bird production cycle starting on day 33 of the weather file). For all other years modelled the annual 98th percentile hourly mean odour concentrations at this receptor are below the 3.0 ou_E/m^3 EA benchmark. At all receptors not connected with the poultry farm, the predicted annual 98th percentile hourly mean odour concentrations are below the 3.0 ou_E/m^3 EA benchmark for all years modelled.

It is therefore concluded that the proposed expansion at the poultry unit would not result in any significant loss of local residential amenity.

6 REFERENCES

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APPENDIX A
CLEARING SPENT FLOOR LITTER – ODOUR MITIGATION OPTIONS

- Avoid clearing spent litter during weekends, public holidays or in the evening unless it is absolutely necessary.
- Avoid clearing if the wind direction is blowing in the direction of near neighbours if at all possible.
- Once started, the clearing process should be completed in as little time as possible while taking account of the above recommended restrictions.
- Only clean out one house at a times and use absolutely minimum ventilation rates in other houses.
- Maintain minimal fan ventilation during cleaning, while remaining consistent with health and safety requirements of the cleaning personnel.
- If an elevator is used for loading spent litter into lorries, the drop height should be minimised and the elevator covered, thus removing the risk of dust blowing on windy days.
- If a loader vehicle is used, spent litter should be carefully tipped into lorry trailers positioned at the entrance to each house or, if possible, inside the building.
- The spent litter should be tipped into the trailer from minimal height and, when full, the trailer should be covered and sealed immediately.
- Surrounding concrete aprons and surfaces should be cleaned immediately after clearing.
- Only Defra approved, non-tainting disinfectants should be used during the clean-out of the houses.
- Dirty water should be transported off-site and ultimately be disposed of, or field spread, in accordance with the guidelines in the Code of Practice (Defra, 2009).

APPENDIX B
SOURCE PARAMETERS

Table B.1: Point Source Parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Temperature (°C)
Scenario 1				
PR1_C1_1	5.5	0.8	8.0	22
PR1_C1_2	5.5	0.8	8.0	22
PR1_C1_3	5.5	0.8	8.0	22
PR1_C1_4	5.5	0.8	8.0	22
PR1_C1_5	5.5	0.8	8.0	22
PR1_C1_6	5.5	0.8	8.0	22
PR2_C1_1	5.5	0.8	8.0	22
PR2_C1_2	5.5	0.8	8.0	22
PR2_C1_3	5.5	0.8	8.0	22
PR2_C1_4	5.5	0.8	8.0	22
PR2_C1_5	5.5	0.8	8.0	22
PR2_C1_6	5.5	0.8	8.0	22
PR3_C1_1	5.5	0.8	8.0	22
PR3_C1_2	5.5	0.8	8.0	22
PR3_C1_3	5.5	0.8	8.0	22
PR3_C1_4	5.5	0.8	8.0	22
PR3_C1_5	5.5	0.8	8.0	22
PR3_C1_6	5.5	0.8	8.0	22
PR4_C1_1	5.5	0.8	8.0	22
PR4_C1_2	5.5	0.8	8.0	22
PR4_C1_3	5.5	0.8	8.0	22
PR4_C1_4	5.5	0.8	8.0	22
PR4_C1_5	5.5	0.8	8.0	22
PR4_C1_6	5.5	0.8	8.0	22
Scenario 2				
PR1_C2_1	5.5	0.8	8.0	22
PR1_C2_2	5.5	0.8	8.0	22
PR1_C2_3	5.5	0.8	8.0	22
PR1_C2_4	5.5	0.8	8.0	22
PR1_C2_5	5.5	0.8	8.0	22
PR1_C2_6	5.5	0.8	8.0	22
PR2_C2_1	5.5	0.8	8.0	22
PR2_C2_2	5.5	0.8	8.0	22
PR2_C2_3	5.5	0.8	8.0	22
PR2_C2_4	5.5	0.8	8.0	22

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Temperature (°C)
PR2_C2_5	5.5	0.8	8.0	22
PR2_C2_6	5.5	0.8	8.0	22
PR3_C2_1	5.5	0.8	8.0	22
PR3_C2_2	5.5	0.8	8.0	22
PR3_C2_3	5.5	0.8	8.0	22
PR3_C2_4	5.5	0.8	8.0	22
PR3_C2_5	5.5	0.8	8.0	22
PR3_C2_6	5.5	0.8	8.0	22
PR4_C2_1	5.5	0.8	8.0	22
PR4_C2_2	5.5	0.8	8.0	22
PR4_C2_3	5.5	0.8	8.0	22
PR4_C2_4	5.5	0.8	8.0	22
PR4_C2_5	5.5	0.8	8.0	22
PR4_C2_6	5.5	0.8	8.0	22
Scenario 3				
PR1_C3_1	5.5	0.8	8.0	22
PR1_C3_2	5.5	0.8	8.0	22
PR1_C3_3	5.5	0.8	8.0	22
PR1_C3_4	5.5	0.8	8.0	22
PR1_C3_5	5.5	0.8	8.0	22
PR1_C3_6	5.5	0.8	8.0	22
PR2_C3_1	5.5	0.8	8.0	22
PR2_C3_2	5.5	0.8	8.0	22
PR2_C3_3	5.5	0.8	8.0	22
PR2_C3_4	5.5	0.8	8.0	22
PR2_C3_5	5.5	0.8	8.0	22
PR2_C3_6	5.5	0.8	8.0	22
PR3_C3_1	5.5	0.8	8.0	22
PR3_C3_2	5.5	0.8	8.0	22
PR3_C3_3	5.5	0.8	8.0	22
PR3_C3_4	5.5	0.8	8.0	22
PR3_C3_5	5.5	0.8	8.0	22
PR3_C3_6	5.5	0.8	8.0	22
PR4_C3_1	5.5	0.8	8.0	22
PR4_C3_2	5.5	0.8	8.0	22
PR4_C3_3	5.5	0.8	8.0	22
PR4_C3_4	5.5	0.8	8.0	22
PR4_C3_5	5.5	0.8	8.0	22
PR4_C3_6	5.5	0.8	8.0	22

Table B.2: Volume Source Parameters

Source ID	Base height (m)	Depth (m)	Volume (m^3)
Scenario 1			
PRv_C1_1	0	4	370
PRv_C1_2	0	4	370
PRv_C1_3	0	4	370
PRv_C1_4	0	4	370
Scenario 2			
PRv_C2_1	0	4	370
PRv_C2_2	0	4	370
PRv_C2_3	0	4	370
PRv_C2_4	0	4	370
Scenario 3			
PRv_C3_1	0	4	370
PRv_C3_2	0	4	370
PRv_C3_3	0	4	370
PRv_C3_4	0	4	370

APPENDIX C
SENSITIVITY ANALYSIS

Table C.1: Scenario 1 (start day 1 of weather file) 98th Percentile Hourly Mean Odour Concentration at the Discrete Receptors

Receptor ID	X (m)	y (m)	98th Percentile Hourly Mean Odour Concentration (ou_E/m^3)					
			2011	2012	2013	2014	2015	Mean
1	320350	315407	2.75	2.12	1.32	3.07	2.19	2.29
2	320219	315311	1.88	1.83	2.17	2.65	1.31	1.97
3	320210	315403	1.65	1.64	1.30	1.68	0.81	1.42
4	320250	315434	1.65	1.52	0.97	1.69	0.92	1.35
5	320561	315521	2.12	1.94	1.48	1.90	1.78	1.85
6	320829	315593	0.91	1.24	0.72	0.97	0.90	0.95
7	320441	314783	0.24	0.29	0.30	0.54	0.54	0.38
8	319332	315029	0.15	0.17	0.23	0.34	0.12	0.20
9	319849	315498	0.48	0.54	0.46	0.50	0.22	0.44
10	320088	315811	0.53	0.31	0.20	0.54	0.39	0.39
11	319676	315586	0.30	0.38	0.29	0.31	0.14	0.28
12	319441	315521	0.23	0.27	0.26	0.31	0.12	0.24
13	319477	315699	0.20	0.24	0.16	0.19	0.08	0.17
14	320040	316126	0.40	0.23	0.15	0.41	0.29	0.29
15	320799	316341	0.20	0.26	0.15	0.22	0.17	0.20
16	321190	316189	0.20	0.28	0.14	0.20	0.18	0.20
17	321365	315748	0.50	0.60	0.48	0.55	0.47	0.52
18	321412	315035	0.20	0.28	0.29	0.18	0.24	0.24

Table C.2: Scenario 2 (start day 16 of weather file) 98th Percentile Hourly Mean Odour Concentration at the Discrete Receptors

Receptor ID	X (m)	y (m)	98th Percentile Hourly Mean Odour Concentration (ou_E/m^3)					
			2011	2012	2013	2014	2015	Mean
1	320350	315407	2.77	2.24	2.68	2.30	2.11	2.42
2	320219	315311	2.13	2.25	2.79	2.45	1.46	2.22
3	320210	315403	1.48	1.39	1.68	1.51	1.10	1.43
4	320250	315434	1.53	1.34	1.49	1.29	1.17	1.36
5	320561	315521	1.85	1.03	2.19	1.75	1.73	1.71
6	320829	315593	1.02	0.82	1.06	1.03	0.93	0.97
7	320441	314783	0.45	0.36	0.24	0.32	0.27	0.33
8	319332	315029	0.20	0.29	0.22	0.21	0.19	0.22
9	319849	315498	0.45	0.53	0.63	0.51	0.34	0.49
10	320088	315811	0.56	0.43	0.47	0.36	0.42	0.45
11	319676	315586	0.28	0.34	0.42	0.29	0.21	0.31

Receptor ID	X (m)	y (m)	98th Percentile Hourly Mean Odour Concentration (ou_E/m^3)					
			2011	2012	2013	2014	2015	Mean
12	319441	315521	0.23	0.29	0.32	0.28	0.19	0.26
13	319477	315699	0.17	0.21	0.26	0.18	0.13	0.19
14	320040	316126	0.44	0.34	0.40	0.27	0.30	0.35
15	320799	316341	0.20	0.12	0.25	0.19	0.21	0.20
16	321190	316189	0.21	0.16	0.26	0.21	0.19	0.21
17	321365	315748	0.52	0.58	0.58	0.53	0.54	0.55
18	321412	315035	0.22	0.26	0.25	0.17	0.17	0.21

Table C.3: Scenario 3 (start day 33 of weather file) 98th Percentile Hourly Mean Odour Concentration at the Discrete Receptors

Receptor ID	X (m)	y (m)	98th Percentile Hourly Mean Odour Concentration (ou_E/m^3)					
			2011	2012	2013	2014	2015	Mean
1	320350	315407	2.89	2.68	2.59	2.84	3.04	2.81
2	320219	315311	1.63	2.13	2.37	2.29	2.33	2.15
3	320210	315403	1.60	1.54	1.58	1.57	2.10	1.68
4	320250	315434	1.72	1.51	1.51	1.61	2.16	1.70
5	320561	315521	2.23	2.04	2.18	1.54	1.76	1.95
6	320829	315593	0.98	1.06	0.96	0.88	0.93	0.96
7	320441	314783	0.19	0.24	0.44	0.43	0.31	0.32
8	319332	315029	0.07	0.23	0.24	0.21	0.17	0.18
9	319849	315498	0.44	0.49	0.53	0.53	0.62	0.52
10	320088	315811	0.49	0.57	0.46	0.50	0.51	0.51
11	319676	315586	0.28	0.33	0.33	0.33	0.40	0.34
12	319441	315521	0.22	0.28	0.27	0.30	0.29	0.27
13	319477	315699	0.19	0.22	0.22	0.20	0.27	0.22
14	320040	316126	0.37	0.42	0.37	0.34	0.35	0.37
15	320799	316341	0.23	0.24	0.21	0.16	0.19	0.21
16	321190	316189	0.21	0.26	0.22	0.21	0.19	0.22
17	321365	315748	0.53	0.57	0.49	0.49	0.50	0.52
18	321412	315035	0.19	0.17	0.24	0.19	0.20	0.20