An Ammonia Concentration Study for the Proposed Redevelopment of the Broiler Rearing Unit at Sutton Veny Farm, Warminster in Wiltshire.

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1. Introduction

ADAS has been commissioned by Mr James Whilding of ACORUS Rural Property Services Ltd. to conduct a dispersion modelling study to assess the impact of ammonia emissions from the proposed redevelopment of the broiler chicken rearing unit at Sutton Veny Farm, Warminster, in Wiltshire.

Ammonia emissions from the poultry houses at the unit have been assessed and quantified using figures obtained from the Environment Agency (Environment Agency, 2011). These emission figures have been used in atmospheric dispersion modelling. The modelling was conducted by the Met Office Rural Environment Team at ADAS.

This report presents modelled ammonia concentration levels for the area surrounding the poultry unit. Particular attention has been given to nearby Local Wildlife Sites (LWSs), Ancient Woodlands (AWs), a Site of Special Scientific Interest (SSSI) and a Special Area of Conservation (SAC).

2. Background

2.1 The poultry unit

There are four existing poultry houses at Sutton Veny Farm. These are several years old, nearing the end of their life span and are currently disused. Under the proposal, they would be demolished and replaced with five new “state of the art” poultry houses. These new poultry houses would be ventilated primarily by high speed ridge mounted fans, augmented by gable end fans during hot weather.

2.2 Geography

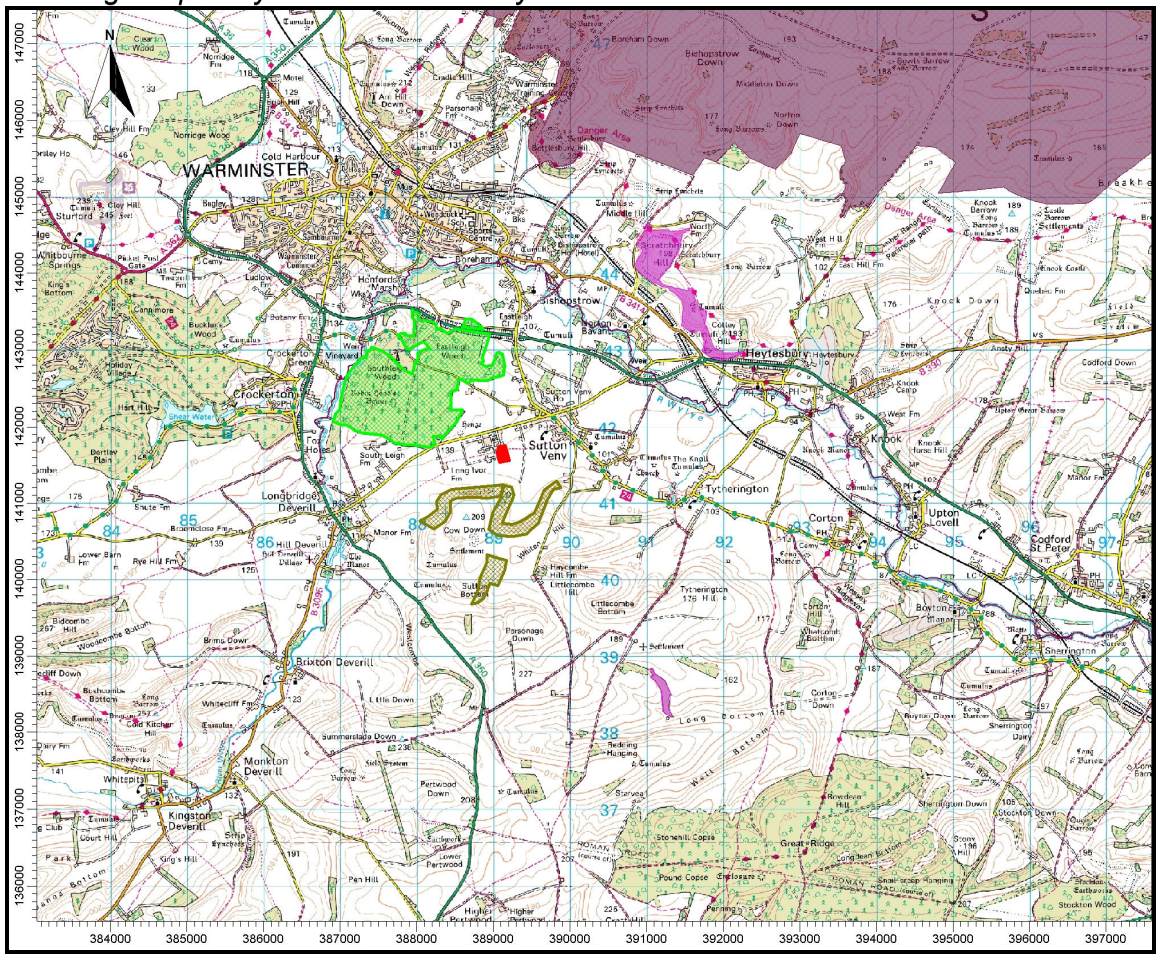
Sutton Veny Farm is in a rural area, approximately 3 km to the south of the town of Warminster, in Wiltshire. The village of Sutton Veny lies 800 m to the east. There are also other scattered farmhouses and residences in the area and some commercial/light industrial premises immediately to the north-west of the site.

The farm is at an elevation of around 120 m, but is situated in a valley with wooded hills to the north, rising to 160 m, and steep escarpments within a few hundred meters to the south, which reach to over 200 m.

There are two areas of ancient woodland within 1 km to the north-west of Sutton Veny Farm. These are known as Southleigh and Eastleigh Woods respectively. To the south, there are three LWSs; namely Longbridge Hill and Whiten Hill Down (two regions). There is also a SSSI, namely Scratchbury & Cotley Hills, approximately 3 km to the north-east of Sutton Veny Farm. Salisbury Plain SAC approximately 3.8 km to the north at it’s nearest point.

A Map of the surrounding area is presented in Figure 1. The site of the poultry unit at Sutton Veny Farm is shaded in red; LWSs are shaded brown, the ancient woodlands are shaded green, the SSSI are shaded pink, and the SAC is shaded maroon.

Figure 1. The area surrounding the poultry unit at Sutton Veny



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3. Ammonia – background levels, sources, and Critical Levels and Loads

3.1 Background levels of ammonia concentrations

Background ammonia concentration in the area surrounding Sutton Veny Farm, the LWSs, the AWs, the SSSI, and the SAC is 1.8 micrograms per metre cubed of air (µg/m^3). The background nitrogen deposition rate for calcareous grassland is 21.1 kilograms per hectare per year (kg-N/ha/yr) and for woodland is 37.5 kg-N/ha/yr. The source of the background levels is the UK Air Pollution Information System (APIS – December 2012).

3.2 Critical Loads and Levels

Critical Loads and Levels are generally defined as: "*a quantitative estimate of exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge*" (Nilsson & Grennfelt, 1988). It is important to distinguish between a Critical Load and a Critical Level. The Critical Load relates to the quantity of pollutant deposited from air to the ground, whereas the Critical Level refers to the gaseous concentration of a pollutant in the air. More detailed descriptions are provided below (APIS).

- **Critical Levels:** The threshold level for the atmospheric concentration of a pollutant above which harmful direct effects can be shown on a habitat or species, according to current knowledge. Pollutant air concentrations above the Critical Level are termed **Critical Level Exceedances**.

- **Critical Loads:** The threshold level for the deposition of a pollutant above which harmful indirect effects can be shown on a habitat or species, according to current knowledge. Additional deposition above the Critical Load is termed **Critical Load Exceedance**.

Exposure to high concentrations of ammonia can lead to direct damage to woodlands, for example, leaf scorching and loss. Severe damage has been found in woodland edges adjacent to fields with high slurry applications in the Netherlands and Belgium (van Herk 1999, 2002) and damage to trees has been reported in the vicinity of farms in the United Kingdom (UKCLAG, 1996, Pitcairn *et al*. 1998). There may also be changes in plant morphology, physiology and biochemistry which can increase growth and also increase sensitivity to other environmental factors such as wind, frost, drought and pests. Excessive nitrogen deposition can lead to acidification and eutrophication of soils. In addition, species richness can be compromised, especially for slow growing species which suffer from increased competition from invasive species (World Health Organisation, 2000).

3.3 Critical Loads at the LWSs, AWs, SSSI and SAC

A Critical Level for ammonia of 3.0 µg/m^3 has been used in this study for the LWSs, AWs, and the SSSI. A Critical Level of 1.0 µg/m³ has been used for the SAC. A Critical Load for nitrogen deposition of 15 kg/ha/yr has been used in this study for the LWSs, and the SSSI. A Critical Load of 10 kg/ha/yr has been used for the AWs. These figures have been obtained from the Environment Agency's Internal AST Assessment, conducted in October 2012. Where a Critical Level of 1.0 µg/m³ is used, the Critical Load is not considered. This is because, in most cases, a Critical Level of 1.0 µg/m³ provides a considerably more strict test that then Critical Load.

3.4 Guidance on the significance of ammonia emissions

Guidance on the significance of ammonia emissions from farming installations can be found in the Environment Agency's Horizontal Guidance Note H1, Annex (b) (Intensive Farming).

On Page 27 of this document, it is stated that "An emission is insignificant where PC is <4% of Critical Levels for SACs, SPAs and Ramsars, <20% for SSSIs, and <50% for local and national nature reserves, ancient woodland and local wildlife sites".

Furthermore, on Page 31, it is stated that "Where modelling predicts a process contribution >20% of the Critical Level/Load at a SAC, SPA or Ramsar, >50% at a SSSI or >100% at a NNR, LNR, ancient woodland or local wildlife site, your proposal may not be considered acceptable. In such cases, your assessment should include proposals to reduce ammonia emissions".

N.B. For AWs and LWSs, the Environment Agency no longer considers other farms acting in-combination. Therefore, a process contribution of up to 100% may be considered acceptable for permitting purposes.

3.5 Sources of ammonia from the poultry housing

Part of the Environment Agency's Pollution Inventory Guidance, entitled "Intensive farming guidance note" (Environment Agency, 2011) provides standardised ammonia emission figures for a variety of poultry housing types and other sources. The figure given for broiler chickens is 0.034 kilograms of ammonia per place per year (kg-NH_3/place/year), which is equivalent to 0.000001077 grams per second (g/s) per bird. This figure has been used as the basis of the estimation of ammonia emission rates used in the modelling study.

The majority of ammonia emissions would arise from the high speed ridge mounted fans on the proposed new poultry houses and gable end fans during hot weather. The houses, being "state of the art", would be well sealed and insulated, therefore fugitive emissions would be minimal.

Under the proposed scenario, Sutton Veny Farm would have a total of 223,900 birds on site. Therefore, the modelled ammonia emission is 0.241229 g-NH_3/s. NB. The Environment Agency's screening was based on 310,000 birds.

4. Dispersion modelling methodology

4.1 Model description

The choice of model for this study is UK Atmospheric Dispersion Modelling System (ADMS) Version 4.2. 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. Importantly, ADMS 4.2 can take into account spatially varying deposition of pollutants and consequent plume depletion. The model calculates downwind pollutant concentration 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 1m. 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 ADAS 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.

4.2 Meteorology

A statistical dispersion modelling run requires hourly meteorological records, preferably over a minimum of five years. There is a requirement to limit the amount of missing records through station selection and pre-processing the weather file (Defra, 2009). Where only a small number of missing records arise, Defra recommends a procedure of ‘in-fill’ by interpolation or near-neighbour substitution. The occurrence of calm conditions must also be considered so that they are not unnecessarily excluded from the modelling study.

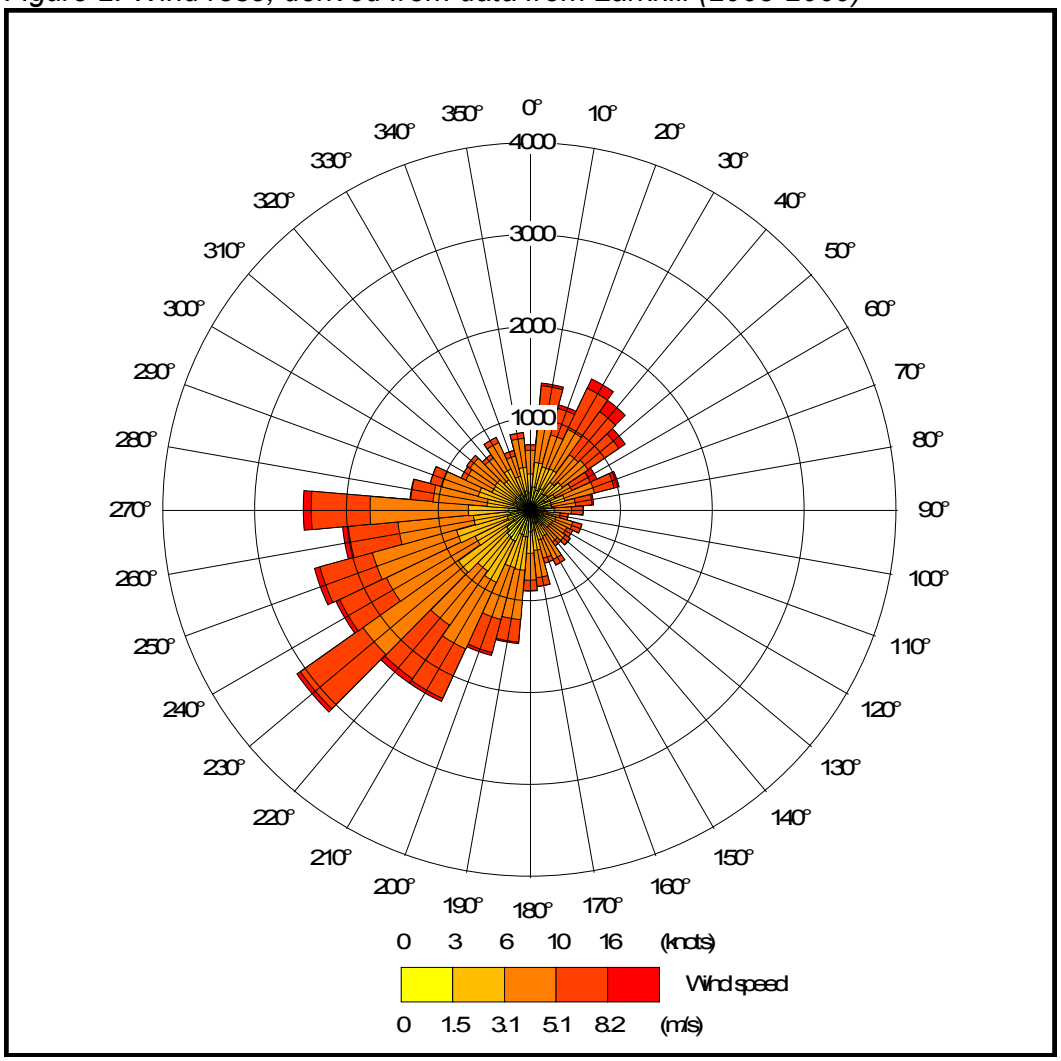
The nearest meteorological station to the area shown in Figure 1 which regularly records all the weather elements required for dispersion modelling is at Larkhill, which is approximately 25 km to the east. It has a similar exposure and is likely to experience similar weather to the area around Sutton Veny Farm, the LWSs, AWs, SSSI, and the SAC. In our opinion as meteorologists,

weather records from Larkhill provide the reasonably good representation of the weather in this area.

The ADAS/Met Office method of dealing with calm periods in the modelled weather files is to set a wind speed of 1.0 m/s and use the last known “good” wind direction (or set to the direction of known katabatic winds if appropriate). However, many of the periods of calms reported in traditional climatological data are not true calms, but represent wind speeds below the minimum recording capabilities of the anemometers, or below the start up speed of the anemometers. This is part of the justification for our standard treatment of calms. Atmospheric dispersion models have internal procedures for dealing with calm periods; however our experience has been that the ADAS method results in the prediction of a larger exposure footprint in the surrounding area the model’s calms procedures. The ADAS/Met Office calms treatment also produces more cautious outcomes than “ignoring” calms by not modelling for hours when there is a calm recorded. The ADAS/Met Office calms treatment has been used in this study.

The wind rose for the weather file used in this study, Larkhill (2005-2009) is shown in Figure 3. This illustrates the relative frequency of wind directions and wind speeds used in the modelling study. NB Within ADMS, the FLOWSTAR module has been used to modify the wind flow so that it better reflects the impact of the local terrain around Sutton Veny Farm. This should mitigate the effects of any differences between the winds at Larkhill and those in the local area.

Figure 2. Wind rose, derived from data from Larkhill (2005-2009)



4.3 Model parameters

4.3.1 Ammonia emissions

For modelling purposes, overall ammonia emission is assumed to be constant. In reality, it will vary through the crop cycle and will be very small, or nil, whilst the housing is empty and clean and high towards the end of the growth cycle. In a long term statistical run, this would have little effect on predicted concentration. However, if short term periods are considered, the stage of the crop cycle and ammonia emission rate would be the most significant variable.

The ammonia emissions from the proposed new poultry houses have been modelled as three point sources for each house to represent the high velocity ridge mounted fans, and one volume source per house to represent the gable end fans. Emissions from the volume sources are assumed to occur when the ambient temperature equals or exceeds 22 Celsius. When these conditions occur, the gable end fans are assumed to account for 50% of the total emission, and emissions from the point sources, are reduced by 50%.

Further details of the source parameters are provided in Table 1a, for the point sources, and Table 1b, for the volume sources. The position of the modelled sources can be seen in Figure 3, where the point sources are marked by red stars, and the volume sources are marked by red rectangles.

Table 1a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Temperature (°C)	Emission rate (per source) (g-NH_3/s)
SH1 a, b & c	6.3	0.8	11.0	22	0.016082 [1]
SH2 a, b & c	6.3	0.8	11.0	22	0.016082 [1]
SH3 a, b & c	6.3	0.8	11.0	22	0.016082 [1]
SH4 a, b & c	6.3	0.8	11.0	22	0.016082 [1]
SH5 a, b & c	6.3	0.8	11.0	22	0.016082 [1]

[1] Reduced by 50% when volume sources are operating

Table 1b. Volume source parameters

Source ID	Base Height (m)	Depth (m)	Volume (m^3)	Emission rate (g-NH_3/s)	Specific emission rate (g-NH_3/m^3/s)
SH1v	0.0	4	464	0.024123 [2]	5.1989×10^{-4} [2]
SH2v	0.0	4	464	0.024123 [2]	5.1989×10^{-4} [2]
SH3v	0.0	4	464	0.024123 [2]	5.1989×10^{-4} [2]
SH4v	0.0	4	464	0.024123 [2]	5.1989×10^{-4} [2]
SH5v	0.0	4	464	0.024123 [2]	5.1989×10^{-4} [2]

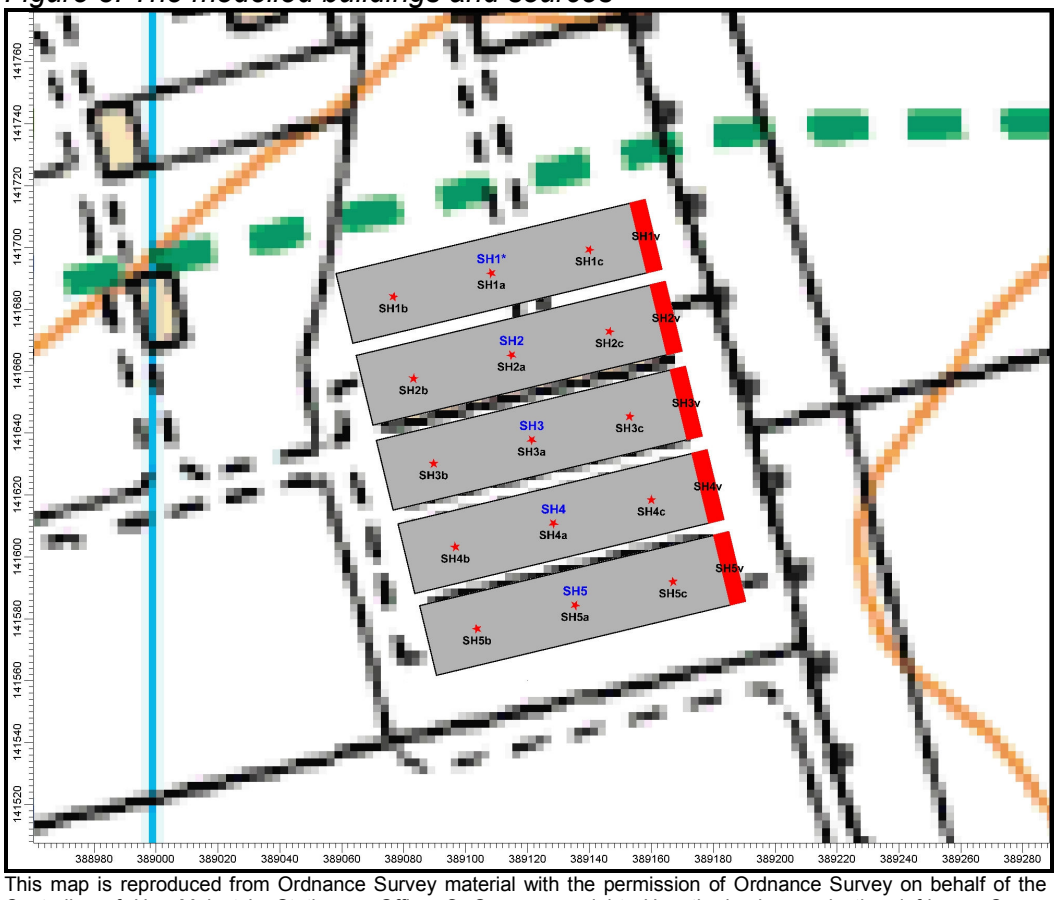
[2] 50% of total emission, only emitted when the ambient temperature equals or exceeds 22 Celsius

4.3.2 Buildings

The structure of the poultry houses will have a significant effect on the behaviour of the plumes from the point sources. Therefore, the buildings are modelled as rectangular blocks within ADMS with a height of 4.6 m. The

position of the modelled buildings can be seen in Figure 3, where they are marked by grey rectangles.

Figure 3. The modelled buildings and sources



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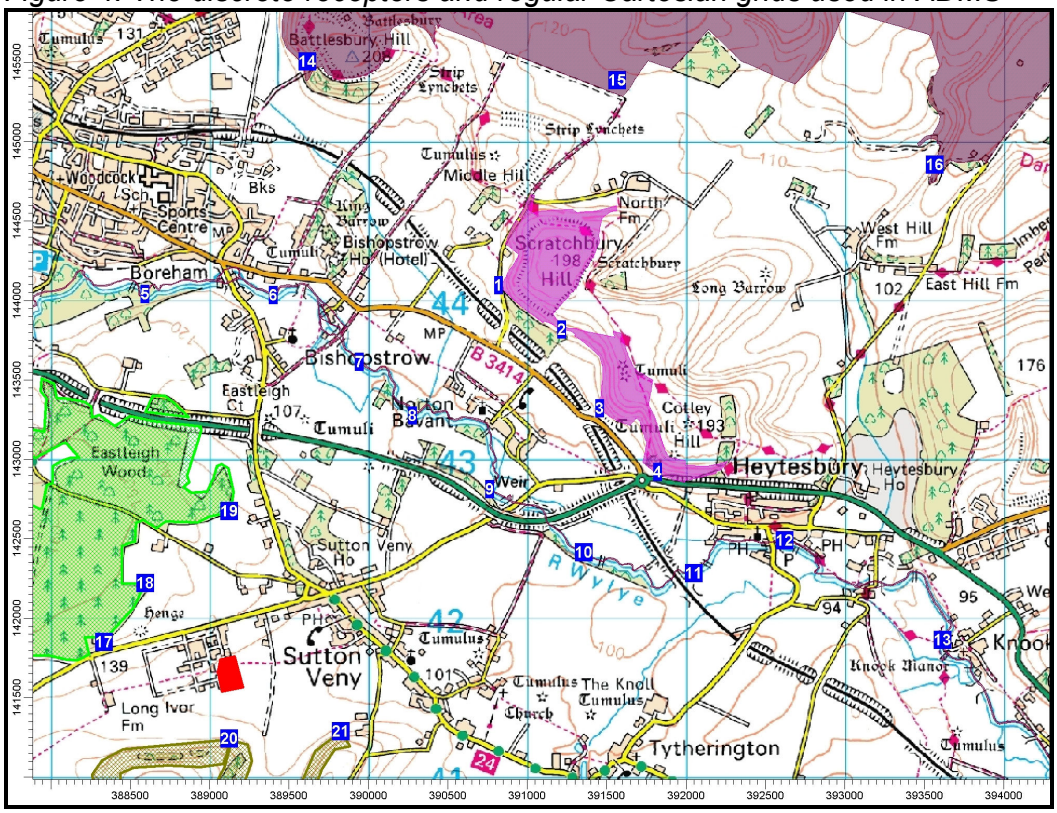
4.3.3 Discrete receptors

Twenty-one discrete receptor points have been defined within the model at the LWSs, AWs, SSSI, and the SAC. These discrete receptors are defined at ground level and their positions are shown in Figure 4, marked by enumerated blue rectangles. The exact positions of the discrete receptors are given in Table 2, in Section 5.

Figure 4. The discrete receptors and regular Cartesian grids used in ADMS



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4.3.4 Terrain and roughness length

The land around Sutton Veny Farm, the LWSs, AWs, SSSIs, and SAC is very steep in places. This is likely to have an effect on wind flow patterns and ground level ammonia concentrations. Consequently, terrain data has been used within ADMS. This is based on the SRTM3 data which is derived from Space Shuttle mission RADAR measurements and has a resolution of approximately 90m. The data have been re-sampled at a horizontal resolution of 400 m for use within ADMS. A fixed roughness length of 0.25 m has been defined within ADMS.

4.3.5 Deposition parameters

Effects of deposition of ammonia and consequent plume depletion have not been modelled explicitly in this study. Where annual nitrogen deposition rates are quoted they are derived by multiplying the predicted ammonia concentration by a deposition velocity of 0.02 for short vegetation or 0.03 for tall vegetation, and by 259.7 to convert units from metres per second (m/s) to the more commonly used kilograms per hectare (kg/ha). The methods are based on EA guidance from the draft document entitled "Guidance on modelling the concentration and deposition of ammonia emitted from intensive farming" (Air Quality Modelling and Assessment Unit, 17 March 2010).

This treatment should be considered precautionary, as depletion of the ammonia plume due to deposition is not modelled explicitly within ADMS.

5. Dispersion and deposition modelling results

Five runs, one for each year in the meteorological record (2005-2009), were performed. Figures for the predicted maximum annual mean ammonia concentration for these five years were then compiled.

The predicted concentrations at the discrete receptors are presented in Table 2, where exposure levels in excess of 100% of the Critical Level for the AWs/LWS, or 50% of the Critical Level for the SSSI, or 20% of the Critical Level for the SAC, are coloured red; those in the range which, for permitting purposes may, or may not, be considered acceptable (50% to 100% for the AWs/LWS, or 20% to 50% for the SSSIs, or 4% to 20% for the SAC) are coloured blue and those that would be deemed insignificant are coloured black. For ease of interpretation of Table 2, rows representing receptors are shaded. Those located at SSSIs are shaded yellow, those at SACs are shaded green, AWs are shaded blue, and those at LWSs are shaded pink. The abbreviations Cle and CLo refer to the Critical Level and Critical Load respectively.

Table 2. Maximum annual ammonia concentration at the discrete receptors

	X (m)	Y (m)	Des	Critical Level (µg/m³)	Critical Load (kg/ha)	Maximum annual mean ammonia concentration		Maximum annual mean nitrogen deposition rate	
						Process Contribution (µg/m³)	Max as % of Cle	Process Contribution (kg/ha)	Max as % of CLo
1	390818	144098	SSSI	3.0	15	0.065	2.15	0.336	2.24
2	391218	143818	SSSI	3.0	15	0.070	2.34	0.364	2.43
3	391455	143322	SSSI	3.0	15	0.083	2.76	0.431	2.87
4	391822	142922	SSSI	3.0	15	0.074	2.45	0.382	2.55
5	388594	144042	SAC	-	-	0.034	-	-	-
6	389400	144034	SAC	-	-	0.047	-	-	-
7	389943	143614	SAC	-	-	0.085	-	-	-
8	390278	143278	SAC	-	-	0.123	-	-	-
9	390763	142814	SAC	-	-	0.150	-	-	-
10	391355	142415	SAC	-	-	0.106	-	-	-
11	392048	142286	SAC	-	-	0.071	-	-	-
12	392618	142493	SAC	-	-	0.056	-	-	-
13	393614	141864	SAC	-	-	0.040	-	-	-
14	389613	145507	SAC	1.0	-	0.023	2.31	-	-
15	391564	145386	SAC	1.0	-	0.034	3.45	-	-
16	393563	144856	SAC	1.0	-	0.030	3.00	-	-
17	388332	141853	AW	3.0	10	0.155	5.16	1.205	12.05
18	388591	142222	AW	3.0	10	0.128	4.27	0.997	9.97
19	389121	142675	AW	3.0	10	0.116	3.85	0.900	9.00
20	389121	141244	LWS	3.0	15	0.600	20.00	3.116	20.78
21	389824	141290	LWS	3.0	15	0.256	8.54	1.331	8.88

6. Summary and conclusions

ADAS has been commissioned by Mr James Whilding of ACORUS Rural Property Services Ltd. to conduct a dispersion modelling study to assess the impact of ammonia emissions from the proposed redevelopment of the broiler chicken rearing unit at Sutton Veny Farm, Warminster in Wiltshire.

Ammonia emissions from the proposed poultry houses at the unit have been assessed and quantified using figures obtained from the Environment Agency (Environment Agency, 2011). These emission figures have been used in atmospheric dispersion modelling. The modelling was conducted by the Met Office Rural Environment Team at ADAS.

This report presents modelled ammonia concentration levels for the area surrounding the poultry unit. Particular attention has been given to nearby Local Wildlife Sites (LWSs), Ancient Woodlands (AWs), a Site of Special Scientific Interest (SSSI) and a Special Area of Conservation (SAC).

The modelling predicts that the process contributions to annual mean ammonia concentration would be below 50% of the Critical Level/Load at the receptors located at the AWs/LWSs, below 20% of the Critical Level/Load at the receptors located at the SSSI, and below 4% of the Critical Level/Load at the receptors located at the SAC. Therefore ammonia emissions from the proposed redevelopment of Sutton Veny Farm would be considered insignificant for permitting purposes.

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