A Report on the Modelling of the Dispersion of Ammonia from the Proposed Free Range Egg Laying Chicken Houses at Cerrigcroes, Llanyre, near Llandrindod Wells in Powys

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19th December 2016

1. Introduction

AS Modelling & Data Ltd. has been instructed by Steve Raasch on behalf of Ross Abberley of A.J. Abberley, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed free range egg laying chicken houses at Cerrigcroes, Lanyre, near Llandrindod Wells in Powys. LD1 6EU.

Ammonia emission rates from the existing and proposed poultry houses have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors. The ammonia emission rates have then been used as inputs to an atmospheric dispersion and deposition model which calculates ammonia exposure levels and nitrogen deposition rates in the surrounding area.

This report is arranged in the following manner:

- Section 2 provides relevant details of the farm and potentially sensitive receptors in the area.

- Section 3 provides some general information on ammonia; details of the method used to estimate ammonia emissions, relevant guidelines and legislation on exposure limits and where relevant, details of likely background levels of ammonia.

- Section 4 provides some information about ADMS, the dispersion model used for this study and details the modelling procedure.

- Section 5 contains the results of the modelling.

- Section 6 provides a discussion of the results and conclusions.

2. Background Details

Cerrigcroes is in a rural location approximately 2.0 km to the west of Llandrindod Wells, in Powys. The land around the farm is used mainly for livestock farming and there are some wooded areas. The site of the poultry unit at Cerrigcroes is at an elevation of around 230 m with the land rising towards hills and mountains to the the north and west and falling towards the River Ithon Valley to the south and east.

Currently there are two layer chicken houses at Cerrigcroes, these provide accommodation for up to 28,000 chickens in total. The existing houses are ventilated by either capped ridge fans or uncapped high speed ridge fans, with gable end fans providing supplementary ventilation during hot weather. The chickens have daytime access to outside ranging areas via a series of pop holes on the sides of the houses.

The proposal involves the construction of an extension to one of the poultry houses, converting it from a flat deck to a multi-tier system and upgrading the ventilation from capped ridge fans to uncapped high speed ridge fans, with additional ventilation being provided by gable end fans during hot weather. The other existing poultry house would remain as a multi-tier house, ventilated by uncapped high speed ridge fans with gable end fans providing supplementary ventilation. Manure would be regularly removed by a belt system from both of the poultry houses and taken off the site. The proposed changes to the poultry houses would enable the poultry unit to provide accommodation for up to 48,000 layer chickens.

There are several areas that are designated as Ancient Woodlands (AWs) within 2 km of the poultry unit at Cerrigcroes. There are a number of sites that are designated as Sites of Special Scientific Interest (SSSI) within 5 km of the farm and additionally there is the River Wye Special Area of Conservation (SAC), Elan Valley Woodlands SAC and Elenydd – Mallaen Specially Protected Area (SPA) within 10 km of Cerrigcroes.

Maps of the surrounding area showing the positions of the poultry unit at Cerrigcroes are provided in Figure 1a, a broad scale view with the focus on the international and statutory sites, and Figure 1b, a smaller scale view with the focus on the non-statutory sites and the closer SSSIs and SPAs. In these figures, the AWs are shaded olive, the SSSIs are shaded green, the SACs are shaded purple, the SPA is shaded orange and the site of the poultry unit at Cerrigcroes is outlined in blue.

Figure 1a. The area surrounding Cerrigcroes – a broad scale view. Concentric circles radii 2 km (olive), 5 km (green) and 10 km (purple)

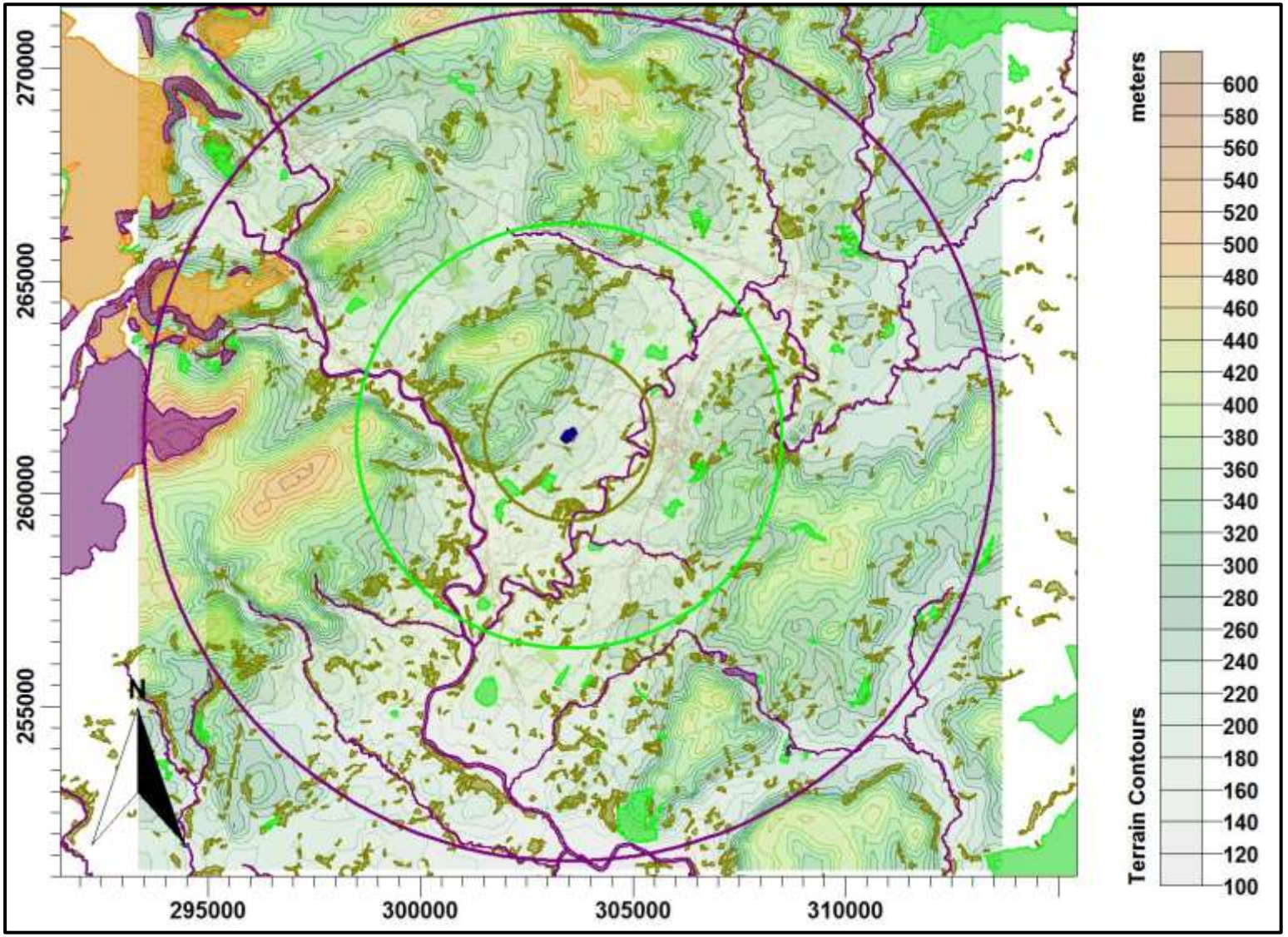
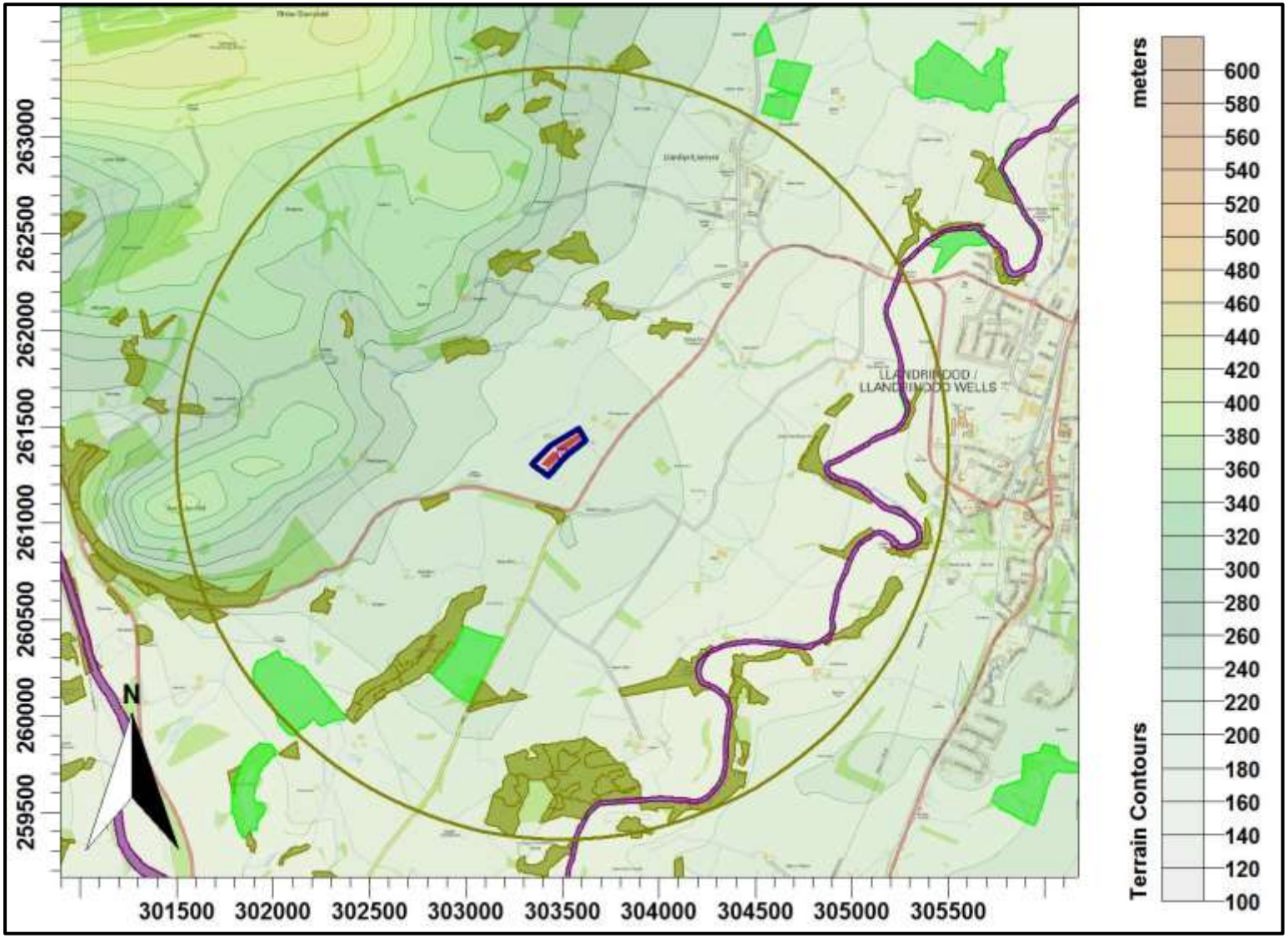


Figure 1b. The area surrounding Cerrigcroes – a large scale view. Concentric circle radii 2 km (olive)



3. Ammonia, Background Levels, Critical Levels & Loads & Emission Rates

3.1 Ammonia concentration and nitrogen and acid deposition

When assessing potential impact on ecological receptors, ammonia concentration is usually expressed in terms of micrograms of ammonia per metre cubed of air ($\mu g\text{-}NH_3/m^3$) as an annual mean. Ammonia in the air may exert direct effects on the vegetation, or indirectly affect the ecosystem through deposition which causes both hyper-eutrophication (excess nitrogen enrichment) and acidification of soils. Nitrogen deposition, specifically in this case the nitrogen load due to ammonia deposition/absorption is usually expressed in kilograms of nitrogen per hectare per year (kg-N/ha/y). Acid deposition is expressed in terms of kilograms equivalent (of H^+ ions) per hectare per year (keq/ha/y).

3.2 Background ammonia levels and nitrogen and acid deposition

The background ammonia concentration (annual mean) in the area around Cerrigcroes and the wildlife sites is 0.9 $\mu g\text{-}NH_3/m^3$. The background nitrogen deposition rate to woodland is 25.62 kg-N/ha/y and to short vegetation is 16.8 kg-N/ha/y. The background acid deposition rate to woodland is 2.03 keq/ha/yr and to short vegetation is 1.37 keq/ha/yr. The source of these background figures is the Air Pollution Information System (APIS).

3.3 Critical Levels & Critical Loads

Critical Levels and Critical Loads are a benchmark for assessing the risk of air pollution impacts to ecosystems. It is important to distinguish between a Critical Level and a Critical Load. The Critical Level is the gaseous concentration of a pollutant in the air, whereas the Critical Load relates to the quantity of pollutant deposited from air to the ground.

Critical Levels are defined as, "concentrations of pollutants in the atmosphere above which direct adverse effects on receptors, such as human beings, plants, ecosystems or materials, may occur according to present knowledge". (UNECE)

Critical Loads are 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". (UNECE)

For ammonia concentration in air, the Critical Level for higher plants is 3.0 $\mu g\text{-}NH_3/m^3$ as an annual mean. For sites where there are sensitive lichens and bryophytes present, or where lichens and bryophytes are an integral part of the ecosystem, the Critical Level is 1.0 $\mu g\text{-}NH_3/m^3$ as an annual mean.

Critical Loads for nutrient nitrogen are set under the Convention on Long-Range Transboundary Air Pollution. They are based on empirical evidence, mainly observations from experiments and gradient studies. Critical Loads are given as ranges (e.g. 10-20 kg-N/ha/y); these ranges reflect variation in ecosystem response across Europe.

The Critical Levels and Critical Loads at the wildlife sites assumed in this study are provided in Table 1. N.B. Where the Critical Level of 1.0 µg-NH_3/m^3 is assumed, it is usually unnecessary to consider the Critical Load as the Critical Level provides the stricter test. However, where a Critical Load of 5.0 kg-N/ha/yr is appropriate, it may be necessary to consider the Critical Load for nitrogen deposition. Normally the Critical Load for nitrogen deposition provides a stricter test than does the Critical Load for acid deposition.

Table 1. Critical Levels and Critical Loads at the wildlife sites

Site	Critical Level (µg-NH_3/m^3)	Critical Load - Nitrogen Deposition (kg-N/ha/y)
AWs	1.0 [1]	-
SSSIs	1.0 [1]	5.0 [1]
River Wye SAC	1.0 [1]	-
Elan Valley Woodlands SAC	1.0 [1]	-
Elenydd SAC	1.0 [1]	3.0 [2]
Elenydd – Mallaen SPA	1.0 [1]	-

1. A precautionary figure, used where details of the site are unavailable, or citations indicate that sensitive lichens and bryophytes may be present in the case of a Critical Level.
2. The lower bound of the range of Critical Loads for the site, obtained from APIS.

3.4 Guidance on the significance of ammonia emissions

The following are obtained from the Environment Agency's horizontal guidance, H1 Environmental Risks Assessment, H1 Annex B - Intensive Farming.

"An emission is insignificant where Process Contribution (PC) is <4% of Critical Levels for SACs, SPAs and Ramsars, <20% for SSSIs, and <50% for local and national nature reserves (LNRs & NNRs), ancient woodland and local wildlife sites." and "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."

This document was withdrawn February 1st 2016 and replaced with a web-page titled "Intensive farming risk assessment for your environmental permit", which contains essentially the same criteria. It is assumed that the upper threshold and lower threshold on the web-page refers to the levels that were previously referred to as levels of insignificance and acceptability in Annex B– Intensive Farming. It is understood that Natural Resources Wales used the same criteria as the Environment Agency Annex B – Intensive Farming and therefore it is assumed that they now use the same criteria as defined in the Environment Agency's web-page "Intensive farming risk assessment for your environmental permit".

Within the range between the lower and upper thresholds; 4% to 20% for SACs, SPAs and Ramsars; 20% to 50% for SSSIs and 100% to 100% for other non-statutory wildlife sites, whether or not the impact is deemed acceptable is at the discretion of the Environment Agency. In making their decision, the Environment Agency will consider whether other farming installations might act in combination with the farm and the sensitivities of the wildlife sites. N.B. In the case of LWSs and AWs, the Environment Agency do not usually consider other farms that may act in combination and therefore a PC of up to 100% of Critical Level or Critical Load is usually deemed acceptable for permitting purposes and therefore the upper and lower thresholds are the same (100%).

3.5 Quantification of ammonia emissions

Ammonia emission rates from poultry houses depend on many factors and are likely to be highly variable. However, the benchmarks for assessing impacts of ammonia, nitrogen and acid deposition are framed in terms of an annual mean ammonia concentration and annual nitrogen or acid deposition rates. To obtain relatively robust figures for these statistics, it is not necessary to model short term temporal variations and a steady continuous emission rate can be assumed. In fact, modelling short term temporal variations might introduce rather more uncertainty than modelling continuous emissions.

The Environment Agency provides an Intensive Farming guidance note which lists standard ammonia emission factors for a variety of livestock, including poultry. For laying chickens with a belt removal system and frequent removal of manure from the site, such as those at Cerrigcroes (as proposed), the Environment Agency figure is 0.035 kg-NH_3/bird place/y. This figure has been used as the basis for the calculation of the ammonia emission rates from the poultry housing used in this modelling study.

As the birds would have access to outdoor ranging areas, some of the birds droppings, which is the source of the ammonia, will be deposited on these ranging areas. For modelling purposes it is assumed that 20% of the droppings are deposited on the ranging areas, this assumption is based upon Environment Agency guidance. To estimate the ammonia emissions from the range, it has been assumed that laying hens produce 0.8 kg-N/y (Misselbrook) in their droppings and that 20% of ammoniacal nitrogen is emitted as ammonia (typically 40% to 50% is emitted as ammonia from stored manure, but this has been reduced to allow for mineralisation and leaching due to the contact with mineral soils). This equates to an emission factor of 0.194 kg-NH_3/bird/y which is rounded up to 0.2 kg-NH_3/bird/y for use in the emission calculations.

Details of the poultry numbers and types and emission factors used and calculated ammonia emission rates are provided in Table 2.

Table 2. Details of poultry numbers and ammonia emission rates

Ammonia source	Animal numbers	Type or weight	Emission factor (kg-NH_3/place/y)	Emission rate (g-NH_3/s)
Housing	48,000 (x0.8)	EA figure for Laying Chickens with frequent belt removal	0.035	0.042589
Ranges	48,000 (x0.2)	AS Modelling & Data Ltd. range emission figure	0.20	0.060841

4. The Atmospheric Dispersion Modelling System (ADMS) and Model Parameters

The Atmospheric Dispersion Modelling System (ADMS) ADMS 5 is a new generation Gaussian plume air dispersion model, which means that the atmospheric boundary layer properties are characterised by two parameters; the boundary layer depth and the Monin-Obukhov length rather than in terms of the single parameter Pasquill-Gifford class.

Dispersion under convective meteorological conditions uses a skewed Gaussian concentration distribution (shown by validation studies to be a better representation than a symmetrical Gaussian expression).

ADMS has a number of model options including: dry and wet deposition; NO_x chemistry; impacts of hills; variable roughness; buildings and coastlines; puffs; fluctuations; odours; radioactivity decay (and γ-ray dose); condensed plume visibility; time varying sources and inclusion of background concentrations.

ADMS has an in-built meteorological pre-processor that allows flexible input of meteorological data both standard and more specialist. Hourly sequential and statistical data can be processed and all input and output meteorological variables are written to a file after processing.

The user defines the pollutant, the averaging time (which may be an annual average or a shorter period), which percentiles and exceedance values to calculate, whether a rolling average is required or not and the output units. The output options are designed to be flexible to cater for the variety of air quality limits which can vary from country to country and are subject to revision.

4.1 Meteorological data

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

The meteorological data used in this study is obtained from assimilation and short term forecast fields of the Numerical Weather Prediction (NWP) system known as the Global Forecast System (GFS). Data from the observational meteorological stations at Sennybridge, Shobdon and Trawscoed has also been considered.

The GFS is a spectral model and data are archived at a horizontal resolution of 0.25 degrees, which is approximately 25 km over the UK (formerly 0.5 degrees, or approximately 50 km). The GFS resolution adequately captures major topographical features and the broad-scale characteristics of the weather over the UK. Smaller scale topological features may be included in the dispersion modelling by using the flow field module of ADMS (FLOWSTAR). The use of NWP data has advantages over traditional meteorological records because:

- Calm periods in traditional observational records may be over represented, this is because the instrumentation used may not record wind speeds 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.

The closest meteorological recording station that records all the parameters required for atmospheric dispersion modelling is at Sennybridge, approximately 34 km to the south of Cerrigcroes. Data from the meteorological recording stations at Shobdon and Trawscoed have also been considered; Shobdon is around 36 km to the east of the site, and Trawscoed around 38 km to the west of Cerrigcroes. However, neither Sennybridge, Shobdon nor Trawscoed has an aspect that in any way could be considered similar to Cerrigcroes; therefore, it should be noted that the frequency of winds from a particular direction in the Sennybridge, Shobdon or Trawscoed data may be either high or low in comparison to what might occur at Cerrigcroes, which means mean concentrations downwind may be either over or under predicted. Additionally, periods of light winds and calms cannot be properly modelled. Therefore, it is the opinion of AS Modelling & Data Ltd. that the results obtained using the GFS data, particularly when modified by using FLOWSTAR, should be given more weight when interpreting the results of the modelling.

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 2a.

The raw GFS wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and where terrain data is included in the modelling wind speeds and directions will be further modified. The terrain and roughness length modified wind rose for the site of Cerrigcroes is shown in Figure 2b. Note that elsewhere in the modelling domain the modified wind roses may differ more markedly and that the resolution of the wind field in the preliminary terrain runs is approximately 750 m and in the detailed modelling runs is approximately 300 m.

The wind roses for Sennybridge, Shobdon and Trawscoed are shown in Figures 2c, 2d and 2e respectively.

Figure 2a. The wind rose. Raw GFS derived data, for 52.242 N, 3.414 W, 2012 – 2015

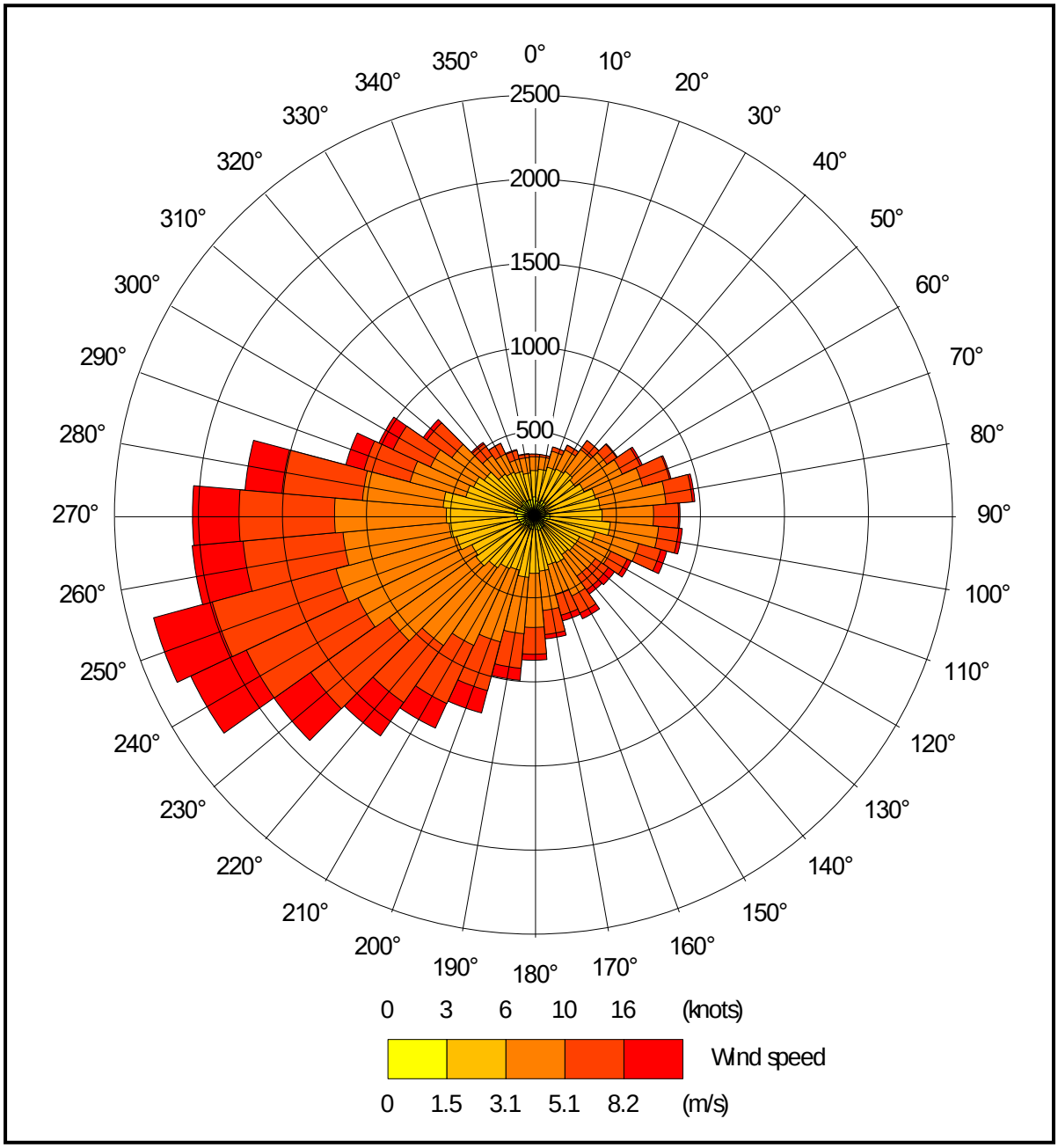


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for 52.242 N, 3.414 W, 2012-2015

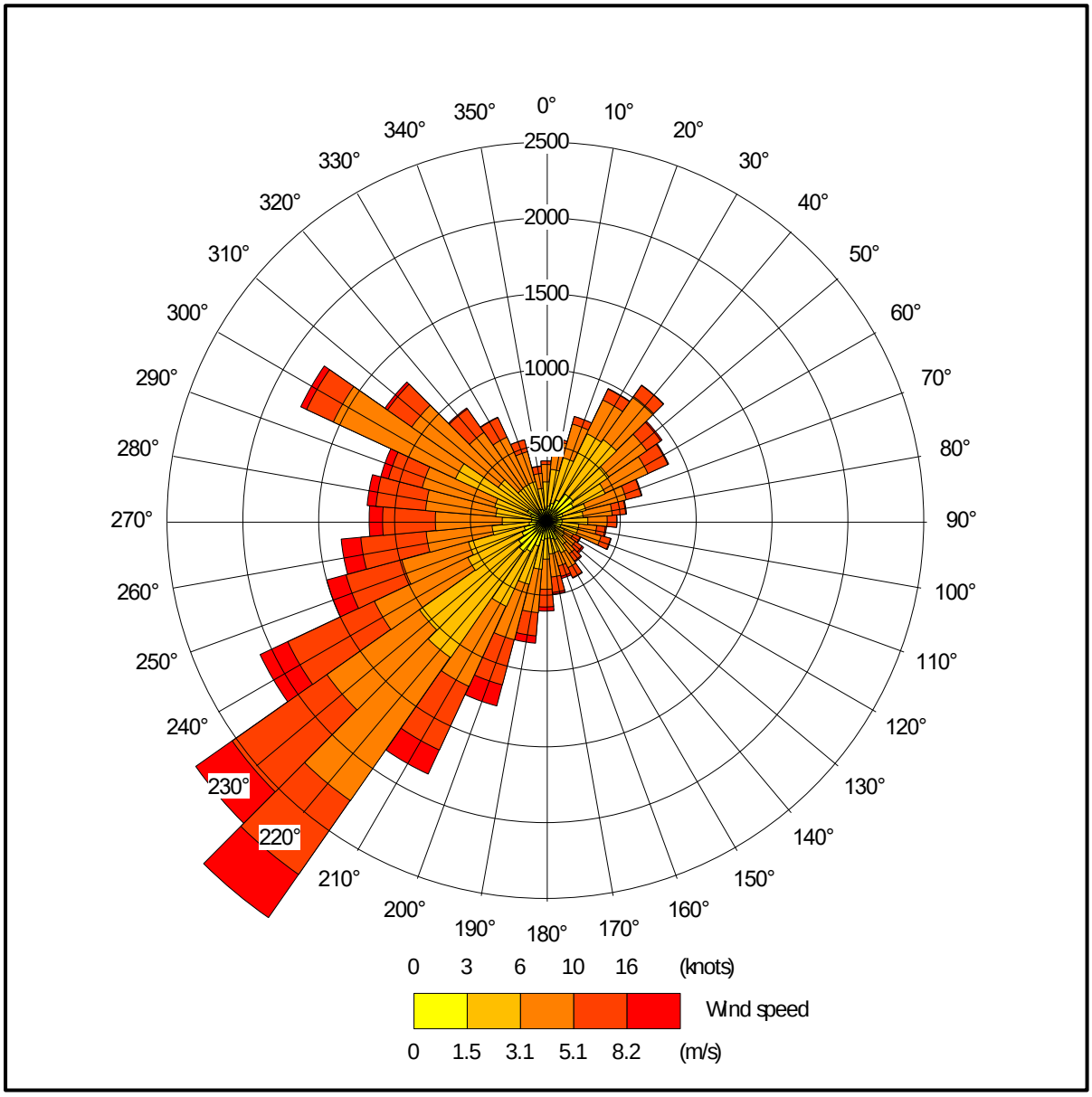


Figure 2c. The wind rose. Recorded meteorological data at Sennybridge, 2012-2015

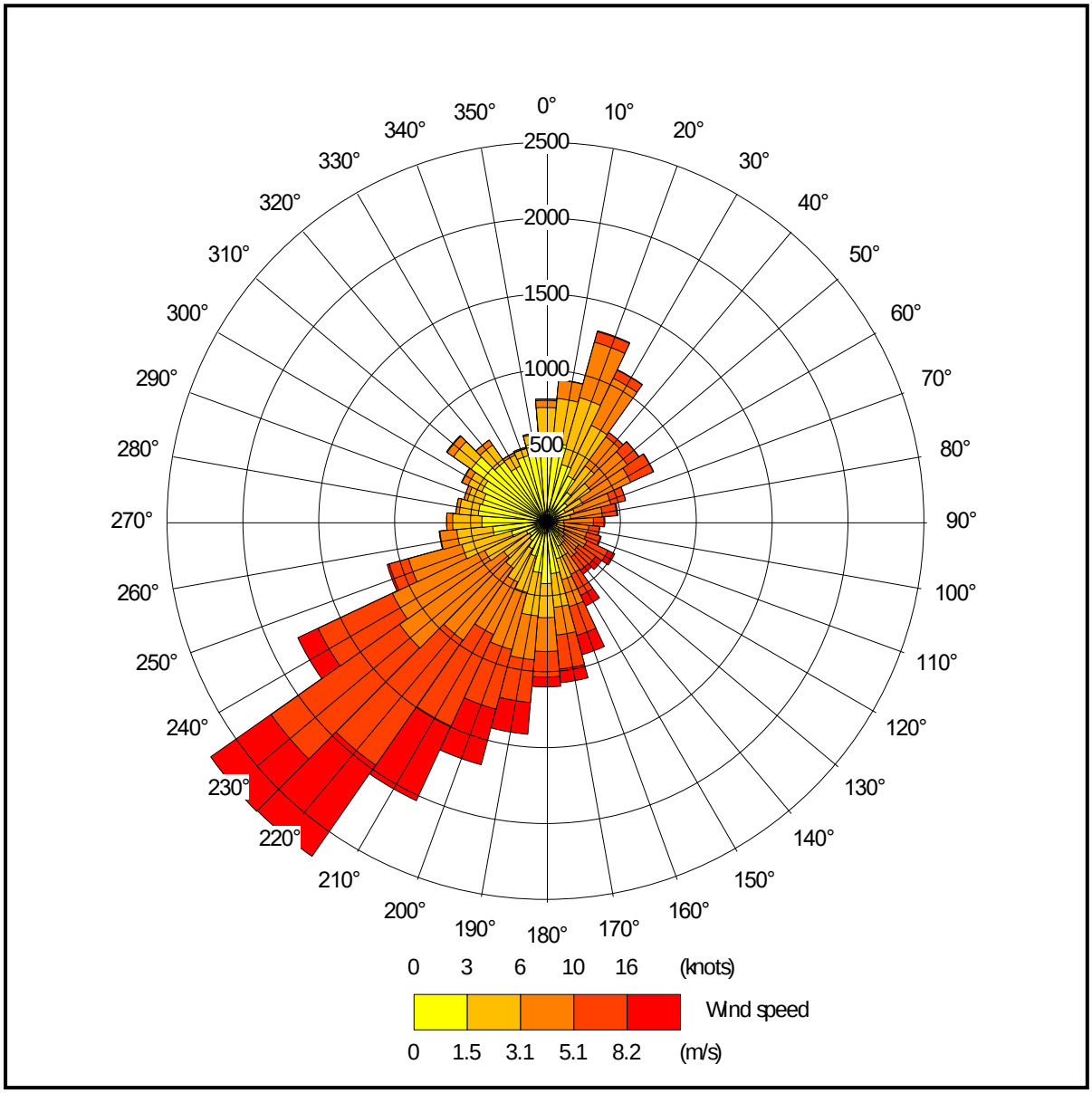


Figure 2d. The wind rose. Recorded meteorological data at Shobdon, 2012-2015

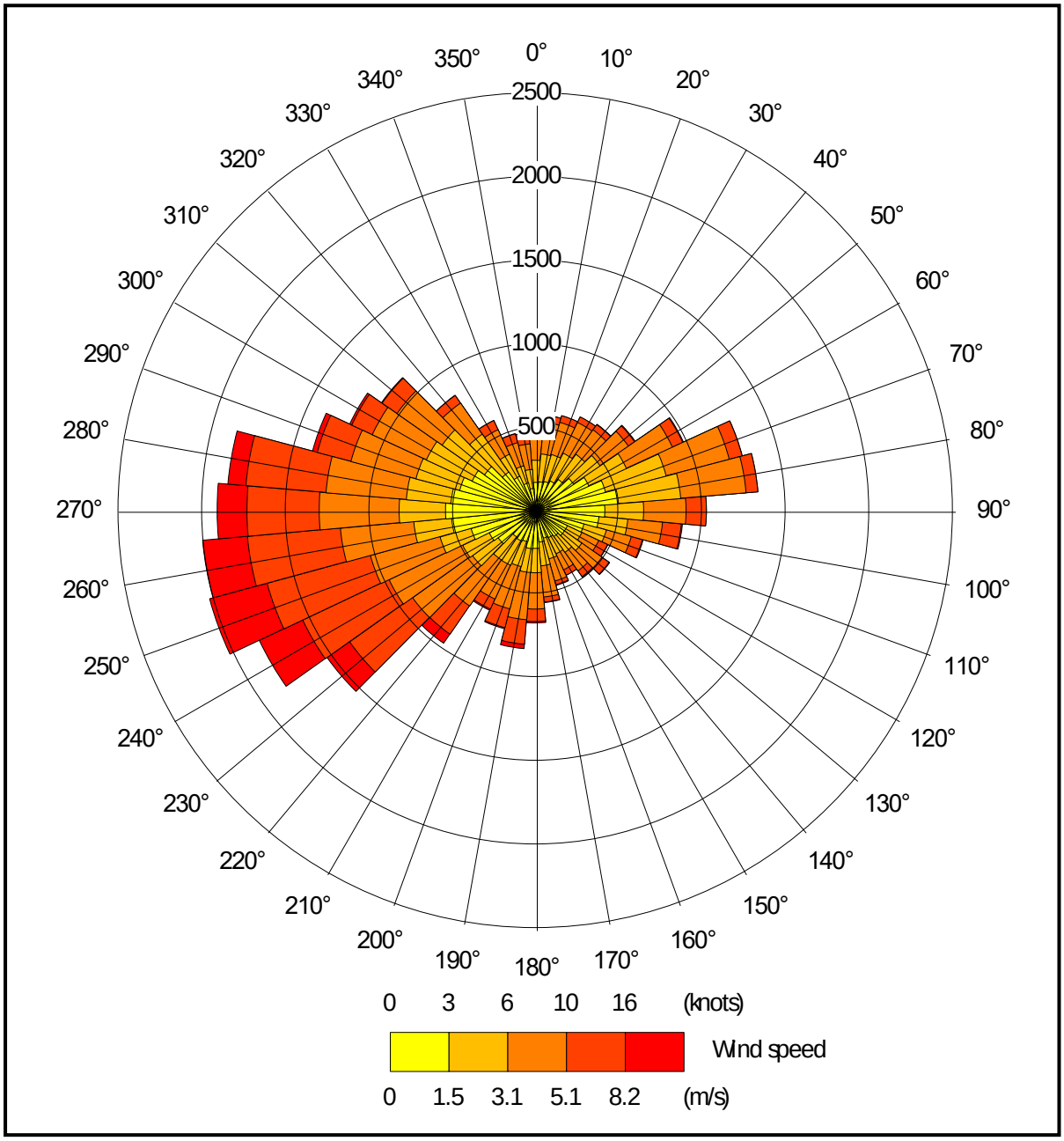
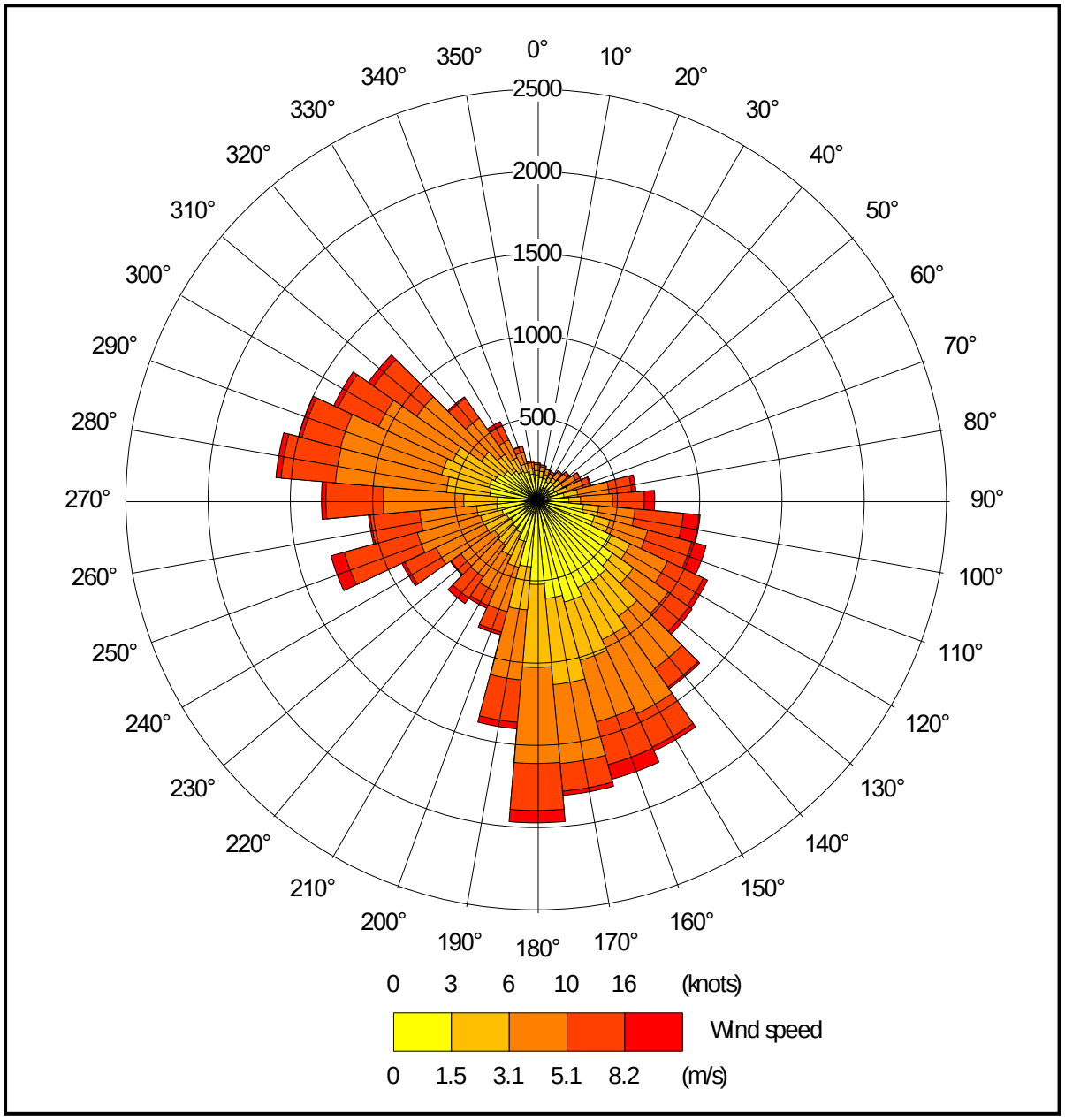


Figure 2e. The wind rose. Recorded meteorological data at Trawscoed, 2012-2015



4.2 Emission sources

Emissions from the chimneys of the uncapped high speed fans that are, or would be, used as the primary source of ventilation for the existing poultry house and the proposed extended poultry house are represented by three point sources per house within ADMS (EX1 and PR1; a, b & c).

Details of these point source parameters are shown in Table 3a. The positions of the point sources are shown in Figure 3, where they are marked by red star symbols.

Table 3a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source (g-NH_3/s)
EX1 a, b & c	5.5	0.8	11.0	Variable	0.004732 [1]
PR1 a, b & c	5.5	0.8	11.0	Variable	0.009464 [1]

1. Reduced by 50% when the ambient temperature equals or exceeds 21 Celsius.

Both the existing poultry house and proposed extended poultry house are fitted with gable end fans, which would be used to augment the primary ventilation during hot weather. The emissions from the gable end fans are represented by a single volume source per house within ADMS (EX1_gab and PR1_gab). These volume sources are assumed to emit 50% of the total emission only when the ambient temperature equals or exceeds 21 Celsius; when the volume sources are emitting, emissions from the associated point sources are reduced by 50%.

Details of the volume source parameters are shown in Table 3b. The positions of the volume sources are shown in Figure 3, where they are represented by red rectangles.

Table 3b. Volume source parameters

Source ID	Length Y (m)	Width X (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (ou_E/s)
EX1_gab	5.0	16.9	3.0	0.0	Ambient	0.007098 [1]
PR1_gab	5.0	21.4	3.0	0.0	Ambient	0.014196 [1]

1. 50% of the total emission is emitted when the ambient temperature equals or exceeds 21 Celsius.

Each of the existing and proposed extended poultry houses has ranging areas. Emissions from these ranging areas are assumed to occur constantly and in addition to those from the houses and have been represented as area sources within ADMS. Note that the area sources cover the parts of the ranges most likely to be used frequently and not the whole ranging area.

Details of the area source parameters are provided in Table 3c. The positions of the area sources are shown in Figure 3, where they are represented by red polygons.

Table 3c. Area source parameters

Source ID	Area (m^2)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
EX1_ran	3,242.8	0.0	Ambient	0.020280
PR1_ran	4,163.5	0.0	Ambient	0.040561

4.3 Modelled buildings

The structure of the proposed new poultry houses and other nearby buildings may affect the plumes from the point sources. Therefore, these buildings are modelled within ADMS. The positions of the modelled buildings may be seen in Figure 3, where they are marked by grey rectangles.

4.4 Discrete receptors

One-hundred-and-three discrete receptors have been defined: thirty-one at the AWs (1 to 31); eighteen at the SSSIs (32 to 35, 49 to 60 and 64 to 65); and fifty-four at the SACs/SPAs. These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figure 4a, a broad scale view, and Figure 4b, a closer view, where they are marked by enumerated pink rectangles.

4.5 Cartesian grid

To produce the contour plots presented in Section 5 of this report and to define the spatially varying deposition velocity field, a regular Cartesian grid has been defined within ADMS. The individual grid receptors are defined at ground level within ADMS. The position of the Cartesian grid may be seen in Figure 4b, where it is marked by grey lines bounded by a purple border.

4.6 Terrain data

Terrain has been considered in the modelling. The terrain data are based upon the Ordnance Survey 50 m Digital Elevation Model. For the preliminary modelling, a 25.0 km x 25.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS for the preliminary modelling and a 10.0 km by 10.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS for the detailed modelling. N.B. The resolution of FLOWSTAR is 32 x 32 grid points; therefore, the effective resolution of the wind field is approximately 750 m for the preliminary modelling and 300 m for the detailed modelling.

4.7 Roughness Length

A fixed surface roughness length of 0.25 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 0.225 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 4a. The discrete receptors – a broad scale view. Concentric circles radii 2 km (olive), 5 km (green) and 10 km (purple)

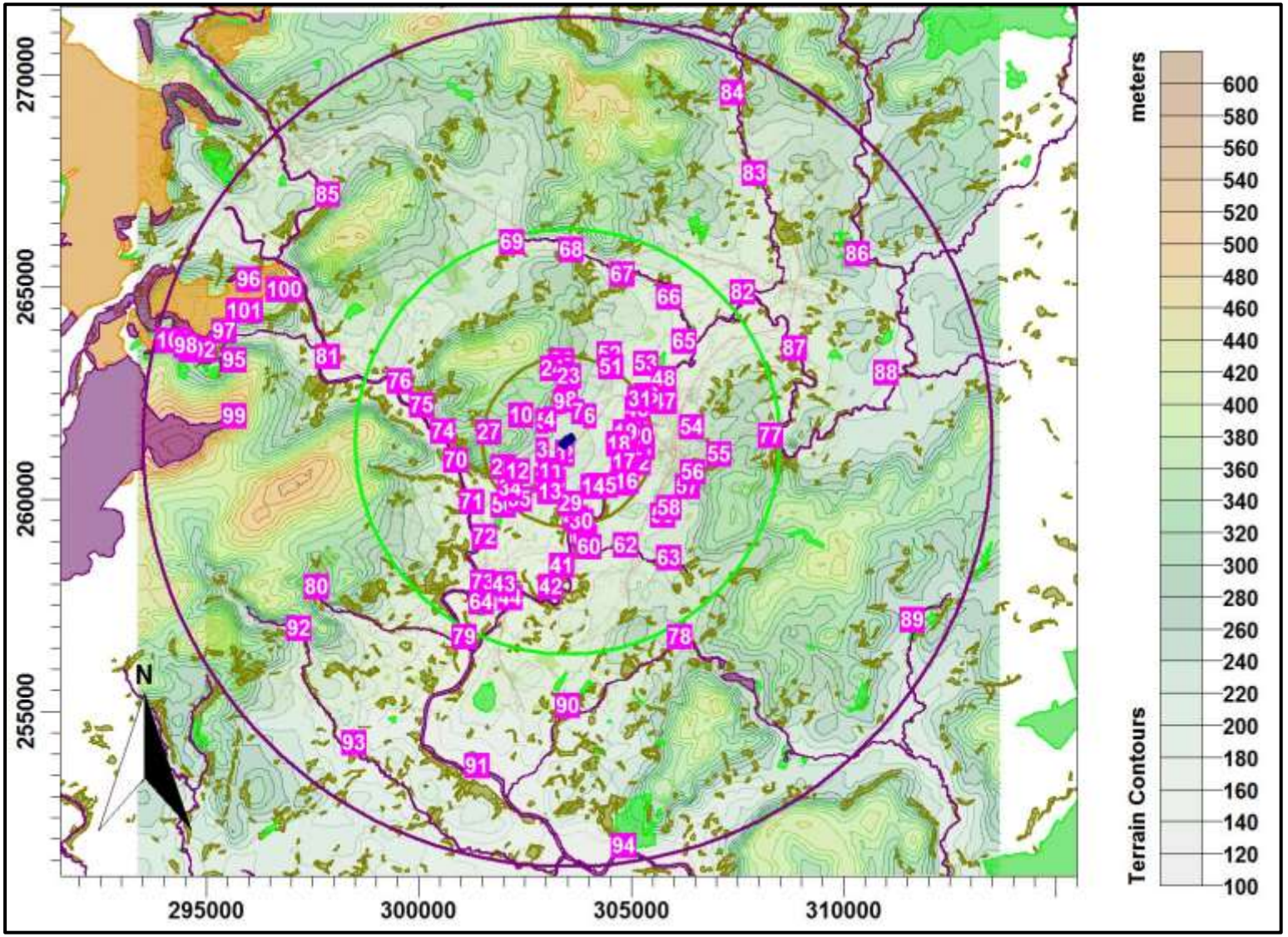
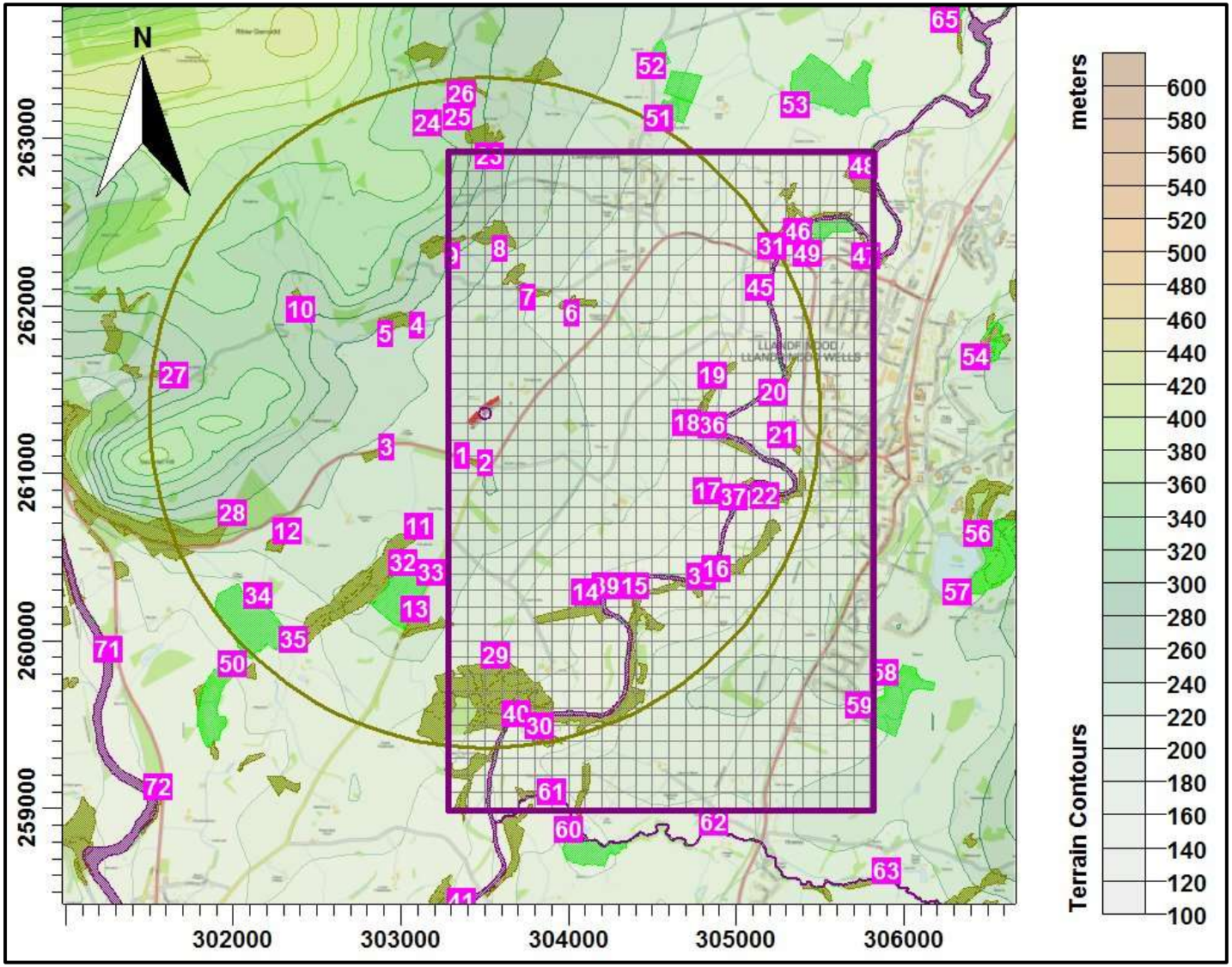


Figure 4b. The discrete receptors and uniform Cartesian grid – a large scale view. Concentric circle radii 2 km (olive)



4.8 Deposition

The method used to model deposition of ammonia and consequent plume depletion is based on a document titled "Guidance on modelling the concentration and deposition of ammonia emitted from intensive farming" from the Environment Agency's Air Quality Modelling and Assessment Unit, 22 November 2010. N.B. AS Modelling & Data Ltd. has restricted deposition over arable farmland and heavily grazed and fertilised pasture; this is to compensate for possible saturation effects due to fertilizer application and to allow for periods when fields are clear of crops (Sutton), the deposition is also restricted over areas with little or no vegetation and the deposition velocity is set to 0.002 m/s where grid points are over the poultry housing and 0.015 m/s over heavily grazed grassland.

In summary the method is as follows:

- A preliminary run of the model without deposition is used to provide an ammonia concentration field.
- The preliminary ammonia concentration field, along with land usage, is used to define a deposition velocity field. The deposition velocities used are provided in Table 4.

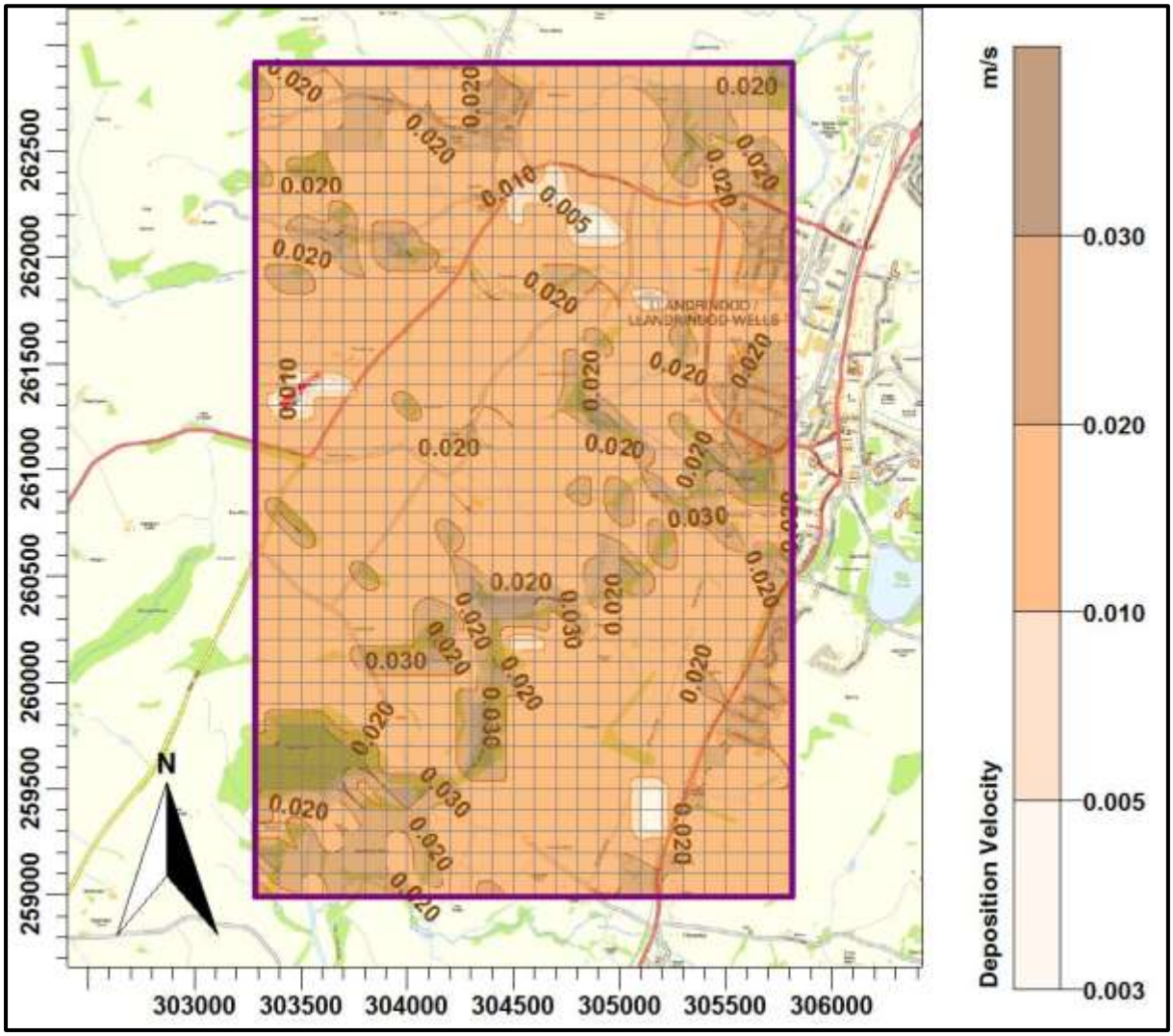
Table 4. Deposition velocities

NH3 concentration (PC + background) ($\mu g/m^3$)	< 10	10 - 20	20 - 30	30 – 80	> 80
Deposition velocity – woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity – short vegetation (m/s)	0.02 (0.015 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity – arable farmland/rye grass (m/s)	0.005	0.005	0.005	0.005	0.003

- The model is then rerun with the spatially varying deposition module.

A contour plot of the spatially varying deposition field is provided in Figure 5.

Figure 5. The spatially varying deposition field



5. Details of the Model Runs and Results

5.1 Preliminary modelling

ADMS was run a total of twenty-four times, once for each year of the meteorological record, in the following three modes:

- In basic mode without calms, or terrain – GFS data.
- With calms and without terrain – GFS data.
- Without calms and with terrain – GFS data.
- In basic mode without calms, or terrain – Sennybridge data.
- In basic mode without calms, or terrain – Shobdon data.
- In basic mode without calms, or terrain – Trawscoed data.

For each mode, statistics for the predicted maximum annual mean ammonia concentration at each receptor were compiled, and the maximum annual nitrogen deposition rate was calculated.

Details of the predicted annual mean ammonia concentrations at each receptor are provided in Table 5. In the Table, predicted ammonia concentrations (or concentrations equivalent to deposition rates) that are in excess of the Environment Agency's upper threshold (20% of Critical Level or Load for a SAC/SPA/Ramsar site, 50% of Critical Level or Load for a SSSI and 100% of Critical Level or Load for a non-statutory wildlife site) are coloured red. Concentrations (or concentrations equivalent to deposition rates) in the range between the Environment Agency's lower and upper threshold (4% and 20% for a SAC/SPA/Ramsar site, 20% and 50% for a SSSI and 50%[1] and 100% for a non-statutory wildlife site) are coloured blue. For convenience, cells referring to the AWs/LWSs are shaded olive, cells referring to the SSSI are shaded green, cells referring to the Ramsar site are shaded blue and cells referring to the SACs are shaded purple.

1. The pre-February 2016 value is used.

Table 5. Predicted maximum annual mean ammonia concentration and nitrogen deposition rate at the discrete receptors – preliminary modelling

Receptor number	X(m)	Y(m)	Site	Maximum annual mean ammonia concentration ($\mu g/m^3$)					
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	Sennybridge No Calms No Terrain	Shobdon No Calms No Terrain	Trawscoed No Calms No Terrain
1	303367	261102	Unnamed AW	**1.08**	**1.07**	**1.57**	**2.53**	**1.38**	0.58
2	303507	261061	Unnamed AW	0.96	0.96	1.00	**2.21**	0.96	0.64
3	302916	261156	Unnamed AW	0.39	0.39	0.43	0.22	0.82	0.19
4	303099	261878	Unnamed AW	0.25	0.25	0.25	0.29	0.24	0.83
5	302907	261831	Unnamed AW	0.18	0.18	0.22	0.15	0.22	0.54
6	304019	261953	Unnamed AW	0.27	0.26	0.36	0.38	0.30	0.26
7	303757	262050	Unnamed AW	0.26	0.26	0.29	0.57	0.31	0.43
8	303592	262342	Unnamed AW	0.17	0.17	0.12	0.42	0.18	0.43
9	303305	262298	Unnamed AW	0.17	0.17	0.13	0.38	0.15	0.58
10	302406	261977	Unnamed AW	0.08	0.08	0.09	0.06	0.10	0.21
11	303106	260685	Unnamed AW	0.22	0.21	0.28	0.41	0.26	0.10
12	302324	260651	Unnamed AW	0.09	0.09	0.08	0.08	0.18	0.04
13	303087	260184	Unnamed AW	0.09	0.09	0.09	0.23	0.12	0.05
14	304107	260291	Unnamed AW	0.11	0.11	0.09	0.17	0.14	0.09
15	304394	260325	Unnamed AW	0.10	0.10	0.08	0.16	0.16	0.10
16	304880	260427	Unnamed AW	0.08	0.08	0.10	0.11	0.16	0.10
17	304831	260889	Unnamed AW	0.11	0.11	0.14	0.14	0.24	0.15
18	304709	261297	Unnamed AW	0.16	0.15	0.16	0.19	0.35	0.15
19	304860	261579	Unnamed AW	0.12	0.11	0.11	0.15	0.27	0.10
20	305225	261482	Unnamed AW	0.08	0.08	0.09	0.11	0.20	0.07
21	305278	261224	Unnamed AW	0.08	0.08	0.10	0.10	0.19	0.08
22	305176	260864	Unnamed AW	0.08	0.08	0.11	0.10	0.18	0.10
23	303534	262891	Unnamed AW	0.09	0.09	0.05	0.21	0.08	0.23
24	303159	263085	Unnamed AW	0.06	0.06	0.04	0.14	0.05	0.21
25	303339	263124	Unnamed AW	0.07	0.07	0.04	0.16	0.06	0.20

Table 5. (continued)

Receptor number	X(m)	Y(m)	Site	Maximum annual mean ammonia concentration ($\mu g/m^3$)					
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	Sennybridge No Calms No Terrain	Shobdon No Calms No Terrain	Trawscoed No Calms No Terrain
26	303363	263260	Unnamed AW	0.06	0.06	0.04	0.14	0.06	0.18
27	301648	261584	Unnamed AW	0.05	0.05	0.05	0.02	0.10	0.06
28	301998	260762	Unnamed AW	0.08	0.08	0.06	0.05	0.16	0.03
29	303568	259907	Unnamed AW	0.07	0.07	0.06	0.17	0.07	0.05
30	303830	259489	Unnamed AW	0.05	0.05	0.05	0.10	0.04	0.03
31	305218	262350	Unnamed AW	0.05	0.05	0.06	0.07	0.09	0.05
32	303011	260466	Dwfnant Pasture SSSI	0.14	0.14	0.16	**0.27**	0.17	0.07
33	303178	260407	Dwfnant Pasture SSSI	0.12	0.12	0.13	**0.32**	0.16	0.07
34	302152	260266	Rhos Dwfnant SSSI	0.06	0.06	0.04	0.07	0.11	0.03
35	302361	260007	Rhos Dwfnant SSSI	0.06	0.06	0.05	0.09	0.08	0.03
36	304862	261283	River Ithon SSSI / River Wye SAC	**0.13**	**0.13**	**0.14**	**0.16**	**0.29**	**0.12**
37	304988	260858	River Ithon SSSI / River Wye SAC	**0.10**	**0.09**	**0.13**	**0.11**	**0.21**	**0.13**
38	304796	260382	River Ithon SSSI / River Wye SAC	**0.08**	**0.08**	**0.09**	**0.12**	**0.16**	**0.10**
39	304229	260324	River Ithon SSSI / River Wye SAC	**0.11**	**0.11**	**0.08**	**0.17**	**0.16**	**0.10**
40	303687	259565	River Ithon SSSI / River Wye SAC	**0.05**	**0.05**	**0.05**	**0.12**	**0.05**	0.03
41	303362	258439	River Ithon SSSI / River Wye SAC	0.02	0.02	0.02	**0.06**	0.02	0.01
42	303111	257948	River Ithon SSSI / River Wye SAC	0.02	0.02	0.02	**0.05**	0.02	0.01
43	302019	258006	River Ithon SSSI / River Wye SAC	0.02	0.02	0.02	**0.04**	0.02	0.01
44	302144	257672	River Ithon SSSI / River Wye SAC	0.01	0.01	0.01	0.04	0.02	0.01
45	305146	262108	River Ithon SSSI / River Wye SAC	**0.06**	**0.06**	**0.07**	**0.09**	**0.12**	**0.06**
46	305371	262442	River Ithon SSSI/River Wye SAC	**0.05**	**0.05**	**0.05**	**0.06**	**0.08**	**0.04**
47	305780	262292	River Ithon SSSI/River Wye SAC	0.04	0.04	**0.04**	**0.05**	**0.07**	0.04
48	305763	262834	River Ithon SSSI / River Wye SAC	0.03	0.03	**0.04**	**0.04**	**0.05**	0.03
49	305430	262309	Crabtree Green Meadow SSSI	0.05	0.05	0.05	0.07	0.08	0.05
50	301994	259857	Aberithon And Bedw Turbaries SSSI	0.04	0.04	0.03	0.06	0.07	0.02
51	304537	263117	Moorlands Pastures SSSI	0.05	0.05	0.06	0.08	0.05	0.06
52	304496	263426	Moorlands Pastures SSSI	0.04	0.04	0.05	0.07	0.05	0.05

Table 5. (continued)

Receptor number	X(m)	Y(m)	Site	Maximum annual mean ammonia concentration ($\mu g/m^3$)					
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	Sennybridge No Calms No Terrain	Shobdon No Calms No Terrain	Trawscoed No Calms No Terrain
53	305354	263193	Gweunydd Coch-Y Dwst SSSI	0.03	0.03	0.05	0.05	0.04	0.03
54	306430	261692	Llanfawr Quarries, Llandrindod Wells SSSI	0.03	0.03	0.04	0.05	0.08	0.03
55	307072	261049	Bach-Y-Graig Stream Section SSSI	0.03	0.03	0.03	0.03	0.06	0.03
56	306447	260641	Lake Wood, Llandrindod Wells SSSI	0.03	0.03	0.05	0.04	0.08	0.04
57	306322	260291	Lake Wood, Llandrindod Wells SSSI	0.03	0.03	0.04	0.04	0.07	0.04
58	305888	259807	Pentrosfa More SSSI	0.03	0.03	0.04	0.05	0.07	0.04
59	305738	259615	Pentrosfa More SSSI	0.03	0.03	0.04	0.05	0.06	0.04
60	304004	258873	Rhos Penrhiw SSSI	0.03	0.03	0.03	0.06	0.03	0.02
61	303904	259098	River Ithon SSSI/River Wye SAC	0.04	0.04	0.04	**0.08**	0.03	0.02
62	304871	258915	River Ithon SSSI/River Wye SAC	0.03	0.03	0.03	**0.05**	0.04	0.02
63	305896	258623	River Ithon SSSI/River Wye SAC	0.02	0.02	0.02	0.03	0.03	0.02
64	301477	257572	Aberithon And Bedw Turbaries SSSI	0.01	0.01	0.01	0.03	0.02	0.01
65	306247	263714	Coed Aberdulas SSSI	0.02	0.02	0.03	0.03	0.03	0.02
66	305884	264752	River Ithon SSSI/River Wye SAC	0.01	0.01	0.02	0.02	0.02	0.02
67	304783	265302	River Ithon SSSI/River Wye SAC	0.01	0.01	0.02	0.03	0.02	0.03
68	303582	265878	River Ithon SSSI/River Wye SAC	0.02	0.02	0.01	0.04	0.02	**0.04**
69	302194	266053	River Ithon SSSI/River Wye SAC	0.01	0.01	0.01	0.03	0.01	**0.04**
70	300881	260912	River Wye SSSI/SAC	0.04	0.04	0.03	0.02	**0.08**	0.02
71	301256	259949	River Wye SSSI/SAC	0.03	0.03	0.02	0.03	**0.06**	0.01
72	301556	259123	River Wye SSSI/SAC	0.03	0.03	0.02	0.04	0.04	0.01
73	301519	258048	River Wye SSSI/SAC	0.02	0.02	0.02	0.03	0.02	0.01
74	300568	261600	River Wye SSSI/SAC	0.03	0.03	0.02	0.01	**0.05**	0.03
75	300068	262225	River Wye SSSI/SAC	0.02	0.02	0.01	0.01	0.03	0.03
76	299555	262776	River Wye SSSI/SAC	0.01	0.01	0.01	0.01	0.02	0.02

Table 5. (continued)

Receptor number	X(m)	Y(m)	Site	Maximum annual mean ammonia concentration ($\mu g/m^3$)					
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	Sennybridge No Calms No Terrain	Shobdon No Calms No Terrain	Trawscoed No Calms No Terrain
77	308279	261506	River Ithon SSSI/River Wye SAC	0.02	0.02	0.01	0.02	**0.04**	0.02
78	306141	256758	River Wye SAC	0.01	0.01	0.01	0.02	0.02	0.01
79	301070	256758	River Wye SAC	0.01	0.01	0.01	0.02	0.01	0.01
80	297589	257941	River Wye SAC	0.01	0.01	0.01	0.01	0.02	0.00
81	297859	263350	River Wye SAC	0.01	0.01	0.00	0.00	0.01	0.01
82	307628	264871	River Wye SAC	0.01	0.01	0.02	0.01	0.02	0.01
83	307899	267677	River Wye SAC	0.01	0.01	0.01	0.01	0.01	0.01
84	307392	269570	River Wye SAC	0.00	0.00	0.00	0.01	0.01	0.01
85	297859	267170	River Wye SAC	0.00	0.00	0.00	0.00	0.00	0.01
86	310333	265784	River Wye SAC	0.01	0.01	0.01	0.01	0.01	0.01
87	308845	263553	River Wye SAC	0.01	0.01	0.01	0.01	0.02	0.01
88	311009	262978	River Wye SAC	0.01	0.01	0.01	0.01	0.02	0.01
89	311617	257164	River Wye SAC	0.01	0.01	0.00	0.01	0.01	0.01
90	303504	255136	River Wye SAC	0.01	0.01	0.01	0.02	0.01	0.00
91	301375	253716	River Wye SAC	0.00	0.00	0.01	0.01	0.01	0.00
92	297183	256961	River Wye SAC	0.01	0.01	0.00	0.01	0.01	0.00
93	298467	254257	River Wye SAC	0.01	0.01	0.01	0.01	0.01	0.00
94	304823	251857	River Wye SAC	0.00	0.00	0.00	0.01	0.00	0.00
95	295662	263282	Elan Valley Woodlands SAC	0.00	0.01	0.00	0.00	0.01	0.01
96	296000	265175	Elan Valley Woodlands SAC/Elenydd - Mallaen SPA	0.00	0.00	0.00	0.00	0.01	0.01
97	295425	263958	Elan Valley Woodlands SAC/Elenydd - Mallaen SPA	0.00	0.00	0.00	0.00	0.01	0.01
98	294512	263620	Elan Valley Woodlands SAC/Elenydd - Mallaen SPA	0.00	0.00	0.00	0.00	0.01	0.01
99	295662	261964	Elenydd SAC/Elenydd - Mallaen SPA	0.01	0.01	0.00	0.00	0.01	0.01
100	296845	264939	Elenydd - Mallaen SPA	0.00	0.00	0.01	0.00	0.01	0.01
101	295901	264439	Elenydd - Mallaen SPA	0.00	0.00	0.01	0.00	0.01	0.01
102	294807	263513	Elenydd - Mallaen SPA	0.00	0.00	0.00	0.00	0.01	0.01
103	294246	263738	Elenydd - Mallaen SPA	0.00	0.00	0.00	0.00	0.01	0.01

5.2 Detailed modelling

The detailed modelling, which includes nitrogen deposition and plume depletion, was carried out over a restricted domain covering the poultry unit at Cerrigcroes, the closest AW and the closer receptors of the River Wye SAC, which are areas where the preliminary modelling indicated that annual mean ammonia concentrations could potentially exceed 100% of the Critical Level or Critical Load for the AW, or 4% of the Critical Level or Critical Load for the SAC. At the other wildlife sites, the preliminary modelling indicated that ammonia levels (and nitrogen deposition rates) would be below the Environment Agency's lower threshold percentage of Critical Level/Load for the designation of the site.

Terrain effects are likely to be significant; therefore, the detailed deposition run was made with terrain. Calms cannot be used with terrain or spatially varying deposition; however, the results of the preliminary modelling indicate that the effect of calms upon the modelling is not significant.

The predicted maximum annual mean ground level ammonia concentrations and nitrogen deposition rates at the discrete receptors within the detailed modelling domain are shown in Table 6. In the Table, predicted ammonia concentrations or nitrogen deposition rates that are in excess of the Environment Agency's upper threshold (20% of Critical Level or Load for a SAC/SPA/Ramsar site, 50% of Critical Level or Load for a SSSI and 100% of Critical Level or Load for a non-statutory wildlife site) are coloured red. Concentrations or deposition rates in the range between the Environment Agency's lower and upper threshold (4% and 20% for a SAC/SPA/Ramsar site, 20% and 50% for a SSSI and 50%[1] and 100% for a non-statutory wildlife site) are coloured blue. The abbreviations PC, CLe and CLo, used in the table mean Process Contribution, Critical Level and Critical Load, respectively. Note that a precautionary deposition velocity of 0.03 m/s has been used to derive nitrogen deposition rates.

A contour plot of the predicted ground level maximum annual mean ammonia concentration is shown in Figure 6a and a contour plot of the maximum nitrogen deposition rate is shown in Figure 6b.

1. The pre-February 2016 value is used.

Table 6. Predicted maximum annual mean ammonia concentration and nitrogen deposition rate at the discrete receptors – detailed modelling

Receptor number	X (m)	Y (m)	Site	Maximum annual ammonia concentration			Maximum nitrogen deposition rate		
				Critical Level (µg/m³)	Maximum annual PC (ug/m3)	%age of CLe	Critical Load (kg/ha)	Maximum annual PC (kg/ha)	%age of CLo
1	303367	261102	Unnamed AW	1.0	0.629	**62.9**	10.0	4.901	49.0
2	303507	261061	Unnamed AW	1.0	0.333	33.3	10.0	2.597	26.0
36	304862	261283	River Ithon SSSI / River Wye SAC	1.0	0.049	**4.9**	10.0	0.384	3.8
37	304988	260858	River Ithon SSSI / River Wye SAC	1.0	0.037	3.7	10.0	0.285	2.8
38	304796	260382	River Ithon SSSI / River Wye SAC	1.0	0.026	2.6	10.0	0.203	2.0
39	304229	260324	River Ithon SSSI / River Wye SAC	1.0	0.028	2.8	10.0	0.218	2.2
40	303687	259565	River Ithon SSSI / River Wye SAC	1.0	0.010	1.0	10.0	0.080	0.8
45	305146	262108	River Ithon SSSI / River Wye SAC	1.0	0.039	3.9	10.0	0.303	3.0
46	305371	262442	River Ithon SSSI/ /River Wye SAC	1.0	0.028	2.8	10.0	0.216	2.2
47	305780	262292	River Ithon SSSI/River Wye SAC	1.0	0.018	1.8	10.0	0.139	1.4
48	305763	262834	River Ithon SSSI / River Wye SAC	1.0	0.019	1.9	10.0	0.149	1.5
61	303904	259098	River Ithon SSSI/River Wye SAC	1.0	0.007	0.7	10.0	0.051	0.5

Figure 6a. Maximum annual ammonia concentration

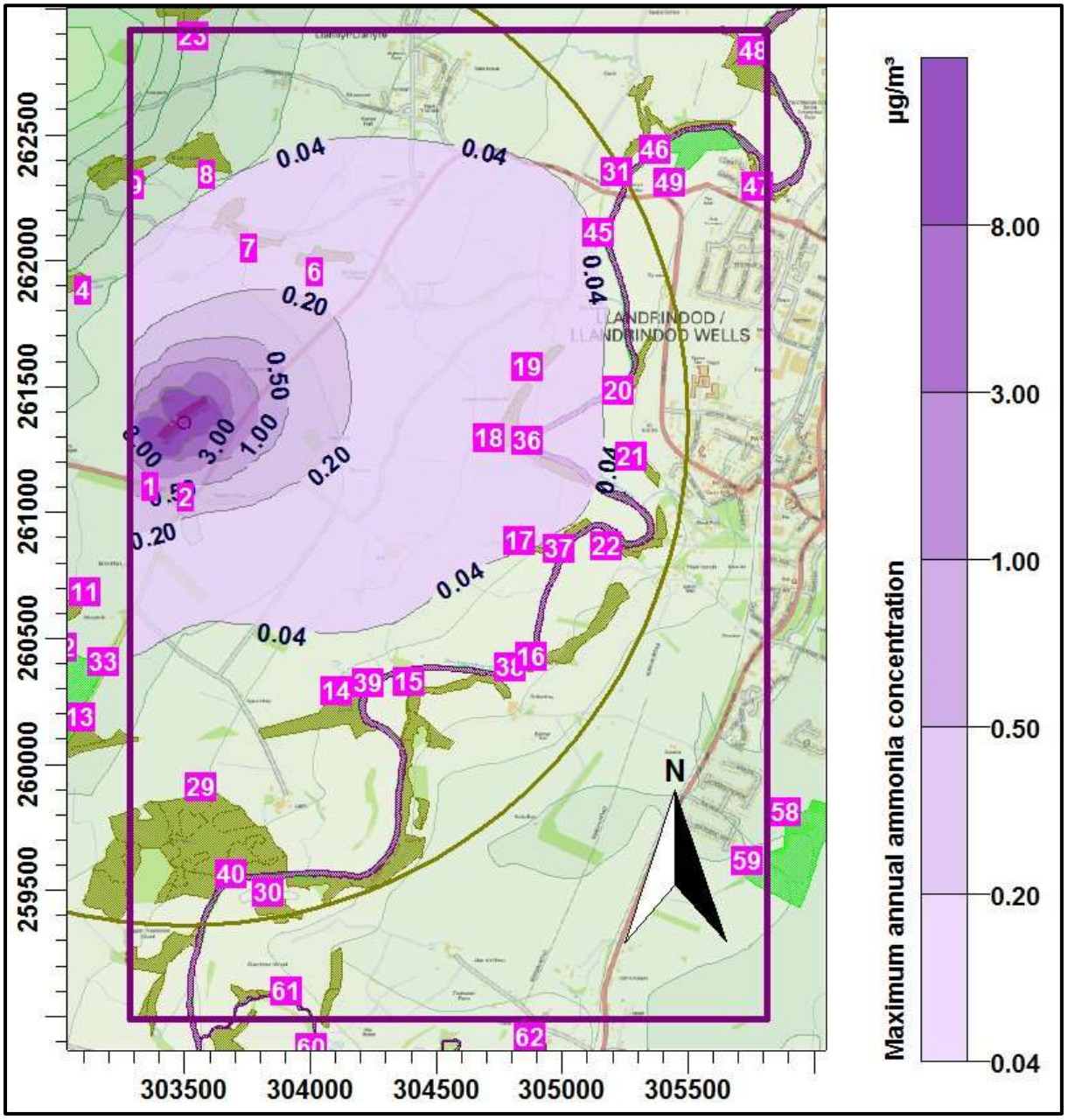
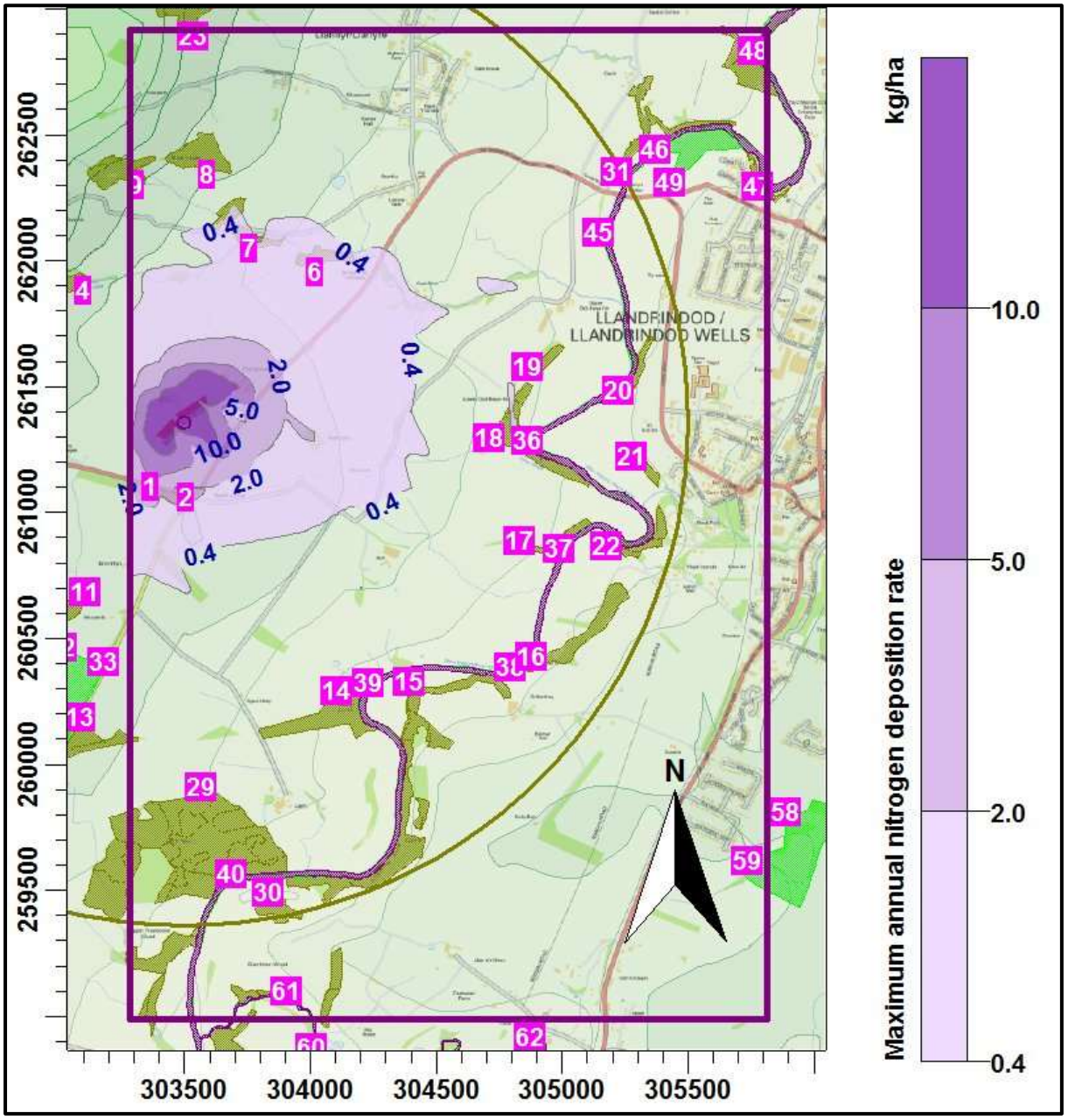


Figure 6b. Maximum annual nitrogen deposition rate



6 Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Steve Raasch on behalf of Ross Abberley of A.J. Abberley, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed free range egg laying chicken houses at Cerrigcroes, Lanyre, near Llandrindod Wells in Powys. LD1 6EU.

Ammonia emission rates from the existing and proposed poultry houses have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors. The ammonia emission rates have then been used as inputs to an atmospheric dispersion and deposition model which calculates ammonia exposure levels and nitrogen deposition rates in the surrounding area.

The preliminary modelling predicts that at the closest Ancient Woodland (AW) and receptors along the River Wye Special Area of Conservation (SAC) there would potentially be exceedances of the Environment Agency's lower threshold percentage of the Critical Level or Load (100% for an AW, or 4% for SACs); therefore, detailed modelling was required for this AW and these parts of the SAC. At all other receptors considered, the preliminary modelling predicted that the process contribution to ammonia concentration and nitrogen deposition rates would be below the Environment Agency's lower threshold percentage of the Critical Level or Load.

The detailed modelling predicts that, at most of the receptors considered, the process contributions to ammonia concentrations and nitrogen deposition rates would be below the Environment Agency's lower threshold percentage of the Critical Level or Critical Load (100% for an AW, 4% for an SAC). However, the modelling predicts that the process contribution to ammonia concentrations at one receptor, located at the River Wye SAC, would exceed the Environment Agency's lower threshold, 4% of the Critical Level. This exceedance is predicted to impact a stretch of the River Wye SAC that is approximately 675 m long.

It should be noted that the Critical Level for the River Wye SAC is precautionary and only relevant where lichens or bryophytes sensitive to ammonia concentrations are presents. Should it be determined that these species are not present then a less strict Critical Load may be adopted.

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