A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Proposed Broiler Chicken Rearing Houses at Cwmafan, Llanafan-Fawr, near to Builth Wells in Powys

Prepared by Phil Edgington

AS Modelling & Data Ltd.

Email: philedgington@asmodata.co.uk

Telephone: 01952 462500

9th April 2019

1. Introduction

AS Modelling & Data Ltd. has been instructed by Gerallt Davies, of Roger Parry & Partners LLP, on behalf of Lyndon Jones, to use computer modelling to assess the impact of ammonia emissions from the proposed broiler chicken rearing houses at Cwmafan, Lanafan-Fawr, near to Builth Wells, in Powys. LD2 3PF.

Ammonia emission rates from the 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 and acid 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

The farmstead at Cwmafan is in a rural area approximately 650 m to the south-west of the small village of Llanafan-Fawr, near to Builth Wells in Powys. The farm is at an elevation of approximately 260 m, with the land rising to Lan Dwpa at a height of 378 m to the north-west, above the Nant yr Esgob, which is to the south and flows eastward into the River Chwefri. The surrounding land is predominantly pasture and there are wooded areas nearby.

Under the proposal, two new poultry houses would be constructed on a green-field site to the north of the existing farm buildings at Cwmafan. These proposed poultry houses would provide accommodation for up to 100,000 broiler chickens and would be ventilated using uncapped high speed ridge mounted fans, each with a short chimney. The chickens would be reared from day old chicks to up to around 38 days old and there would be approximately 7.5 crops per year.

There are numerous areas of Ancient Woodlands (AWs) within 2 km of Cwmafan and there are also seven Sites of Special Scientific Interest (SSSIs) within 5 km. Further afield, there are stretches of the River Irfon SSSI and Upper Wye Tributaries SSSI, constituent components of the River Wye Special Area of Conservation (SAC) and Elenydd/Elenydd – Mallean Special Protection Area (SPA) within 10 km of the proposed poultry houses.

A broad scale map of the surrounding area showing the positions of the proposed poultry houses at Cwmafan, the AWs, the SSSIs, the SPA and the SAC is provided in Figure 1a and a closer view of the nearby designations is provided in Figure 1b. In the figures, the AWs are shaded in olive, the SSSIs are shaded in green, the SPA is shaded orange, the SAC is shaded in purple and the position of the proposed poultry houses is indicated by a blue rectangle.

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

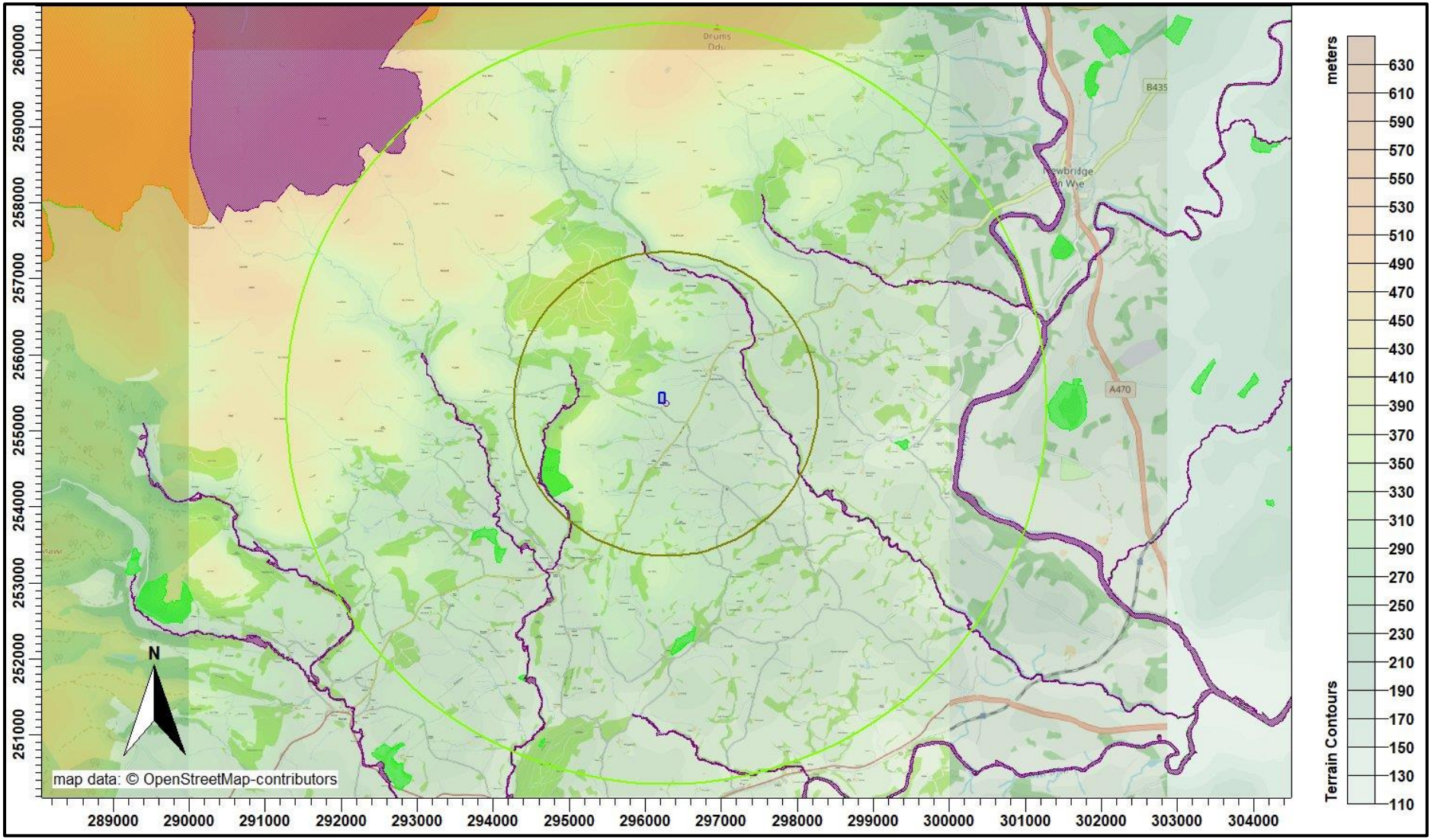
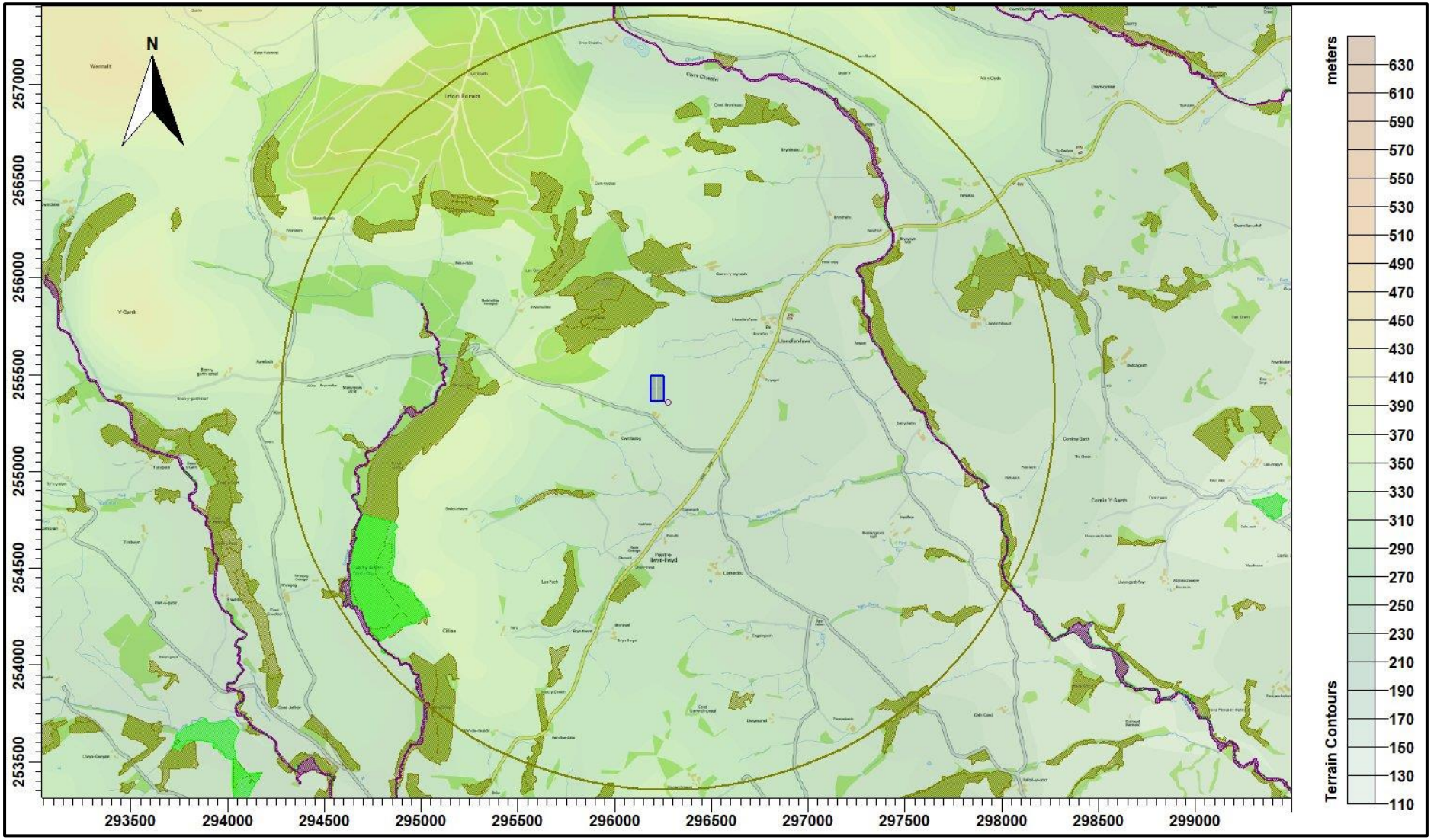


Figure 1b. The area surrounding Cwmafan, a closer view – concentric circle radius 2 km (olive)



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 Cwmafan is 0.79 $\mu g\text{-}NH_3/m^3$. The background nitrogen deposition rate to woodland is 25.34 kg-N/ha/y and to short vegetation is 16.24 kg-N/ha/y. The background acid deposition rate to woodland is 1.97 keq/ha/y and to short vegetation is 1.30 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS, January 2019).

3.3 Critical Levels and 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. Note that the citation for Garth Bank Quarry SSSI indicates that this site is designated due to geological reasons; it has therefore not been considered further. 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. Normally, the Critical Load for nitrogen deposition provides a stricter test than 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)	Critical Load - Acid Deposition (keq/ha/y)
AWs	1.0 [1]	10.0	-
Coed Y Ciliau SSSI	1.0 [1]	5.0 [3]	-
River Irfon SSSI, Caeau Llwyn Gwrgan SSSI	1.0 [1]	8.0 [3]	-
Cae Comin Coch SSSI	3.0 [2]	8.0 [3]	-
Tyncoed Pasture SSSI, Cors Y Llyn SSSI	1.0 [1]	10.0 [3]	-
Upper Wye Tributaries SSSI	3.0 [2]	10.0 [3]	-
River Wye SAC, Elenydd – Mallean SPA	1.0 [1]	10.0 [3]	-
Elenydd SAC/SSSI	1.0 [1]	3.0 [3]	-

1. A precautionary figure, used where details of the site are unavailable, or citations indicate that sensitive lichens and bryophytes may be present.
2. Based on the SSSI citation.
3. APIS (January, 2019).

3.4 Guidance on the Significance of Ammonia Emissions

In March 2017, Natural Resources Wales (Regulation and Permitting Department, EPP) published Operational Guidance Note 41 (OGN 41), "Assessment of ammonia and nitrogen impacts from livestock units when applying for an Environmental Permit or Planning Permission". This guidance was intended to update the way Natural Resources Wales (NRW) assessed emissions, in particular by changing the thresholds of insignificance and the upper threshold process contributions for designated sites. These designated sites include European sites, such as Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Ramsar sites as well as Sites of Special Scientific Interest (SSSIs).

Table 1 in OGN 41 describes the revised screening distance and thresholds for livestock developments; the threshold of insignificant percentage of the designated site Critical Level or Load is given as 1%; the upper threshold percentage of the designated site Critical Level or Load is given as 8%.

Table 2 in OGN 41 describes the possible outcomes of assessment and for detailed modelling of the application alone, where process contributions, considered in isolation, are up to 1% of the designated site Critical Level or Load, then it should be determined that there is no significant environmental effect/no likely significant effect/damage to scientific interest.

Where process contributions, considered in isolation, are between 1% and 8% of the designated site Critical Level or Load, an in-combination assessment is required. Should the in-combination process contributions be between 1% and 8% of the designated site Critical Level or Load then it should be determined that the application would cause no significant environmental effect/likely significant effect/damage to scientific interest.

When considering process contributions in isolation or in-combination, if they exceed 1% of the designated site Critical Level or Load it is necessary to consider background concentrations and whether the designated site Critical Level or Load is breached and whether additional controls may be necessary. The application will then be determined based on whether there will be significant environmental effect/adverse effect/damage to scientific interest.

For Local Nature Reserves (LNRs), Local Wildlife Sites (LWSs) and Ancient Woodlands (AWs), the current assessment procedure still applies, namely the Environment Agency's horizontal guidance, H1 Environmental Risks Assessment, H1 Annex B - Intensive Farming. The following are taken from this document.

"An emission is insignificant where Process Contribution (PC) is <50% for local and national nature reserves (LNRs & NNRs), ancient woodland and local wildlife sites." And "Where modelling predicts a process contribution >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.

Within the range between the lower and upper thresholds, whether or not the impact is deemed acceptable is at the discretion of the Environment Agency. 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 IAQM Position Statement on the use of the 1% criterion

A Position Statement issued by the Institute of Air Quality Management (IAQM) in January 2016 further clarifies the use of the 1% criterion for the determination of an '*insignificant*' effect of air quality impacts on sensitive habitats. The Position Statement states: "*the use of a criterion of 1% of an environmental standard or assessment level in the context of habitats should be used only to screen out impacts that will have an insignificant effect. It should not be used as a threshold above which damage is implied*". Furthermore, if the impacts are plainly above 1% then this should be regarded as potentially significant; where impacts are just slightly greater than 1% then a degree of professional judgement should be applied with regards to the theoretical risk.

3.6 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 and nitrogen deposition are framed in terms of an annual mean ammonia concentration and annual nitrogen 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 provided an Intensive farming guidance note which lists standard ammonia emission factors for a variety of livestock, including broiler chickens. The emission factor for broiler chickens is 0.034 kg-NH_3/bird place/y; this figure is used to calculate the emissions from the proposed poultry houses.

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

Source	Animal numbers	Type or weight	Emission factor (kg-NH_3/place/y)	Emission rate (g-NH_3/s)
Proposed Housing	100,000	Broiler Chickens	0.034	0.107739

4. The Atmospheric Dispersion Modelling System (ADMS) and model parameters

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

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

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

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

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

4.1 Meteorological data

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

The meteorological data used in this study is obtained from assimilation and short term forecast fields of the Numerical Weather Prediction (NWP) system known as the Global Forecast System (GFS). Observational meteorological data from Sennybridge have also been considered.

The GFS is a spectral model: the physics/dynamics model has an equivalent resolution of approximately 13 km (latterly 9km); terrain is understood to be resolved at a resolution of approximately 2 km (with sub-13 km terrain effects parameterised) and data are archived at a resolution of 0.25 degrees. Site specific data may be extrapolated from nearby archive grid points or a most representative grid point chosen. The GFS resolution adequately captures major topographical features and the broad-scale characteristics of the weather over the UK. Smaller scale topological features may be included in the dispersion modelling by using the flow field module of ADMS (FLOWSTAR). The use of NWP data has advantages over traditional meteorological records because:

- Calm periods in traditional records may be over represented, this is because the instrumentation used may not record wind speed below approximately 0.5 m/s and start up wind speeds may be greater than 1.0 m/s. In NWP data, the wind speed is continuous down to 0.0 m/s, allowing the calms module of ADMS to function correctly.

- Traditional records may include very local deviations from the broad-scale wind flow that would not necessarily be representative of the site being modelled; these deviations are difficult to identify and remove from a meteorological record. Conversely, local effects at the site being modelled are relatively easy to impose on the broad-scale flow and provided horizontal resolution is not too great, the meteorological records from NWP data may be expected to represent well the broad-scale flow.

- Information on the state of the atmosphere above ground level which would otherwise be estimated by the meteorological pre-processor may be included explicitly.

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

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 modified. The terrain and roughness length modified wind rose for Cwmafan 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 terrain runs is approximately 300 m for the preliminary modelling runs and approximately 150 m for the detailed modelling runs. Please also note that FLOWSTAR is used to obtain a local flow field, not to explicitly model dispersion in complex terrain as defined in the ADMS User Guide; therefore, the ADMS default value for minimum turbulence length has been amended.

Data from the meteorological recording station at Sennybridge have also been considered. However, Sennybridge does not have an aspect that in any way could be considered similar to Cwmafan; therefore, it should be noted that the frequency of winds from a particular direction in the Sennybridge data may be either high or low in comparison to what might occur at Cwmafan, 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. The wind rose for Sennybridge is shown in Figure 2c.

Figure 2a. The wind rose. Raw GFS derived data, for 52.187 N, 3.518 W, 2014 – 2017

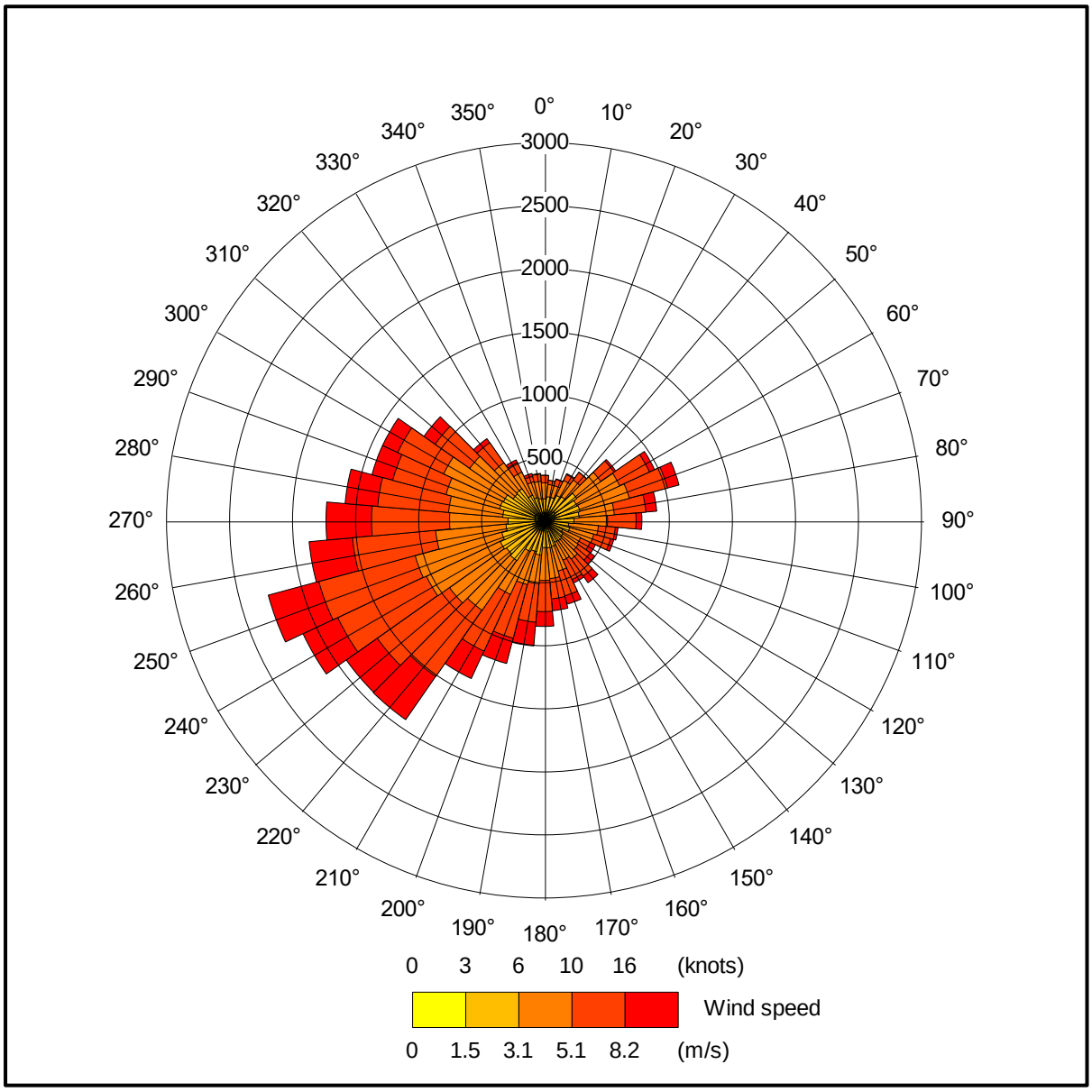


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 296300, 255360, 2014-2017

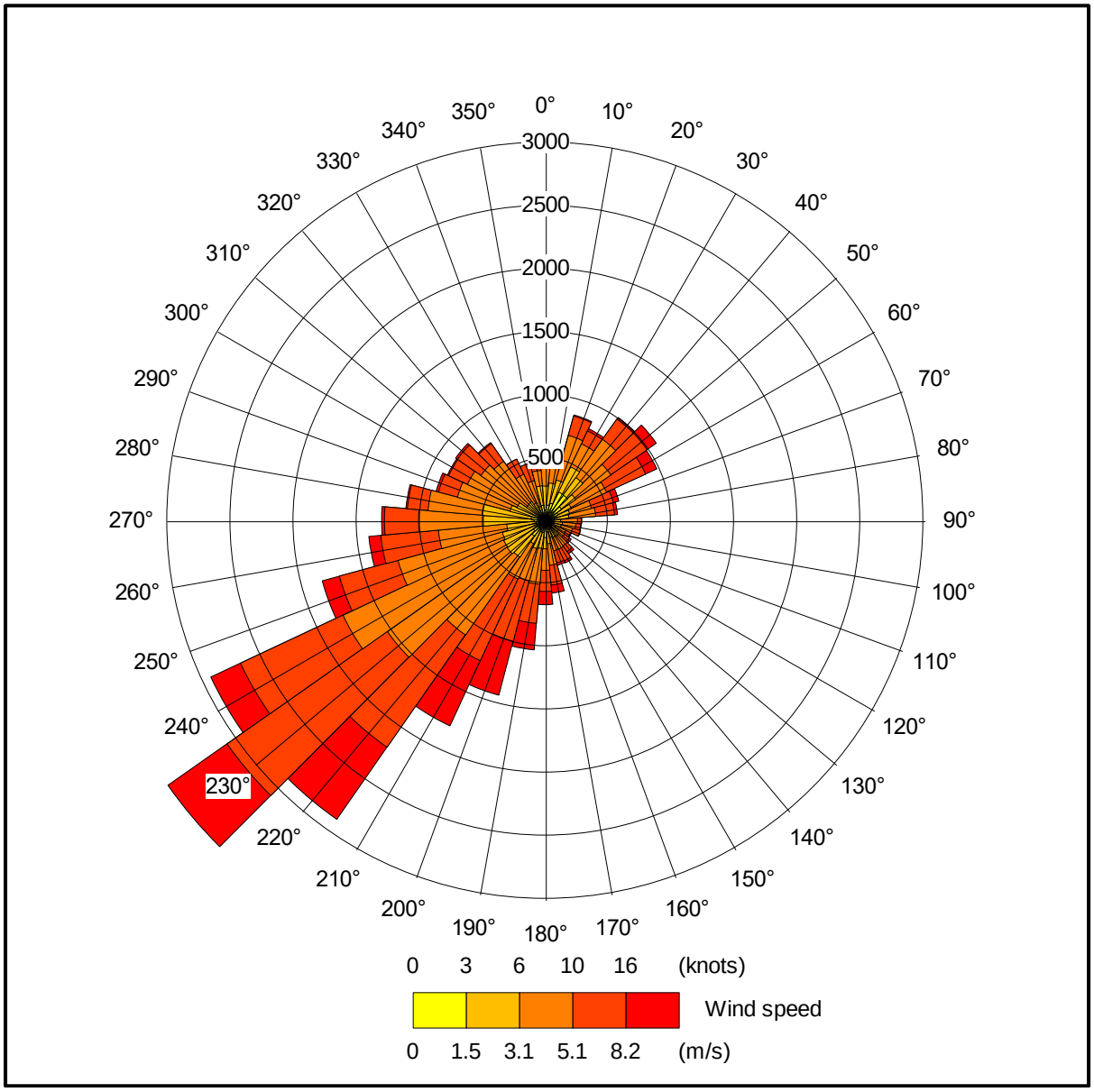
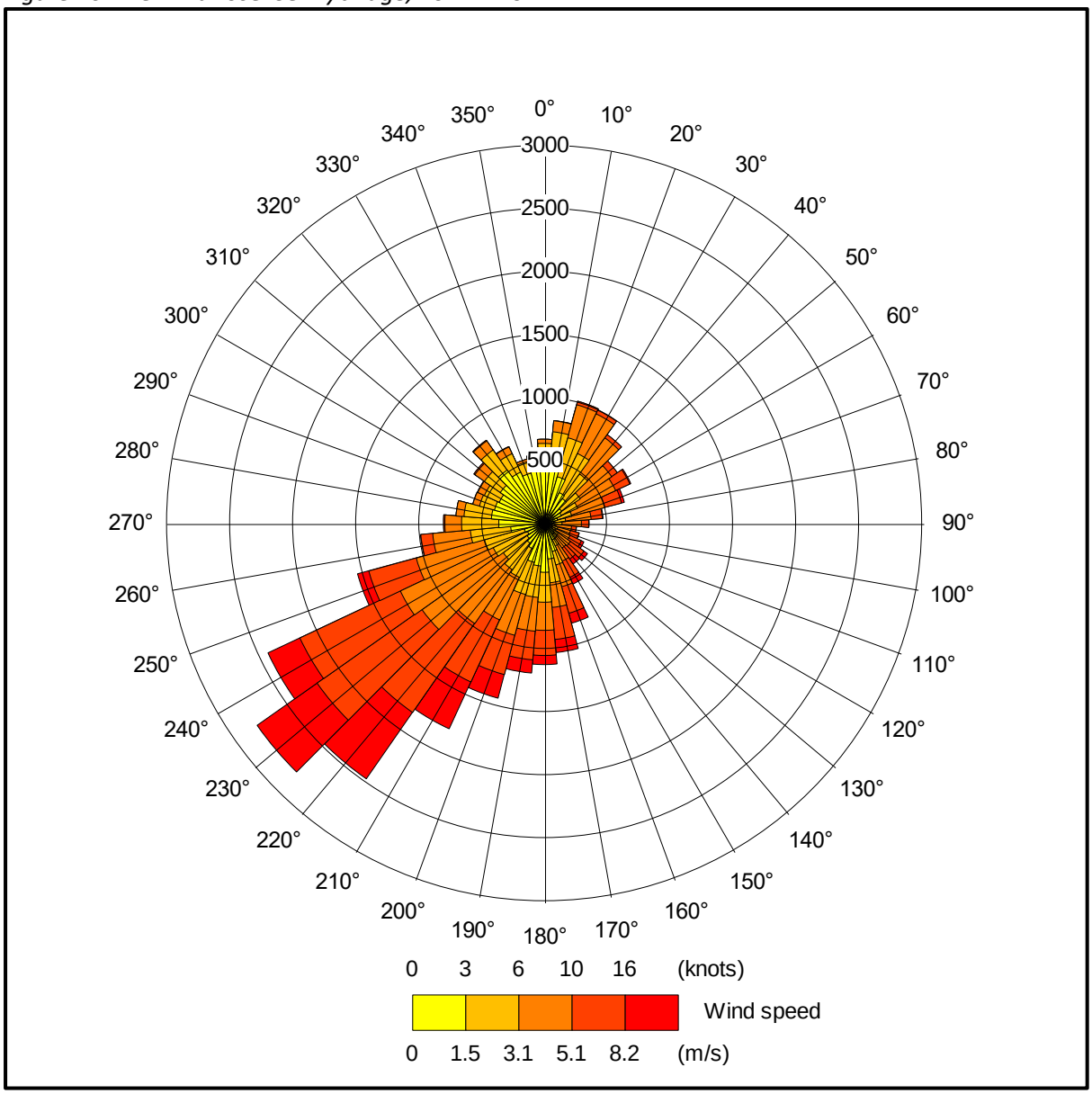


Figure 2c. The wind rose. Sennybridge, 2014 – 2017



4.2 Emission sources

Emissions from the chimneys of the high speed ridge fans that would be used to ventilate the proposed poultry houses are represented by three point sources per house within ADMS (PR1 and PR2; a, b & c). Details of the point source parameters are shown in Table 3. The positions of the sources may be seen in Figure 3.

Table 3. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source (g-NH_3/s)
PR1 & PR2; a, b & c	5.5	0.92	12.0	21.0	0.017957

4.3 Modelled buildings

The structure of the proposed poultry houses may affect the odour plumes from the point sources. Therefore, the 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

Ninety discrete receptors have been defined: fifty-one at the AWs (1 to 51), ten at the SSSIs (52 to 61) and twenty-nine at the SAC/SPA (62 to 90). These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figures 4a and 4b, 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 fields used in the detailed modelling, 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.

4.6 Terrain data

Terrain has been considered in the modelling. The terrain data are based upon the Ordnance Survey 50 m Digital Elevation Model. A 20.0 km x 20.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS for the preliminary modelling and a 10.0 km x 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 64 x 64 grid points; therefore, the effective resolution of the wind field for the terrain runs is approximately 300 m for the preliminary modelling runs and approximately 150 m for the detailed modelling runs.

Figure 3. The positions of modelled buildings and sources

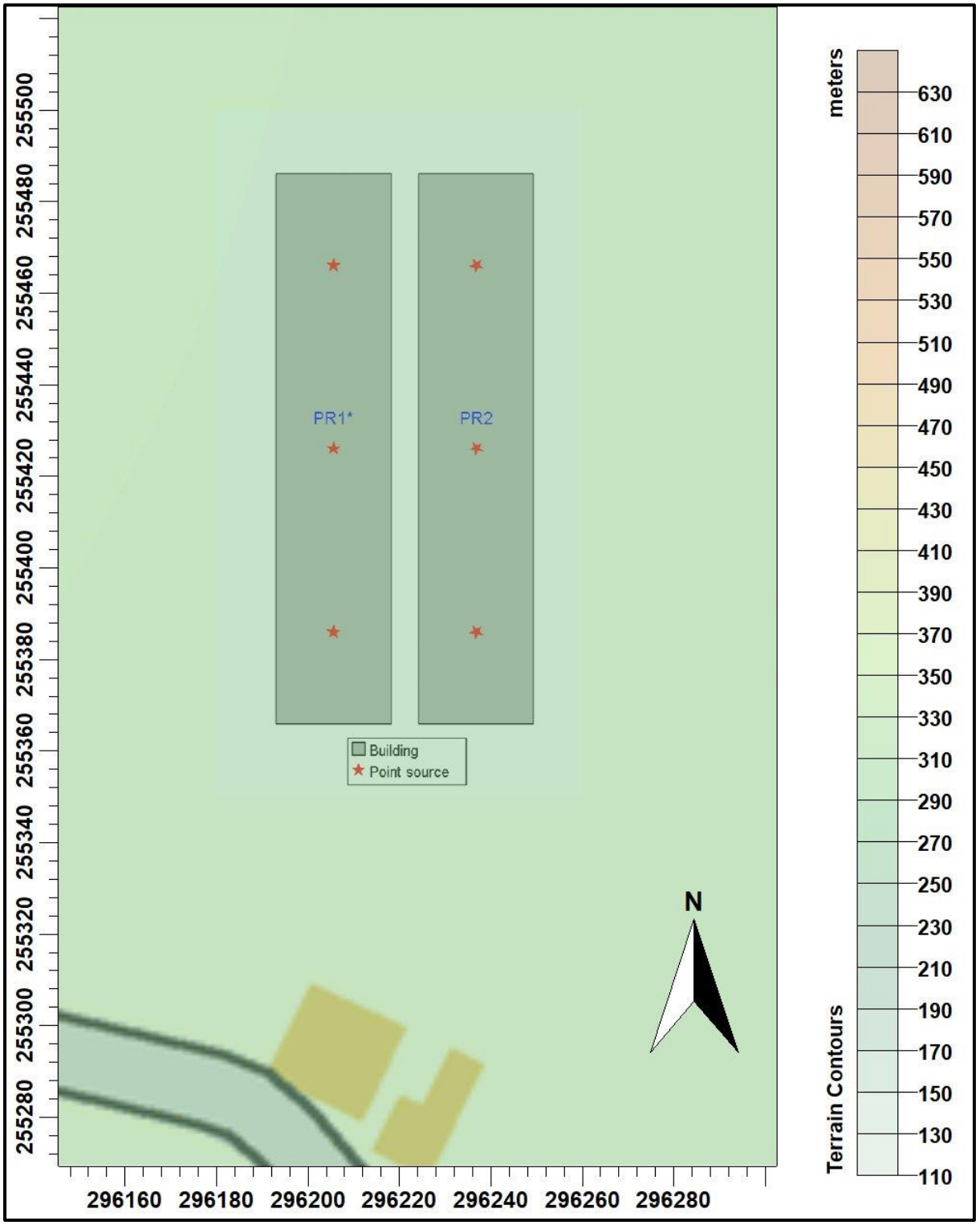


Figure 4a. The discrete receptors

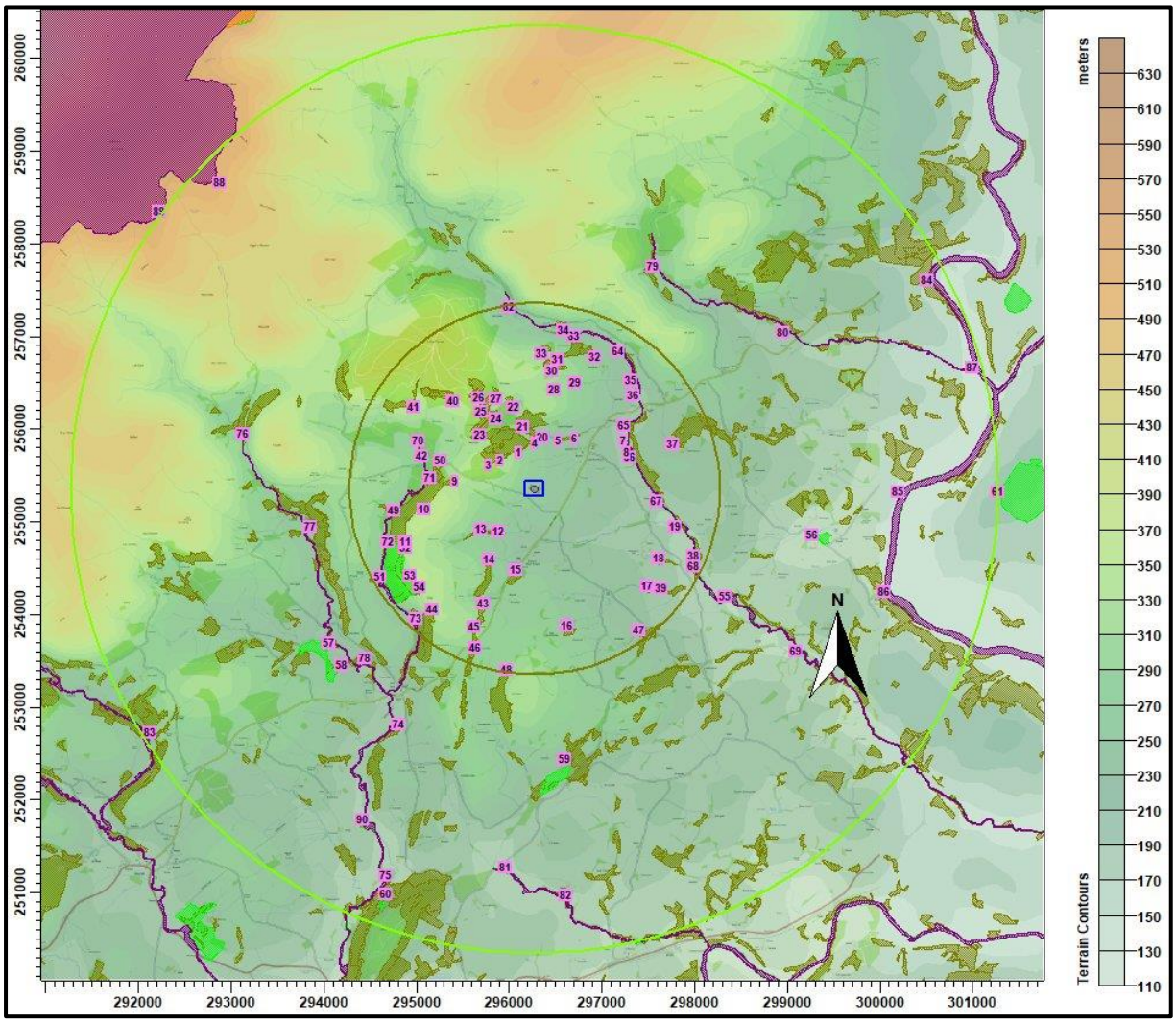
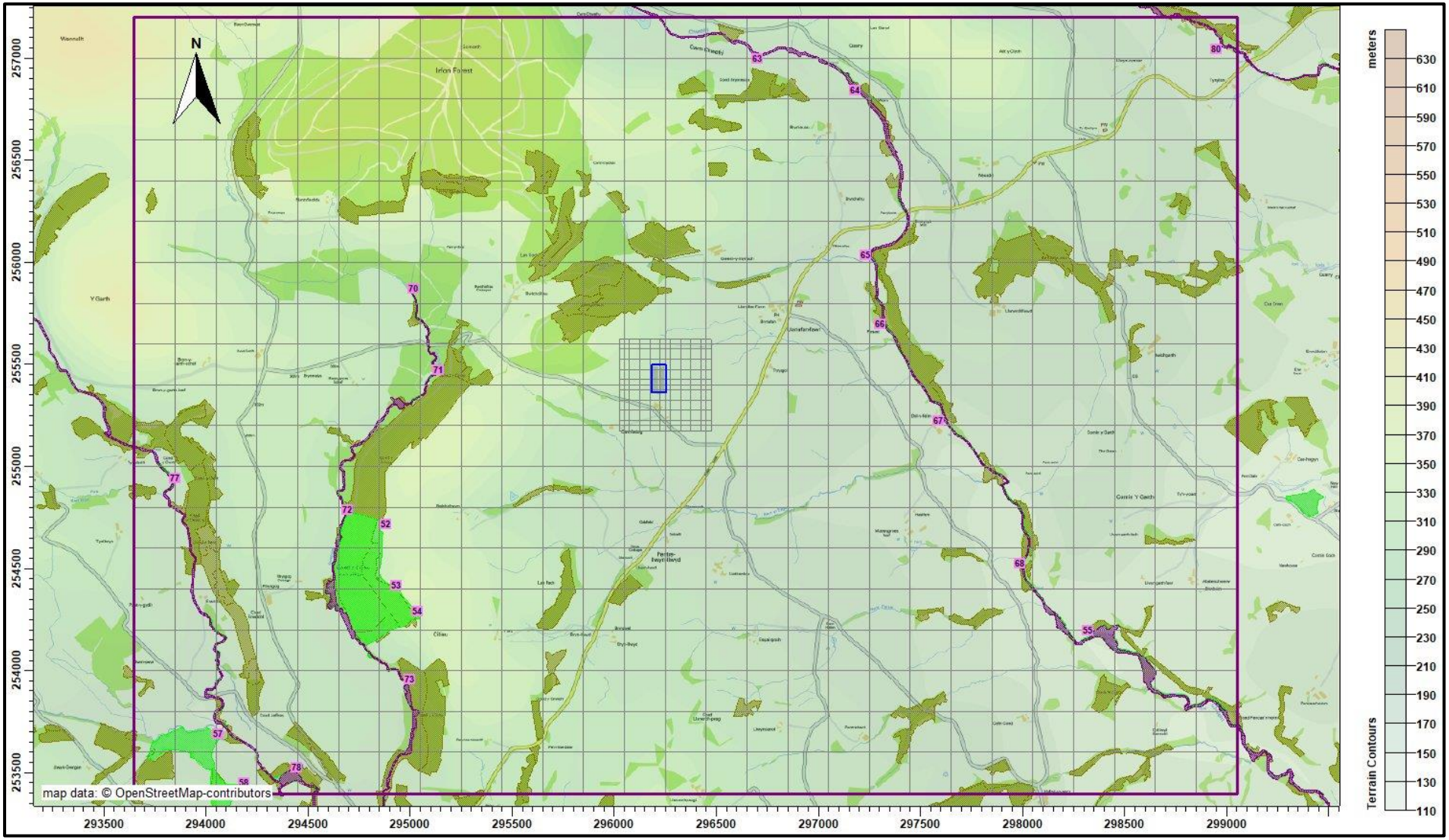


Figure 4b. The discrete receptors and regular Cartesian grid used in the detailed modelling



4.7 Roughness Length

A fixed surface roughness length of 0.35 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 0.325 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.

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. N.B deposition to water surfaces is calculated assuming a deposition velocity of 0.005 m/s.

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.

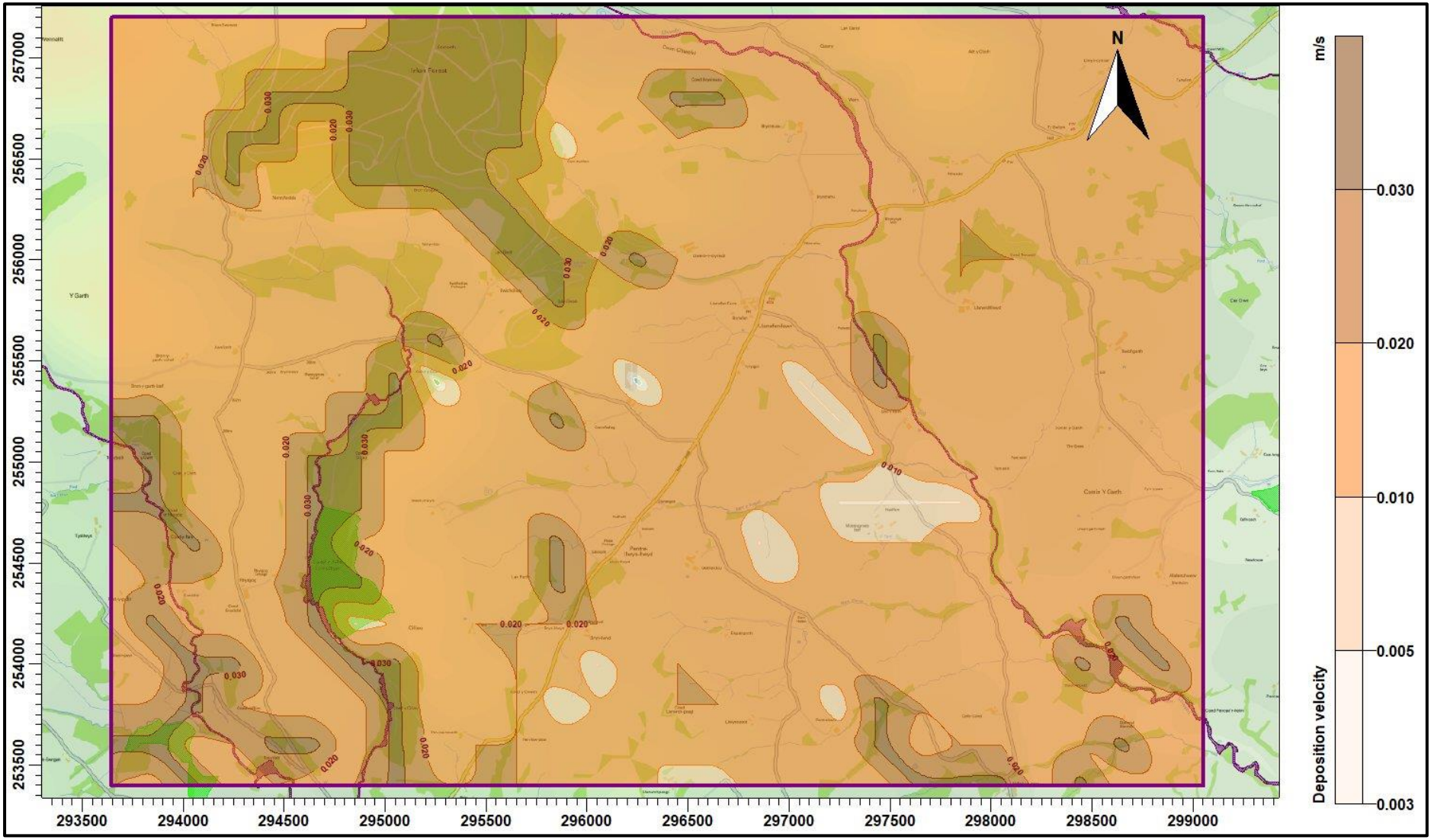
Table 4. Deposition velocities

NH_3 concentration (PC + background) (µg/m³)	< 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 and model sensitivity tests

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

- In basic mode without calms, or terrain – GFS data.
- With calms and without terrain – GFS data.
- Without calms and with terrain – GFS data.
- Without calms and with terrain – GFS data with a fixed deposition at 0.003 m/s.
- In basic mode without calms, or terrain – Sennybridge data.

For each mode, statistics for the maximum annual mean ammonia concentration at each receptor were compiled.

Details of the predicted annual mean ammonia concentrations at each receptor are provided in Table 5. In the Table, predicted ammonia concentrations (or those equivalent to a nitrogen deposition rate) that are in excess of the Natural Resources Wales upper threshold (8% of Critical Level or Load for a SAC/SPA/SSSI and 100% of a Critical Level or Load for an AW) are coloured red. Concentrations (or those equivalent to a nitrogen deposition rate) in the range between the Natural Resources Wales upper threshold and lower threshold (1% to 8% for a SAC/SPA/SSSI and 50%[1] to 100% for an AW) are coloured blue. For convenience, cells referring to the AWs are shaded olive, cells referring to the SSSIs are shaded green and cells referring to the SAC/SPA/SSSIs are shaded purple.

1. The 2016 figure has been retained

Table 5. Predicted maximum annual mean ammonia concentration at the discrete receptors - preliminary modelling

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m^3)				
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s	Sennybridge No Calms No Terrain
1	296099	255744	Unnamed AW	0.173	0.172	0.135	0.129	0.164
2	295896	255654	Unnamed AW	0.098	0.097	0.070	0.061	0.072
3	295779	255607	Unnamed AW	0.091	0.090	0.071	0.062	0.050
4	296280	255853	Unnamed AW	0.155	0.154	0.157	0.151	0.213
5	296522	255874	Unnamed AW	0.179	0.177	0.152	0.146	0.248
6	296701	255902	Unnamed AW	0.148	0.146	0.145	0.139	0.197
7	297228	255867	Unnamed AW	0.074	0.074	0.110	0.103	0.089
8	297271	255753	Unnamed AW	0.074	0.074	0.087	0.081	0.078
9	295408	255433	Unnamed AW	0.056	0.055	0.050	0.045	0.034
10	295077	255138	Unnamed AW	0.041	0.041	0.044	0.036	0.028
11	294884	254786	Unnamed AW	0.031	0.031	0.037	0.029	0.027
12	295882	254897	Unnamed AW	0.059	0.059	0.074	0.069	0.132
13	295697	254915	Unnamed AW	0.063	0.062	0.068	0.062	0.095
14	295787	254600	Unnamed AW	0.031	0.031	0.034	0.030	0.075
15	296073	254483	Unnamed AW	0.026	0.026	0.017	0.016	0.059
16	296626	253877	Unnamed AW	0.011	0.011	0.016	0.011	0.016
17	297484	254306	Unnamed AW	0.028	0.028	0.017	0.016	0.022
18	297610	254607	Unnamed AW	0.035	0.035	0.026	0.023	0.021
19	297785	254947	Unnamed AW	0.037	0.037	0.043	0.036	0.025
20	296360	255905	Unnamed AW	0.137	0.136	0.121	0.116	0.201
21	296150	256021	Unnamed AW	0.085	0.085	0.070	0.067	0.110
22	296041	256234	Unnamed AW	0.048	0.048	0.036	0.033	0.068
23	295688	255940	Unnamed AW	0.037	0.037	0.050	0.042	0.028
24	295856	256105	Unnamed AW	0.046	0.045	0.045	0.039	0.043
25	295692	256189	Unnamed AW	0.033	0.033	0.027	0.022	0.025
26	295671	256332	Unnamed AW	0.029	0.029	0.020	0.016	0.025
27	295853	256322	Unnamed AW	0.033	0.033	0.029	0.024	0.042
28	296486	256420	Unnamed AW	0.042	0.042	0.020	0.018	0.074
29	296709	256496	Unnamed AW	0.041	0.040	0.025	0.023	0.066
30	296459	256630	Unnamed AW	0.032	0.032	0.017	0.015	0.058
31	296527	256747	Unnamed AW	0.028	0.028	0.017	0.015	0.053
32	296922	256777	Unnamed AW	0.029	0.029	0.023	0.022	0.050
33	296342	256811	Unnamed AW	0.026	0.026	0.018	0.016	0.048
34	296585	257064	Unnamed AW	0.020	0.020	0.016	0.015	0.042
35	297312	256523	Unnamed AW	0.040	0.040	0.034	0.031	0.056
36	297336	256367	Unnamed AW	0.045	0.044	0.050	0.046	0.063
37	297761	255835	Unnamed AW	0.041	0.040	0.048	0.043	0.042
38	297985	254626	Unnamed AW	0.028	0.028	0.025	0.021	0.019
39	297639	254275	Unnamed AW	0.027	0.026	0.016	0.015	0.020
40	295396	256299	Unnamed AW	0.019	0.019	0.013	0.010	0.014
41	294967	256235	Unnamed AW	0.013	0.013	0.009	0.007	0.011
42	295059	255704	Unnamed AW	0.025	0.025	0.038	0.032	0.013
43	295722	254119	Unnamed AW	0.017	0.017	0.011	0.009	0.048
44	295171	254056	Unnamed AW	0.016	0.016	0.017	0.011	0.037
45	295620	253865	Unnamed AW	0.014	0.014	0.010	0.008	0.040
46	295630	253641	Unnamed AW	0.012	0.012	0.009	0.007	0.035
47	297395	253831	Unnamed AW	0.017	0.017	0.012	0.010	0.025
48	295976	253407	Unnamed AW	0.010	0.010	0.004	0.003	0.028
49	294750	255120	Unnamed AW	0.028	0.028	0.033	0.027	0.019
50	295257	255658	Unnamed AW	0.034	0.033	0.044	0.037	0.017
51	294607	254402	Unnamed AW	0.020	0.020	0.028	0.022	0.022

Table 5. (continued)

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)				
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s	Sennybridge No Calms No Terrain
52	294881	254718	Coed Y Ciliau SSSI	**0.030**	**0.029**	**0.036**	**0.027**	**0.027**
53	294934	254415	Coed Y Ciliau SSSI	**0.022**	**0.022**	**0.028**	**0.020**	**0.030**
54	295036	254290	Coed Y Ciliau SSSI	**0.020**	**0.019**	**0.024**	**0.016**	**0.034**
55	298322	254194	River Irfon SSSI	**0.020**	**0.020**	**0.014**	**0.012**	**0.015**
56	299268	254861	Cae Comin Coch SSSI	**0.016**	**0.015**	**0.020**	**0.016**	0.015
57	294059	253690	Caeau Llwyn Gwrgan SSSI	**0.011**	**0.011**	**0.019**	**0.014**	**0.017**
58	294189	253452	Caeau Llwyn Gwrgan SSSI	0.010	0.010	**0.016**	**0.011**	**0.018**
59	296599	252444	Tyncoed Pasture SSSI	0.005	0.006	0.005	0.004	**0.013**
60	294672	250980	Garth Bank Quarry SSSI	0.004	0.004	0.004	0.003	0.014
61	301270	255317	Cors Y Llyn SSSI	0.008	0.008	0.007	0.005	0.009
62	295993	257313	River Wye SAC/ River Irfon SSSI	**0.015**	**0.015**	**0.013**	**0.012**	**0.032**
63	296701	256996	River Wye SAC/ River Irfon SSSI	**0.022**	**0.022**	**0.017**	**0.016**	**0.043**
64	297179	256841	River Wye SAC/ River Irfon SSSI	**0.030**	**0.029**	**0.020**	**0.019**	**0.045**
65	297233	256033	River Wye SAC/ River Irfon SSSI	**0.064**	**0.064**	**0.106**	**0.099**	**0.088**
66	297300	255696	River Wye SAC/ River Irfon SSSI	**0.072**	**0.071**	**0.075**	**0.070**	**0.071**
67	297590	255224	River Wye SAC/ River Irfon SSSI	**0.048**	**0.047**	**0.051**	**0.044**	**0.033**
68	297987	254524	River Wye SAC/ River Irfon SSSI	**0.027**	**0.026**	**0.021**	**0.018**	**0.018**
69	299085	253601	River Wye SAC/ River Irfon SSSI	**0.013**	**0.013**	0.007	0.006	**0.011**
70	295017	255871	River Wye SAC/ River Irfon SSSI	**0.021**	**0.021**	**0.028**	**0.023**	**0.011**
71	295138	255474	River Wye SAC/ River Irfon SSSI	**0.035**	**0.035**	**0.042**	**0.036**	**0.020**
72	294693	254786	River Wye SAC/ River Irfon SSSI	**0.028**	**0.027**	**0.036**	**0.028**	**0.022**
73	294996	253958	River Wye SAC/ River Irfon SSSI	**0.014**	**0.014**	**0.015**	**0.011**	**0.032**
74	294801	252813	River Wye SAC/ River Irfon SSSI	0.007	0.007	**0.011**	0.007	**0.021**
75	294673	251189	River Wye SAC/ River Irfon SSSI	0.005	0.005	0.005	0.003	**0.015**
76	293124	255952	River Wye SAC/ River Irfon SSSI	0.007	0.007	0.008	0.005	0.004
77	293851	254941	River Wye SAC/ River Irfon SSSI	**0.015**	**0.015**	**0.018**	**0.013**	0.010
78	294444	253527	River Wye SAC/ River Irfon SSSI	**0.010**	**0.010**	**0.018**	**0.012**	**0.021**
79	297549	257757	River Wye SAC/Upper Wye Tributaries SSSI	**0.014**	**0.014**	0.008	0.007	**0.026**
80	298951	257043	River Wye SAC/Upper Wye Tributaries SSSI	**0.016**	**0.016**	**0.021**	**0.018**	**0.020**
81	295964	251273	River Wye SAC/ River Irfon SSSI	0.004	0.004	0.002	0.002	**0.014**
82	296604	250970	River Wye SAC/ River Irfon SSSI	0.004	0.004	0.004	0.002	**0.010**
83	292127	252724	River Wye SAC/ River Irfon SSSI	0.007	0.006	**0.010**	0.006	0.008
84	300504	257607	River Wye SAC/SSSI	0.009	0.009	**0.013**	**0.010**	**0.011**
85	300189	255323	River Wye SAC/SSSI	**0.011**	**0.011**	**0.012**	0.009	**0.012**
86	300038	254238	River Wye SAC/SSSI	**0.011**	**0.011**	**0.015**	**0.010**	**0.011**
87	300997	256661	River Wye SAC/SSSI	0.008	0.008	0.010	0.008	0.010
88	292871	258654	Elenydd SAC/SSSI	0.003	0.003	0.001	0.001	0.003
89	292228	258339	Elenydd SAC/SSSI/Elenydd - Mallean SPA	0.003	0.003	0.001	0.001	0.003
90	294414	251784	River Wye SAC/ River Irfon SSSI	0.005	0.005	0.007	0.004	**0.015**

5.2 Detailed modelling

The detailed modelling, which includes ammonia deposition and the consequent plume depletion, was carried out over a restricted domain that includes the proposed poultry houses at Cwmafan, Coed Y Ciliau SSSI, Caeau Llwyn Gwrgan SSSI and closer stretches of the River Irfon SSSI, the Upper Wye Tributaries SSSI and the River Wye SAC, the areas where preliminary modelling (GFS fixed deposition run) indicated that annual mean ammonia concentrations or nitrogen deposition rates would potentially exceed 1% of the Critical Level, which is the Natural Resources Wales lower threshold percentage for SSSIs, SPAs and SACs.

At the other wildlife sites, the preliminary modelling indicated that ammonia levels (and nitrogen deposition rates) would be below Natural Resources Wales relevant lower threshold percentage of Critical Level/Load for the designation of the site.

Calms cannot be used with terrain or spatially varying deposition; therefore, calms have not been included in the detailed modelling; however, the results of the preliminary modelling indicate that the effects of calms are insignificant in this case.

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 6a. In Table 6b the impact of mitigation, namely the installation of heat exchanger units within the proposed poultry houses, is presented. The use of heat exchanger units has been shown to reduce the impact of ammonia from poultry housing; therefore, for this mitigation measure, the impacts have been reduced by 35%. Note that where receptors are outside of the deposition field, the precautionary deposition velocity of 0.03 m/s is applied.

In these tables, predicted ammonia concentrations or nitrogen deposition rates that are in excess of the Natural Resources Wales upper threshold (8% of Critical Level or Load for a SAC/SPA/SSSI) are coloured red. Ammonia concentrations or nitrogen deposition rates that are in the range between the Natural Resources Wales lower and upper threshold (1% to 8% for a SAC/SPA/SSSI) are coloured blue.

Contour plots of the predicted ground level maximum annual mean ammonia concentrations for the proposed poultry houses, with and without mitigation, are shown in Figures 6a and 6b respectively. Contour plots of the maximum nitrogen deposition rate for the proposed poultry houses, with and without mitigation, are shown in Figures 7a and 7b respectively.

Table 6a. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
52	294881	254718	Coed Y Ciliau SSSI	0.03	1.0	5.0	0.021	**2.1**	0.165	**3.3**
53	294934	254415	Coed Y Ciliau SSSI	0.03	1.0	5.0	0.015	**1.5**	0.120	**2.4**
54	295036	254290	Coed Y Ciliau SSSI	0.03	1.0	5.0	0.014	**1.4**	0.106	**2.1**
55	298322	254194	River Irfon SSSI	0.02	1.0	8.0	0.010	1.0	0.051	0.6
56	299268	254861	Cae Comin Coch SSSI	0.02	3.0	8.0	0.012	0.4	0.061	0.8
57	294059	253690	Caeau Llwyn Gwrgan SSSI	0.02	1.0	8.0	0.010	**1.0**	0.053	0.7
58	294189	253452	Caeau Llwyn Gwrgan SSSI	0.02	1.0	8.0	0.008	0.8	0.043	0.5
62	295993	257313	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.009	0.9	0.068	0.7
63	296701	256996	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.013	**1.3**	0.103	**1.0**
64	297179	256841	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.016	**1.6**	0.123	**1.2**
65	297233	256033	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.081	**8.1**	0.635	**6.3**
66	297300	255696	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.059	**5.9**	0.459	**4.6**
67	297590	255224	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.036	**3.6**	0.282	**2.8**
68	297987	254524	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.015	**1.5**	0.116	**1.2**
69	299085	253601	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.005	0.5	0.037	0.4
70	295017	255871	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.017	**1.7**	0.134	**1.3**
71	295138	255474	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.029	**2.9**	0.222	**2.2**
72	294693	254786	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.022	**2.2**	0.169	**1.7**
73	294996	253958	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.008	0.8	0.061	0.6
74	294801	252813	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.005	0.5	0.037	0.4
77	293851	254941	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.009	0.9	0.074	0.7
78	294444	253527	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.009	0.9	0.068	0.7
79	297549	257757	River Wye SAC/Upper Wye Tributaries SSSI	0.03	1.0	10.0	0.006	0.6	0.045	0.5
80	298951	257043	River Wye SAC/SSSI	0.03	1.0	10.0	0.014	**1.4**	0.105	**1.1**
84	300504	257607	River Wye SAC/SSSI	0.03	1.0	10.0	0.007	0.7	0.058	0.6
85	300189	255323	River Wye SAC/SSSI	0.03	1.0	10.0	0.007	0.7	0.055	0.6
86	300038	254238	River Wye SAC/SSSI	0.03	1.0	10.0	0.007	0.7	0.057	0.6

Table 6b. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors – mitigation (heat exchangers)

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
52	294881	254718	Coed Y Ciliau SSSI	0.03	1.0	5.0	0.014	**1.4**	0.107	**2.1**
53	294934	254415	Coed Y Ciliau SSSI	0.03	1.0	5.0	0.010	**1.0**	0.078	**1.6**
54	295036	254290	Coed Y Ciliau SSSI	0.03	1.0	5.0	0.009	0.9	0.069	**1.4**
55	298322	254194	River Irfon SSSI	0.02	1.0	8.0	0.006	0.6	0.033	0.4
56	299268	254861	Cae Comin Coch SSSI	0.02	3.0	8.0	0.008	0.3	0.040	0.5
57	294059	253690	Caeau Llwyn Gwrgan SSSI	0.02	1.0	8.0	0.007	0.7	0.034	0.4
58	294189	253452	Caeau Llwyn Gwrgan SSSI	0.02	1.0	8.0	0.005	0.5	0.028	0.4
62	295993	257313	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.006	0.6	0.044	0.4
63	296701	256996	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.009	0.9	0.067	0.7
64	297179	256841	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.010	**1.0**	0.080	0.8
65	297233	256033	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.053	**5.3**	0.413	**4.1**
66	297300	255696	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.038	**3.8**	0.298	**3.0**
67	297590	255224	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.024	**2.4**	0.184	**1.8**
68	297987	254524	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.010	1.0	0.075	0.8
69	299085	253601	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.003	0.3	0.024	0.2
70	295017	255871	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.011	**1.1**	0.087	0.9
71	295138	255474	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.019	**1.9**	0.144	**1.4**
72	294693	254786	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.014	**1.4**	0.110	**1.1**
73	294996	253958	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.005	0.5	0.040	0.4
74	294801	252813	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.003	0.3	0.024	0.2
77	293851	254941	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.006	0.6	0.048	0.5
78	294444	253527	River Wye SAC/ River Irfon SSSI	0.03	1.0	10.0	0.006	0.6	0.044	0.4
79	297549	257757	River Wye SAC/Upper Wye Tributaries SSSI	0.03	1.0	10.0	0.004	0.4	0.030	0.3
80	298951	257043	River Wye SAC/SSSI	0.03	1.0	10.0	0.009	0.9	0.068	0.7
84	300504	257607	River Wye SAC/SSSI	0.03	1.0	10.0	0.005	0.5	0.037	0.4
85	300189	255323	River Wye SAC/SSSI	0.03	1.0	10.0	0.005	0.5	0.036	0.4
86	300038	254238	River Wye SAC/SSSI	0.03	1.0	10.0	0.005	0.5	0.037	0.4

Figure 6a. Maximum annual mean ammonia concentration

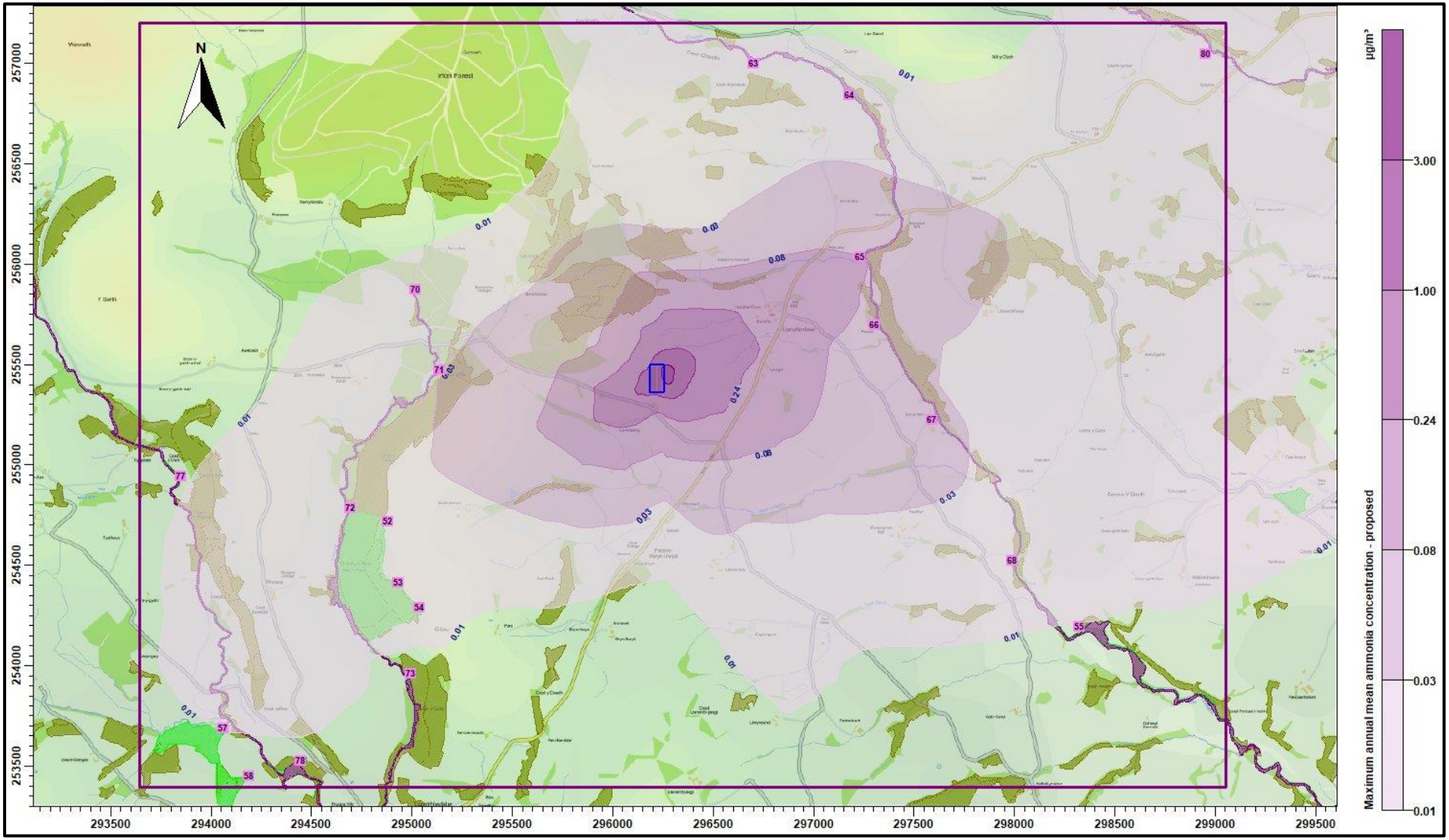


Figure 6b. Maximum annual mean ammonia concentration – mitigation (heat exchangers)

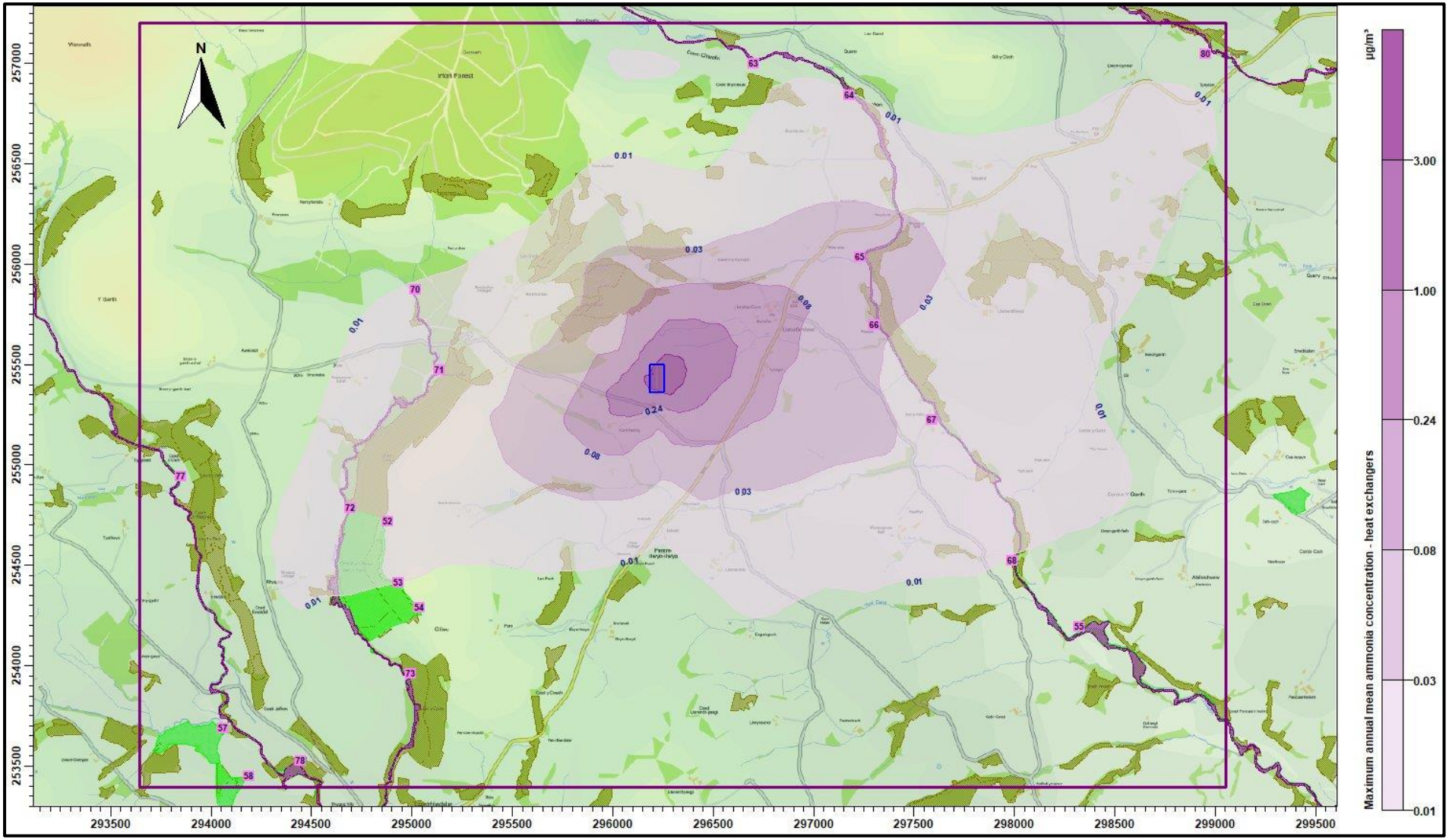


Figure 7a. Maximum annual nitrogen deposition rates

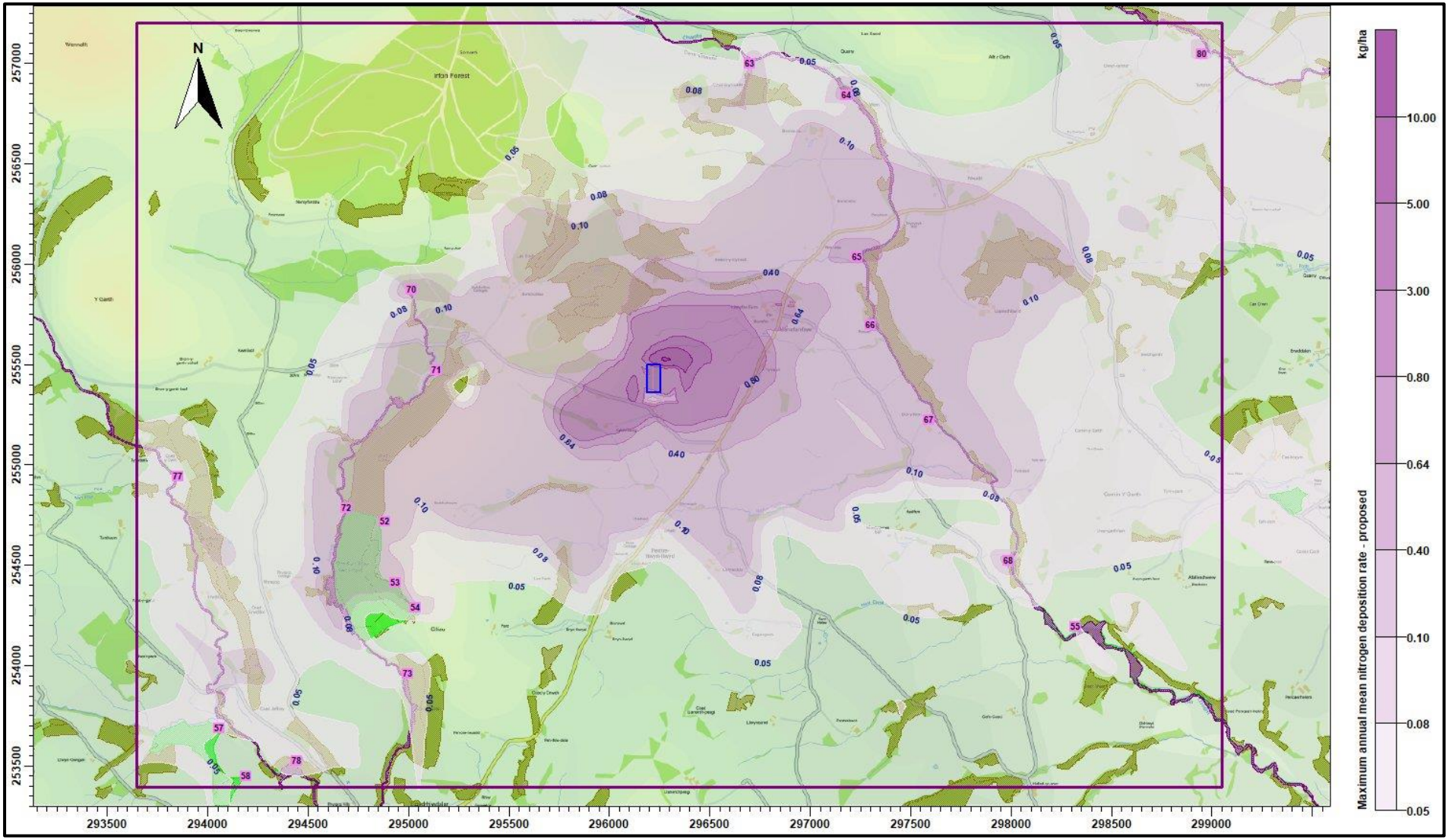
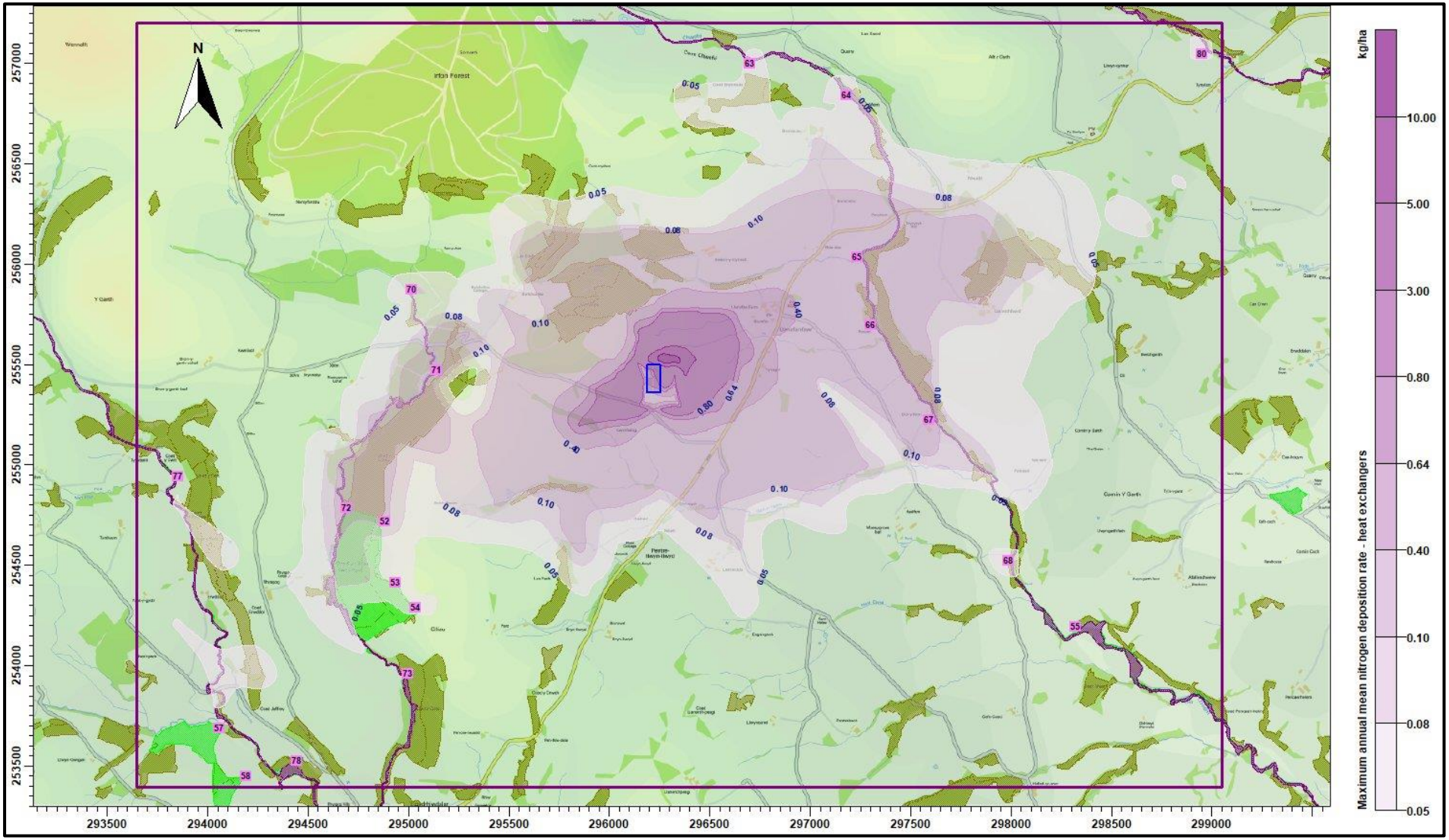


Figure 7b. Maximum annual nitrogen deposition rates – mitigation (heat exchangers)



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Gerallt Davies, of Roger Parry & Partners LLP, on behalf of Lyndon Jones, to use computer modelling to assess the impact of ammonia emissions from the proposed broiler chicken rearing houses at Cwmafan, Lanafan-Fawr, near to Builth Wells, in Powys. LD2 3PF.

Ammonia emission rates from the 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 and acid deposition rates in the surrounding area.

Preliminary modelling

The preliminary modelling predicts that:

- The process contribution from the proposed poultry houses to the annual mean ammonia concentration and the nitrogen deposition rate would potentially exceed the Natural Resources Wales lower threshold percentage of the Critical Level or Critical Load (1% for a SSSI or SAC) at Coed Y Ciliau SSSI, Cae Comin Coch SSSI, Caeau Llwyn Gwrgan SSSI and closer stretches of the River Irfon SSSI, the Upper Wye Tributaries SSSI and the River Wye SAC.

- At the other wildlife sites, the preliminary modelling indicated that ammonia levels (and nitrogen deposition rates) would be below the Natural Resources Wales lower threshold percentage of Critical Level/Load for the designation of the site.

Detailed deposition modelling

The detailed modelling, which includes nitrogen deposition and consequent plume depletion predicts that:

- The process contribution to annual mean ammonia concentration would marginally exceed the Natural Resources Wales lower threshold percentage of the Critical Level of 1.0 µg-NH_3/m^3 at Coed Ciliau SSSI and there would also be exceedances of the lower threshold percentage of the lower bound of the Critical Load of 5.0 kg-N/ha at this SSSI.

- The process contribution to annual mean ammonia concentration would also marginally exceed the Natural Resources Wales lower threshold percentage of the Critical Level of 1.0 µg-NH_3/m^3 at Caeau Llwyn Gwrgan SSSI.

- The process contribution to annual mean ammonia concentration would exceed the Natural Resources Wales lower threshold percentage of the Critical Level of 1.0 µg-NH_3/m^3 at the River Wye SAC/River Irfon SSSI and there would also be exceedances of the lower threshold percentage of the Critical Load of 10.0 kg-N/ha at this SAC/SSSI.

Mitigation

The detailed modelling predicts that, should heat exchanger units be installed in the proposed poultry houses, impacts would be reduced at all receptors. However, there would still be an exceedance of Natural Resources Wales' lower threshold percentage of the Critical Level and Critical Load at Coed Ciliau SSSI and the River Wye SAC/River Irfon SSSI. In such cases, where the predicted process contributions to ammonia concentrations and nitrogen deposition rates are between the Natural Resources Wales/Environment Agency's lower and upper thresholds, depending on the sensitivity of the wildlife sites and the presence, or not, of other ammonia sources, an in-combination assessment may be necessary as part of the competent authority's appropriate assessment.

7. References

Beasley. *et al*. Agroforestry Systems for Ammonia Abatement. Defra project AC0103.

Cambridge Environmental Research Consultants (CERC) (website).
http://www.cerc.co.uk/environmental-software/ADMS-model.html

Environment Agency H1 Risk Assessment (website).
https://www.gov.uk/government/collections/horizontal-guidance-environmental-permitting

M. A. Sutton *et al*. Measurement and modelling of ammonia exchange over arable croplands.
https://enviro.doe.gov.my/lib/digital/1386301476-1-s2.0-S0166111606802748-main.pdf

Misselbrook. *et al*. Inventory of Ammonia Emissions from UK Agriculture 2011
http://uk-air.defra.gov.uk/assets/documents/reports/cat07/1211291427_nh3inv2011_261112_FINAL_corrected.pdf

Frederik Schrader and Christian Brümmer. Land Use Specific Ammonia Deposition Velocities: a Review of Recent Studies (2004–2013)
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4176955/

United Nations Economic Commission for Europe (UNECE) (website).
http://www.unece.org/env/lrtap/WorkingGroups/wge/definitions.htm

UK Air Pollution Information System (APIS) (website).
http://www.apis.ac.uk/