A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing and Proposed Broiler Chicken Rearing Houses at Ddole Farm, Llanbister, Llandrindod Wells, Powys

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24th July 2018

1. Introduction

AS Modelling & Data Ltd. has been instructed by Steve Raasch, on behalf of the applicant Andrew Lewis, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed broiler chicken rearing houses at land near to Ddole Farm, Llanbister, Llandrindod Wells, Powys. LD1 6ST.

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 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 site of the existing and proposed poultry houses at Ddole Farm is in a rural area approximately 2 km to the east-south-east of the village of Llanbister in Powys. The site is within a valley of a tributary of the River Ithon at an elevation of around 280 m, with the land rising towards hill and mountain tops to the north and south. The surrounding land is predominantly pasture, although there are some wooded areas nearby.

There are currently four existing poultry houses at Ddole Farm. The existing poultry houses are ventilated primarily using uncapped high speed ridge mounted fans, each with a short chimney, but there are also gable end fans to provide supplementary ventilation in hot weather.

Under the proposal, two new poultry houses would be constructed at Ddole Farm. The proposed poultry sheds would be ventilated by high speed ridge or roof fans, each with a short chimney. The existing and proposed poultry houses would provide accommodation for up to 256,000 broiler chickens. 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 several areas of Ancient Woodlands (AWs) within 2 km of Ddole Farm. There are eight Sites of Special Scientific Interest (SSSIs) within 5 km of the farm, namely: Maelienydd; Cwmsaise; Lower Caerfaelog Pastures; River Lugg; Coed Bryn-Person; Gweunydd Crycell; Far Hall Meadow and River Ithon SSSIs. The River Ithon SSSI is also designated as part of the River Wye Special Area of Conservation (SAC). There are no other internationally designated sites within 5 km of Ddole Farm.

A broad scale map of the surrounding area showing the positions of the existing and proposed poultry houses at Ddole Farm, the AWs, the SSSIs and the SACs 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 SAC is shaded in purple and the positions of the poultry houses are indicated by blue rectangles.

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

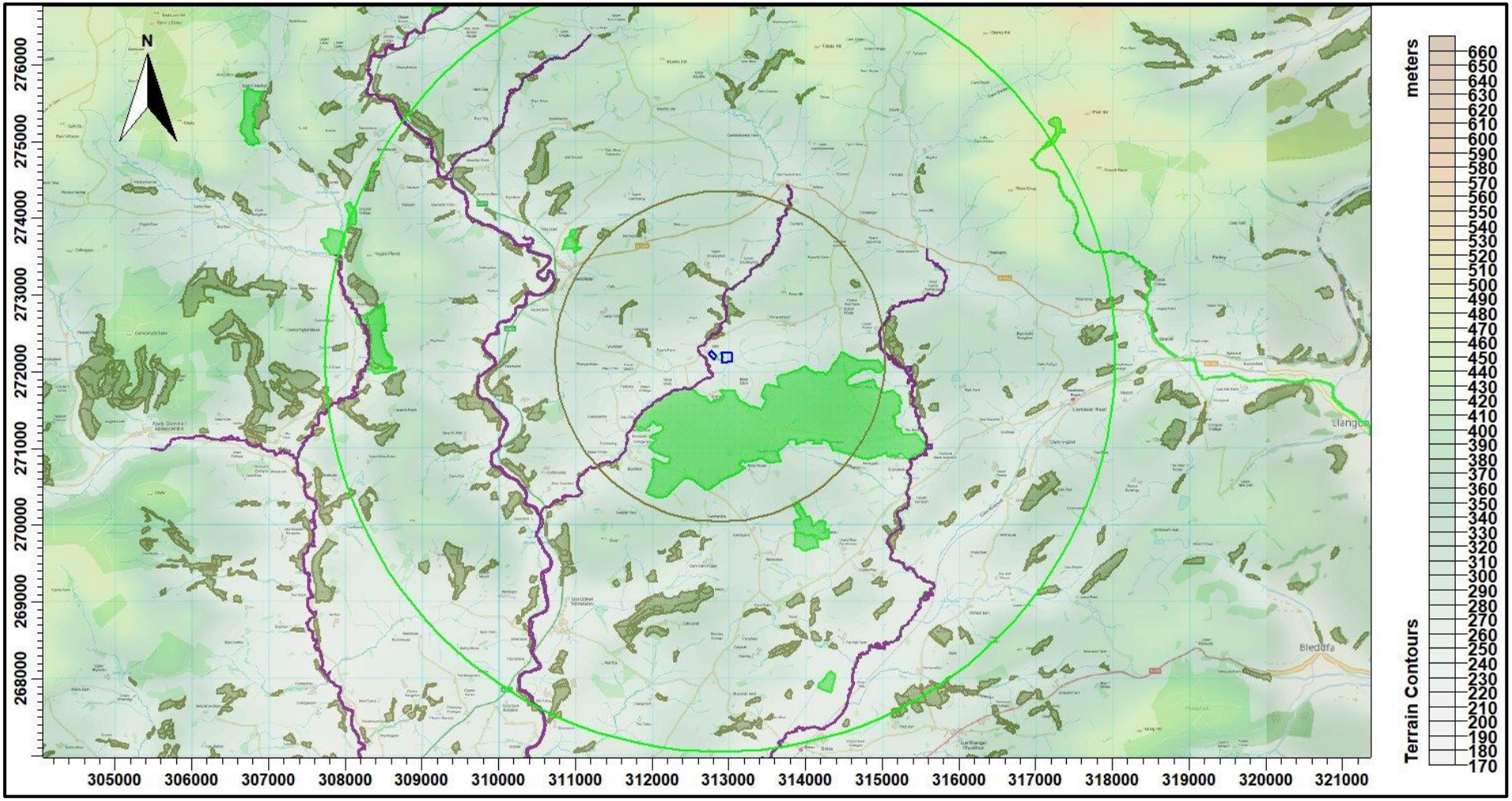
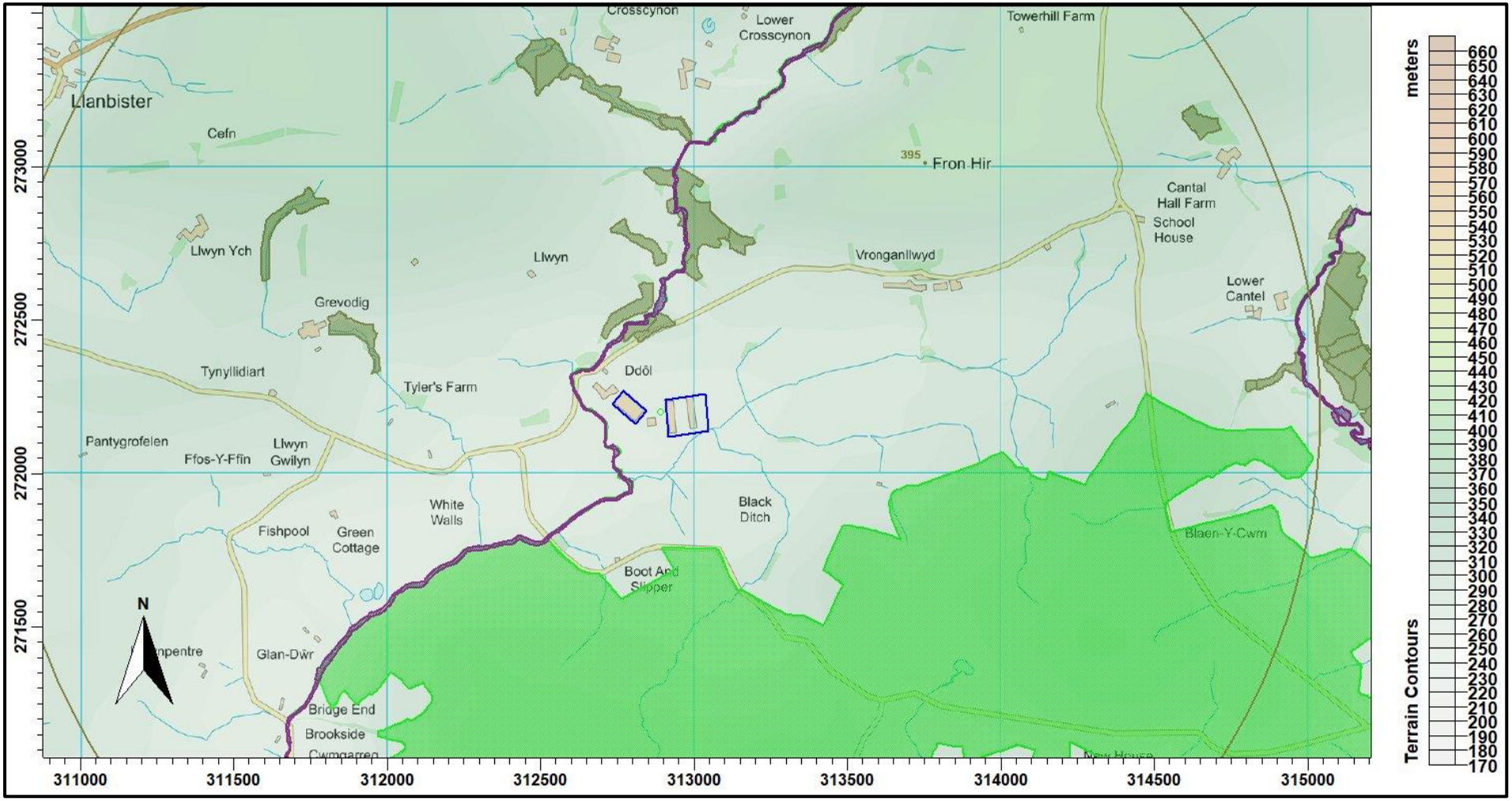


Figure 1b. The area surrounding Ddole Farm, a closer view



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 Ddole Farm is 1.08 $\mu g\text{-}NH_3/m^3$. The background nitrogen deposition rate to woodland is 25.34 kg-N/ha/y and to short vegetation is 15.54 kg-N/ha/y. The background acid deposition rate to woodland is 1.95 keq/ha/y and to short vegetation is 1.23 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS).

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. 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]	-	-
Maelienydd; Cwmsaise; Lower Caerfaelog Pastures; River Lugg; Coed Bryn-Person; Gweunydd Crychell; River Ithon SSSIs	1.0 [1&2]	5.0 [2]	-
Far Hall Meadow SSSI	1.0 [1&2]	10.0 [2]	-
River Wye SAC	1.0 [2]	5.0 [2]	-

1. A precautionary figure, used where details of the site are unavailable, or citations indicate that sensitive lichens and bryophytes may be present.
2. APIS (July, 2018).

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 house.

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	256,000	Broiler Chickens	0.034	0.275813

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). Observational meteorological data from Sennybridge, Shobdon and Trawscoed have 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 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 Ddole Farm 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 180 m for the preliminary and low resolution detailed modelling runs, 150 m for the medium resolution detailed modelling runs and 100 m for the high resolution 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 stations at Sennybridge, Shobdon and Trawscoed have also been considered. However, neither Sennybridge, Shobdon nor Trawscoed, has an aspect that in any way could be considered similar to Ddole Farm; therefore, it should be noted that the frequency of winds from a particular direction in the Sennybridge, Shobdon and Trawscoed data may be either high or low in comparison to what might occur at Ddole Farm, 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 roses for Sennybridge, Shobdon and Trawscoed are shown in Figures 2c, 2d and 2e.

Figure 2a. The wind rose. Raw GFS derived data, for 52.341 N, 3.279 W, 2014 – 2017

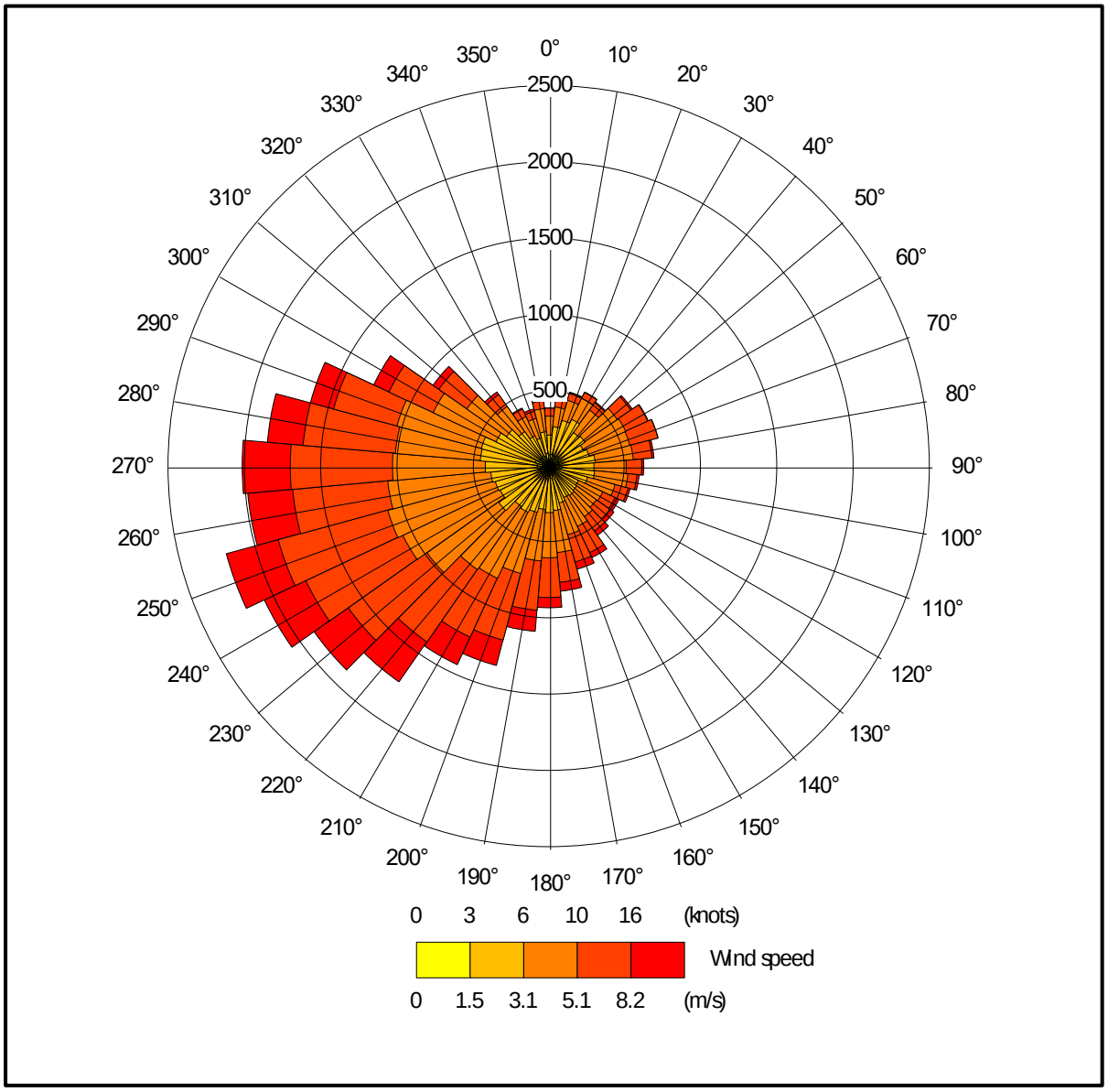


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 312880, 272200, 2014-2017

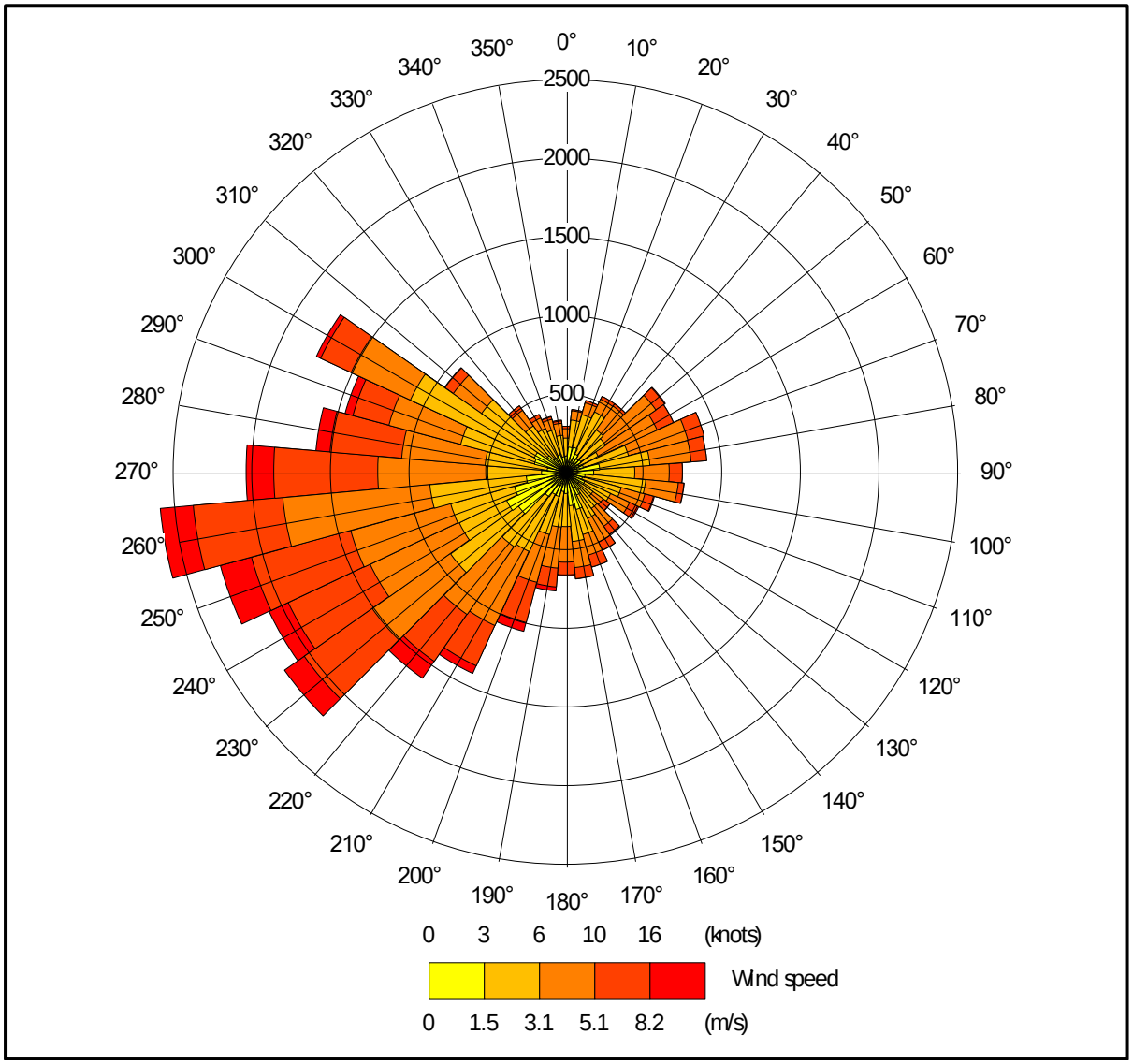


Figure 2c. The wind rose. Sennybridge, 2014 – 2017

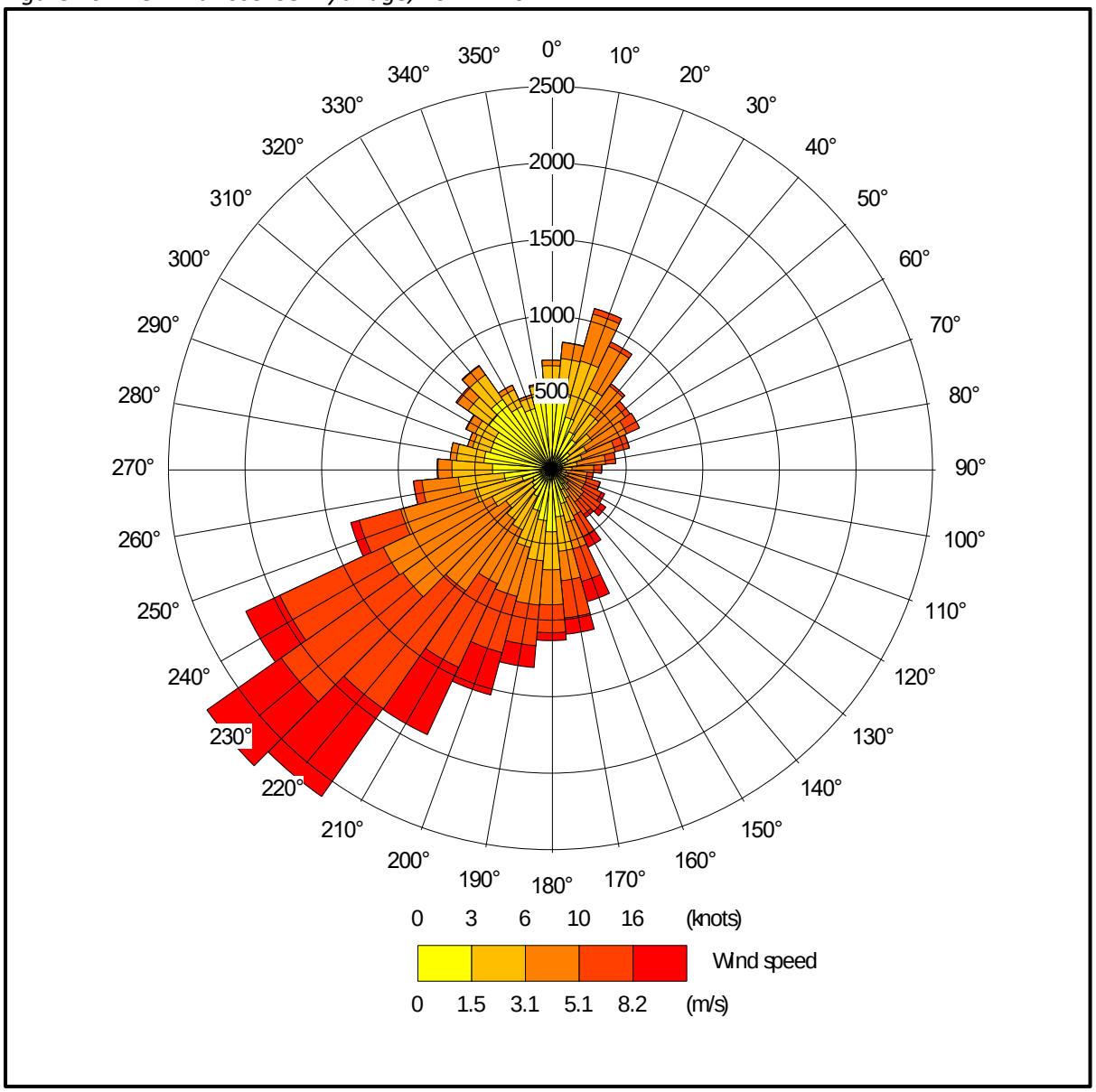


Figure 2d. The wind rose. Shobdon, 2014 – 2017

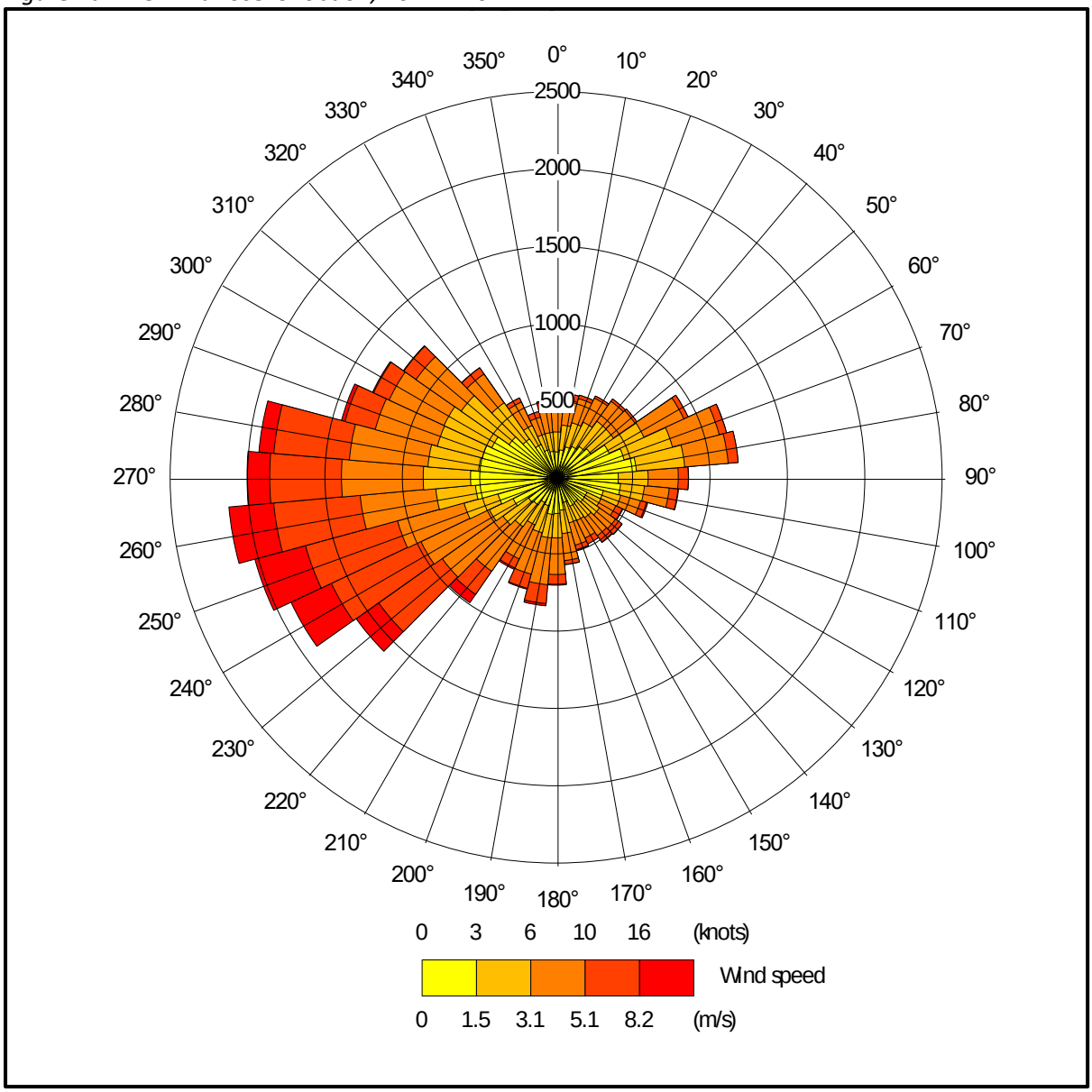
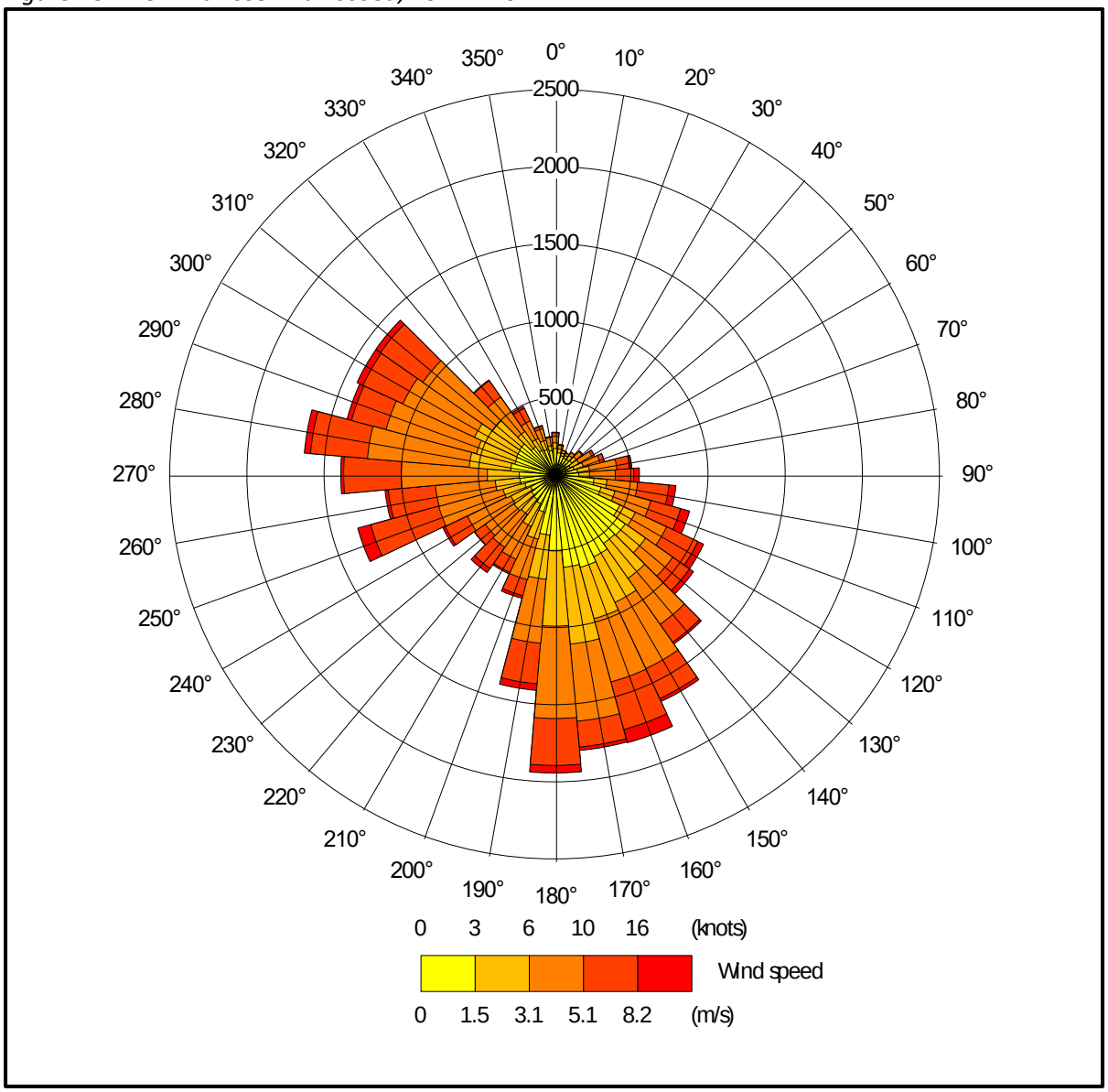


Figure 2e. The wind rose. Trawscoed, 2014 – 2017



4.2 Emission sources

Emissions from the high speed ridge/roof fans that would be used to ventilate the existing and proposed poultry houses are represented by three point sources per house within ADMS (EX1 a, b & c to EX4 a, b & c and PR1 a, b & c to PR2 a, b & c).

The existing poultry houses are also fitted with gable end fans which are used to provide supplementary ventilation in hot weather conditions. The emissions from these gable end fans are represented by four volume sources within ADMS (EX1_GAB to EX4_GAB and PR1_GAB to PR2_GAB).

Details of the point and volume source parameters are shown in Tables 3a and 3b. The positions of the sources may be seen in Figure 3.

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 to EX4 a, b & c	5.5	0.8	11.0	Variable [1]	0.015323 [2]
PR1 a, b & c and PR2 a, b & c	5.5	0.8	11.0	Variable [1]	0.015323

Table 3b. Volume source parameters

Source ID	Length Y (m)	Width X (m)	*Depth (m)*	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
EX1_GAB	17.9	5.0	3.0	0.0	Ambient	0.022984 [3]
EX2_GAB	17.9	5.0	3.0	0.0	Ambient	0.022984 [3]
EX3_GAB	21.0	5.0	3.0	0.0	Ambient	0.022984 [3]
EX4_GAB	21.0	5.0	3.0	0.0	Ambient	0.022984 [3]

1. Dependent on ambient temperature.
2. Reduced by 50% when the ambient temperature equals or exceeds 21 Celsius.
3. 50% of the total emission emitted only when the ambient temperature equals or exceeds 21 Celsius.

4.3 Modelled buildings

The structure of the existing and proposed poultry houses and other farm buildings 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

Fifty-four discrete receptors have been defined: sixteen at the AWs (1 to 16), eighteen at the SSSIs (17 to 34) and twenty at the SACs/SSSIs (35 to 54). 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 high, medium and low resolution detailed modelling, three regular Cartesian grids have been defined within ADMS. The individual grid receptors are defined at ground level within ADMS. The positions of the Cartesian grids may be seen in Figures 4a and 4b, where they are 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 12.0 km x 12.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS for the preliminary and low resolution detailed modelling. A 10.0 km x 10.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS for the medium resolution detailed modelling. A 6.4 km x 6.4 km domain has been resampled at 50 m horizontal resolution for use within ADMS for the high resolution 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 180 m for the preliminary and low resolution detailed modelling runs, is approximately 150 m for the medium resolution detailed modelling runs and is 100 m for the high resolution modelling runs.

4.7 Roughness Length

A fixed surface roughness length of 0.275 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 0.25 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 3. The positions of modelled sources

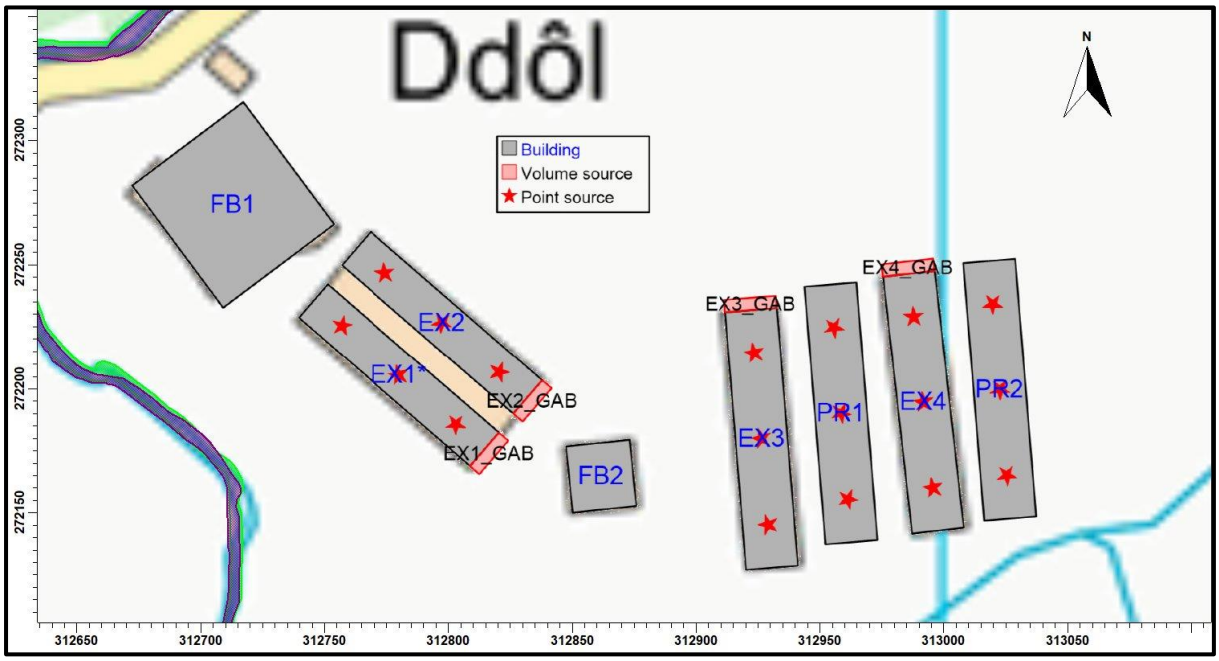


Figure 4a. The discrete receptors and low resolution regular Cartesian grid

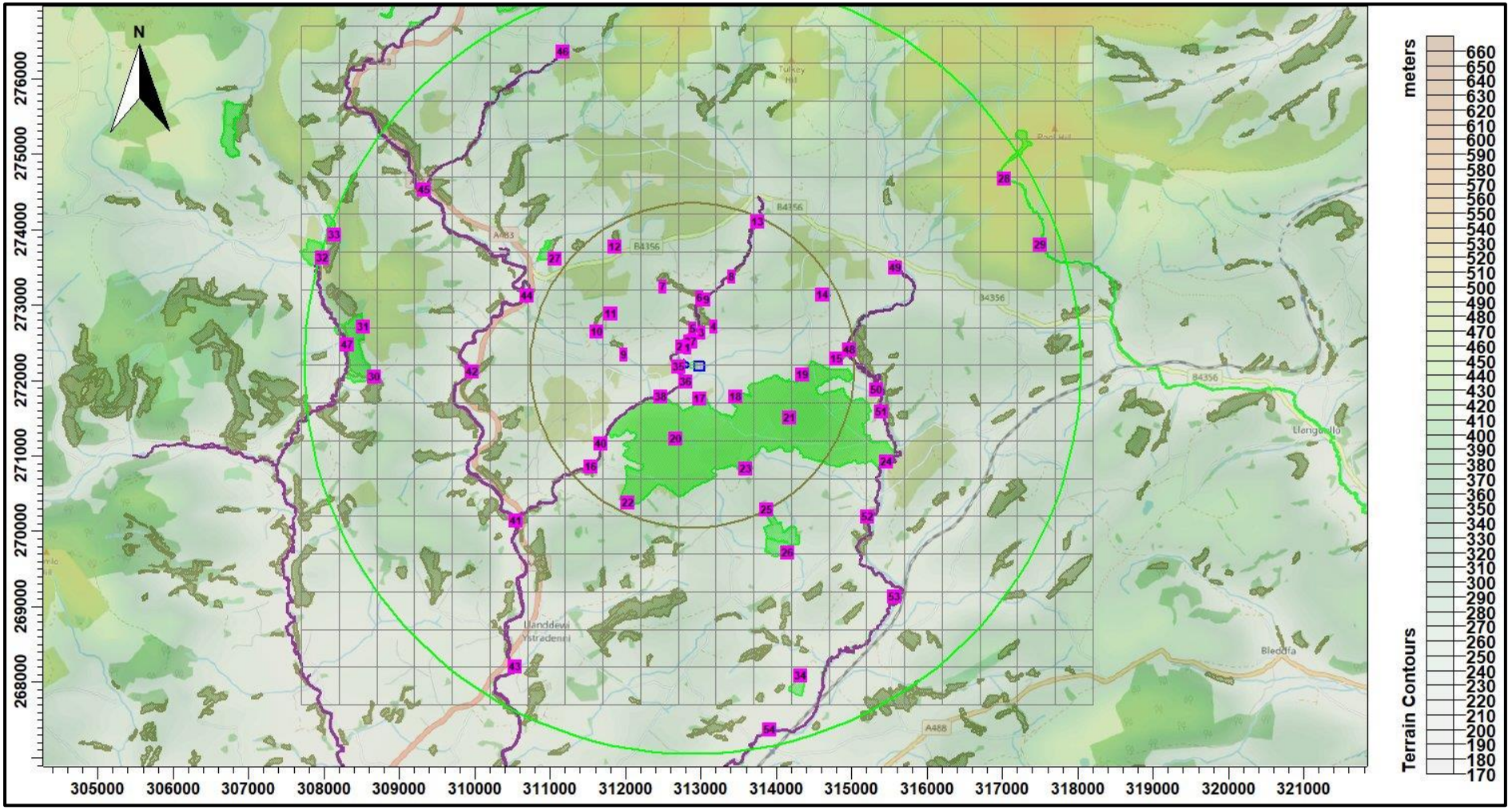
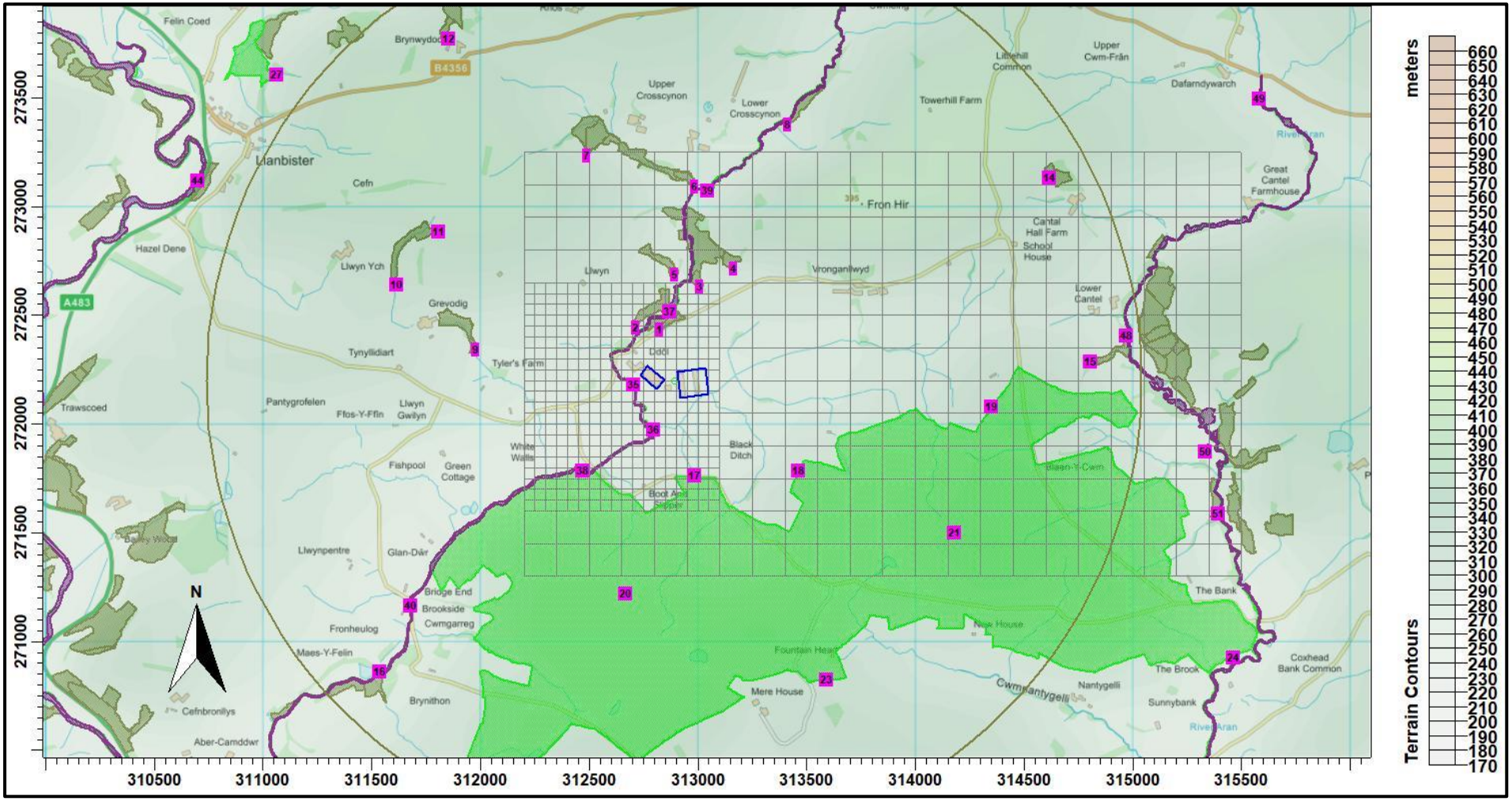


Figure 4b. The discrete receptors and medium and high regular Cartesian grids



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

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.

Contour plots of the high, medium and low resolution spatially varying deposition fields are provided in Figures 5a, 5b and 5c respectively.

Figure 5a. The spatially varying deposition field - high resolution

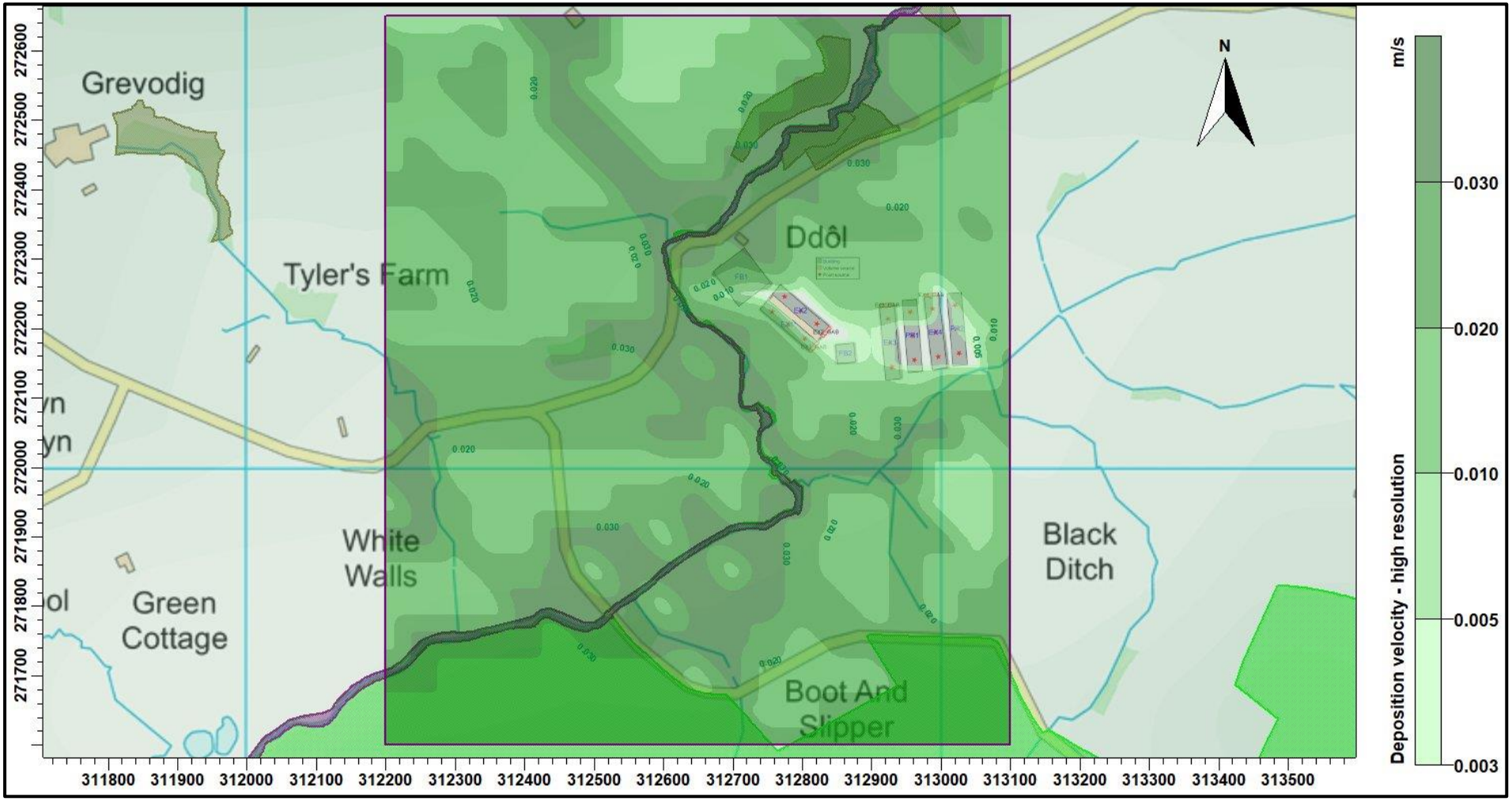


Figure 5b. The spatially varying deposition field - medium resolution

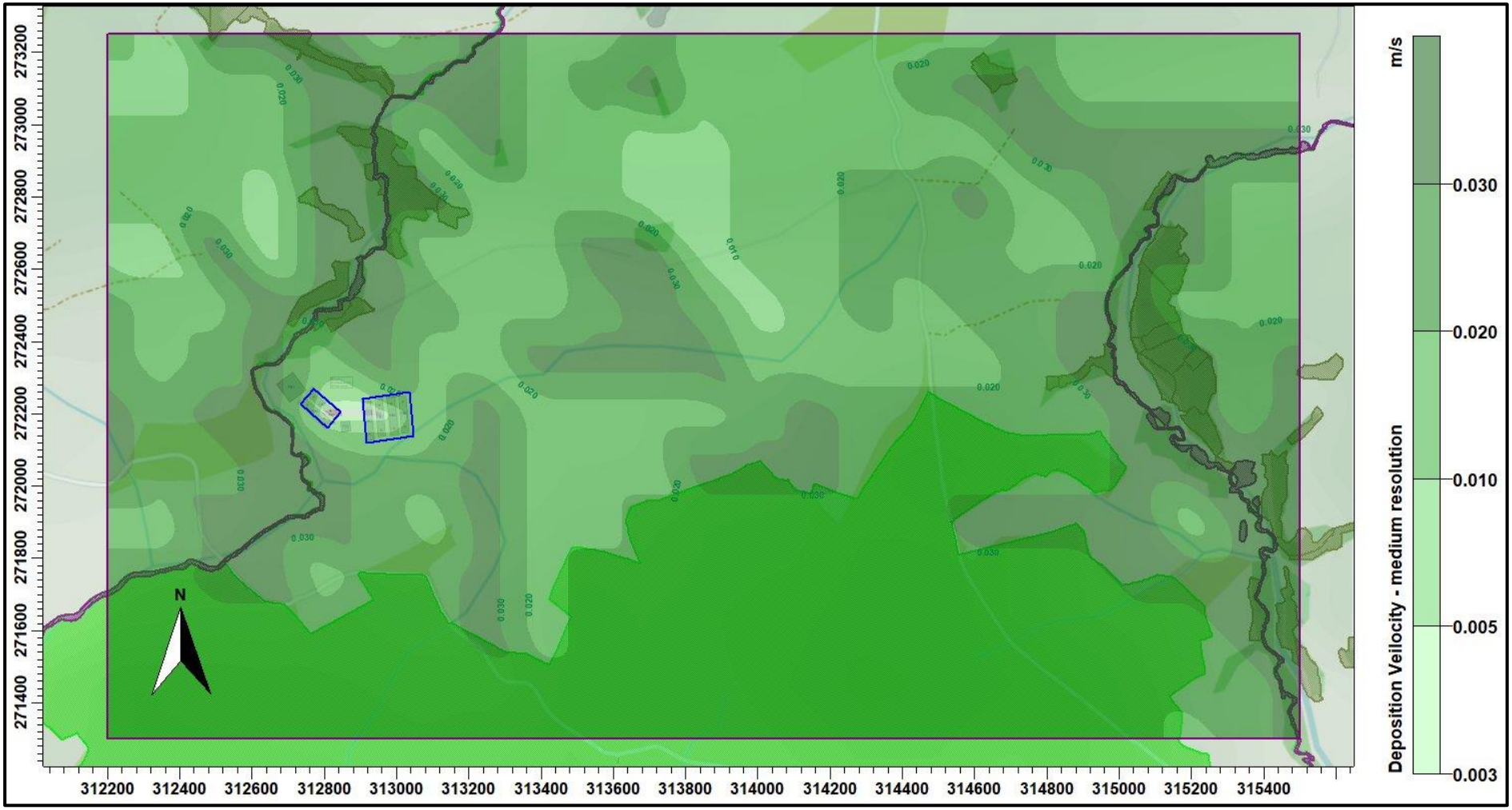
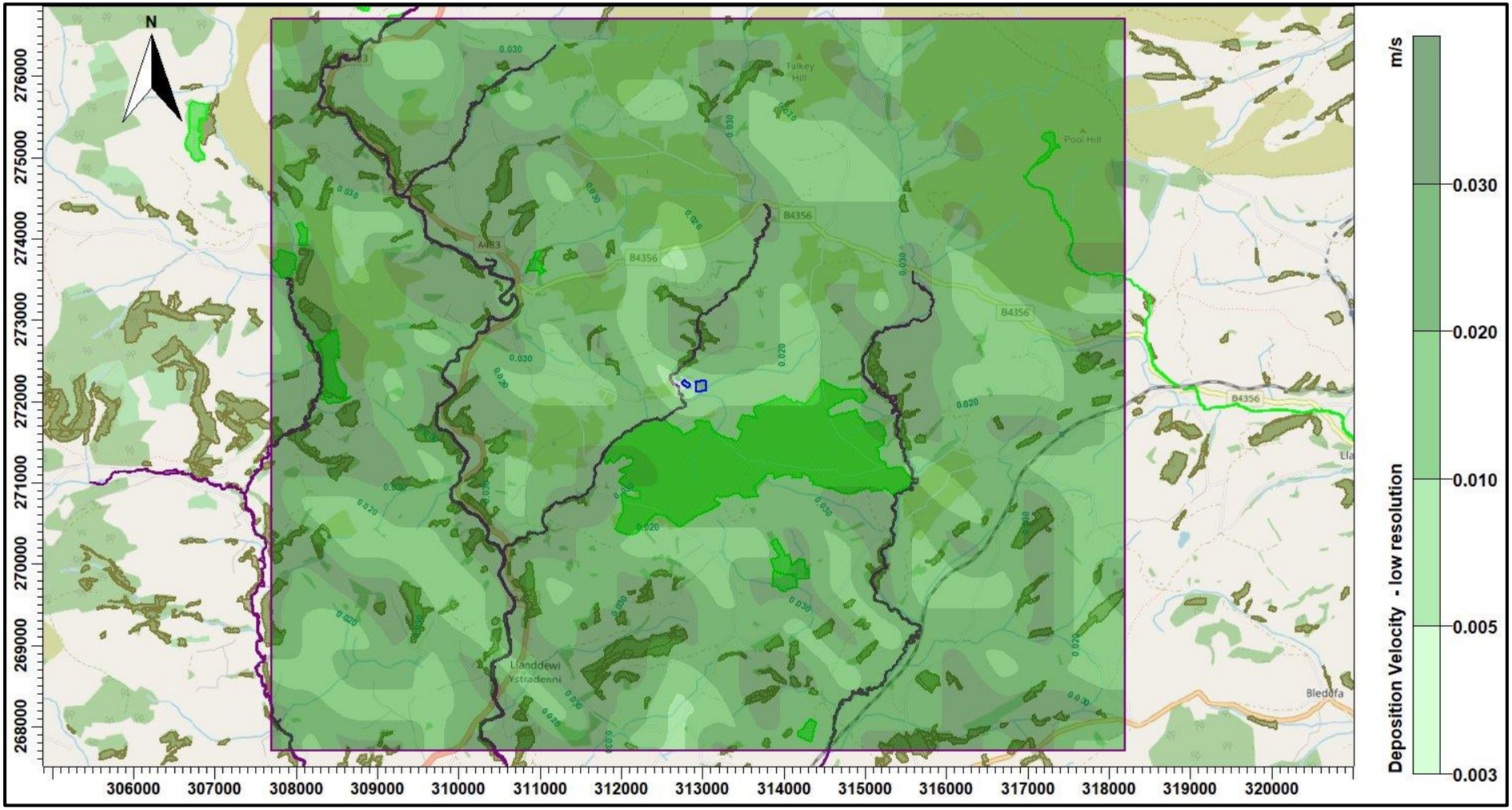


Figure 5c. The spatially varying deposition field - low resolution



5. Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

ADMS was run a total of twenty-eight times, once for each year in the meteorological record in the following seven 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.
- In basic mode without calms, or terrain – Shobdon data.
- In basic mode without calms, or terrain – Trawscoed 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, including those that would lead 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/SSSI and 100% of a Critical Level or Load for an AW) are coloured red. Concentrations in the range between the Natural Resources Wales upper threshold and lower threshold (1% to 8% for a SAC/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 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/m³)						
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed Dep 0.003 m/s	Sennybridge No Calms No Terrain	Shobdon No Calms No Terrain	Trawscoed No Calms No Terrain
1	312821	272431	Unnamed AW	1.094	1.077	1.168	1.123	0.949	0.771	1.714
2	312714	272444	Unnamed AW	0.658	0.650	0.551	0.526	0.524	0.529	1.313
3	313007	272631	Ddol Wood AW	0.623	0.613	0.663	0.628	0.647	0.394	0.760
4	313164	272715	Ddol Wood AW	0.473	0.465	0.400	0.372	0.525	0.290	0.369
5	312890	272686	Llwyn Wood AW	0.452	0.445	0.552	0.517	0.486	0.304	0.760
6	312983	273089	Treforgan Wood AW	0.197	0.194	0.293	0.267	0.249	0.142	0.333
7	312489	273233	Treforgan Wood AW	0.095	0.094	0.092	0.081	0.115	0.074	0.270
8	313413	273377	Unnamed AW	0.133	0.131	0.174	0.156	0.169	0.093	0.116
9	311975	272339	Unnamed AW	0.135	0.134	0.112	0.095	0.071	0.122	0.132
10	311615	272637	Unnamed AW	0.078	0.077	0.046	0.041	0.037	0.066	0.091
11	311805	272885	Unnamed AW	0.076	0.076	0.043	0.037	0.038	0.064	0.118
12	311853	273770	Unnamed AW	0.044	0.043	0.042	0.030	0.037	0.040	0.137
13	313758	274105	Unnamed AW	0.064	0.064	0.073	0.063	0.103	0.052	0.066
14	314618	273131	Unnamed AW	0.098	0.097	0.071	0.056	0.117	0.096	0.060
15	314802	272285	Unnamed AW	0.112	0.111	0.124	0.105	0.081	0.171	0.084
16	311536	270859	Unnamed AW	0.047	0.047	0.056	0.043	0.061	0.074	0.014
17	312982	271760	Maelienydd SSSI	0.202	0.201	0.131	0.120	0.234	0.257	0.136
18	313461	271786	Maelienydd SSSI	0.317	0.314	0.272	0.245	0.168	0.402	0.433
19	314348	272077	Maelienydd SSSI	0.172	0.170	0.148	0.127	0.098	0.232	0.133
20	312665	271219	Maelienydd SSSI	0.105	0.104	0.082	0.059	0.179	0.109	0.024
21	314177	271501	Maelienydd SSSI	0.137	0.136	0.121	0.101	0.071	0.202	0.147
22	312025	270382	Maelienydd SSSI	0.056	0.056	0.053	0.033	0.093	0.051	0.012
23	313592	270824	Maelienydd SSSI	0.044	0.044	0.039	0.027	0.077	0.067	0.048
24	315459	270926	Maelienydd SSSI	0.058	0.058	0.073	0.056	0.041	0.108	0.060
25	313871	270290	Cwmsaise SSSI	0.032	0.032	0.028	0.018	0.061	0.049	0.035
26	314154	269713	Cwmsaise SSSI	0.024	0.024	0.027	0.016	0.050	0.038	0.027
27	311063	273604	Lower Caerfaelog Pastures SSSI	0.036	0.036	0.026	0.021	0.019	0.032	0.075
28	317017	274674	River Lugg SSSI	0.027	0.027	0.013	0.009	0.035	0.032	0.020
29	317505	273801	River Lugg SSSI	0.028	0.028	0.016	0.011	0.030	0.046	0.022
30	308665	272044	Coed Bryn-Person SSSI	0.027	0.026	0.035	0.020	0.010	0.042	0.019
31	308524	272710	Coed Bryn-Person SSSI	0.024	0.023	0.019	0.011	0.008	0.032	0.022
32	307980	273625	Gweunydd Crychell SSSI	0.017	0.017	0.011	0.007	0.006	0.023	0.022
33	308134	273926	Gweunydd Crychell SSSI	0.016	0.016	0.009	0.006	0.007	0.020	0.024
34	314318	268088	Far Hall Meadow SSSI	0.015	0.015	0.018	0.010	0.027	0.021	0.014

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 Dep 0.003 m/s	Sennybridge No Calms No Terrain	Shobdon No Calms No Terrain	Trawscoed No Calms No Terrain
35	312703	272180	River Wye SAC / River Ithon SSSI	1.736	1.705	1.933	1.879	1.275	1.881	1.125
36	312794	271975	River Wye SAC / River Ithon SSSI	0.587	0.579	0.502	0.476	0.741	0.660	0.187
37	312870	272515	River Wye SAC / River Ithon SSSI	0.810	0.798	0.981	0.930	0.780	0.535	1.260
38	312467	271785	River Wye SAC / River Ithon SSSI	0.233	0.229	0.210	0.189	0.271	0.270	0.058
39	313042	273072	River Wye SAC / River Ithon SSSI	0.211	0.208	0.300	0.276	0.254	0.149	0.309
40	311677	271162	River Wye SAC / River Ithon SSSI	0.061	0.060	0.052	0.047	0.074	0.093	0.020
41	310542	270140	River Wye SAC / River Ithon SSSI	0.027	0.027	0.027	0.020	0.034	0.049	0.010
42	309962	272110	River Wye SAC / River Ithon SSSI	0.040	0.040	0.095	0.055	0.016	0.057	0.028
43	310536	268204	River Wye SAC / River Ithon SSSI	0.022	0.022	0.033	0.017	0.037	0.024	0.006
44	310698	273118	River Wye SAC / River Ithon SSSI	0.037	0.036	0.028	0.023	0.016	0.036	0.053
45	309329	274520	River Wye SAC / River Ithon SSSI	0.017	0.016	0.014	0.010	0.010	0.018	0.039
46	311171	276357	River Wye SAC / River Ithon SSSI	0.018	0.017	0.020	0.011	0.029	0.015	0.064
47	308314	272464	River Wye SAC / River Ithon SSSI	0.023	0.023	0.029	0.017	0.008	0.033	0.019
48	314968	272404	River Wye SAC / River Ithon SSSI	0.096	0.095	0.113	0.096	0.077	0.151	0.072
49	315582	273493	River Wye SAC / River Ithon SSSI	0.054	0.054	0.056	0.042	0.062	0.064	0.036
50	315332	271873	River Wye SAC / River Ithon SSSI	0.083	0.082	0.079	0.063	0.057	0.136	0.068
51	315392	271587	River Wye SAC / River Ithon SSSI	0.076	0.075	0.077	0.061	0.053	0.126	0.065
52	315215	270192	River Wye SAC / River Ithon SSSI	0.037	0.036	0.037	0.028	0.041	0.083	0.060
53	315561	269128	River Wye SAC / River Ithon SSSI	0.021	0.021	0.021	0.014	0.039	0.048	0.033
54	313910	267369	River Wye SAC / River Ithon SSSI	0.013	0.013	0.010	0.006	0.025	0.017	0.010

5.2 Detailed modelling

The detailed modelling, which includes ammonia deposition and the consequent plume depletion, was carried out over three restricted domains covering the existing and proposed poultry houses at Ddole Farm, four AWs, Maelienydd SSSI, Cwmsaise SSSI, Lower Caerfaelog Pastures SSSI, the River Lugg SSSI, Coed Bryn-Person SSSI and River Wye SAC/River Ithon SSSI, 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 SACs and SSSIs or 100% of the Critical Level, which is the Natural Resources Wales lower threshold percentage for an AW.

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.

Terrain effects may be significant at some receptors; therefore, the detailed deposition run was made with terrain. 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 6. In the Table, 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/SSSI and 100% of Critical Level or Load for AW) are coloured red. Concentrations that are in the range between the Natural Resources Wales lower and upper threshold (1% to 8% for a SAC/SSSI and 50%[1] to 100% for AW) are coloured blue.

Contour plots of the predicted ground level maximum annual mean ammonia concentration at high, medium and low resolution are shown in Figures 6a, 6b and 6c respectively. Contour plots of the maximum nitrogen deposition rate at high, medium and low resolution are shown in Figures 7a, 7b and 7c respectively.

1. The 2016 figure has been retained.

Table 6a. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors – high resolution detailed modelling

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
1	312821	272431	Unnamed AW	0.030	1.0	10.0	0.99	**99.0**	7.71	**77.1**
2	312714	272444	Unnamed AW	0.030	1.0	10.0	0.50	49.9	3.88	38.8
3	313007	272631	Ddol Wood AW	0.030	1.0	10.0	0.49	49.5	3.85	38.5
17	312982	271760	Maelienydd SSSI	0.020	1.0	5.0	0.12	**11.5**	0.60	**12.0**
35	312703	272180	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	1.58	**157.9**	12.30	**246.0**
36	312794	271975	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.45	**45.4**	3.54	**70.8**
37	312870	272515	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.75	**75.4**	5.88	**117.5**
38	312467	271785	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.18	**17.7**	1.38	**27.6**

Table 6b. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors – medium resolution detailed modelling

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m^3)	Critical Load (kg/ha)	Process Contribution (µg/m^3)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
18	313461	271786	Maelienydd SSSI	0.020	1.0	5.0	0.20	**19.6**	1.02	**20.4**
19	314348	272077	Maelienydd SSSI	0.020	1.0	5.0	0.11	**11.2**	0.58	**11.6**
21	314177	271501	Maelienydd SSSI	0.020	1.0	5.0	0.08	**7.5**	0.39	**7.8**
39	313042	273072	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.19	**19.1**	1.49	**29.8**
48	314968	272404	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.08	**7.5**	0.59	**11.8**
50	315332	271873	River Wye SAC / River Ithon SSSI	0.03	1.0	5.0	0.05	**5.1**	0.4	**7.9**
51	315392	271587	River Wye SAC / River Ithon SSSI	0.03	1.0	5.0	0.04	**4.4**	0.3	**6.8**

Table 6c. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors – low resolution detailed modelling

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
20	312665	271219	Maelienydd SSSI	0.020	1.0	5.0	0.05	**4.5**	0.24	**4.7**
21	314177	271501	Maelienydd SSSI	0.020	1.0	5.0	0.08	**7.6**	0.39	**7.9**
22	312025	270382	Maelienydd SSSI	0.020	1.0	5.0	0.02	**2.3**	0.12	**2.4**
23	313592	270824	Maelienydd SSSI	0.030	1.0	5.0	0.02	**2.1**	0.16	**3.2**
24	315459	270926	Maelienydd SSSI	0.030	1.0	5.0	0.04	**3.9**	0.31	**6.1**
25	313871	270290	Cwmsaise SSSI	0.030	1.0	5.0	0.01	**1.3**	0.10	**2.1**
26	314154	269713	Cwmsaise SSSI	0.030	1.0	5.0	0.01	**1.1**	0.09	**1.8**
27	311063	273604	Lower Caerfaelog Pastures SSSI	0.030	1.0	5.0	0.02	**1.6**	0.12	**2.5**
28	317017	274674	River Lugg SSSI	0.030	1.0	5.0	0.01	0.6	0.05	0.9
29	317505	273801	River Lugg SSSI	0.030	1.0	5.0	0.01	0.8	0.06	**1.2**
30	308665	272044	Coed Bryn-Person SSSI	0.030	1.0	5.0	0.01	**1.1**	0.09	**1.8**
31	308524	272710	Coed Bryn-Person SSSI	0.030	1.0	5.0	0.01	0.7	0.05	**1.0**
32	307980	273625	Gweunydd Crychell SSSI	0.030	1.0	5.0	0.00	0.4	0.03	0.6
33	308134	273926	Gweunydd Crychell SSSI	0.030	1.0	5.0	0.00	0.4	0.03	0.5
34	314318	268088	Far Hall Meadow SSSI	0.030	1.0	10.0	0.01	0.6	0.05	0.5

Table 6c. Continued

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
40	311677	271162	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.04	**3.5**	0.27	**5.5**
41	310542	270140	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.01	**1.3**	0.10	**2.0**
42	309962	272110	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.04	**3.5**	0.27	**5.5**
43	310536	268204	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.01	0.9	0.07	**1.4**
44	310698	273118	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.02	**1.7**	0.13	**2.6**
45	309329	274520	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.01	0.7	0.05	**1.0**
46	311171	276357	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.01	0.7	0.05	**1.1**
47	308314	272464	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.01	0.9	0.07	**1.5**
49	315582	273493	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.03	**2.9**	0.23	**4.5**
52	315215	270192	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.02	**1.8**	0.14	**2.8**
53	315561	269128	River Wye SAC / River Ithon SSSI	0.030	1.0	5.0	0.01	0.9	0.07	**1.4**

Figure 6a. Maximum annual ammonia concentration – high resolution

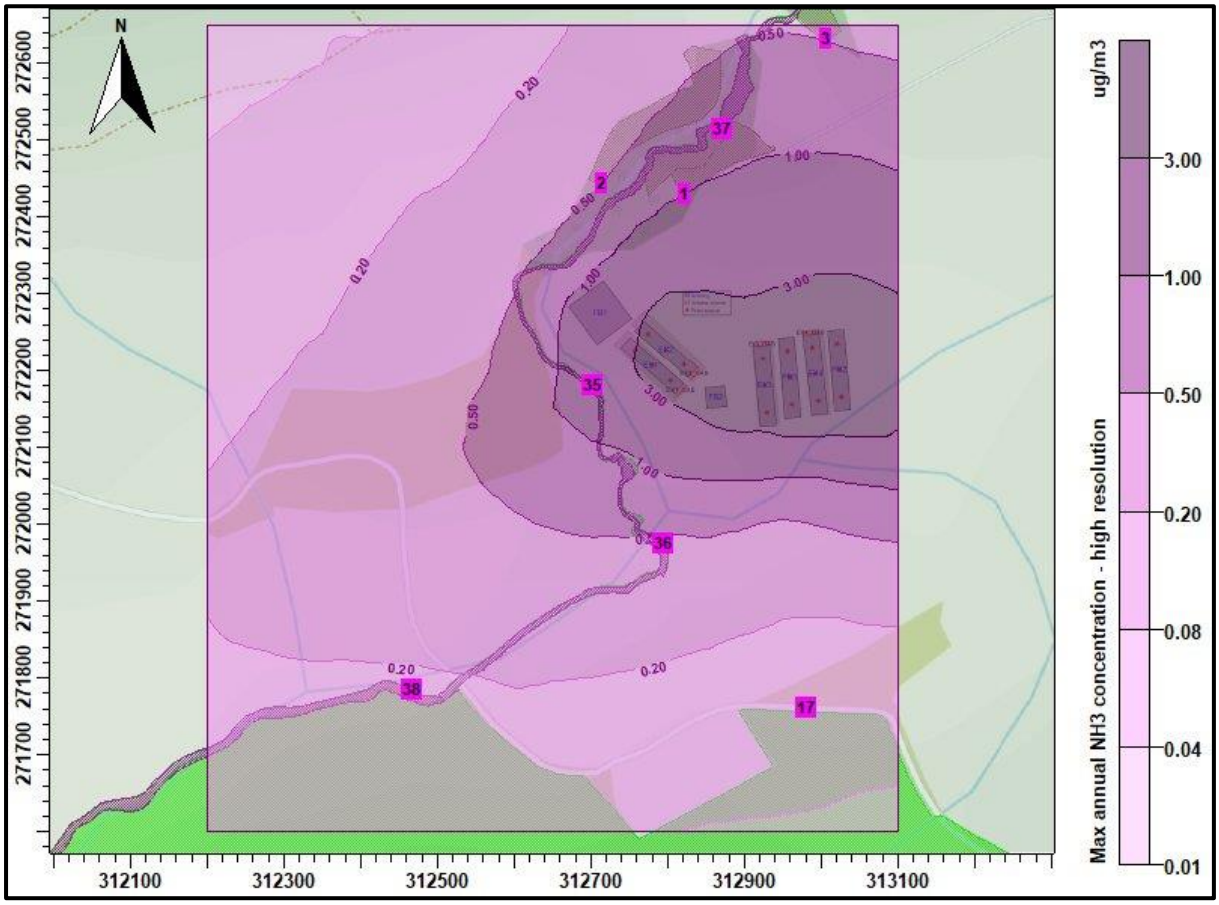


Figure 6b. Maximum annual ammonia concentration – medium resolution

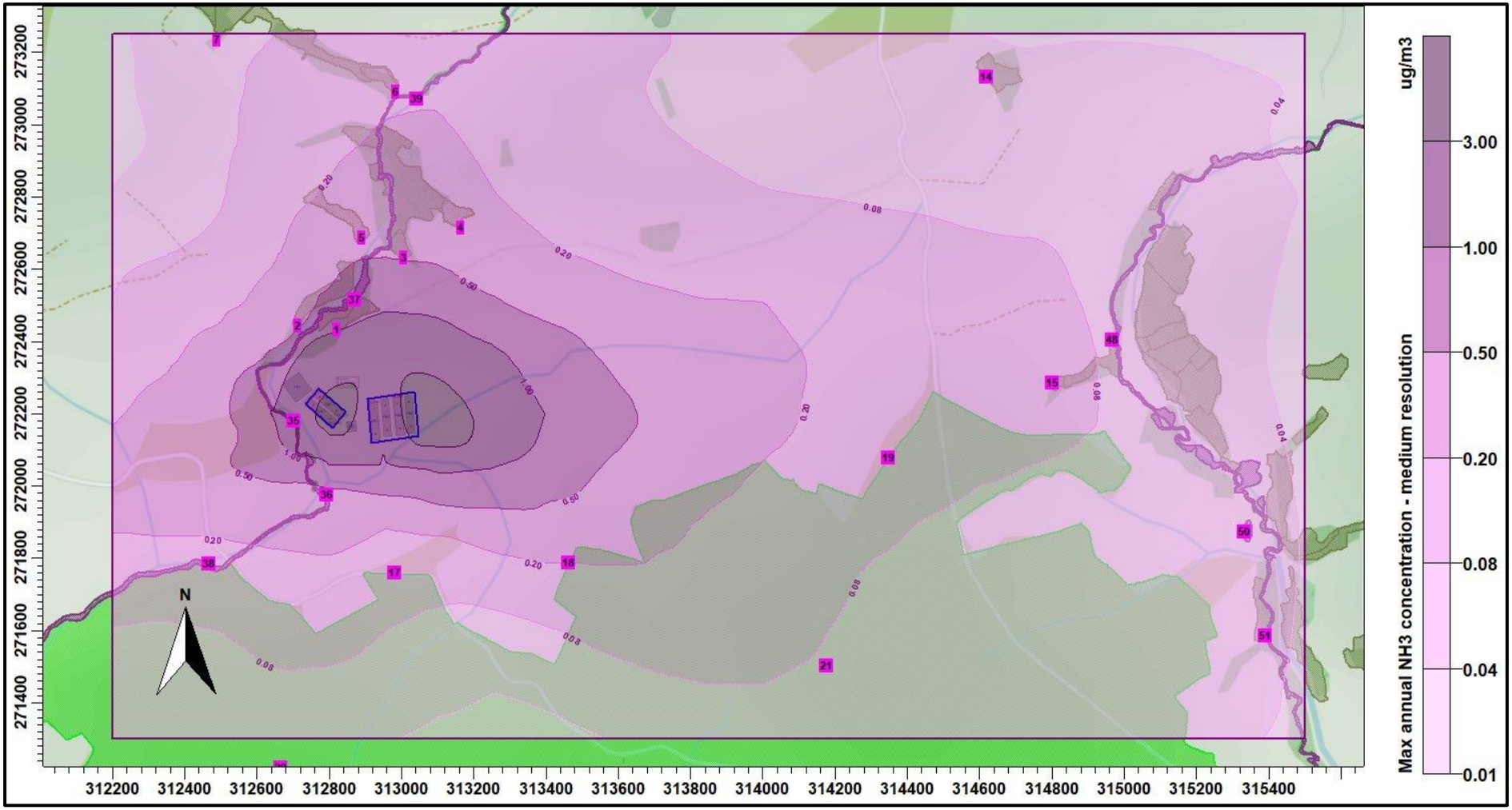


Figure 6c. Maximum annual ammonia concentration – low resolution

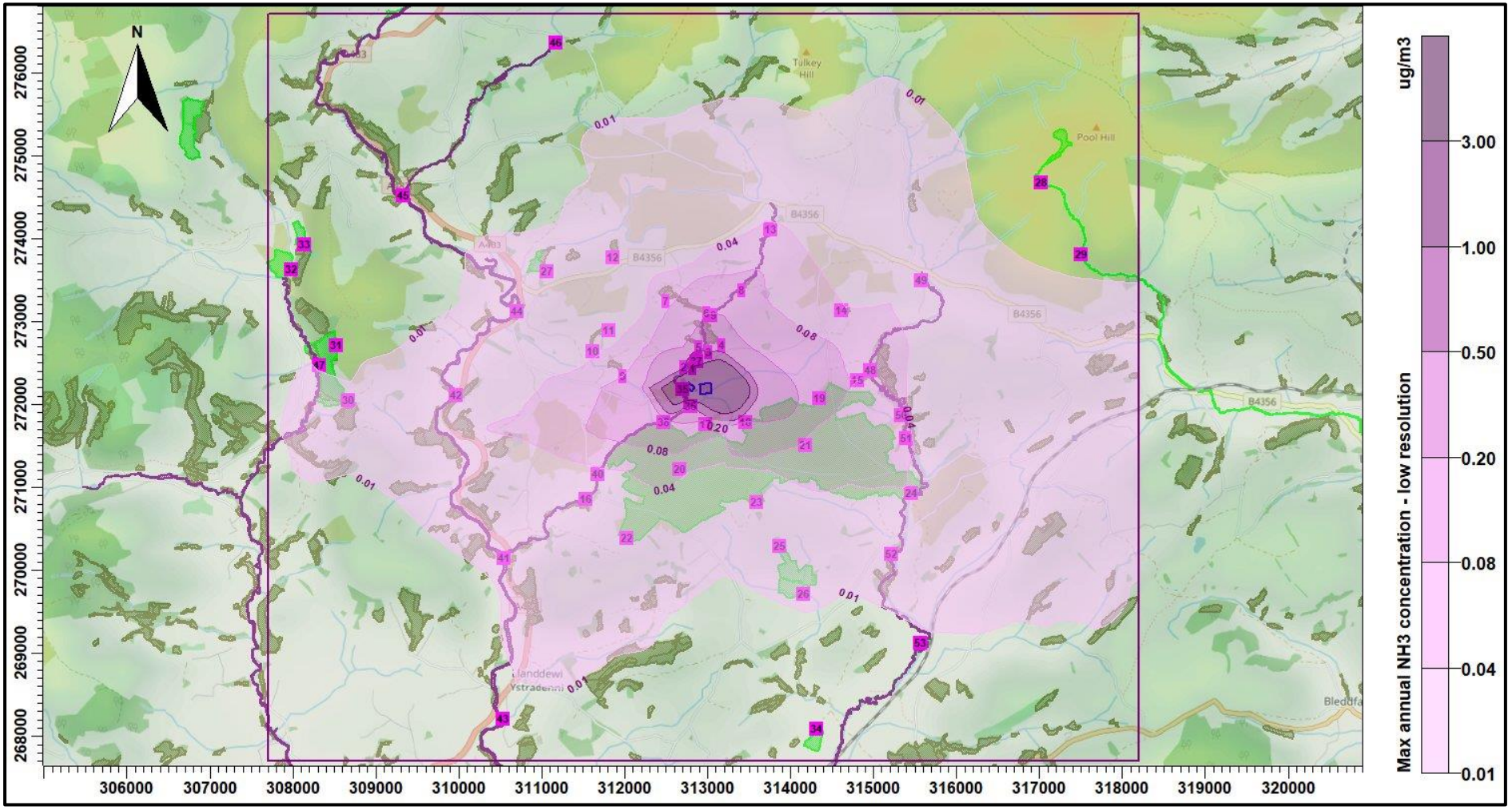


Figure 7a. Maximum annual nitrogen deposition rates – high resolution

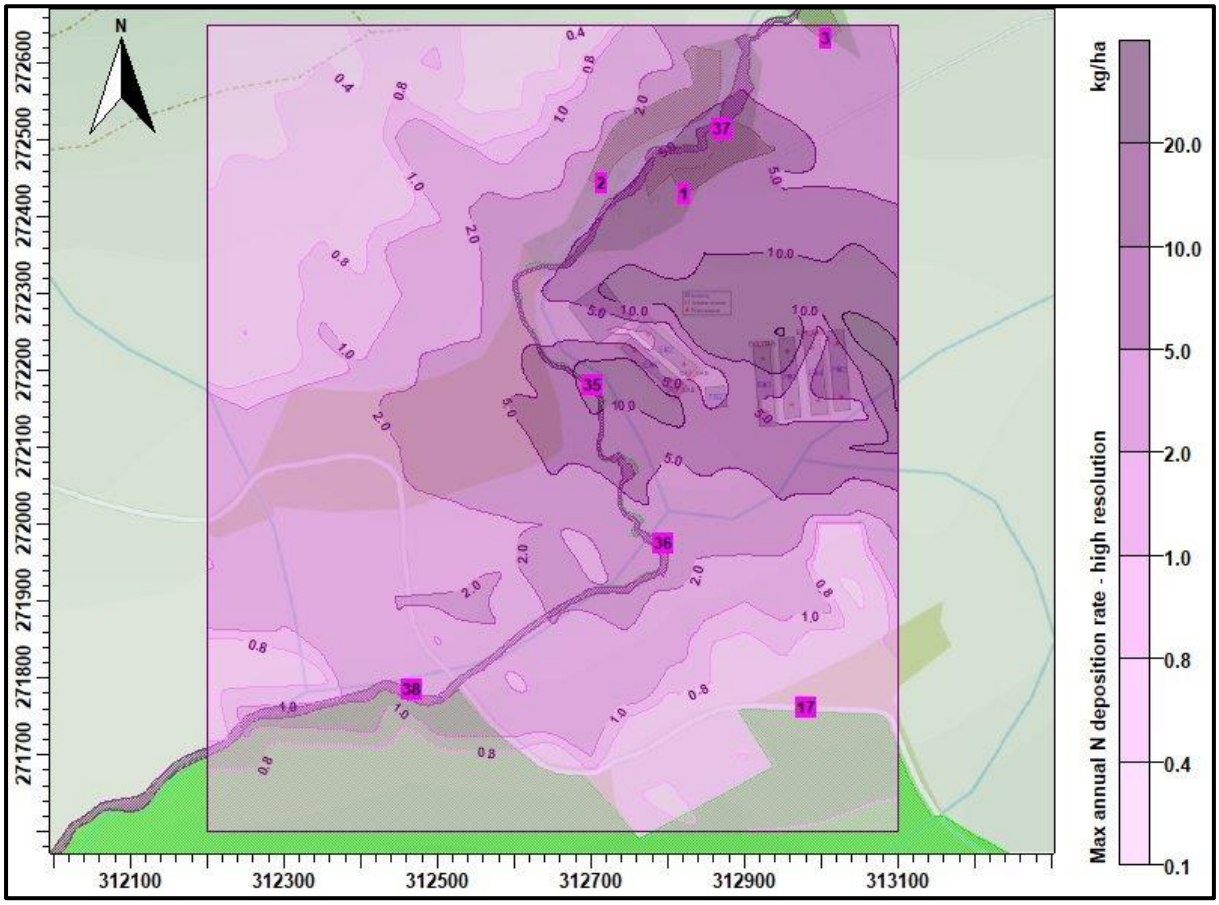


Figure 7b. Maximum annual nitrogen deposition rates – medium resolution

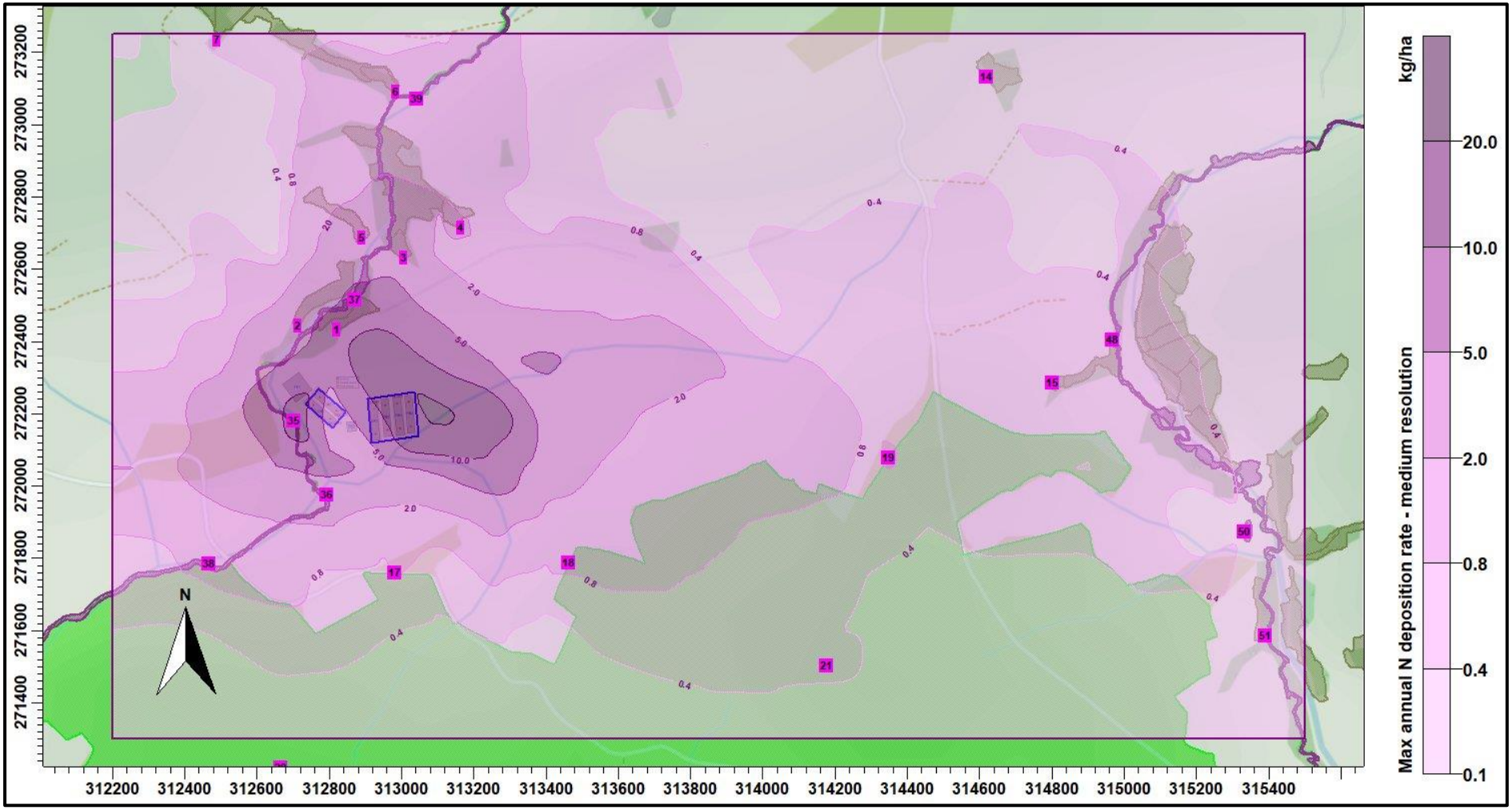
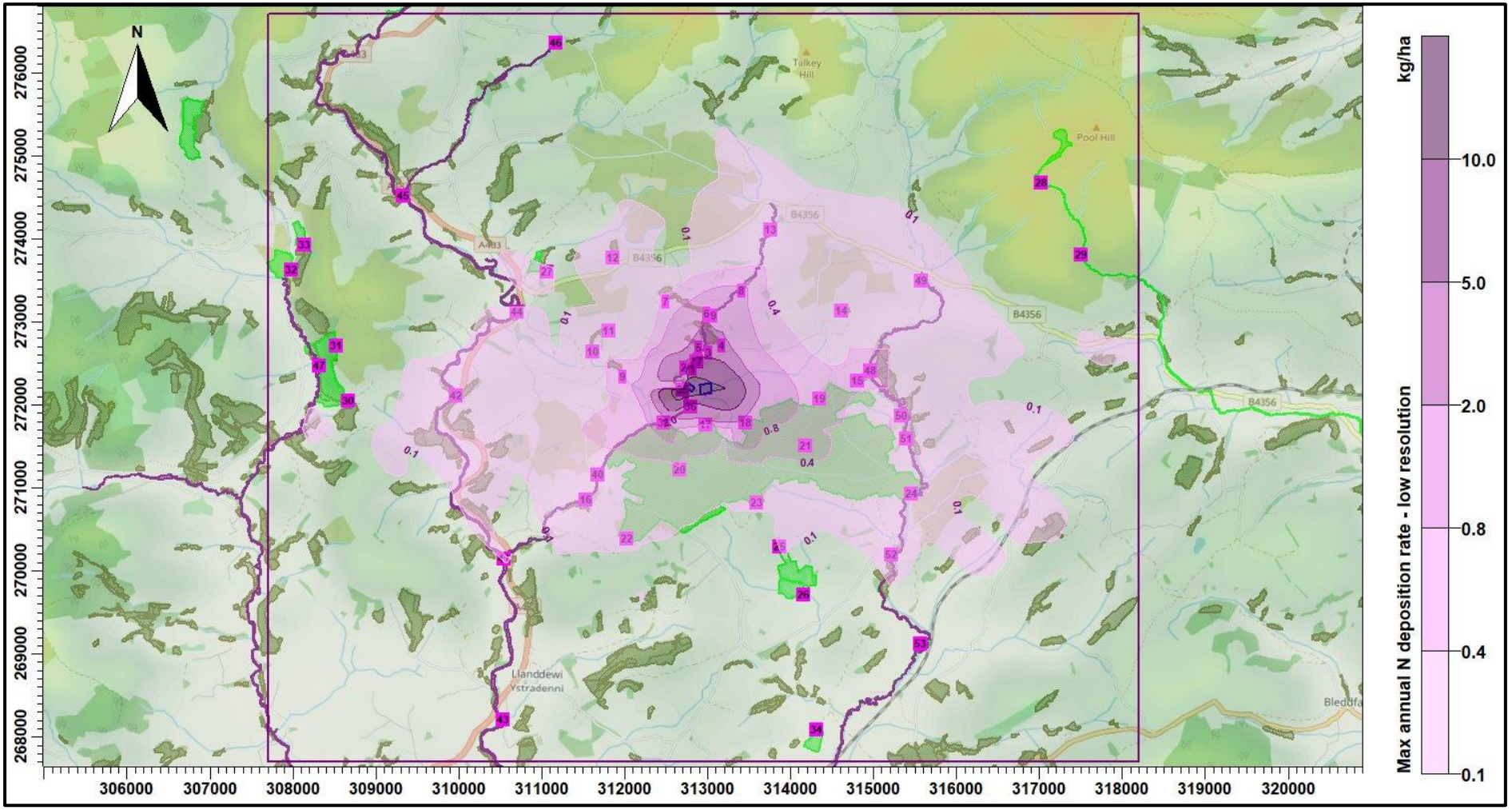


Figure 7c. Maximum annual nitrogen deposition rates – low resolution



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Steve Raasch, on behalf of the applicant Andrew Lewis, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed broiler chicken rearing houses at land near to Ddole Farm, Llanbister, Llandrindod Wells, Powys. LD1 6ST.

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 and acid deposition rates in the surrounding area.

Preliminary modelling

The preliminary modelling predicts that the process contribution of the existing and proposed poultry houses to the annual ammonia concentration and the nitrogen deposition rate would potentially exceed the Natural Resources Wales lower threshold percentage of the Critical Level or Load (1% for a SAC/SSSI and 100% for an AW) at: one unnamed AW to the north of the poultry houses; Maelienydd SSSI; Cwmsaise SSSI; Lower Caerfaelog Pastures SSSI; the River Lugg SSSI; Coed Bryn-Person SSSI and River Wye SAC/River Ithon SSSI.

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 high, medium and low resolution detailed modelling predicts that the process contribution:

- Would be below the Natural Resources Wales lower threshold of 100% of the precautionary Critical Level of 1.0 µg-NH_3/m^3 at the unnamed AW to the north of the poultry houses.
- Would exceed the Natural Resources Wales upper threshold of 8% of the Critical Level of 1.0 µg-NH_3/m^3 and the Critical Load of 5.0 kg/ha/y over parts of Maelienydd SSSI and River Wye SAC/River Ithon SSSI.
- Would be below the Natural Resources Wales upper threshold of 8% of the Critical Level of 1.0 µg-NH_3/m^3 and the Critical Load of 5.0 kg/ha/y at Cwmsaise SSSI, Lower Caerfaelog Pastures SSSI and Coed Bryn-Person SSSI.
- Be below the Natural Resources Wales lower threshold of 1% of the Critical Level of 1.0 µg-NH_3/m^3 at the River Lugg 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, an in-combination assessment may be necessary as part of the competent authority's appropriate assessment. Furthermore, where the predicted process contributions to ammonia concentrations and nitrogen deposition rates above the Natural Resources Wales upper threshold, mitigation of the ammonia emissions would normally be required.

7. References

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