A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing and Proposed Free Range Egg-laying Chicken Houses at Braich-yr-Alarch, Clawdd-newydd, Near Ruthin in Denbighshire

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Gail Jenkins, of Roger Parry & Partners LLP, on behalf of W.B. & L.E. Jones, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed free range egg-laying chicken houses at Braich-yr-Alarch, Clawdd-newydd, near Ruthin, Denbighshire. LL15 2NN.

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. Ammonia emission from ranging areas have been assessed and quantified based upon a range of sources. 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 free range egg-laying chicken houses at Braich-yr-Alarch is in a rural area, approximately 2 km to the west-south-west of the village of Clawdd-newydd in the community of Derwen, Denbighshire. The surrounding land is almost exclusively pasture, but there are some isolated areas of semi-natural woodlands and arable fields nearby. The site is at an elevation of around 280 m, with the land rising towards higher ground to the north and west and falling towards the Nant Mynian, a tributary of the River Clywyd to the east.

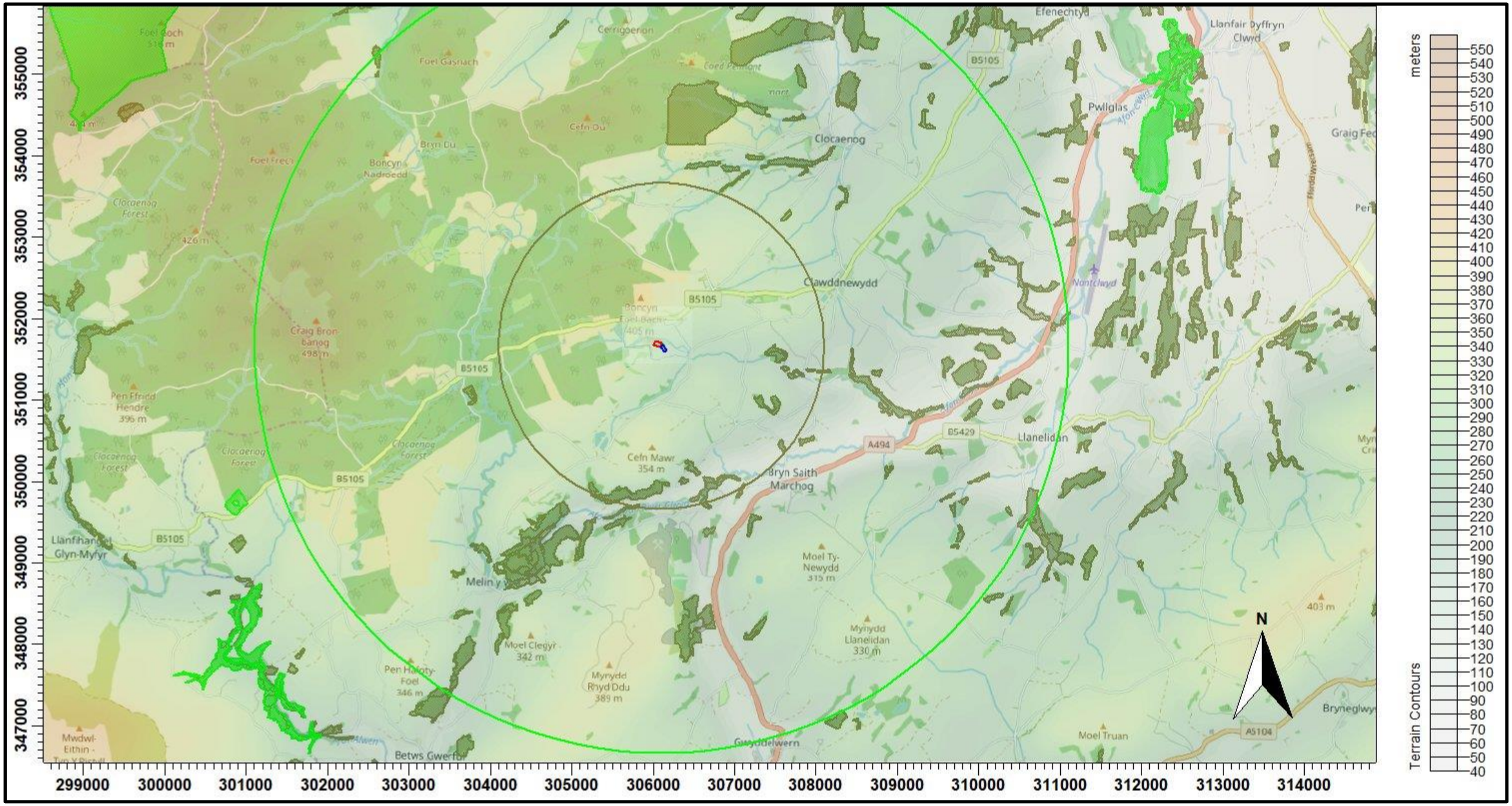
Under the proposal, a single poultry house would be constructed to the south-east of the existing two poultry houses at Braich-yr-Alarch. The three poultry houses would provide accommodation for up to 48,000 egg-laying chickens. Ventilation is/would be provided by gable end fans and manure is/would be removed from the poultry houses using a belt system twice weekly and removed from the site. The chickens have/would have daytime access to outside ranging areas via a series of pop holes in the sides of the houses.

There are several areas of Ancient Woodlands (AWs) within 2 km of Braich-yr-Alarch. There also three Sites of Special Scientific Interest (SSSIs) that lie just outside 5 km of the farm. Further details of the SSSIs are provided below:

- Craig Adwy-Wynt A Choed Cil-Y-Groeslwyd Ac Eyart SSSI - Approximately 6.1 km to the east-north-east - Of special interest for its botanical and entomological features; semi-natural woodland and calcareous grassland.
- Cefn Rofft SSSI - Approximately 5.4 km to the west-south-west - Of special interest for its unimproved neutral grassland which occurs in association with small areas of wet acidic grassland, woodland, scrub and bracken.
- Coedydd Dyffryn Alwen SSSI - Approximately 5.6 km to the west-south-west - Of special interest for its semi-natural broadleaved woodland.

A map of the surrounding area showing the positions of the existing and proposed poultry houses and the nearby wildlife sites is provided in Figure 1. In this figure, the AWs are outlined in olive, the SSSIs are shaded green, the site of the existing poultry houses is outlined in red and the site of the proposed poultry houses is outlined in blue.

Figure 1. The area surrounding Braich-yr-Alarch – concentric circles radii 5 km (green) and 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 (µg-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 Braich-yr-Alarch and the wildlife sites is 1.31 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 28.56 kg-N/ha/y and to short vegetation is 18.76 kg-N/ha/y. The background acid deposition rate to woodland is 1.69 keq/ha/y and to short vegetation is 1.22 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS, October 2020).

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 µg-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 µg-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 (kg-N/ha/y)	Critical Load Acid (keq/ha/y)
The AWs	1.0 [1]	-	-
Craig Adwy-Wynt A Choed Cil-Y-Groeslwyd Ac Eyart SSSI	1.0 [1]	5.0 [2]	-
Cefn Rofft SSSI	1.0 [1]	8.0 [2]	-
Coedydd Dyffryn Alwen SSSI	1.0 [1]	5.0 [2]	-

1. A precautionary figure used where no details of the ecology of the site are available, or the citation for the site contains reference to sensitive lichens and/or bryophytes.
2. The lower bound of the range of Critical Loads for the habitats obtained from APIS.

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.

The latter Natural Resources Wales document OGN 020 contains essentially the same thresholds.

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 Quantification of ammonia emissions

3.5.1 Housing Emissions

Ammonia emission rates from poultry houses, ranging areas and manure spreading 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 provides an Intensive farming guidance note which lists standard ammonia emission factors for a variety of livestock, including egg laying chickens. The emission factor for egg laying chickens in an aviary system with manure belts is 0.08 kg-NH_3/bird place/y; this figure is used to calculate regulatory baseline emissions from the proposed poultry house.

3.5.2 Ranging area emissions

As the birds would have access to outdoor ranging areas, some of the birds' droppings, which is the source of the ammonia, would be deposited on these ranging areas.

Three scenarios are considered for ranging area emissions:

- Scenario 1 – The Realistic Scenario – in which ranging emissions are based upon a figure of 7.34% range usage obtained from recent peer reviewed scientific investigations of very similar housing/ranging systems (Pettersson et al).
- Scenario 2 – The Pessimistic Scenario - in which ranging emissions based upon a figure of 12% range usage which is at the higher end of the range of percentages obtained from available peer reviewed scientific investigations (Campbell *et al*; Larsen *et al*; Chielo *et al*; Dawkins *et al*; Hegelund *et al*; Pettersson *et al*; Sossidou *et al* and Whay *et al*).
- Scenario 3 – The Unsound Scenario - in which ranging emissions based upon a figure of 20% range usage which is a figure that has been suggested by Natural Resources Wales, but is not based upon any peer reviewed literature and has not been included in the UK Ammonia Emission Inventory since 2015 (prior to which the figure was mentioned, but only as personal correspondence, with no reference to any peer reviewed work).

To estimate the ammonia emissions from the ranges for each scenario, it has been assumed that laying hens produce 0.8 kg-N/y (Misselbrook) in their droppings and that 35% of ammoniacal nitrogen is emitted as ammonia (Misselbrook and Defra). This equates to an emission factor of 0.34 kg-NH_3/bird/y.

It should be noted that the national atmospheric Emissions Inventory (NAEI) provides a figure for grazing layer chickens which is equivalent to 4% to 5% droppings occurring on the ranging area, and that in their recent consultation documentation on ammonia Natural Resources Wales propose the use of the NAEI emission factors.

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). Of the nearby observational meteorological stations, none are representative of the area around Braich-yr-Alarch and none can provide data that are at all suitable for dispersion modelling purposes.

The GFS is a spectral model: the physics/dynamics model has an equivalent resolution of approximately 13 km (latterly 9 km); terrain is understood to be resolved at a resolution of approximately 2 km, with sub-13/9 km terrain effects parameterised. 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 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 because terrain data is included in the modelling, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for Braich-yr-Alarch is shown in Figure 2b; it should be noted that elsewhere in the modelling domain the modified wind roses may differ, reflecting the local flow in that part of the domain. The resolution of the wind field in terrain runs is approximately 300 m. 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.

Figure 2a. The wind rose. Raw GFS derived data, for 53.054 N, 3.402 W, 2016 – 2019

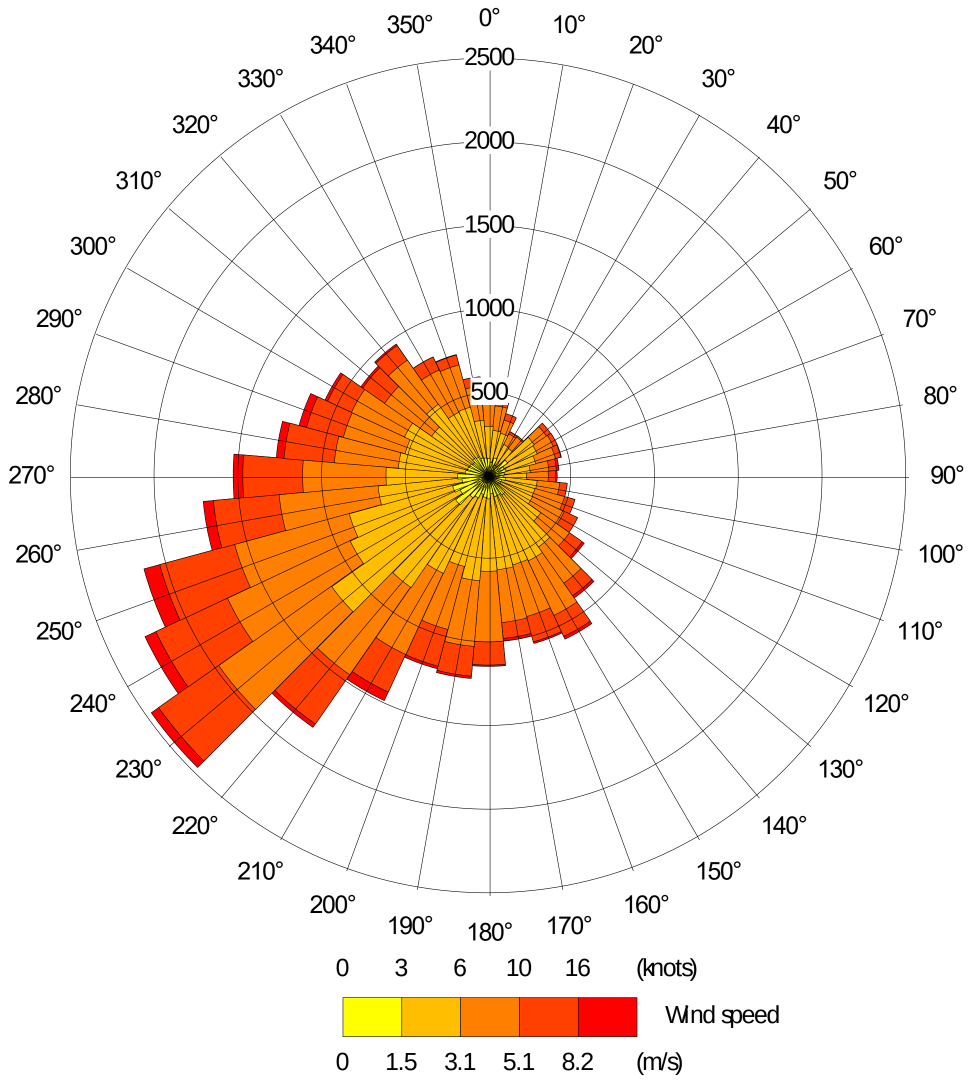
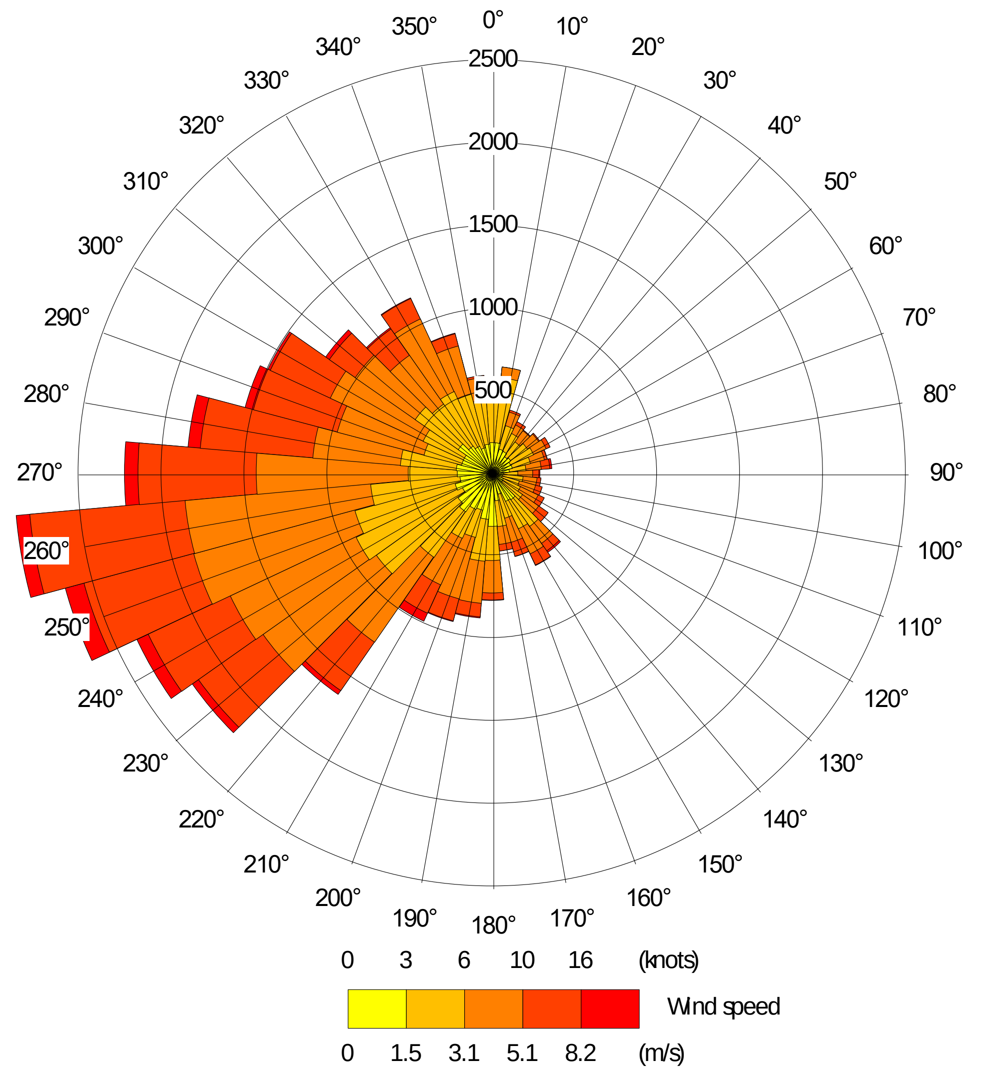


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 306050, 351700, 2016-2019



4.2 Emission sources

Emissions from the gable end fans that are currently/would be used to ventilate the existing and proposed poultry houses are represented by a single volume source per house within ADMS. Details of the volume source parameters are shown in Table 2a and the positions may be seen in Figure 3, where they are indicated by red rectangles.

Table 2a. Volume source parameters

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
EX1_gab	20.21	5.0	3.0	0.5	Ambient	0.037584
EX2_gab	20.21	5.0	3.0	0.5	Ambient	0.037584
PR_gab	20.77	5.0	3.0	0.5	Ambient	0.037584

The poultry houses have/would have ranging areas, which are represented by two area sources within ADMS (EX_RAN and PR_RAN). Note that the area sources cover the parts of the ranges most likely to be used frequently and not the whole ranging area. Details of the area source parameters are provided in Table 2b. The positions of the area sources are shown in Figure 4.

Table 2b. Area source parameters

Source ID	Area (m^2)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
EX_RAN	4,383.9	0.0	Ambient	0.025306
PR_RAN	5,283.1	0.0	Ambient	0.012653

The emission figures in Tables 2a and 2b are based upon Scenario 1, which assumes that 7.34% of droppings occur on the ranging areas and 92.66% of droppings occur within in the housing.

4.3 Modelled buildings

Not modelled.

4.4 Discrete receptors

Eighteen discrete receptors have been defined at nearby wildlife sites: fifteen at the AWs (1 to 15), and three at the SSSIs (16 to 18). These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figure 4, 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 field used in the detailed modelling, a nested 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 4, 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. 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.

4.7 Roughness Length

A fixed surface roughness length of 0.25 m has been applied over the entire modelling domain. As a precautionary measure, the GFS meteorological data is assumed to have a roughness length of 0.225 m. The effect of the difference in roughness length is precautionary as it increases the frequency of low wind speeds and the stability and therefore increases predicted ground level concentrations.

Figure 3. The positions of modelled sources

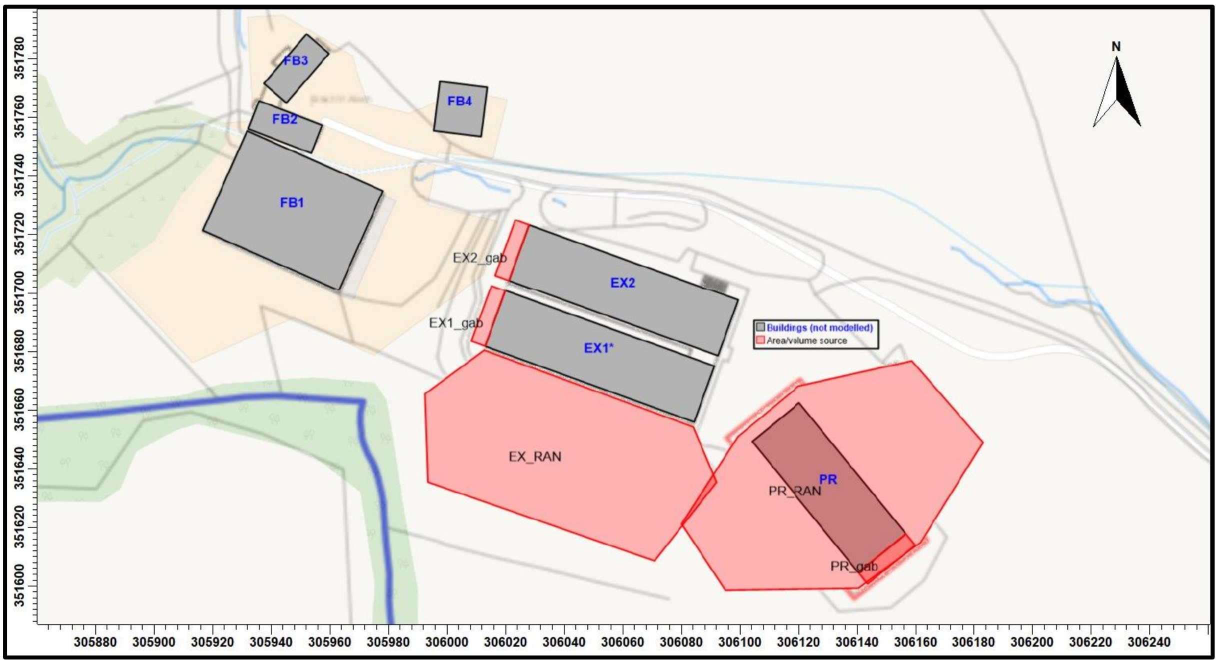
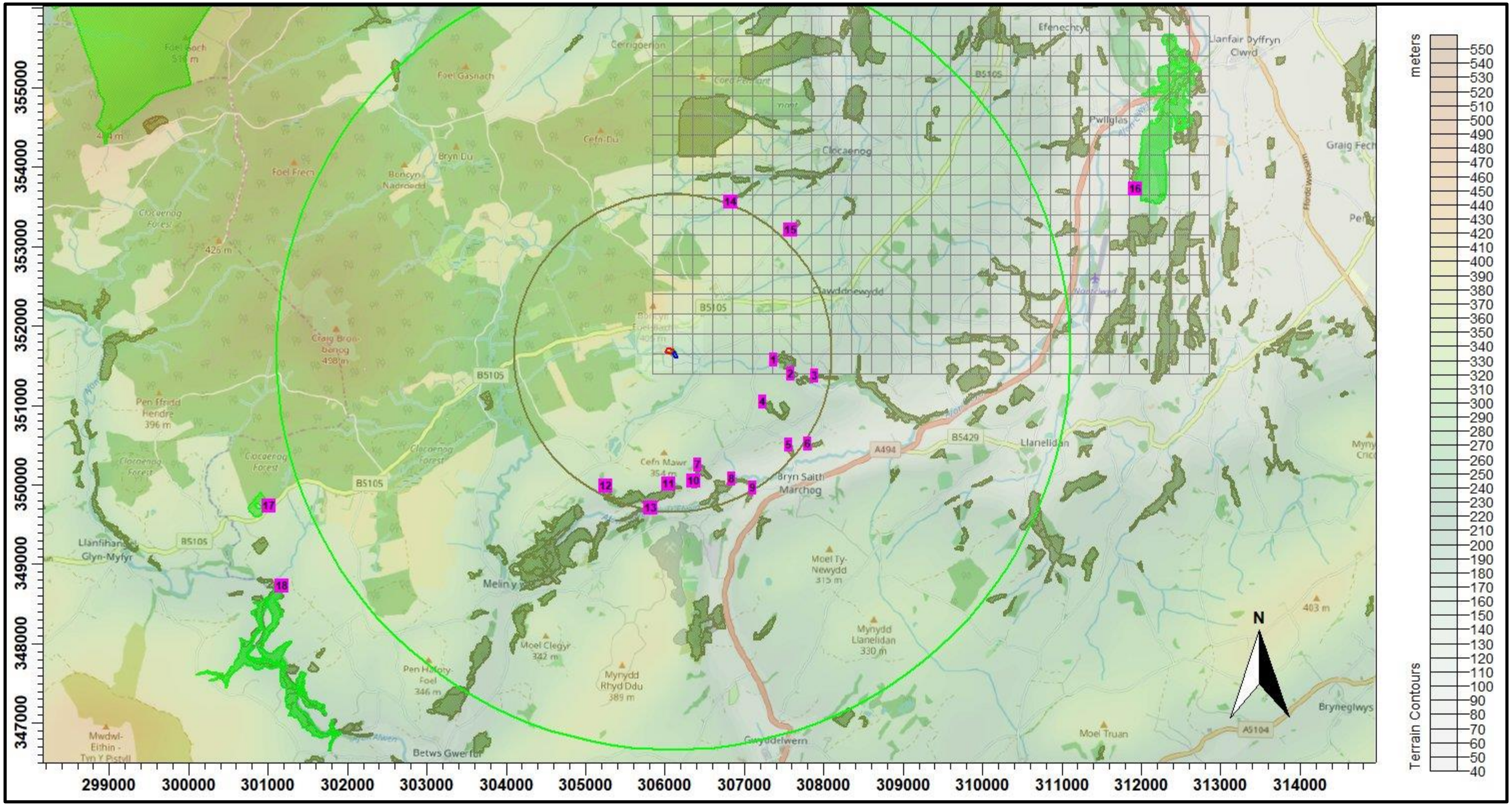


Figure 4. The discrete receptors and regular Cartesian grid



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4.8 Deposition

The method used to model deposition of ammonia and consequent plume depletion is based primarily upon Frederik Schrader and Christian Brümmer. Land Use Specific Ammonia Deposition Velocities: a Review of Recent Studies (2004–2013). 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 0.010 m/s over heavily grazed grassland. Where deposition over water surfaces is calculated, a deposition velocity of 0.005 m/s is used. 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, has been used to define a deposition velocity field. The deposition velocities used are provided in Table 3.

Table 3. Deposition velocities

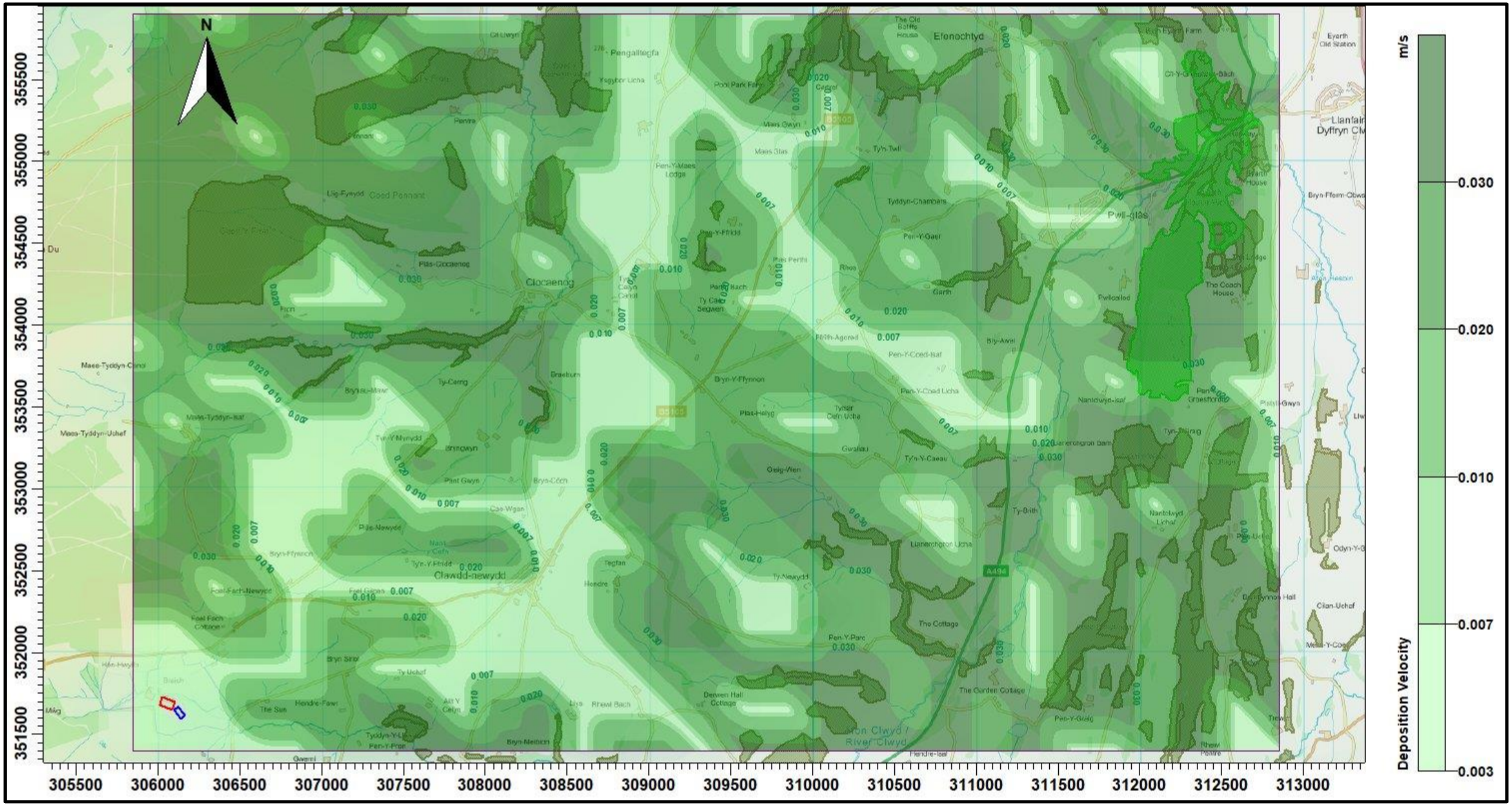
NH_3 concentration (PC + background) (μg/m^3)	< 10	10 - 20	20 - 30	30 – 80	> 80
Deposition velocity – woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity – short vegetation (m/s)	0.02 (0.010 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity – arable farmland/rye grass (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.

In this case, the model has also been run with a fixed deposition at 0.003 m/s and similarly to not modelling deposition at all, the predicted ammonia concentrations (and nitrogen deposition rates) are always higher than if deposition were modelled explicitly as Environment Agency guidance, particularly where there is some distance between the source and a receptor.

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 sixteen times; once for each year of the meteorological record and in the following four modes:

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

For each mode, statistics for the maximum annual mean ammonia concentration at each receptor were compiled. Note that these are preliminary results for screening and sensitivity testing. Please also note that, because deposition of ammonia and the consequent plume depletion are not accounted for or not fully accounted for, the results are precautionary. Therefore, predicted ammonia concentrations (and nitrogen deposition rates) are always higher than if deposition were modelled explicitly, particularly where there is some distance between the source and a receptor. In this case, a preliminary fixed deposition velocity run has been conducted, it should be noted that this is also precautionary, compared to full spatially varying deposition modelling.

Details of the predicted annual mean ammonia concentrations at each receptor due to the process contribution from the existing and proposed housing and ranging area are provided in Tables 4a (Realistic Scenario), 4b (Pessimistic Scenario) and 4c (Unsound Scenario). In the Tables, predicted ammonia concentrations (or concentrations equivalent to deposition rates) that are in excess of the Natural Resources Wales upper threshold (8% of a Critical Level or Critical Load for a statutory site or 100% of a Critical Level or Critical Load for a non-statutory site) are coloured red. Concentrations (or concentrations equivalent to deposition rates) in the range between the Natural Resources Wales lower and upper threshold (1% and 8% of Critical Level or Critical Load for a statutory site or 100% and 100% of Critical Level or Critical Load for a non-statutory site) are coloured blue. For convenience, cells referring to the AWs are shaded olive and cells referring to the SSSIs are shaded green.

Table 4a. Predicted annual mean ammonia concentration at the discrete receptors – preliminary modelling – Realistic Scenario

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 Calms Correction Terrain Fixed depo 0.003 m/s
1	307372	351573	AW	0.338	0.385	0.294	0.172
2	307578	351401	AW	0.247	0.282	0.219	0.116
3	307885	351367	AW	0.181	0.206	0.168	0.086
4	307233	351039	AW	0.295	0.337	0.250	0.129
5	307561	350500	AW	0.142	0.165	0.146	0.077
6	307797	350517	AW	0.128	0.148	0.141	0.074
7	306417	350256	AW	0.227	0.263	0.197	0.099
8	306842	350071	AW	0.169	0.197	0.188	0.095
9	307098	349962	AW	0.133	0.156	0.175	0.086
10	306362	350046	AW	0.169	0.200	0.170	0.086
11	306042	350008	AW	0.126	0.160	0.124	0.060
12	305255	349983	AW	0.109	0.135	0.097	0.042
13	305823	349714	AW	0.090	0.117	0.124	0.056
14	306825	353560	AW	0.189	0.206	0.183	0.097
15	307587	353210	AW	0.205	0.224	0.170	0.097
16	311930	353731	Craig Adwy-Wynt A Choed Cil-Y-Groeslwyd Ac Eyart SSSI	**0.034**	**0.036**	**0.040**	**0.018**
17	301007	349732	Cefn Rofft SSSI	**0.025**	**0.028**	**0.018**	0.006
18	301170	348732	Coedydd Dyffryn Alwen SSSI	**0.025**	**0.028**	**0.019**	0.007

Table 4b. Predicted annual mean ammonia concentration at the discrete receptors – preliminary modelling – Pessimistic Scenario

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 Calms Correction Terrain Fixed depo 0.003 m/s
1	307372	351573	AW	0.379	0.423	0.334	0.187
2	307578	351401	AW	0.278	0.310	0.249	0.126
3	307885	351367	AW	0.203	0.227	0.190	0.094
4	307233	351039	AW	0.331	0.370	0.283	0.139
5	307561	350500	AW	0.159	0.181	0.165	0.084
6	307797	350517	AW	0.144	0.163	0.158	0.080
7	306417	350256	AW	0.255	0.289	0.223	0.107
8	306842	350071	AW	0.190	0.216	0.213	0.102
9	307098	349962	AW	0.150	0.172	0.197	0.092
10	306362	350046	AW	0.191	0.219	0.192	0.092
11	306042	350008	AW	0.142	0.173	0.140	0.065
12	305255	349983	AW	0.122	0.146	0.109	0.045
13	305823	349714	AW	0.101	0.127	0.140	0.061
14	306825	353560	AW	0.211	0.227	0.206	0.105
15	307587	353210	AW	0.229	0.247	0.191	0.105
16	311930	353731	Craig Adwy-Wynt A Choed Cil-Y-Groeslwyd Ac Eyart SSSI	**0.038**	**0.039**	**0.045**	**0.019**
17	301007	349732	Cefn Rofft SSSI	**0.028**	**0.031**	**0.020**	0.007
18	301170	348732	Coedydd Dyffryn Alwen SSSI	**0.028**	**0.031**	**0.022**	0.007

Table 4c. Predicted annual mean ammonia concentration at the discrete receptors – preliminary modelling – Unsound Scenario

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 Calms Correction Terrain Fixed depo 0.003 m/s
1	307372	351573	AW	0.451	0.488	0.402	0.213
2	307578	351401	AW	0.330	0.358	0.300	0.145
3	307885	351367	AW	0.241	0.261	0.228	0.107
4	307233	351039	AW	0.395	0.427	0.340	0.156
5	307561	350500	AW	0.190	0.208	0.197	0.094
6	307797	350517	AW	0.172	0.187	0.189	0.090
7	306417	350256	AW	0.304	0.333	0.268	0.119
8	306842	350071	AW	0.227	0.249	0.254	0.114
9	307098	349962	AW	0.178	0.198	0.235	0.103
10	306362	350046	AW	0.227	0.252	0.231	0.103
11	306042	350008	AW	0.169	0.197	0.168	0.072
12	305255	349983	AW	0.145	0.167	0.132	0.051
13	305823	349714	AW	0.121	0.144	0.168	0.068
14	306825	353560	AW	0.250	0.262	0.245	0.118
15	307587	353210	AW	0.271	0.287	0.227	0.118
16	311930	353731	Craig Adwy-Wynt A Choed Cil-Y-Groeslwyd Ac Eyart SSSI	**0.045**	**0.046**	**0.054**	**0.021**
17	301007	349732	Cefn Rofft SSSI	**0.033**	**0.036**	**0.024**	0.007
18	301170	348732	Coedydd Dyffryn Alwen SSSI	**0.033**	**0.036**	**0.026**	0.008

5.2 Detailed modelling

The detailed modelling, which includes ammonia deposition and the consequent plume depletion, was carried out over a restricted domain covering the existing and proposed poultry houses and ranges at Braich-yr-Alarch and Craig Adwy-Wynt A Choed Cil-Y-Groeslwyd Ac Eyart SSSI, where the preliminary modelling (GFS fixed deposition run – realistic scenario) indicated that annual mean ammonia concentrations (or concentrations equivalent to deposition rates) would potentially exceed 1% of the precautionary Critical Level of 1.0 µg-NH_3/m^3. At all other wildlife sites considered, the preliminary modelling indicated that ammonia levels would be below the Natural Resources Wales lower threshold percentage of the Critical Level 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, to account for calms the results are multiplied by a factor of 1.09 (obtained from the difference between calms mode and basic mode in the preliminary modelling).

The predicted maximum annual mean ground level ammonia concentrations and nitrogen deposition rates at the discrete receptors within the detailed modelling domain due to the process contribution from the proposed housing and ranging are shown in Tables 5a (Realistic Scenario), 5b (Pessimistic Scenario) and 5c (Unsound Scenario). In the 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 statutory site and 100% of Critical Level or Load for a non-statutory site) are coloured red. Concentrations that are in the range between the Natural Resources Wales lower and upper threshold (1% to 8% for a statutory site and 100% to 100% for a non- statutory site) are coloured blue.

Contour plots of the predicted ground level maximum annual mean ammonia concentration and the maximum nitrogen deposition rate for the Realistic Scenario are shown in Figures 6a and 6b. Please note that upon request, similar contour plots can be provided for any, or all, of the partial process contributions for any Scenario.

Table 5a. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors - detailed modelling – Realistic Scenario

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
16	311930	353731	Craig Adwy-Wynt A Choed Cil-Y-Groeslwyd Ac Eyart SSSI	0.03	1.0	5.0	0.008	0.78	0.061	**1.22**

Table 5b. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors - detailed modelling – Pessimistic Scenario

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
16	311930	353731	Craig Adwy-Wynt A Choed Cil-Y-Groeslwyd Ac Eyart SSSI	0.03	1.0	5.0	0.009	0.87	0.067	**1.35**

Table 5c. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors - detailed modelling – Unsound Scenario

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
16	311930	353731	Craig Adwy-Wynt A Choed Cil-Y-Groeslwyd Ac Eyart SSSI	0.03	1.0	5.0	0.010	**1.01**	0.079	**1.58**

Figure 6a. Maximum annual ammonia concentration – Proposed housing and ranging emissions - Realistic Scenario

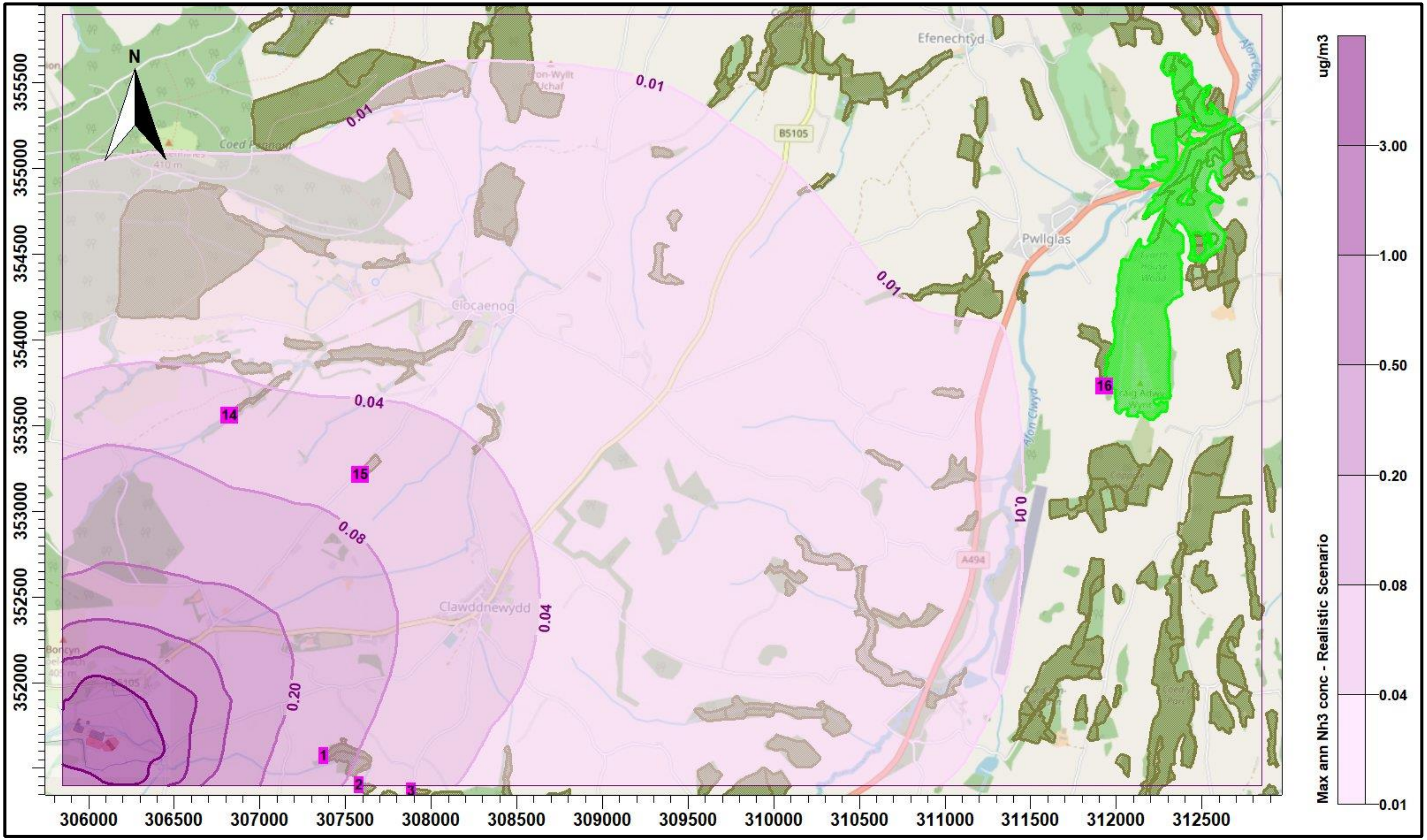
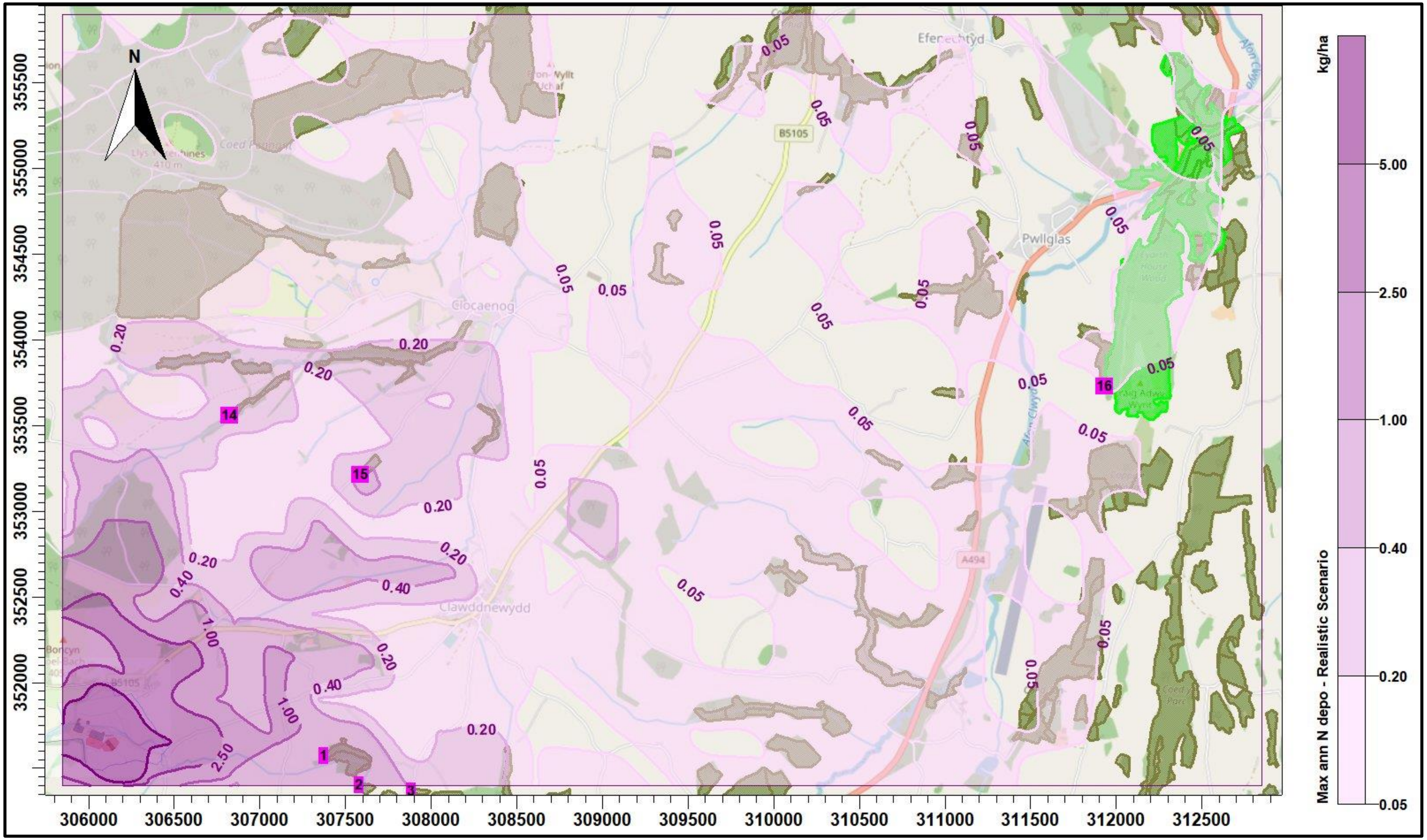


Figure 6b. Maximum annual nitrogen deposition rates – Proposed housing and ranging emissions - Realistic Scenario



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Gail Jenkins, of Roger Parry & Partners LLP, on behalf of W.B. & L.E. Jones, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed free range egg-laying chicken houses at Braich-yr-Alarch, Clawdd-newydd, near Ruthin, Denbighshire. LL15 2NN.

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. Ammonia emission from ranging areas have been assessed and quantified based upon a range of sources. 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.

Realistic Scenario Results

For the Realistic Scenario, the detailed modelling of emissions predicts that:

- The process contribution from the proposed housing and ranging to the annual ammonia concentration would be below 1% of the Critical Level of 1.0 µg-NH_3/m^3 at Craig Adwy-Wynt A Choed Cil-Y-Groeslwyd Ac Eyart SSSI. However, nitrogen deposition rates would be slightly in excess of 1% of the Critical Load of 5.0 kg-N/ha/yr over closer parts of the site.

- The annual ammonia concentrations and nitrogen deposition rates would be below 1% of the precautionary Critical Level of 1.0 µg-NH_3/m^3 at Cefn Rofft SSSI and Coedydd Dyffryn Alwen SSSI.

- The annual ammonia concentrations would be below 100% of the precautionary Critical Level of 1.0 µg-NH_3/m^3 at all the nearby AWs considered.

Discussion about the Other Scenarios

The extent to which the predicted process contribution to nitrogen deposition rates exceeds 1% at Craig Adwy-Wynt A Choed Cil-Y-Groeslwyd Ac Eyart SSSI depends on the proportions of the ranging and housing emissions.

Natural Resources Wales are currently mandating that a 20% ranging:80% housing emissions split is considered. However, AS Modelling & Data Ltd. are compelled to point out that it appears that this figure is not backed up by any peer reviewed research or literature and is based purely on reported personal correspondence in older versions of the Ammonia Emissions Inventory for the UK (UKAIE). Indeed, it should be noted that Natural Resources Wales rely on a reference to "Inventory of Ammonia Emissions from UK Agriculture 2015", which is not the latest version of the UKAIE and that the later versions do not contain the 20% figure.

It should be noted that the National Atmospheric Emissions Inventory (NAEI) provides a figure for grazing layer chickens which is equivalent to 4% to 5% droppings occurring on the ranging area, and that in their recent consultation documentation on ammonia Natural Resources Wales propose the use of the NAEI emission factors.

AS Modelling & data Ltd. have labelled the scenario with the 20% ranging:80% housing emissions split, the Unsound Scenario. This is not done frivolously; the Realistic and Pessimistic Scenarios are based upon figures from valid peer reviewed scientific research and papers (see Section 7. References), the Unsound scenario is based on personal correspondence reported in old annual reports, which have been superseded and AS Modelling & Data Ltd. would ask all concerned in the determination of this application to consider why a supposedly science-based organisation such as Natural Resources Wales should wish to uphold such a weak figure.

7. References

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