



A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Proposed Free Range Egg Laying Chicken Houses at Cae Mor, near Llwynmawr in Denbighshire.

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Rosina Bloor, of Roger Parry & Partners LLP, on behalf of Cae Mor Poultry, to use computer modelling to assess the impact of ammonia emissions from the proposed free range egg laying chicken houses at Cae Mor, Llwynmawr, Llangollen, Denbighshire. LL20 7BE.

Ammonia emission rates from the proposed poultry houses have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors. Ammonia emissions from ranging areas have been assessed and quantified based upon the baseline parameters used to calculate the National Atmospheric Emission Inventory (NAEI) emission factor for grazing free range hens and information from a variety of peer reviewed scientific papers. 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 proposed free range chicken houses at Cae Mor is in a rural area, 850 m to the south-south-east of the village of Llwynmawr in Denbighshire. The surrounding land is used predominately for livestock farming, although there are some wooded areas. The site is on the southern slopes of the valley of the Afon Ceiriog at an altitude of around 245 m, with the land rising to hills/mountains to the south and falling towards the Afon Ceiriog to the north.

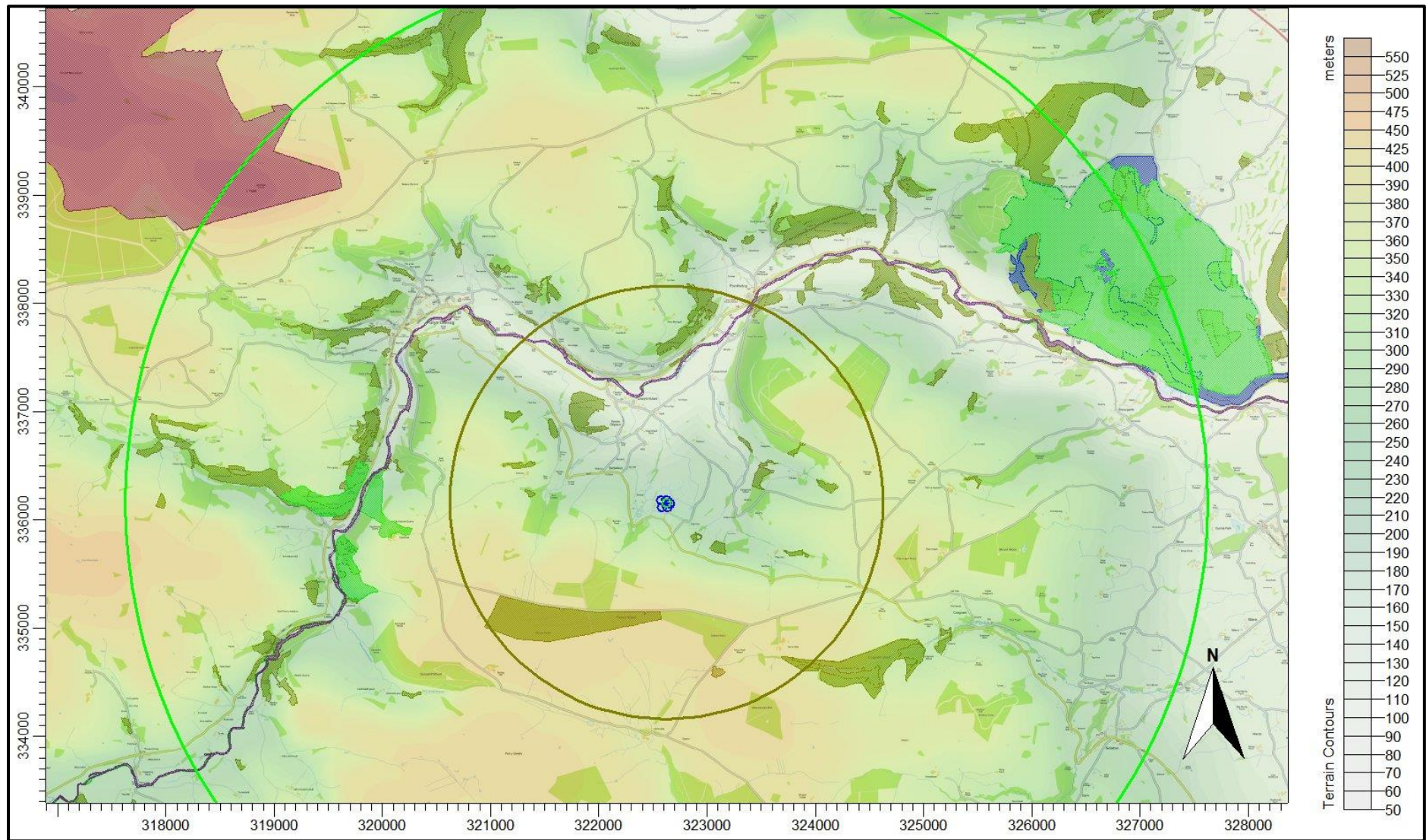
It is proposed that four poultry houses be constructed at Cae Mor. The proposed poultry houses would provide accommodation for up to 24,000 free range egg laying chickens. The poultry houses would have pop holes which would provide the birds with daytime access to an outside ranging area. Ventilation would be provided by high speed ridge or roof fans, each with a short chimney. Every four days, the birds' droppings would be removed from the housing by a belt collection system and stored temporarily on the farm, prior to removal from the site, or spreading to land.

There are several areas of remnant Ancient Woodlands (AWs) within 2 km of the site of the proposed poultry houses at Cae Mor. There are four Sites of Special Scientific Interest (SSSIs) within 5 km of the site, two of which are also designated as Special Areas of Conservation (SAC) and one of which is also designated as a Special Protected Area (SPA). There is also one area designated by Natural resources Wales as an ammonia sensitive AW within 5 km of the farm. Further details of the SSSIs/SACs/SPA are provided below:

- Pandy Quarries SSSI - Approximately 2.3 km to the west - Designated for geological features.
- Castell Y Waun A'I Barcdir SSSI - Approximately 3.7 km to the north-east - Of special interest as one of the best examples of ancient wood pasture and parkland in Wales. One area of grassland supports a diverse assemblage of grassland fungi which is of special interest and of national importance.
- Afon Dyfrdwy SSSI/SAC - Approximately 900 m to the north at its closet point - Of special interest for its fluvial geomorphology, Carboniferous geology, range of river habitat types, saltmarsh transition habitats, populations of floating water plantain *Luronium natans*, slender hare's-ear *Bupleurum tenuissimum*, sea barley *Hordeum marinum*, hard-grass *Parapholis strigosa*, otter *Lutra lutra*, salmon *Salmo salar*, bullhead *Cottus gobio*, brook lamprey *Lampetra planeri*, river lamprey *Lampetra fluviatilis*, sea lamprey *Petromyzon marinus*, club-tailed dragonfly *Gomphus vulgatissimus* and other aquatic invertebrates.
- Berwyn SSSI/SAC/SPA - Approximately 4.0 km to the north-west - Of national and international importance for its moorland breeding birds and vegetation, particularly *Calluna* dominated heath and blanket mire. The dominant species are heather *Calluna vulgaris*, hare's tail cottongrass *Eriochorum vaginatum* and a number of bog moss *Sphagnum* species which often form "lawns".

A map of the surrounding area showing the positions of the proposed poultry houses and the nearby wildlife sites is provided in Figure 1. In this figure, the AWs are outlined in olive, the ammonia sensitive AW is shaded in blue, the SSSIs are shaded green, the SACs/SPA are shaded purple and the positions of the proposed poultry houses are outlined in blue.

Figure 1. The area surrounding Land near Cae Mor - concentric circles radii 5 km (green) and 2 km (olive)



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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 ($\mu\text{g-NH}_3/\text{m}^3$) 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 the poultry houses at Cae Mor and the wildlife sites is $1.45 \mu\text{g-NH}_3/\text{m}^3$. The background nitrogen deposition rate to woodland is 33.32 kg-N/ha/y and to short vegetation is 21.98 kg-N/ha/y . The background acid deposition rate to woodland is 2.09 keq/ha/y and to short vegetation is 1.47 keq/ha/y . The source of these background figures is the Air Pollution Information System (APIS, March 2021).

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 $3.0 \mu\text{g-NH}_3/\text{m}^3$ 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 $1.0 \mu\text{g-NH}_3/\text{m}^3$ 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 $1.0 \mu\text{g-NH}_3/\text{m}^3$ 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 ($\mu\text{g-NH}_3/\text{m}^3$)	Critical Load Nitrogen (kg-N/ha/y)	Critical Load Acid (keq/ha/y)
AWs	1.0 ¹	-	-
Berwyn SSSI/SAC/SPA	1.0 ¹	5.0 ³	-
Pandy Quarries SSSI	n/a ⁴	n/a ⁴	n/a ⁴
Castell Y Waun A'I Barcdir SSSI and Afon Dyfrdwy SSSI/SAC	3.0 ²	10.0 ^{2&3}	-

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. Based upon the SSSI citation and information from Natural Resources Wales (website).
3. The lower bound of the range of Critical Loads for the habitats obtained from APIS.
4. Not sensitive (Natural Resources Wales: website).

3.4 Guidance on the Significance of Ammonia Emissions

In June 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%).

3.6 Quantification of ammonia emissions

3.6.1 Housing 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-NH₃/bird place/y; this figure is used to calculate emissions from the proposed poultry houses.

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. To estimate the ammonia emissions from the ranges for each scenario, it is assumed that laying hens produce 0.75 kg-N/y in their droppings (NAEI) of which 70% is ammoniacal nitrogen, that is nitrogen in a form that may readily be converted to ammonia (NAEI), and that 35% of ammoniacal nitrogen is emitted as ammonia (NAEI).

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*). This equates to an emission factor of 0.016 kg-NH₃/bird-place/y.
- 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*). This equates to an emission factor of 0.027 kg-NH₃/bird-place/y.
- Scenario 3 - The Unsound Scenario - in which ranging emissions based upon a figure of 20% range usage which is a figure that has been mandated 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). It should be noted that the maintainers of the NAEI state the following, "We have no specific measurement/observational data for this number". This equates to an emission factor of 0.045 kg-NH₃/bird-place/y.

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 Cae Mor and none can provide data that are 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 the site of the proposed poultry houses 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 150 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 52.917 N, 3.151 W, 2017 – 2020

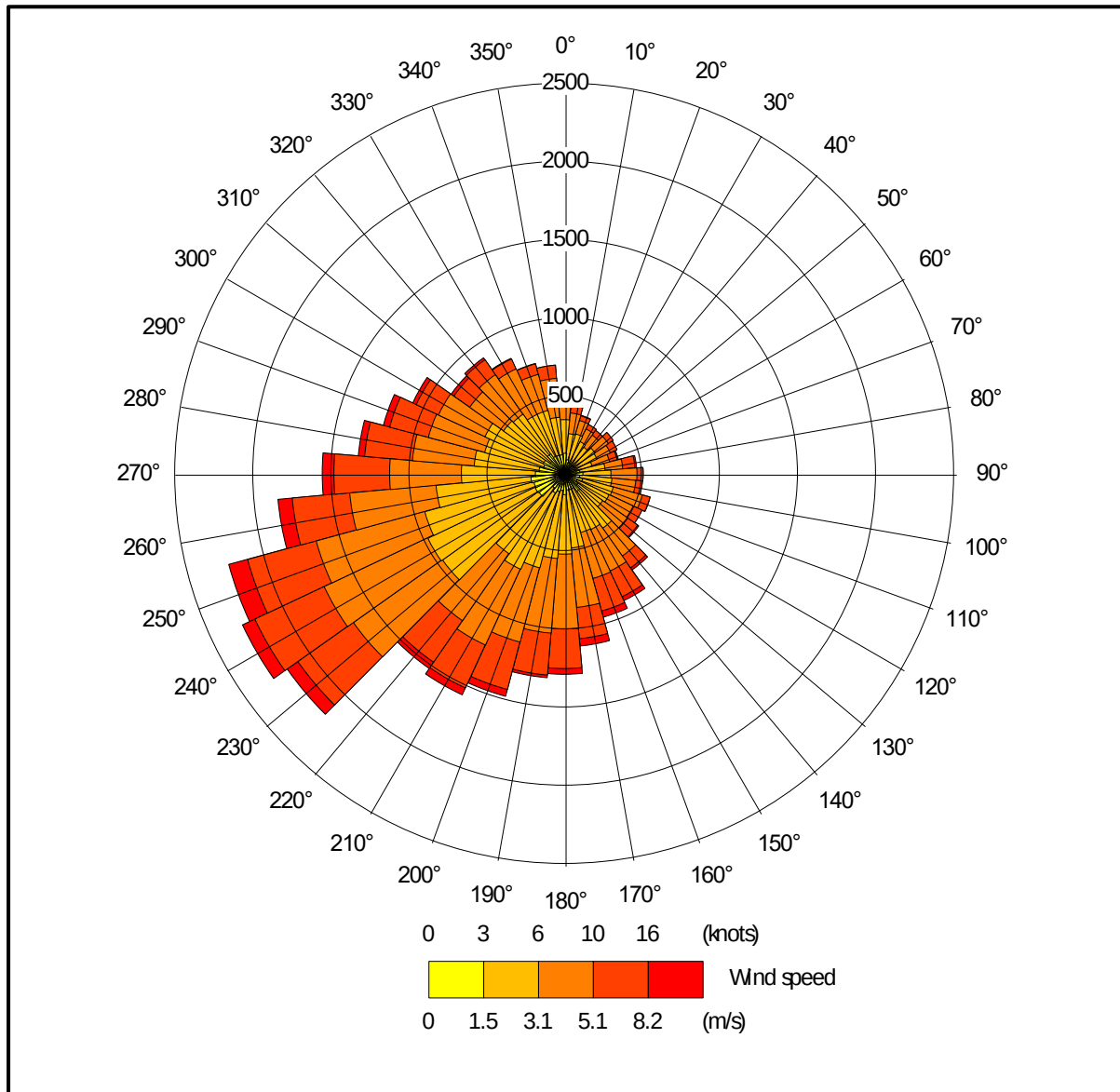
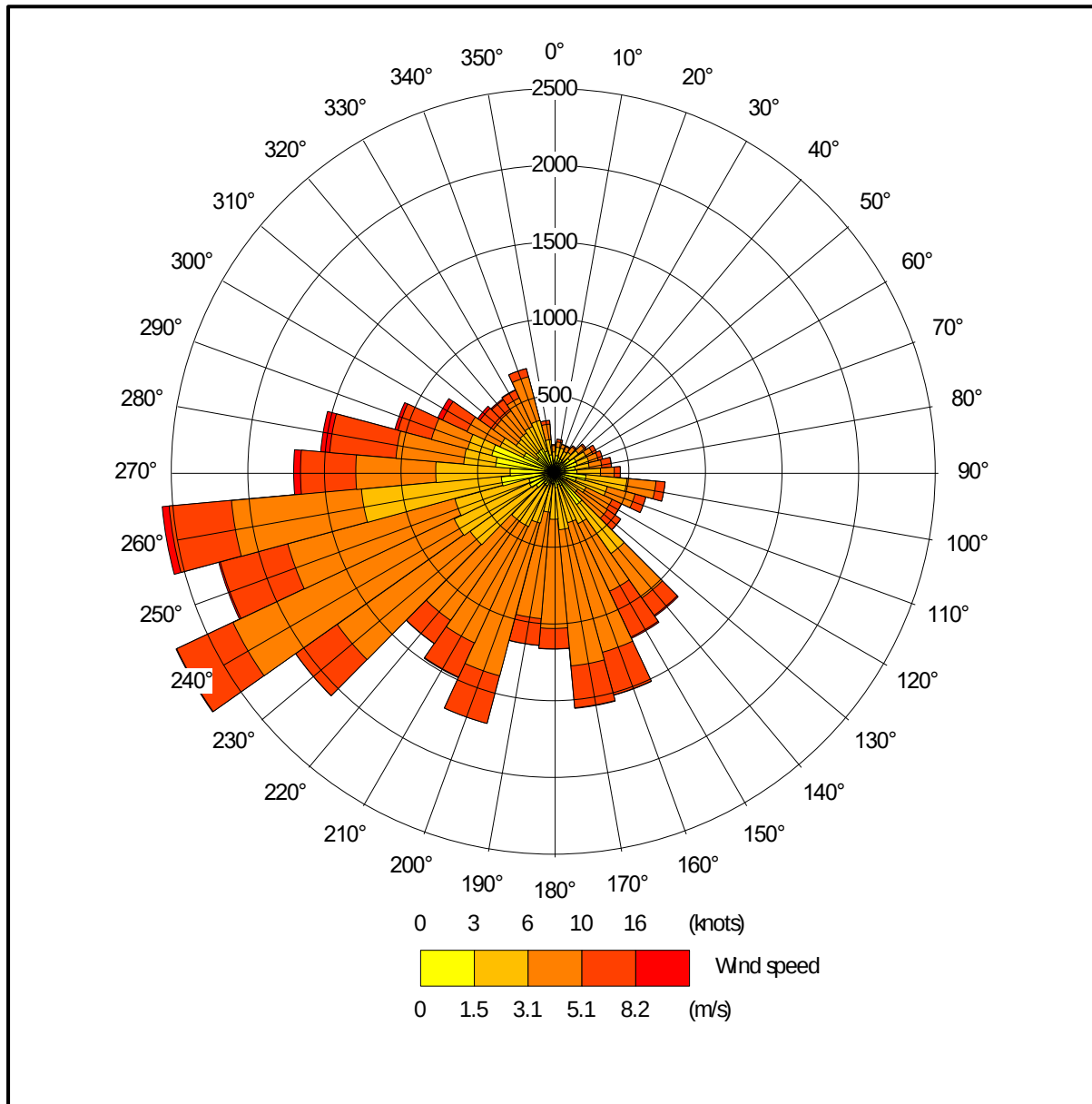


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 322650, 336150, 2017-2020



4.2 Emission sources

Emissions from the high speed ridge fans on the poultry houses are represented by three point sources per house within ADMS (H1 to H4; 1, 2 & 3). Details of the point source parameters are shown in Table 2a. The positions of the point sources may be seen in Figure 3 (green circles).

Table 2a. Point source parameters, modelled scrubber emissions

Source ID (Scenario)	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (°C)	Emission rate per source (g-NH ₃ /s)
H1 to H4; 1, 2 & 3 (Unsound)	6.25	0.8	11.0	21.0	0.004056
H1 to H4; 1, 2 & 3 (Pessimistic)	6.25	0.8	11.0	21.0	0.004462
H1 to H4; 1, 2 & 3 (Realistic)	6.25	0.8	11.0	21.0	0.004698

The poultry house would have a ranging area, which is represented by an area source within ADMS (H1_RAN to H4_RAN). Note that the area source covers the parts of the range 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 (red shaded polygon).

Table 2b. Area source parameters

Source ID (Scenario)	Area (m ²)	Base height (m)	Emission temperature (°C)	Emission rate per source (g-NH ₃ /s)
H1_RAN to H4_RAN (Unsound)	863.9, 858.9, 1,027.9, 1,018.0	0.0	Ambient	0.008556
H1_RAN to H4_RAN (Pessimistic)	863.9, 858.9, 1,027.9, 1,018.0	0.0	Ambient	0.005133
H1_RAN to H4_RAN (Realistic)	863.9, 858.9, 1,027.9, 1,018.0	0.0	Ambient	0.003042

4.3 Modelled buildings

The structure of the proposed poultry houses and other nearby farm buildings may affect the plumes from the point sources. Therefore, the buildings are modelled within ADMS. The positions of the modelled buildings may be seen in Figure 3 (blue rectangles).

4.4 Discrete receptors

Forty-seven discrete receptors have been defined at the AWs, the SSSIs and the SACs/SPA. 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 fields used in the detailed modelling, a regular Cartesian grid has been 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

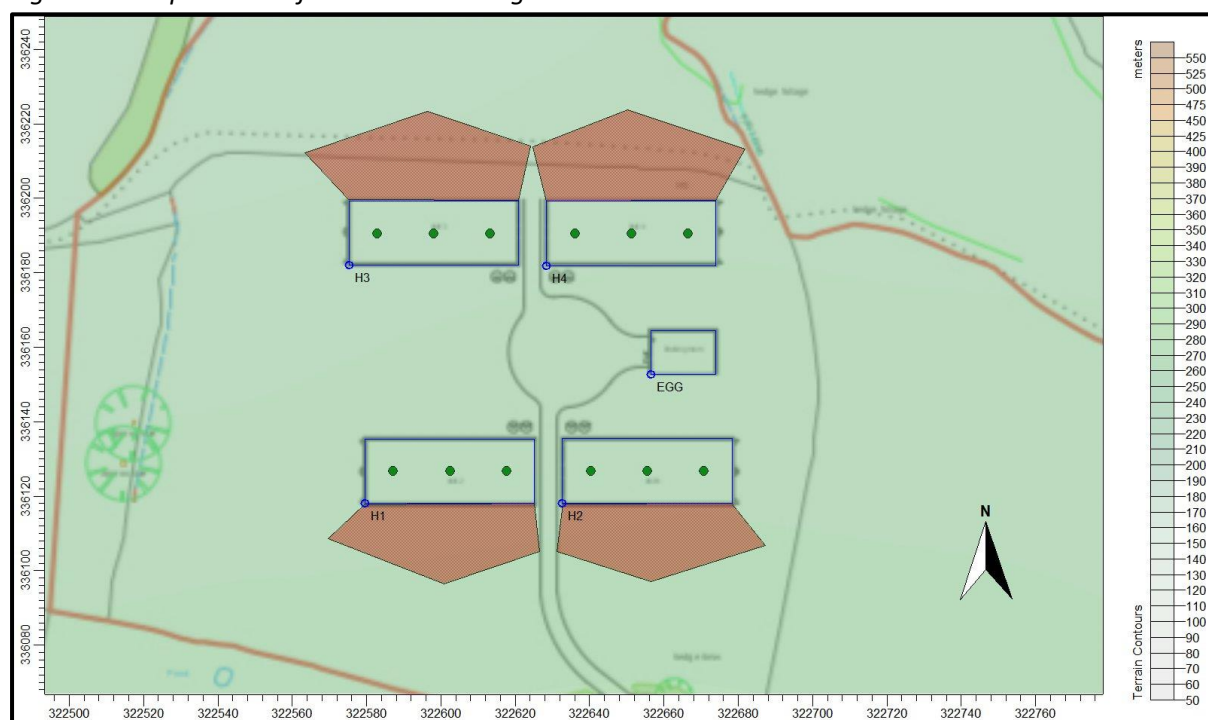
Terrain has been considered in the modelling. The terrain data are based upon the Ordnance Survey 50 m Digital Elevation Model. A 10.0 km x 10.0 km domain has been resampled at 100 m horizontal

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 150 m.

4.7 Roughness Length

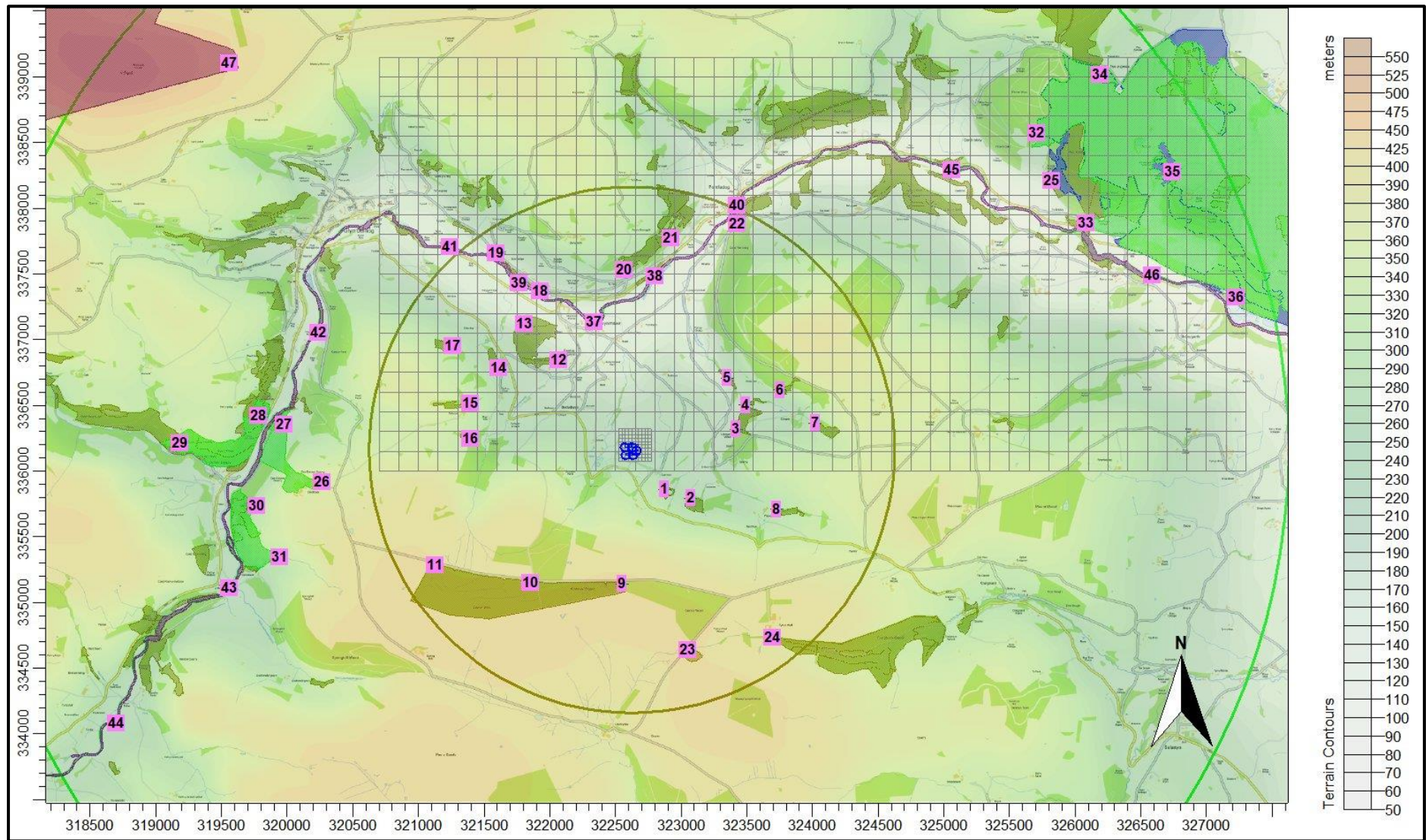
A fixed surface roughness length of 0.25 m has been applied over the entire modelling domain. As a precautionary measure, the GFS meteorological data is assumed to have a roughness length of 0.225 m. The effect of the difference in roughness length is precautionary as it increases the frequency of low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

Figure 3. The positions of modelled buildings and sources



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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 houses and closer parts of the ranging areas and 0.010 m/s to 0.015 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

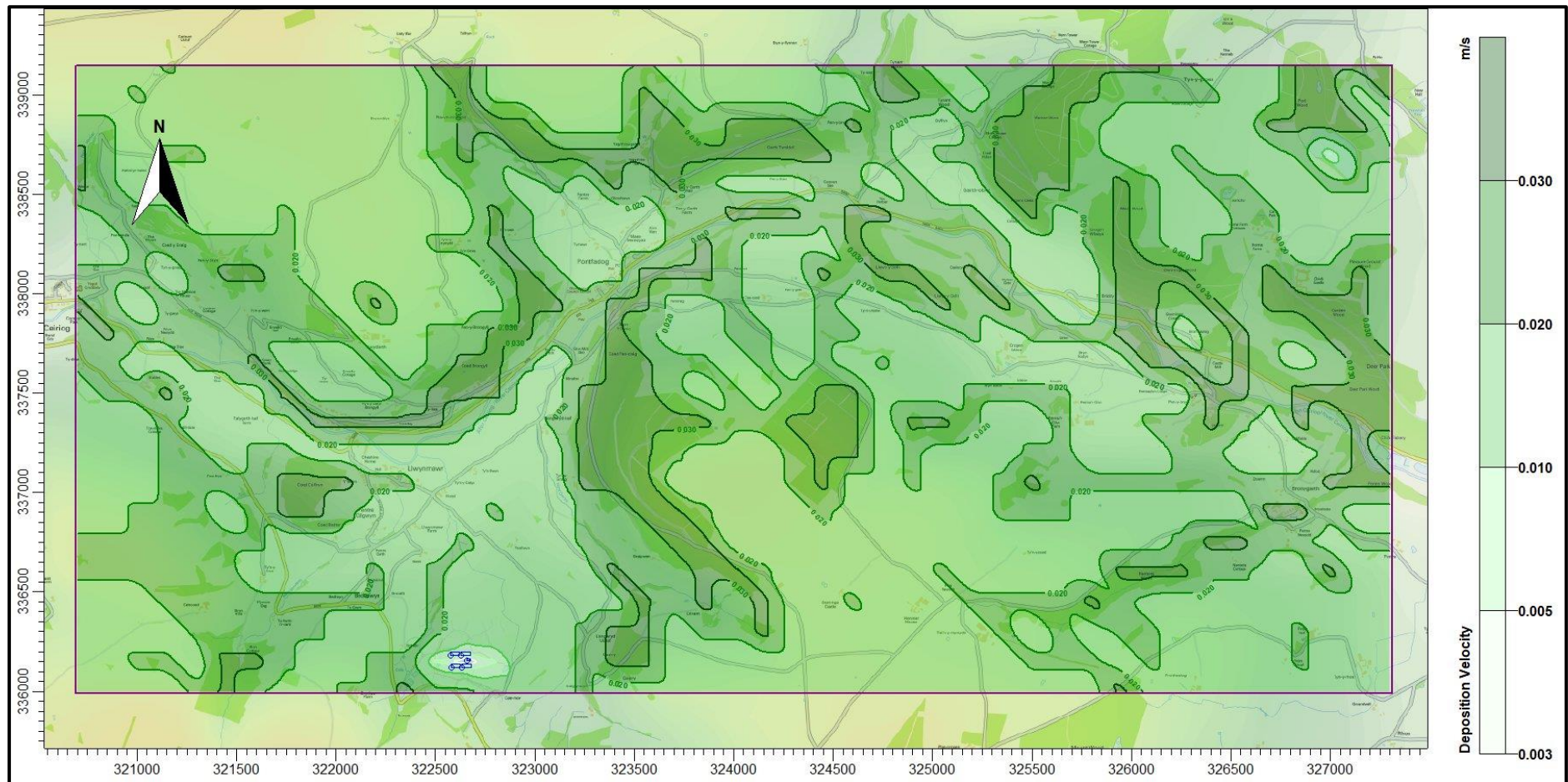
NH ₃ concentration (PC + background) (µg/m ³)	< 10	10 - 20	20 - 30	30 – 80	> 80
Deposition velocity – woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity – short vegetation (m/s)	0.02 (0.010 to 0.015 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity – arable farmland/rye 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 high and low resolution spatially varying deposition field is provided in Figure 5.

Outside of the spatially varying deposition fields, a fixed deposition of 0.003 m/s is set and similarly to not modelling deposition at all, the predicted ammonia concentrations (and nitrogen and acid deposition rates) are always higher than if deposition were modelled explicitly, particularly where there is some distance between the source and a receptor.

Figure 5. The spatially varying deposition field



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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 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.
- Without calms, 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 and acid 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 are provided in Table 4 (Unsound Scenario). In the Table, 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 SSSI/SAC/SPA 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 SSSI/SAC/SPA 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, cells referring to the ammonia sensitive AWs are shaded blue, cells referring to the SSSIs are shaded green, cells referring to the SACs are shaded purple, cells referring to the SPAs are shaded orange.

Table 4. Predicted annual mean ammonia concentration – preliminary modelling - Unsound Scenario figures

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - ($\mu\text{g}/\text{m}^3$)			
				Proposed 24,000 layers - Unsound Scenario			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s
1	322872	335862	AW	0.6857	0.6711	0.8689	0.4410
2	323072	335794	AW	0.3866	0.3764	0.4859	0.2307
3	323417	336317	AW	0.3386	0.3310	0.4343	0.2525
4	323488	336504	AW	0.3053	0.2937	0.3458	0.1762
5	323351	336709	AW	0.2876	0.2785	0.3233	0.1661
6	323750	336616	AW	0.1982	0.1909	0.1762	0.0792
7	324020	336364	AW	0.1340	0.1311	0.1292	0.0637
8	323728	335709	AW	0.1378	0.1326	0.1499	0.0616
9	322550	335142	AW	0.1088	0.1083	0.1037	0.0357
10	321853	335151	AW	0.0409	0.0426	0.0453	0.0162
11	321124	335282	AW	0.0251	0.0256	0.0217	0.0088
12	322071	336843	AW	0.1407	0.1374	0.1633	0.0784
13	321809	337118	AW	0.0767	0.0751	0.0815	0.0438
14	321613	336782	AW	0.0799	0.0785	0.0872	0.0358
15	321399	336516	AW	0.0726	0.0710	0.0711	0.0223
16	321399	336246	AW	0.0729	0.0719	0.0789	0.0269
17	321259	336952	AW	0.0510	0.0502	0.0438	0.0175
18	321928	337371	AW	0.0733	0.0717	0.0672	0.0278
19	321588	337656	AW	0.0459	0.0450	0.0431	0.0169
20	322564	337527	AW	0.0960	0.0951	0.0851	0.0340
21	322923	337771	AW	0.0808	0.0798	0.0636	0.0304
22	323424	337880	AW	0.0697	0.0684	0.0766	0.0421
23	323052	334640	AW	0.0595	0.0583	0.0531	0.0182
24	323694	334734	AW	0.0522	0.0514	0.0480	0.0162
25	325817	338208	Ammonia sensitive AW	0.0339	0.0331	0.0306	0.0144
26	320265	335918	Pandy Quarries SSSI	0.0206	0.0208	0.0165	0.0060
27	319979	336353	Pandy Quarries SSSI	0.0223	0.0222	0.0260	0.0088
28	319784	336421	Pandy Quarries SSSI	0.0203	0.0202	0.0208	0.0065
29	319180	336214	Pandy Quarries SSSI	0.0143	0.0143	0.0115	0.0037
30	319766	335738	Pandy Quarries SSSI	0.0142	0.0145	0.0149	0.0056
31	319946	335344	Pandy Quarries SSSI	0.0124	0.0128	0.0098	0.0041
32	325704	338574	Castell Y Waun A'I Barcdir SSSI	0.0292	0.0287	0.0246	0.0108
33	326083	337889	Castell Y Waun A'I Barcdir SSSI	0.0348	0.0338	0.0315	0.0151
34	326191	339015	Castell Y Waun A'I Barcdir SSSI	0.0229	0.0226	0.0221	0.0088
35	326739	338274	Castell Y Waun A'I Barcdir SSSI	0.0267	0.0261	0.0282	0.0119
36	327226	337323	Castell Y Waun A'I Barcdir SSSI	0.0225	0.0221	0.0225	0.0105
37	322338	337134	Afon Dyfrdwy SSSI/SAC	0.1296	0.1263	0.1539	0.0756
38	322801	337485	Afon Dyfrdwy SSSI/SAC	0.1091	0.1078	0.1065	0.0512
39	321767	337428	Afon Dyfrdwy SSSI/SAC	0.0608	0.0595	0.0564	0.0248
40	323429	338019	Afon Dyfrdwy SSSI/SAC	0.0631	0.0620	0.0818	0.0429
41	321244	337702	Afon Dyfrdwy SSSI/SAC	0.0343	0.0337	0.0340	0.0155
42	320239	337049	Afon Dyfrdwy SSSI/SAC	0.0247	0.0244	0.0250	0.0110
43	319561	335113	Afon Dyfrdwy SSSI/SAC	0.0098	0.0102	0.0124	0.0047
44	318701	334080	Afon Dyfrdwy SSSI/SAC	0.0062	0.0065	0.0059	0.0024
45	325059	338287	Afon Dyfrdwy SSSI/SAC	0.0362	0.0356	0.0408	0.0222
46	326587	337490	Afon Dyfrdwy SSSI/SAC	0.0290	0.0282	0.0266	0.0129
47	319561	339104	Berwyn SSSI/SAC/SPA	0.0113	0.0113	0.0199	0.0059

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 proposed poultry houses, at the ammonia sensitive AW, Cae Mor, Castell Y Waun A'I Barcdir SSSI and closer parts of the Afon Dyfrdwy SSSI/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.

Terrain effects are likely to 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 likely to be insignificant in this case.

The predicted process contribution to maximum annual mean ground level ammonia concentrations and nitrogen deposition rates at the discrete receptors within the detailed modelling domain are shown in Tables 5a (Unsound Scenario), 5b (Pessimistic Scenario), and 5c (Realistic 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 SPA/SAC/SSSI and 100% of Critical Level or Load for an AW) are coloured red. Concentrations that are in the range between the Natural Resources Wales lower and upper threshold (1% to 8% for a SPA/SAC/SSSI and 100% to 100% for an AW) 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. Contour plots for other scenarios can be provided upon request.

Table 5a. Predicted total process contribution to maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors - proposed poultry houses and ranges – Unsound Scenario

Receptor number	X(m)	Y(m)	Designation	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
25	325817	338208	Ammonia sensitive AW	0.020	1.0	10.0	0.008	0.8	0.04	0.4
32	325704	338574	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.006	0.6	0.05	0.5
33	326083	337889	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.008	0.8	0.06	0.6
34	326191	339015	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.004	0.4	0.03	0.3
35	326739	338274	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.006	0.6	0.04	0.4
36	327226	337323	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.005	0.5	0.04	0.4
37	322338	337134	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.037	3.7	0.29	2.9
38	322801	337485	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.024	2.4	0.19	1.9
39	321767	337428	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.012	1.2	0.09	0.9
40	323429	338019	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.022	2.2	0.17	1.7
41	321244	337702	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.008	0.8	0.06	0.6
42	320239	337049	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.006	0.6	0.04	0.4
43	319561	335113	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.003	0.3	0.02	0.2
44	318701	334080	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.001	0.1	0.01	0.1
45	325059	338287	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.013	1.3	0.10	1.0
46	326587	337490	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.007	0.7	0.05	0.5
47	319561	339104	Berwyn SSSI/SAC/SPA	0.030	1.0	5.0	0.002	0.2	0.02	0.3

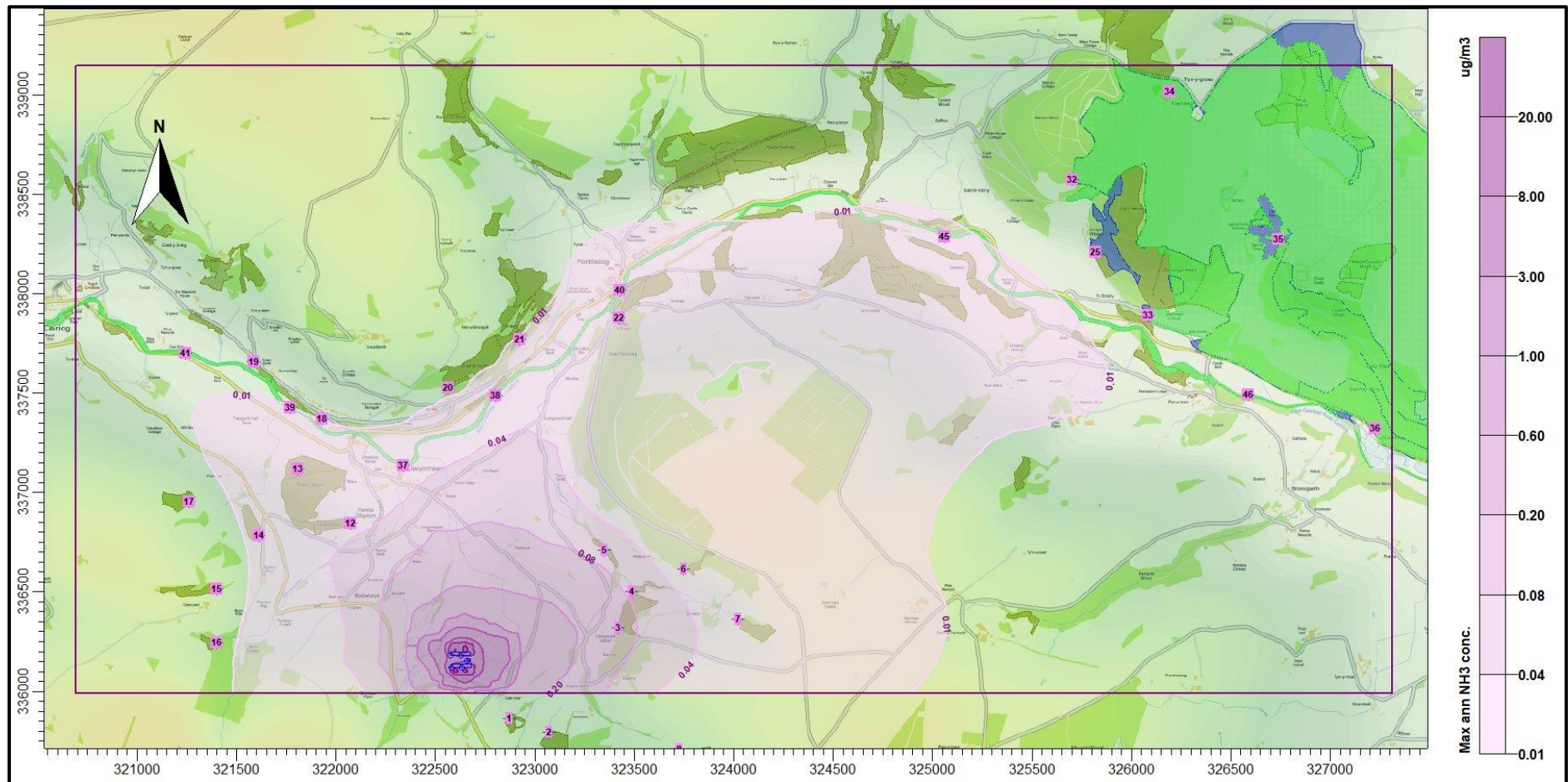
Table 5b. Predicted total process contribution to maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors - proposed poultry houses and ranges - Pessimistic Scenario

Receptor number	X(m)	Y(m)	Designation	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
25	325817	338208	Ammonia sensitive AW	0.020	1.0	10.0	0.007	0.7	0.04	0.4
32	325704	338574	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.005	0.5	0.04	0.4
33	326083	337889	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.008	0.8	0.06	0.6
34	326191	339015	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.004	0.4	0.03	0.3
35	326739	338274	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.005	0.5	0.04	0.4
36	327226	337323	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.005	0.5	0.04	0.4
37	322338	337134	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.028	2.8	0.22	2.2
38	322801	337485	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.020	2.0	0.15	1.5
39	321767	337428	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.011	1.1	0.08	0.8
40	323429	338019	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.019	1.9	0.15	1.5
41	321244	337702	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.007	0.7	0.06	0.6
42	320239	337049	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.005	0.5	0.04	0.4
43	319561	335113	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.002	0.2	0.02	0.2
44	318701	334080	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.001	0.1	0.01	0.1
45	325059	338287	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.012	1.2	0.09	0.9
46	326587	337490	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.006	0.6	0.05	0.5
47	319561	339104	Berwyn SSSI/SAC/SPA	0.030	1.0	5.0	0.002	0.2	0.02	0.3

Table 5c. Predicted total process contribution to maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors - proposed poultry houses and ranges - Realistic Scenario

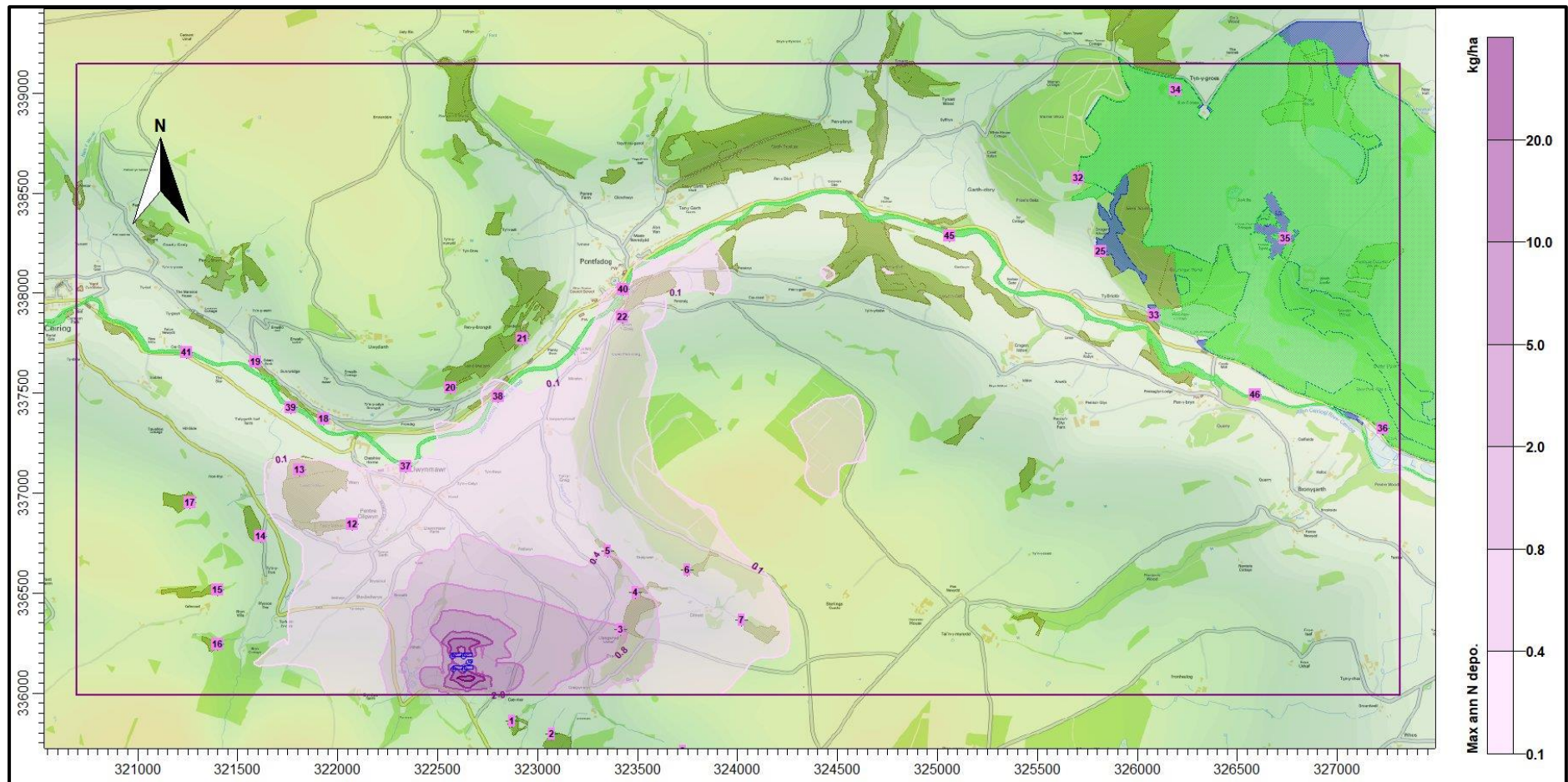
Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level ($\mu\text{g}/\text{m}^3$)	Critical Load (kg/ha)	Process Contribution ($\mu\text{g}/\text{m}^3$)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
25	325817	338208	Ammonia sensitive AW	0.020	1.0	10.0	0.007	0.7	0.04	0.4
32	325704	338574	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.005	0.5	0.04	0.4
33	326083	337889	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.007	0.7	0.06	0.6
34	326191	339015	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.004	0.4	0.03	0.3
35	326739	338274	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.005	0.5	0.04	0.4
36	327226	337323	Castell Y Waun A'I Barcdir SSSI	0.030	1.0	10.0	0.005	0.5	0.04	0.4
37	322338	337134	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.023	2.3	0.18	1.8
38	322801	337485	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.017	1.7	0.13	1.3
39	321767	337428	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.010	1.0	0.08	0.8
40	323429	338019	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.017	1.7	0.13	1.3
41	321244	337702	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.007	0.7	0.06	0.6
42	320239	337049	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.004	0.4	0.03	0.3
43	319561	335113	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.002	0.2	0.02	0.2
44	318701	334080	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.001	0.1	0.01	0.1
45	325059	338287	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.011	1.1	0.09	0.9
46	326587	337490	Afon Dyfrdwy SSSI/SAC	0.030	1.0	10.0	0.006	0.6	0.05	0.5
47	319561	339104	Berwyn SSSI/SAC/SPA	0.030	1.0	5.0	0.002	0.2	0.01	0.3

Figure 6a. Maximum annual ammonia concentration - proposed poultry house and range - Realistic Scenario



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Figure 6b. Maximum annual nitrogen deposition rates - proposed poultry house and range - Realistic Scenario



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6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Rosina Bloor, of Roger Parry & Partners LLP, on behalf of Cae Mor Poultry, to use computer modelling to assess the impact of ammonia emissions from the proposed free range egg laying chicken houses at Cae Mor, Llwynmawr, Llangollen, Denbighshire. LL20 7BE.

Ammonia emission rates from the proposed poultry houses have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors. Ammonia emissions from ranging areas have been assessed and quantified based upon the baseline parameters used to calculate the National Atmospheric Emission Inventory (NAEI) emission factor for grazing free range hens and information from a variety of peer reviewed scientific papers. 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.

The modelling predicts that:

- Under all three Scenarios, the process contribution to the annual ammonia concentration would be in excess of 1% of the Critical Level and the Critical Load at closer parts of Afon Dyfrdwy SSSI/SAC. The extent and magnitude of the exceedances depends on the proportion of ranging/housing emissions assumed.
- Under all Scenarios, the process contribution to the annual ammonia concentration and the nitrogen deposition rate would be below 100% of the precautionary Critical Level of $1.0 \mu\text{g-NH}_3/\text{m}^3$ at all AWs considered.
- Under all Scenarios, the process contribution to the annual ammonia concentration and the nitrogen deposition rate would be below 1% of the Critical Level and Critical Load at Castell Y Waun A'I Barcdir SSSI and Berwyn SSSI/SAC/SPA.

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