A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Proposed Free Range Egg-Laying Chicken Houses at Cae Mawr, near Llanerch y Medd, Anglesey

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Gail Lewis, of Roger Parry & Partners LLP, on behalf of D. B. and B. E. Evans, to use computer modelling to assess the impact of ammonia emissions from the proposed free range egg-laying chicken houses at Cae Mawr, Llanerch y Medd, Anglesey. LL71 8AN.

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

This report is arranged in the following manner:

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

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

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

- Section 5 contains the results of the modelling.

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

2. Background Details

The site of the proposed free range egg-laying chicken houses at Cae Mawr is in a rural area, approximately 1.9 km to the north of the village of Llanerch y Medd, in Anglesey. The surrounding land is almost exclusively pasture, but there are some isolated areas of semi-natural woodlands nearby. The site is at an elevation of around 58 m, with the land rising towards slightly higher ground to the south and falling gently towards the Llyn Alaw reservoir to the north-west.

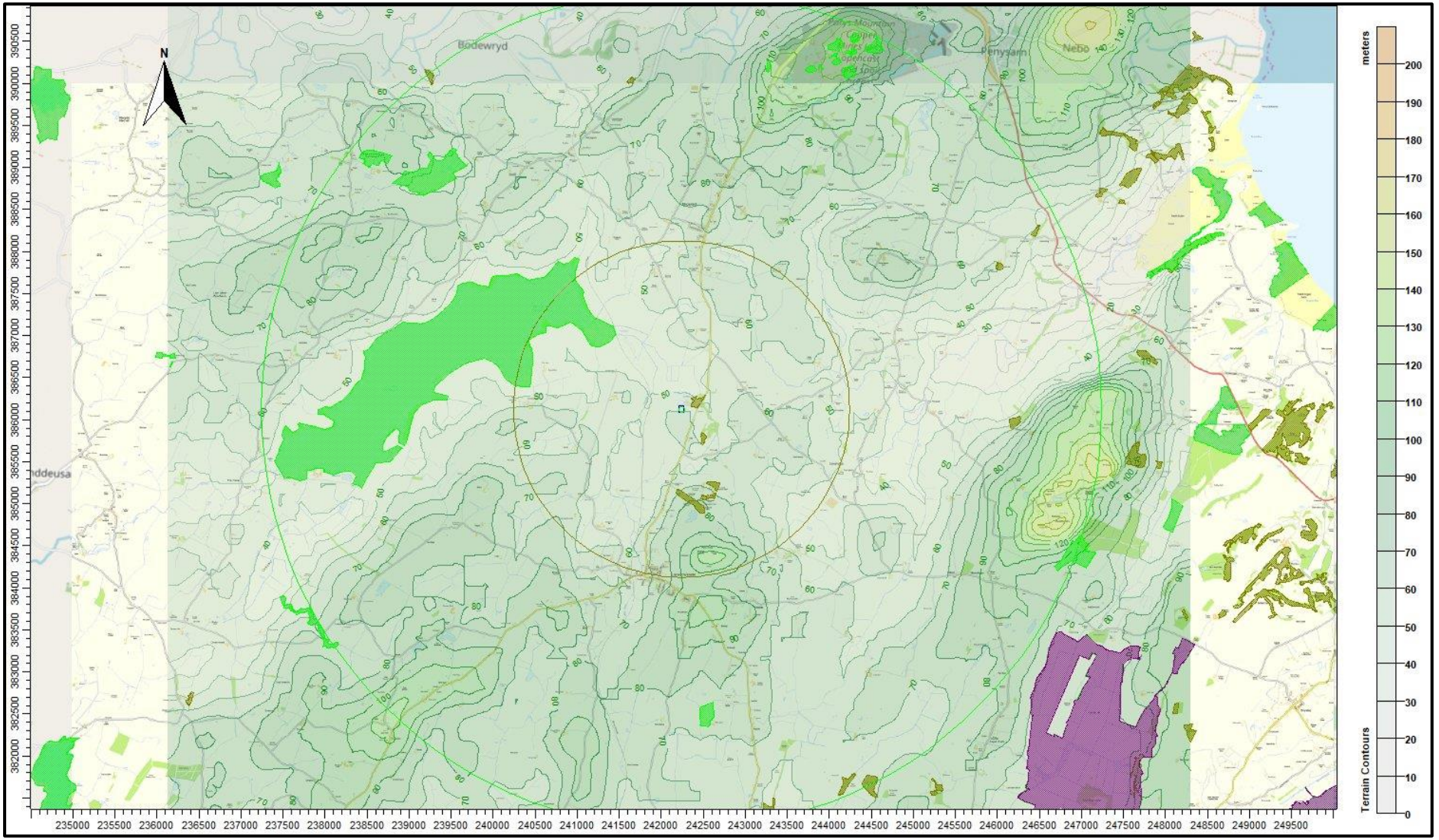
Under the proposal, an adjoined pair of poultry houses would be constructed on land to the south-west of the existing farm buildings at Cae Mawr. The poultry houses would provide accommodation for up to 32,000 egg-laying chickens and would be ventilated via uncapped high speed ridge mounted fans, each with a short chimney. The chickens would have daytime access to outdoor ranging areas via a series of pop holes along the sides of the proposed poultry houses. Every four days, the birds' droppings would be removed by a belt collection system and stored temporarily, prior to being removed from site, or spreading to land.

There are five areas of remnant Ancient Woodlands (AWs) within 2 km of Cae Mawr. There are six Sites of Special Scientific Interest (SSSIs) within 5 km of the farm. There are no internationally designated wildlife sites within 5 km of the farm. Further details of the SSSIs are provided below.

- Llyn Alaw SSSI – at its closest point, approximately 1.1 km to the north-west.
- Llyn Hafodol & Cors Clegyrog SSSI – approximately 3.8 km to the north-west.
- Mynydd Parys SSSI – approximately 4.1 km to the north-north-east.
- Maen Gwyn SSSI – approximately 3.4 km to the south (designated for geological features).
- Tyddyn Y,Waen SSSI – approximately 4.8 km to the east-south-east.
- Nantanog SSSI – approximately 4.9 km to the south-west (designated for geological features).

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 SSSIs are shaded green and the site of the proposed poultry houses is outlined in blue.

Figure 1. The area surrounding Cae Mawr – concentric circles radii 2 km (olive) and 5 km (green)



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 the poultry houses at Cae Mawr and the wildlife sites is 1.38 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 22.96 kg-N/ha/y and to short vegetation is 14.84 kg-N/ha/y. The background acid deposition rate to woodland is 1.77 keq/ha/y and to short vegetation is 1.18 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS, August 2018).

3.3 Critical Levels & Critical Loads

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

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

Critical Loads are defined as, "a quantitative estimate of exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" (UNECE).

For ammonia concentration in air, the Critical Level for higher plants is 3.0 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. Note; Crychan Forest Tracks SSSI is designated for geological features and is therefore not further considered. N.B. Where the Critical Level of 1.0 µg-NH_3/m^3 is assumed, it is usually unnecessary to consider the Critical Load as the Critical Level provides the stricter test. However, it may be necessary to consider nitrogen deposition should a Critical Load of 5.0 kg-N/ha/y, or lower, be appropriate. 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)
Unnamed AWs	1.0 [1]	-	-
Llyn Alaw SSSI and Tyddyn Y,Waen SSSI	3.0 [2]	10.0 [3]	-
Llyn Hafodol & Cors Clegyrog SSSI and Mynydd Parys SSSI	1.0 [1 & 2]	10.0 [3]	-
Maen Gwyn SSSI and Nantanog SSSI	n/a	n/a	n/a

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.
3. 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.

For Local Nature Reserves (LNRs), Local Wildlife Sites (LWSs) and Ancient Woodlands (AWs), the current assessment procedure usually applied is based on 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, 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.

3.6.1 Proposed chicken housing ammonia emissions

The Environment Agency provides an Intensive Farming guidance note which lists standard ammonia emission factors for a variety of livestock, including poultry. For free range egg-laying chickens housed in an aviary system, where manure is removed frequently using a belt system, such as the proposed poultry house, the Environment Agency figure is 0.08 kg-NH_3/bird place/year.

3.6.2 Proposed ranging area ammonia 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. For modelling purposes, it is assumed that 12%[1] of the droppings are deposited on the ranging areas; this assumption is based upon figures from "Ammonia emission factors for UK agriculture" (Misselbrook *et al*). To estimate the ammonia emissions from the ranges, 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.

1. A figure of 20% is sometimes assumed. However, it should be noted that this figure is probably based primarily upon the widely accepted figure of 80% of dropping occurring at night when birds are housed and a single report; however, because, even under optimal conditions, not all of the birds go outside (50% is considered a high percentage), this does not imply that 20% of droppings occur outside the house.

Details of the poultry numbers and types, 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)
Housing (proposed)	32,000 (x 0.88)	Egg laying chickens, aviary system	0.08 (EA figure)	0.071387
Ranges (proposed)	32,000 (x 0.12)	Ranging areas	0.34 (AS Modelling & Data figure)	0.041372

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).

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

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

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

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

The raw GFS wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and where terrain data is included in the modelling, wind speeds and directions will be further modified. The raw GFS wind rose is shown in Figure 2a and the terrain and roughness length modified wind rose for Cae Mawr is shown in Figure 2b. The resolution of the wind field is approximately 180 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 53.348 N, 4.370 W, 2014-2017

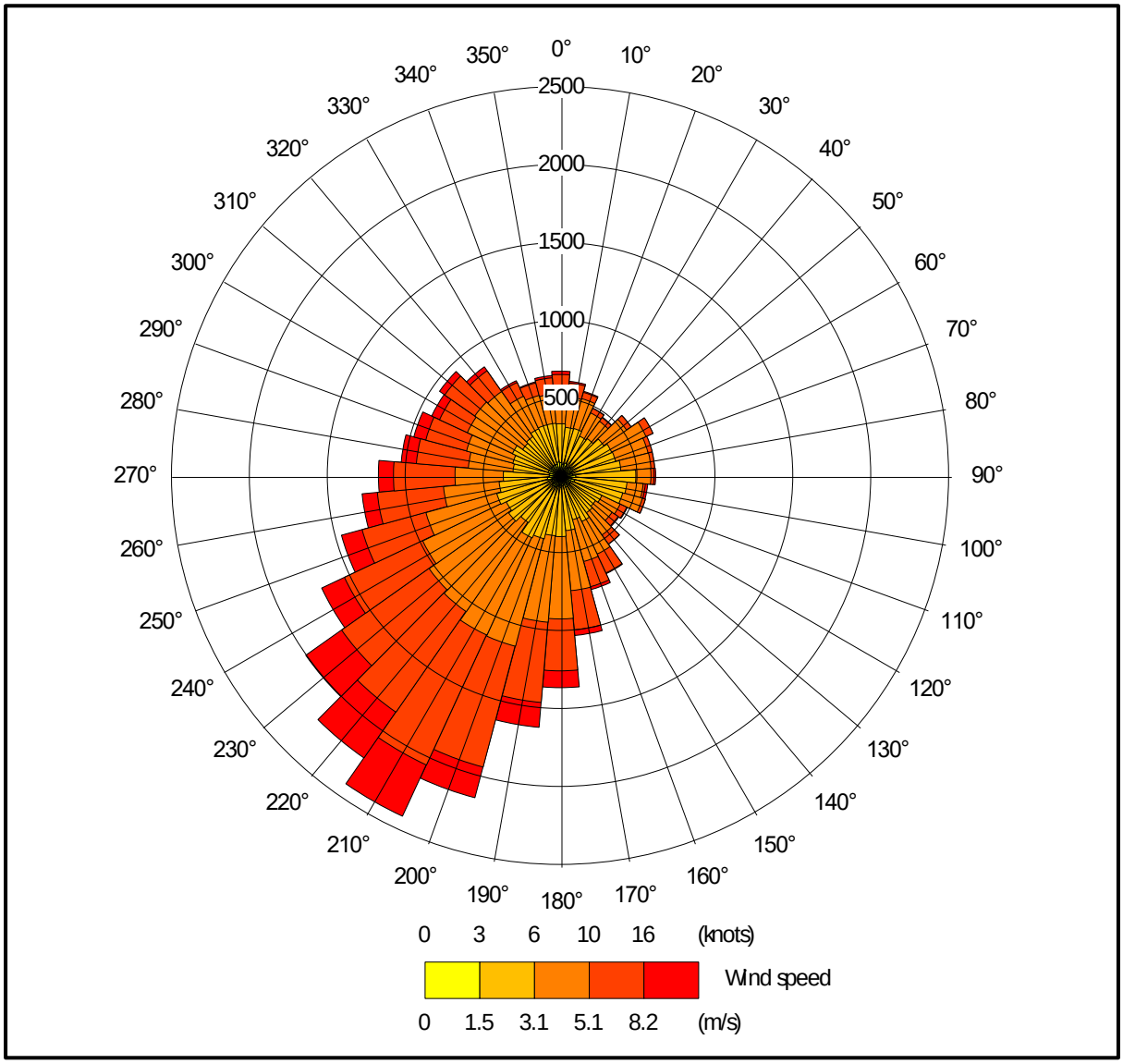
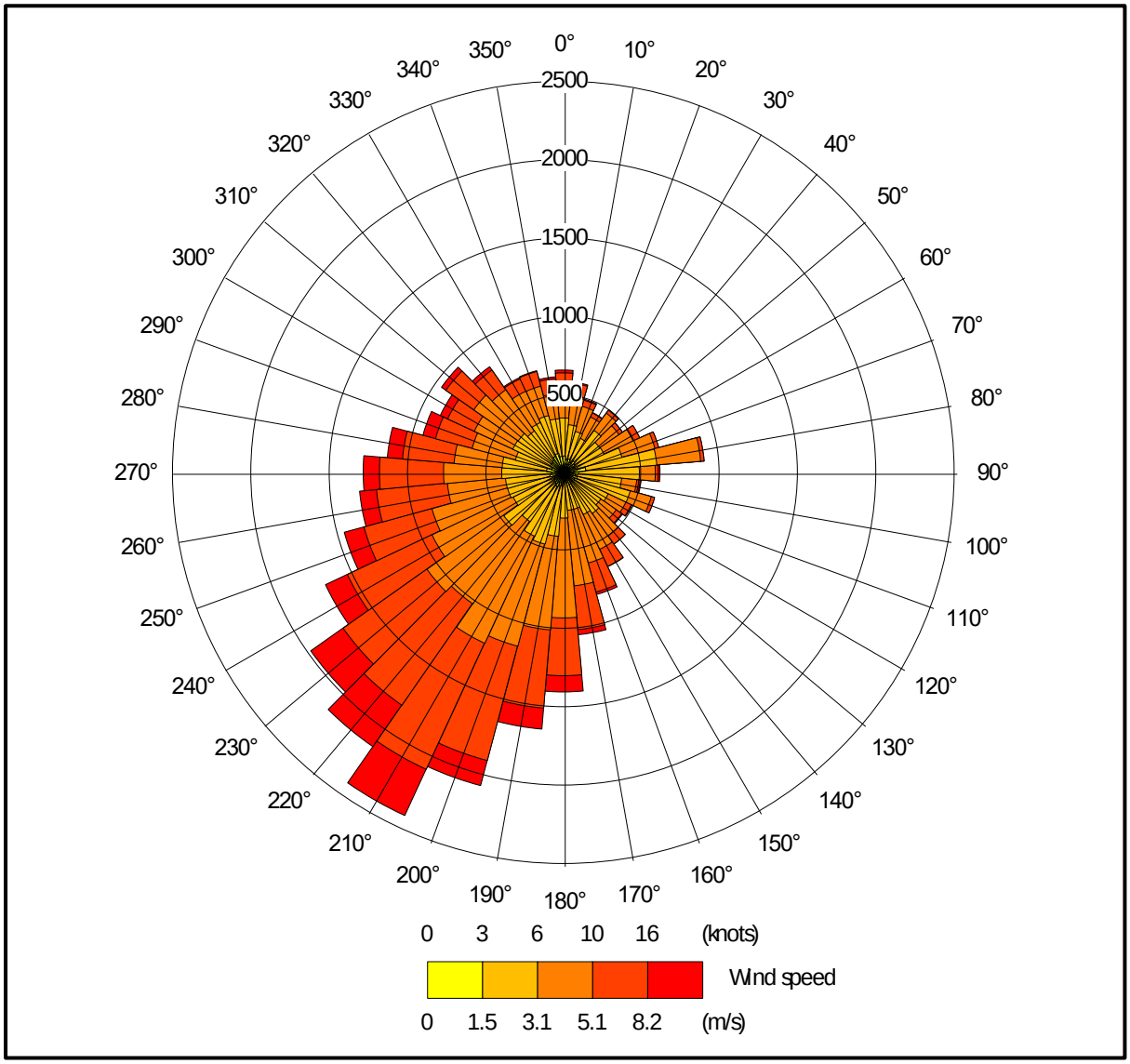


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 242200, 386100



4.2 Emission sources

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

The poultry houses would have ranging areas, which are represented by two area sources within ADMS (RAN_W & RAN_E). Note that the area sources cover the parts of the ranges most likely to be used frequently and not the whole of the ranging areas.

Details of the area parameters are provided in Tables 3a and 3b. The positions of the sources are shown 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)
PR1 and PR2 a, b & c	6.5	0.8	11.0	21.0	0.011898

Table 3b. Area source parameters

Source ID	Area (m^2)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
PR1 RAN	2,374.5	0.0	Ambient	0.020686
PR2 RAN	2,108.7	0.0	Ambient	0.020686

4.3 Modelled buildings

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

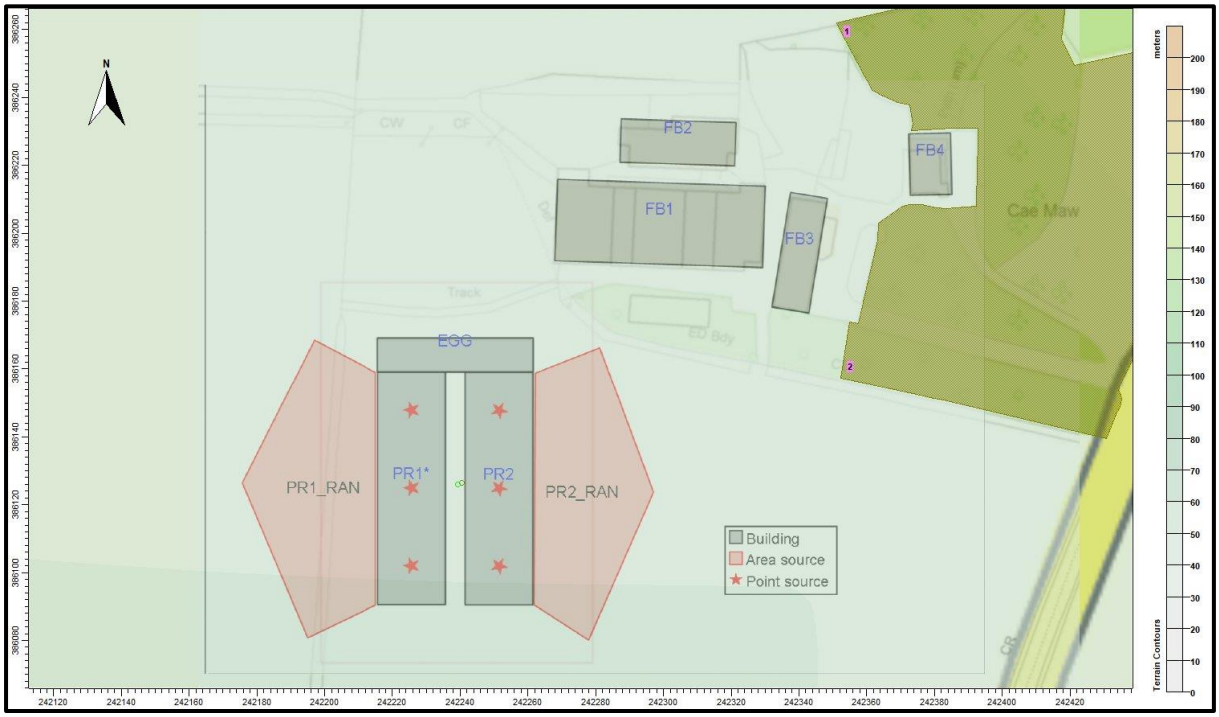
4.4 Discrete receptors

Twenty-nine discrete receptors have been defined: eight at the AWs (1 to 8) and twenty-one at the SSSIs (9 to 29). 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 grids

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, two nested regular Cartesian grids have been defined within ADMS. The grid receptors for both Cartesian grids are defined at ground level and the positions of the Cartesian grids may be seen in Figure 4, where they are marked by grey lines.

Figure 3. The positions of the modelled buildings and sources



4.6 Roughness Length

A fixed surface roughness length of 0.2 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 0.175 m. The effect of the difference in roughness length is precautionary as it increases the frequency of low wind speeds and stability and therefore increases predicted ground level concentrations.

4.7 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. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is approximately 180 m.

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. 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 4.

Table 4. Deposition velocities

NH3 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 (0.015 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity – arable farmland/rye grass, water (m/s)	0.005	0.005	0.005	0.005	0.003

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

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

Figure 4. The discrete receptors and regular Cartesian grids

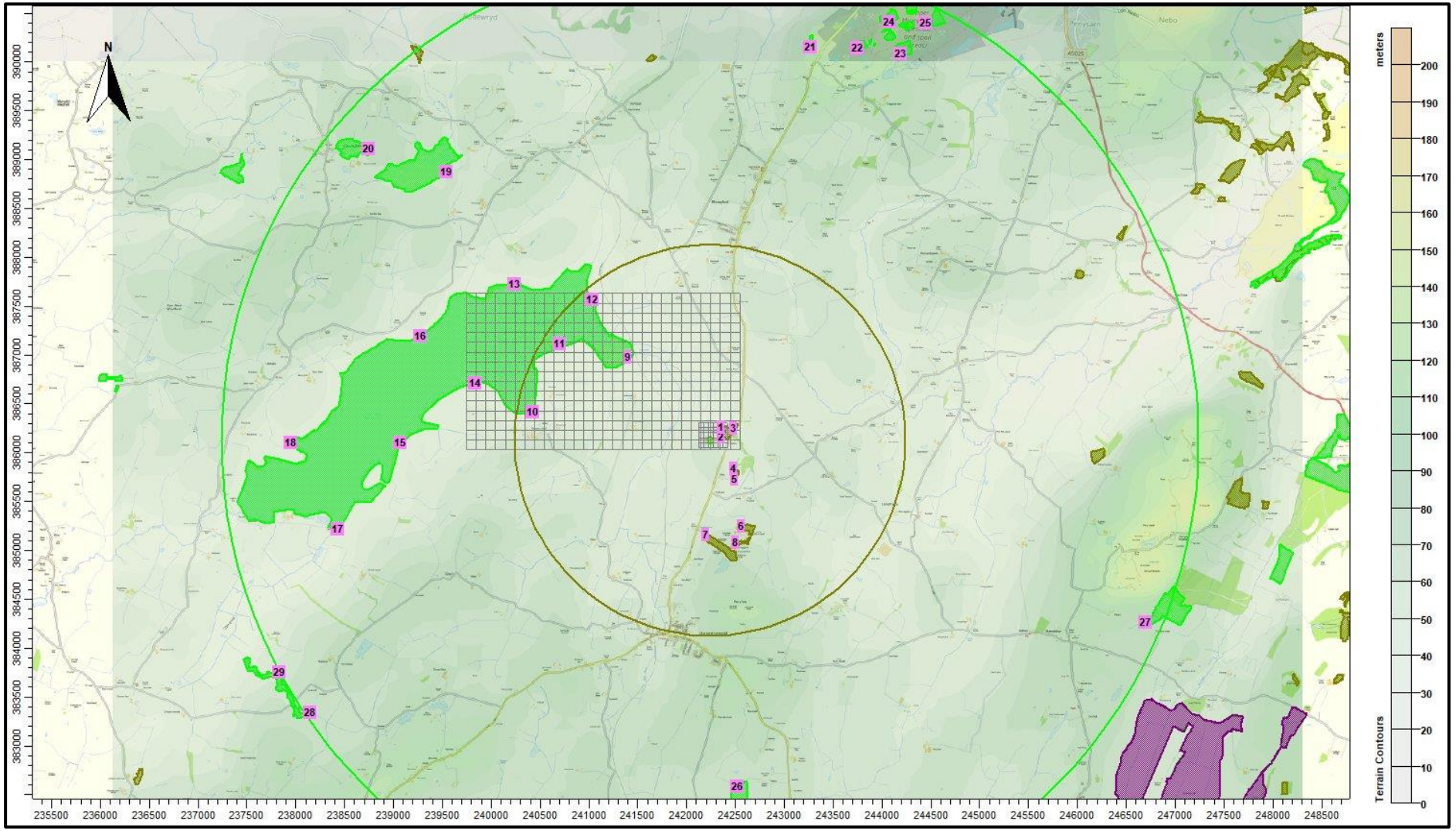
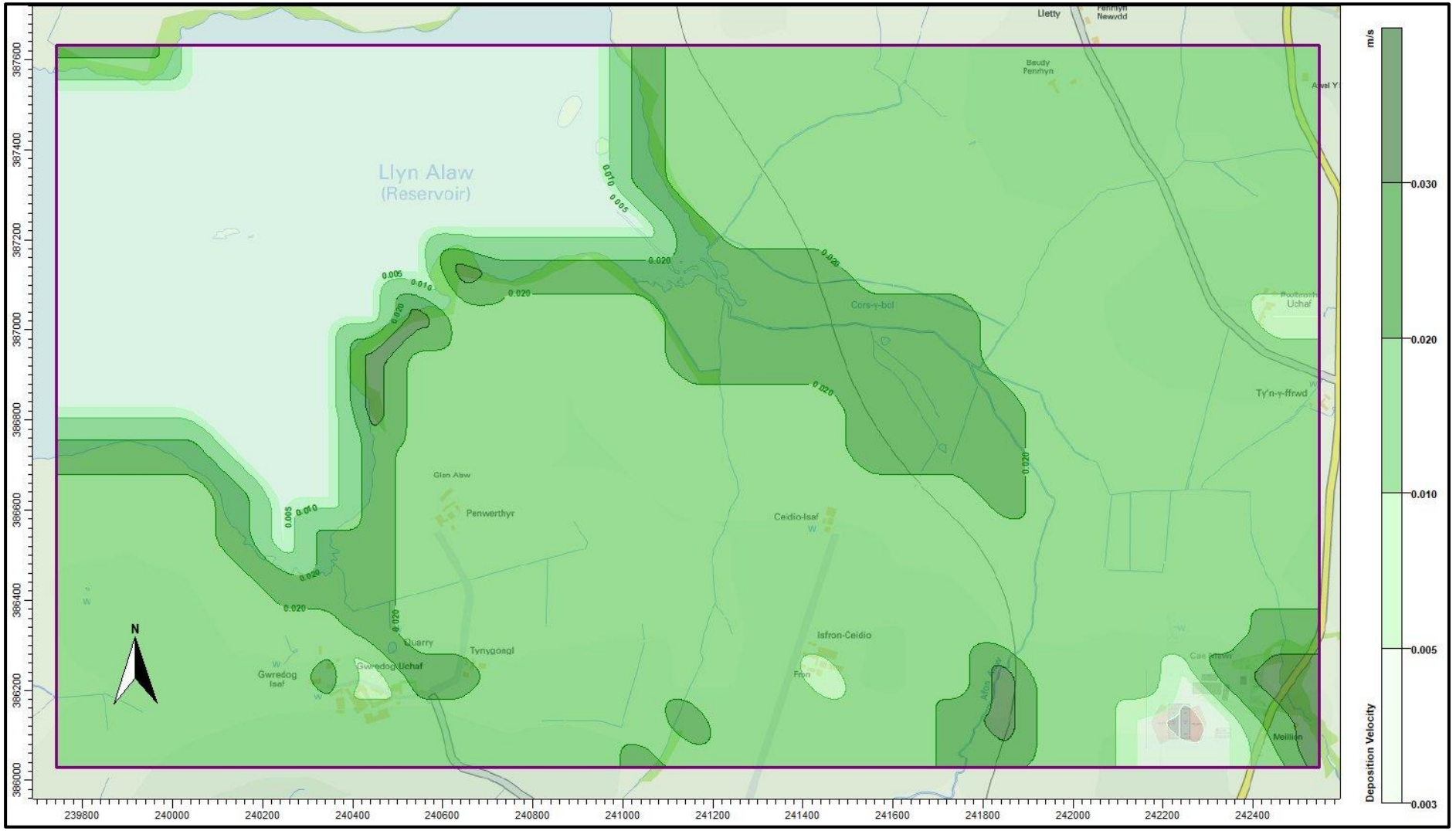


Figure 5a. The spatially varying deposition field



5. Details of the Model Runs and Results

5.1 Preliminary modelling

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

- In basic mode without calms or terrain – GFS data.
- With calms and without terrain – GFS data.
- Without calms and with terrain – GFS data.
- Without calms, 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 5. 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 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 a Critical Level or Critical Load for a SSSI or 50% of a 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.

Note that where a Critical Level of 3.0 µg-NH_3/m^3 (and Critical Load of 10 kg-N/ha/y then the Critical Load provides the stricter test and the following conversion may be useful when reading Table 5:

- 1% of the Critical Load of 10.0 kg-N/ha/y is equivalent to an annual mean ammonia concentration of 0.0129 µg-NH_3/m^3 (assuming a deposition velocity of 0.03 m/s).
- 1% of the Critical Load of 10.0 kg-N/ha/y is equivalent to an annual mean ammonia concentration of 0.0193 µg-NH_3/m^3 (assuming a deposition velocity of 0.02 m/s).

Table 5. Predicted maximum annual mean ammonia concentration at the discrete receptors (preliminary results for screening and sensitivity testing)

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m^3)			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s
1	242354	386259	AW	**2.506**	**2.464**	**2.617**	**1.963**
2	242355	386161	AW	**3.329**	**3.297**	**3.687**	**2.738**
3	242478	386247	AW	**1.193**	**1.177**	**1.235**	**0.890**
4	242477	385838	AW	0.384	0.385	0.428	0.318
5	242490	385723	AW	0.259	0.259	0.297	0.194
6	242555	385244	AW	0.096	0.096	0.099	0.052
7	242189	385155	AW	0.099	0.098	0.103	0.047
8	242495	385083	AW	0.075	0.075	0.076	0.036
9	241396	386975	Llyn Alaw SSSI	**0.081**	**0.081**	**0.086**	**0.048**
10	240426	386415	Llyn Alaw SSSI	**0.069**	**0.069**	**0.069**	**0.035**
11	240695	387116	Llyn Alaw SSSI	**0.052**	**0.052**	**0.055**	**0.027**
12	241029	387570	Llyn Alaw SSSI	**0.041**	**0.041**	**0.043**	**0.023**
13	240240	387719	Llyn Alaw SSSI	**0.030**	**0.030**	**0.032**	0.015
14	239834	386713	Llyn Alaw SSSI	**0.046**	**0.046**	**0.046**	**0.022**
15	239067	386103	Llyn Alaw SSSI	**0.030**	**0.030**	**0.034**	0.016
16	239272	387196	Llyn Alaw SSSI	**0.032**	**0.032**	**0.033**	0.015
17	238433	385215	Llyn Alaw SSSI	0.018	0.018	**0.023**	0.010
18	237944	386103	Llyn Alaw SSSI	**0.020**	**0.020**	**0.024**	0.011
19	239542	388869	Llyn Hafodol & Cors Clegyrog SSSI	**0.016**	**0.016**	**0.016**	0.007
20	238747	389110	Llyn Hafodol & Cors Clegyrog SSSI	**0.013**	**0.014**	**0.012**	0.005
21	243262	390147	Mynydd Parys SSSI	**0.018**	**0.018**	**0.015**	0.008
22	243748	390140	Mynydd Parys SSSI	**0.017**	**0.017**	**0.014**	0.007
23	244193	390080	Mynydd Parys SSSI	**0.017**	**0.017**	**0.014**	0.007
24	244071	390411	Mynydd Parys SSSI	**0.016**	**0.015**	**0.012**	0.006
25	244445	390396	Mynydd Parys SSSI	**0.015**	**0.015**	**0.012**	0.006
26	242521	382582	Maen Gwyn SSSI	0.016	0.016	0.014	0.006
27	246698	384259	Tyddyn Y,Waen SSSI	0.011	0.011	0.008	0.004
28	238145	383337	Nantanog SSSI	0.013	0.013	0.010	0.004
29	237826	383757	Nantanog SSSI	0.013	0.013	0.011	0.005

5.2 Detailed deposition modelling

The detailed modelling was carried out over a restricted domain that includes closer parts of the Llyn Alaw SSSI/SAC and the area of AW to the east of Cae Mawr, the area where the preliminary modelling run with a fixed deposition rate indicated that annual mean ammonia concentrations (or nitrogen deposition rates) would potentially exceed the Natural Resources Wales lower threshold of the relevant Critical Level or Critical Load. At the other receptors considered, the preliminary modelling runs with a fixed deposition rate indicated that ammonia levels (and nitrogen and acid deposition rates) would be below the Natural Resources Wales lower threshold percentage of Critical Level/Load for the designation of the site.

Spatially varying deposition and terrain cannot be modelled in conjunction with calms; however, in this case, the preliminary modelling indicated that calms do not have a significant effect.

The predicted maximum annual mean ground level ammonia concentrations and nitrogen deposition rates are shown in Table 6. In this table, predicted ammonia concentrations and nitrogen deposition rates that are in excess of the Natural Resources Wales upper threshold percentages (8% of Critical Level or Load for a SSSI and 100% of Critical Level or Load for a non-statutory site) are coloured red. Ammonia concentrations and nitrogen deposition rates in the range between the Natural Resources Wales lower and upper threshold percentages (1% and 8% for a SSSI and 50% and 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 low resolution detailed modelling are shown in Figures 6a and 6b.

Table 6. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors – 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
1	242354	386259	AW	0.030	1.0	10.0	1.666	**166.6**	12.98	**129.8**
2	242355	386161	AW	0.030	1.0	10.0	2.516	**251.6**	19.60	**196.0**
3	242478	386247	AW	0.030	1.0	10.0	0.684	**68.4**	5.33	**53.3**
9	241396	386975	Llyn Alaw SSSI	0.020	3.0	10.0	0.031	**1.0**	0.16	**1.6**
10	240426	386415	Llyn Alaw SSSI	0.020	3.0	10.0	0.020	0.7	0.11	**1.1**
11	240695	387116	Llyn Alaw SSSI	0.030	3.0	10.0	0.017	0.6	0.13	**1.3**
12	241029	387570	Llyn Alaw SSSI	0.030	3.0	10.0	0.015	0.5	0.12	**1.2**
14	239834	386713	Llyn Alaw SSSI	0.020	3.0	10.0	0.013	0.4	0.07	0.7

Figure 6a. Maximum annual ammonia concentration

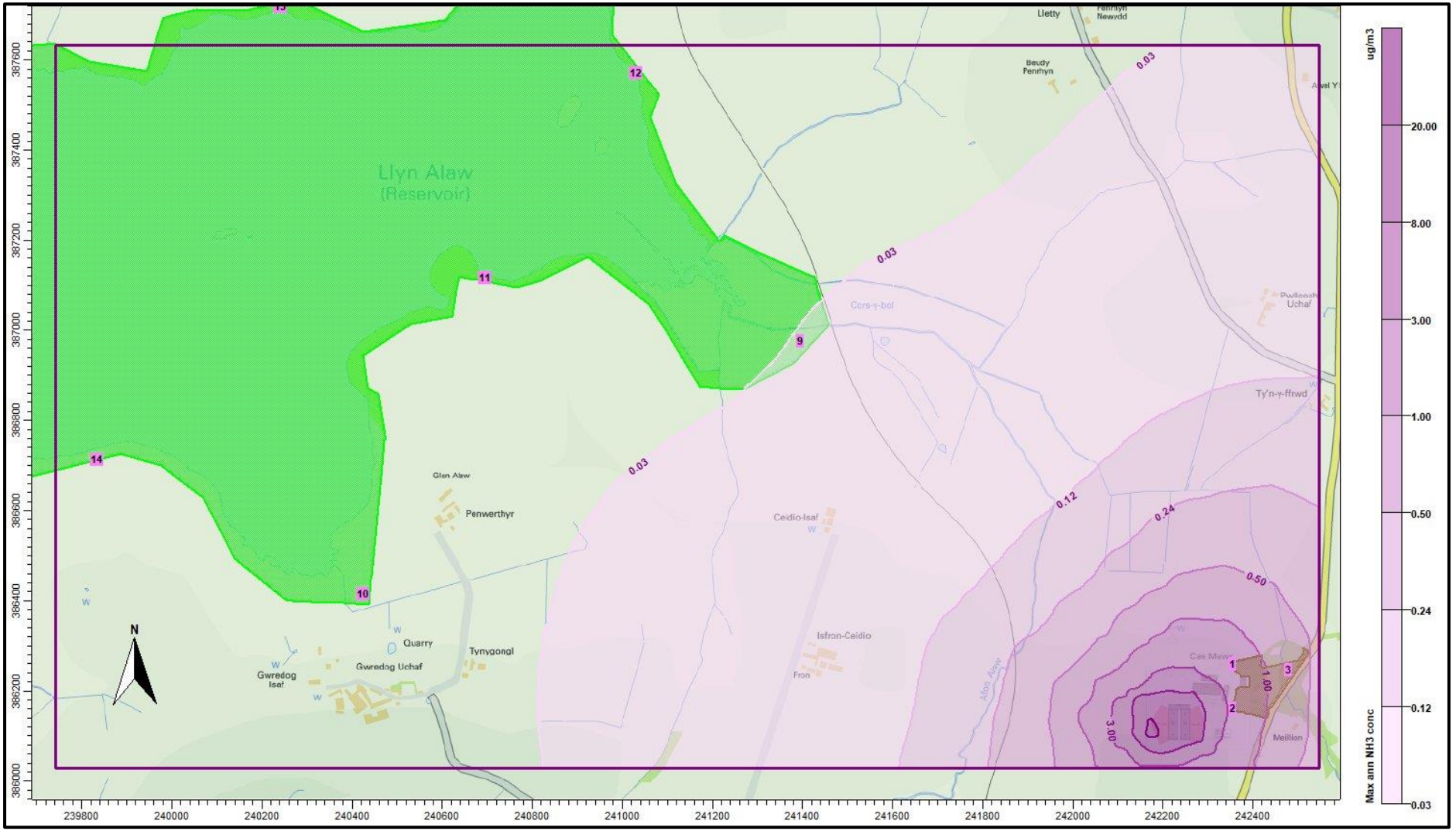
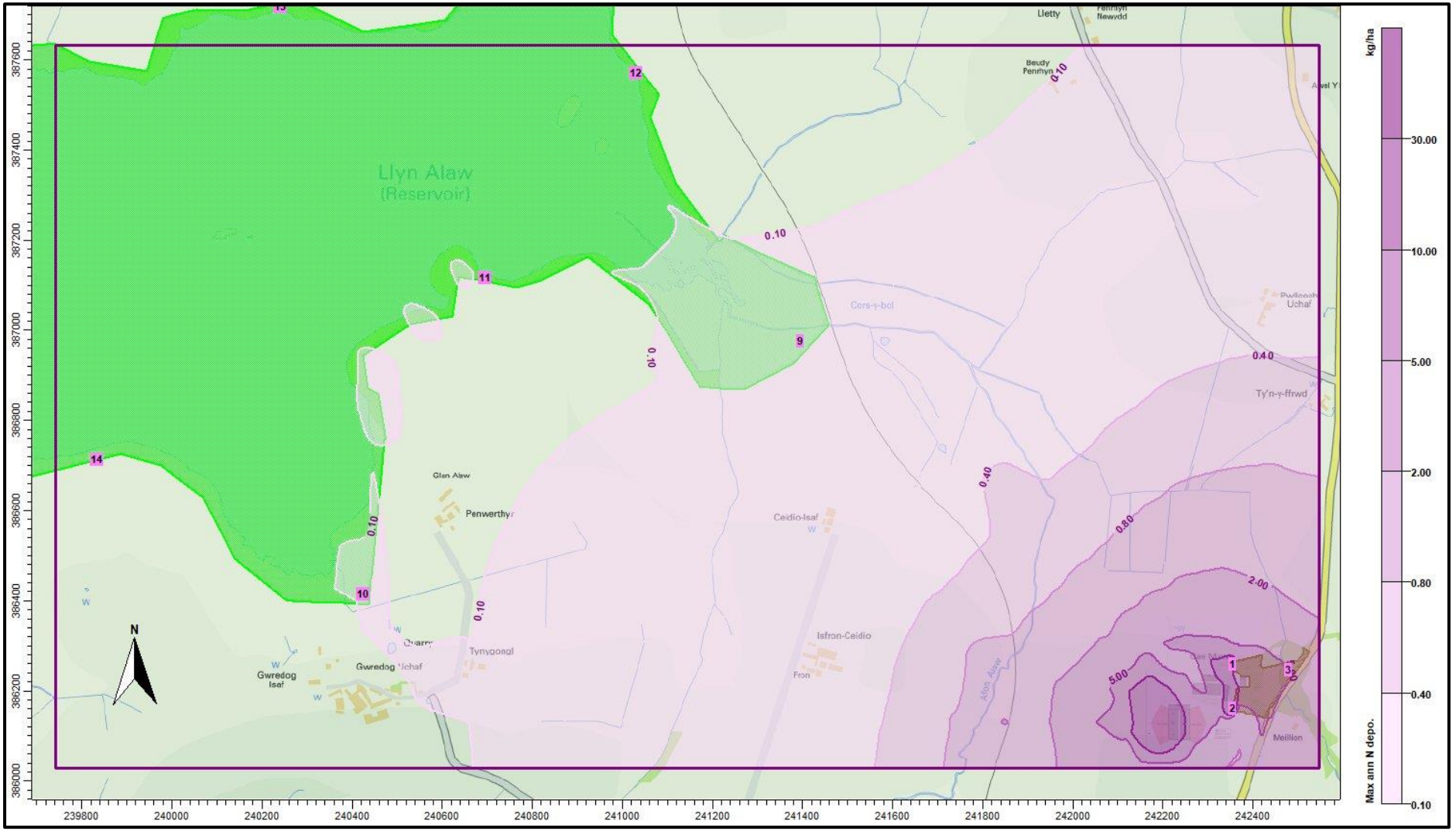


Figure 6b. Maximum annual nitrogen deposition rates



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Gail Lewis, of Roger Parry & Partners LLP, on behalf of D. B. and B. E. Evans, to use computer modelling to assess the impact of ammonia emissions from the proposed free range egg-laying chicken houses at Cae Mawr, Llanerch y Medd, Anglesey. LL71 8AN.

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

Preliminary modelling

The preliminary modelling predicts that:

- The process contribution from the proposed poultry houses at Cae Mawr to annual mean ammonia concentration would potentially exceed the Natural Resources Wales lower threshold percentage of the precautionary Critical Level of 1.0 µg-NH_3/m^3 at the AW directly to the east of Cae Mawr.

- The process contribution from the proposed poultry houses at Cae Mawr to annual mean ammonia concentration would potentially exceed the Natural Resources Wales lower threshold percentage of the Critical Level of 3.0 µg-NH_3/m^3 and the Critical Load of 10.0 kg-N/ha/y at closer parts of Llyn Alaw SSSI.

- At all other receptors considered in the modelling, the modelling predicts that the process contribution from the proposed poultry houses would not exceed the Natural Resources Wales lower threshold percentage of the relevant Critical Level or Critical Load.

Detailed modelling

The detailed modelling predicts that, when deposition processes and consequent plume depletion are fully considered:

- The process contribution from the proposed poultry houses at Cae Mawr to annual mean ammonia concentration would exceed the Natural Resources Wales lower threshold percentage of the precautionary Critical Level of 1.0 µg-NH_3/m^3 over the western half of the AW directly to the east of Cae Mawr.

- The process contribution from the proposed poultry houses at Cae Mawr to annual mean ammonia concentration would exceed the Natural Resources Wales lower threshold percentage of the Critical Level of 3.0 µg-NH_3/m^3 over a small part of Llyn Alaw SSSI and would exceed the Natural Resources Wales lower threshold percentage of the Critical Load of 10.0 kg-N/ha/y over eastern parts of Llyn Alaw SSSI.

7. References

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

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

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

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

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

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

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

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