A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing and Proposed Free Range Egg-Laying Chicken Houses at Gwynfaes, Rhandirmwyn, Llandovery in Carmarthenshire

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12th June 2019

1. Introduction

AS Modelling & Data Ltd. has been instructed by Gail Lewis, of Roger Parry & Partners LLP, on behalf of AS, S and ME Reah, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed free range egg-laying chicken houses at Gwynfaes, Rhandirmwyn, Landovery in Carmarthenshire. SA20 0NG.

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

This report is arranged in the following manner:

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

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

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

- Section 5 contains the results of the modelling.

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

2. Background Details

The site of the free range egg-laying chicken houses at Gwynfaes is in a rural area, approximately 6 km to the north of the town of Llandovery, in Carmarthenshire. The surrounding land is used predominantly for pasture and there are also some semi-natural woodlands nearby. The site is at an elevation of around 180 m in a hilly area on the slopes above the River Tywi.

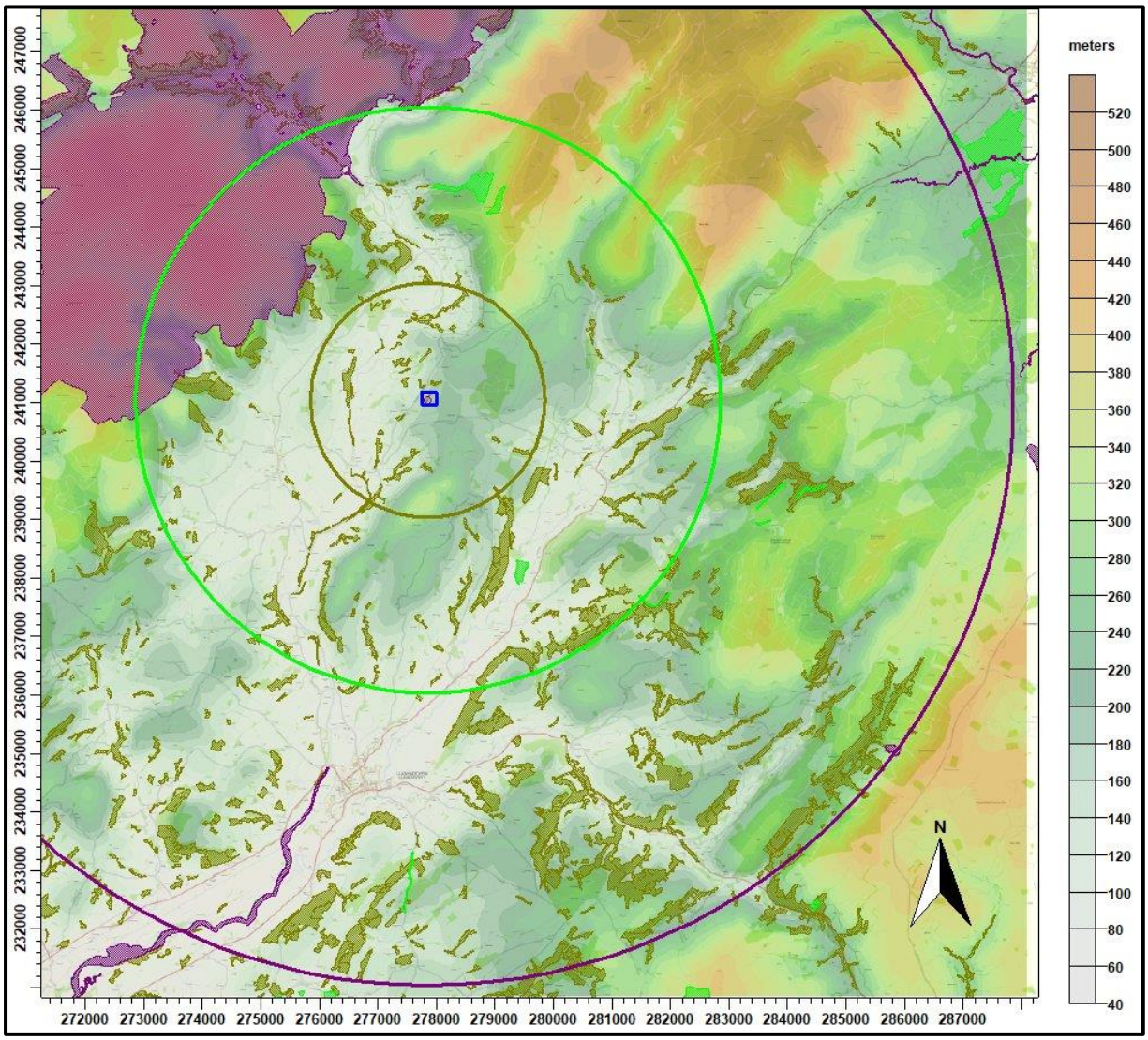
The poultry unit at Gwynfaes provides accommodation for up to 22,000 egg-laying chickens in two houses, one with an aviary system and belts that regularly remove manure and in the other there is a flat deck, whereby the chicken's manure accumulates within the house during the production period. Both houses are ventilated naturally with supplementary tunnel ventilation systems for use during hot weather. The chickens have daytime access to outdoor ranging areas via a series of pop holes along the sides of the houses.

Under the proposal, a third poultry house would be constructed on a greenfield site to the south of the existing poultry houses. This poultry house would provide accommodation for up to 8,000 egg-laying chickens and would be ventilated naturally. The chickens would have daytime access to outdoor ranging areas via a series of pop holes along the sides of the proposed poultry house and manure belts would be installed that would regularly remove manure from the house. In addition, the proposals include the installation of high speed ridge or roof fans to ventilate the most northerly of the existing poultry houses. Once complete, the poultry unit at Gwynfaes would provide accommodation for up to 30,000 egg-laying chickens.

There are a number of areas designated as Ancient Woodlands (AWs) within 2 km of Gwynfaes. There are also three areas that are designated as Sites of Special Scientific Interest (SSSIs) within 5 km of the farm, namely: Rhos Dolau-Bran SSSI; Mwyngloddfa Nantmwyn SSSI and Crychan Forest Tracks SSSI. There are also four areas designated as Special Areas of Conservation (SACs), namely: Cwm Doethie – Mynydd Mallaen SAC, areas of which are also designated as part of Elenydd Mallaen Specially Protected Area (SPA); the River Tywi SAC; the River Wye SAC and Mynydd Epynt SAC.

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

Figure 1. The area surrounding Gwynfaes – concentric circles radii at 2 km (olive), 5 km (green) and 10 km (purple)



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 house at Gwynfaes and the wildlife sites is 0.86 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 20.44 kg-N/ha/y and to short vegetation is 13.58 kg-N/ha/y. The background acid deposition rate to woodland is 1.64 keq/ha/y and to short vegetation is 1.13 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS, June 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]	10.0 [3]	-
Rhos Dolau-Bran SSSI	3.0 [2]	10.0 [3]	-
Mwyngloddfa Nantmwyn SSSI	1.0 [1]	5.0 [3]	-
Cwm Doethie – Mynydd Mallaen SAC/Elenydd Mallaen SPA	1.0 [1]	8.0 [3]	-
River Tywi SAC	1.0 [1]	-	-
River Wye SAC	1.0 [1]	10.0 [3]	-
Mynydd Epynt SSSI	1.0 [1]	10.0 [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.
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 Existing and 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 one of the existing poultry houses and the proposed new house which would have manure belts installed, the Environment Agency figure is 0.08 kg-NH_3/bird place/year and for free range egg-laying chickens where litter accumulates in the house during the production period, such as the most northerly existing poultry house, the Environment Agency figure is 0.29 kg-NH_3/bird place/year.

3.6.2 Proposed ranging area ammonia emissions

As the birds from the existing and proposed poultry houses have, or 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)
EX1 Housing	16,000 (x 0.88)	Egg laying chickens, aviary system	0.08 (EA figure)	0.035693
EX1 Ranges	16,000 (x 0.12)	Ranging areas	0.34 (AS Modelling & Data figure)	0.020686
EX2 Housing	6,000 (x 0.88)	Egg laying chickens, flat deck	0.29 (EA figure)	0.048521
EX2 Ranges	6,000 (x 0.12)	Ranging areas	0.34 (AS Modelling & Data figure)	0.007757
PR1 Housing	8,000 (x 0.88)	Egg laying chickens, manure belts	0.08 (EA figure)	0.017847
PR1 Ranges	8,000 (x 0.12)	Ranging areas	0.34 (AS Modelling & Data figure)	0.010343

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: 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 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 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 Gwynfaes is shown in Figure 2b; it should be noted elsewhere in the modelling domain the modified wind roses may differ markedly, reflecting the local flow in that part of the domain. The resolution of the wind field is approximately 300 m in the preliminary modelling and low resolution detailed modelling and is approximately 150 m in the high resolution detailed modelling. Please 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 52.055 N, 3.782 W, 2014-2017

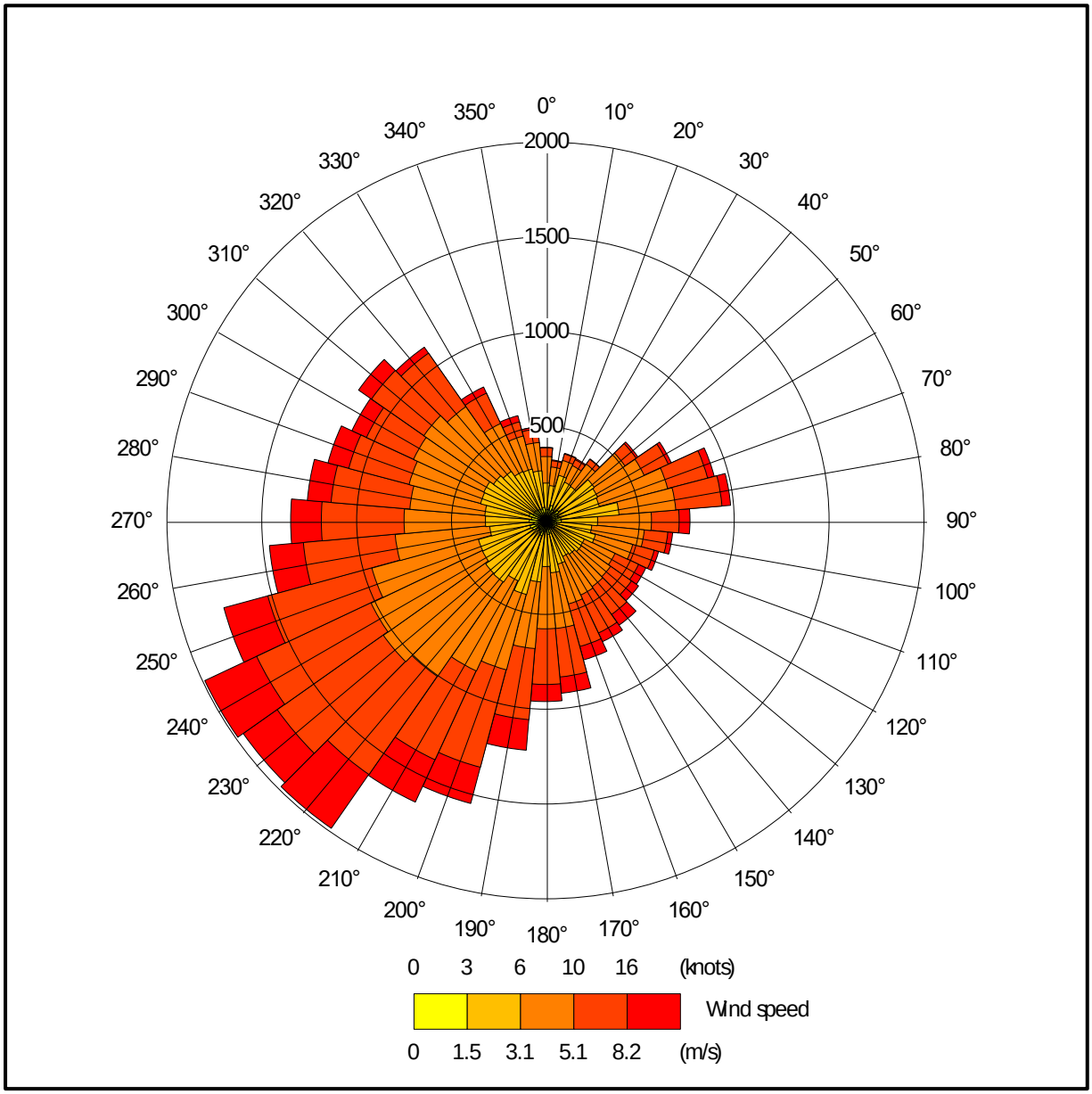
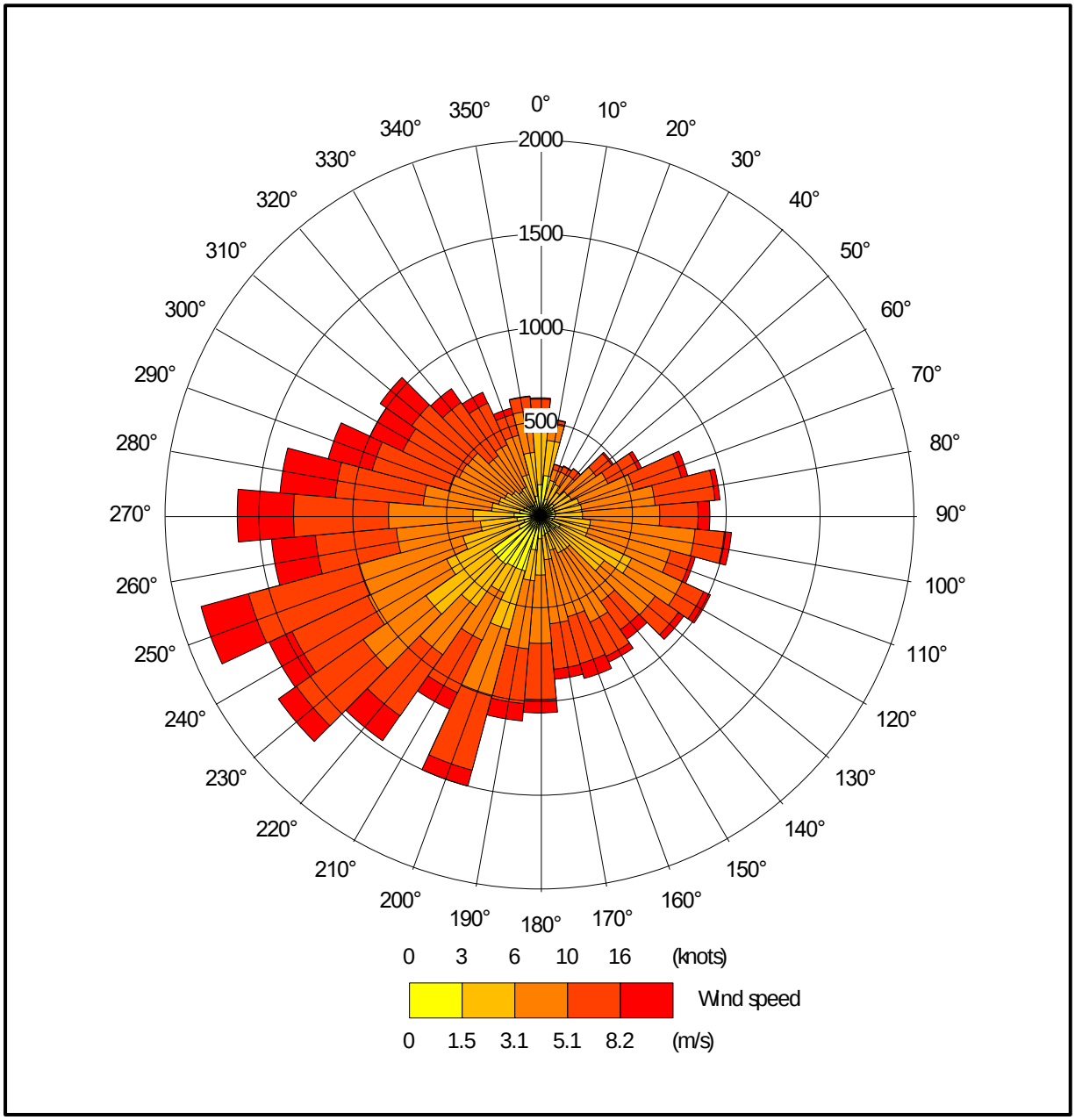


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 277855, 241050



4.2 Emission sources

Emissions from the naturally ventilated existing and proposed poultry houses are represented by a single volume source per house within ADMS (EX1v, EX2v and PR1v). Details of the volume source parameters may be seen in Table 3a and the positions of the volume sources may be seen in Figure 3, where they are indicated by hatched red rectangles.

Table 3a. Volume source parameters

Source ID	Length Y (m)	Width X (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
EX1v	64.0	19.0	3.0	0.5	Ambient	0.035694
EX2v	25.0	24.0	3.0	0.5	Ambient	0.048521
PR1v	96.0	15.0	3.0	0.5	Ambient	0.017847

Under the proposals, the most northerly of the existing poultry houses would be retrofitted with high speed ridge or roof fans. Emissions from the chimneys of these high speed ridge or roof fans have been represented by three point sources along the roof of this house (EX2 a, b and c). Details of the point source parameters may be seen in Table 3b and the positions of the point sources may be seen in Figure 3, where they are indicated by red stars.

Table 3b. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source (g-NH_3/s)
EX2 a, b & c	5.5	0.8	11.0	21.0	0.016174

The existing and proposed poultry houses have, or would have, ranging areas, which are represented by area sources within ADMS (EX1_ranA, EX1_ranB, PR1_ranA, PR1_ranB and EX2_ran). Note that the area sources cover the parts of the ranges that are most likely to be used frequently and not the whole ranging areas. Details of the area source parameters are shown in Table 3c and the positions of the area sources may be seen in Figure 3, where they are indicated by hatched red polygons.

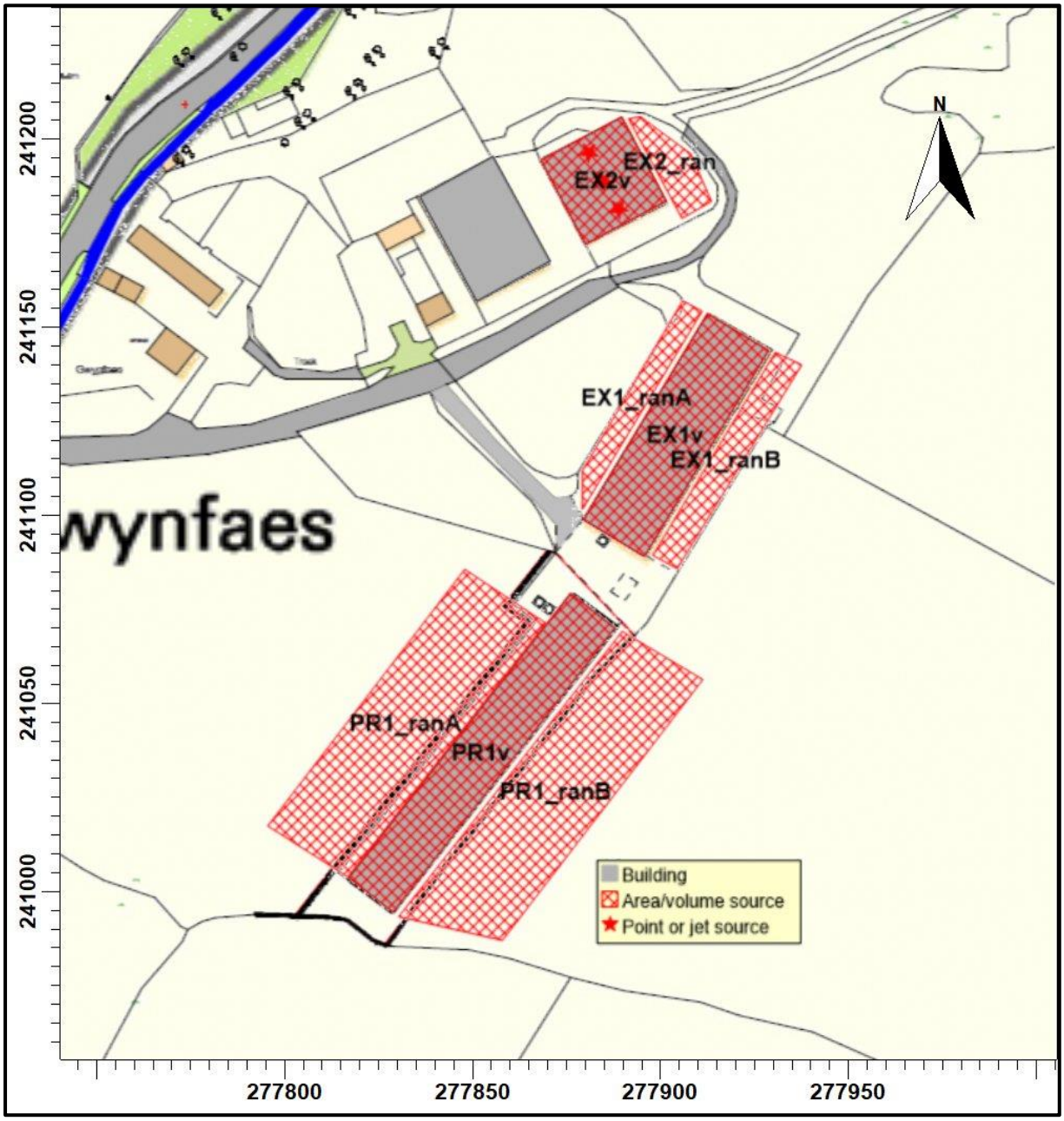
Table 3c. Area source parameters

Source ID	Area (m^2)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
EX1_ranA	320	0.0	Ambient	0.010343
EX1_ranB	479	0.0	Ambient	0.010343
PR1_ranA	2,185	0.0	Ambient	0.005171
PR1_ranB	2,323	0.0	Ambient	0.005171
EX2_ran	235	0.0	Ambient	0.007757

4.3 Modelled buildings

The structure of the poultry houses and other nearby farm buildings may affect the plumes from the point sources to be retrofit on the most northerly existing house under the proposals; therefore, these buildings are modelled within ADMS. The positions of the modelled buildings may be seen in Figure 3, where they are marked by grey rectangles.

Figure 3. The positions of the modelled buildings and sources



4.4 Discrete receptors

Fifty-eight discrete receptors have been defined: forty-four at the AWs (1 to 44), four at the SSSIs (45 to 48) and ten at the SACs/SPA (49 to 58). These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figures 4a and 4b, where they are marked by enumerated pink rectangles.

4.5 Cartesian 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 regular Cartesian grids have been defined within ADMS, one at a resolution of 250 m (low resolution) for the detailed modelling of the statutory sites and one at a resolution of 25 m (high resolution) for the detailed modelling of the nearby non-statutory sites. The grid receptors for both Cartesian grids are defined at ground level and the position of the Cartesian grids may be seen in Figure 4a, a broad scale view and in Figure 4b, a closer view focussing on the non-statutory sites, where they are marked by grey lines bounded by purple rectangles.

4.6 Terrain data

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

4.7 Roughness Length

A fixed surface roughness length of 0.35 m has been applied over the entire modelling domain. As a precautionary measure, the GFS meteorological data is assumed to have a roughness length of 0.325 m. The effect of the difference in roughness length is precautionary as it increases the frequency of low wind speeds and stability and therefore increases predicted ground level concentrations.

Figure 4a. The discrete receptors and low resolution (250 m) Cartesian grid – a broad scale view

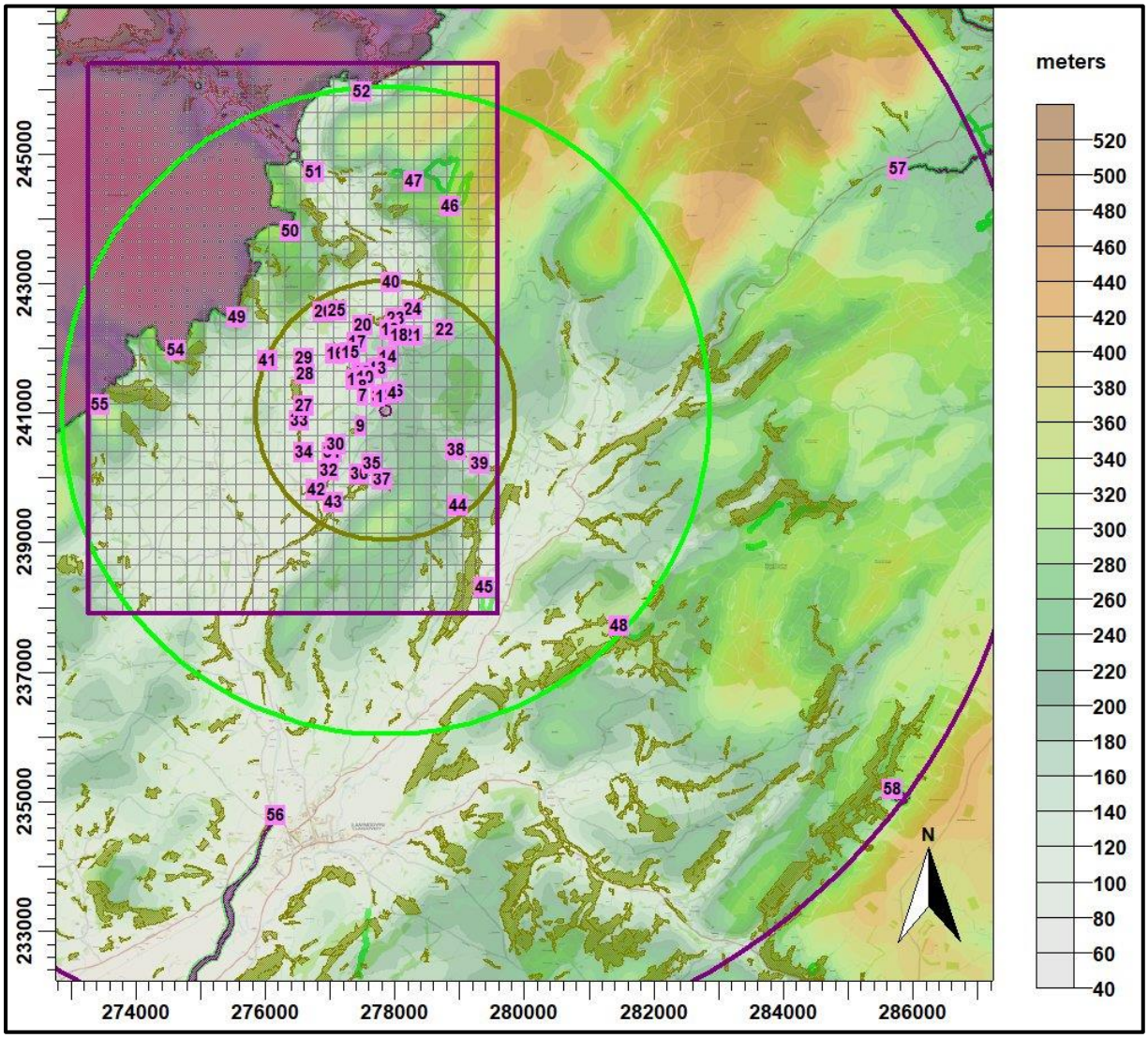
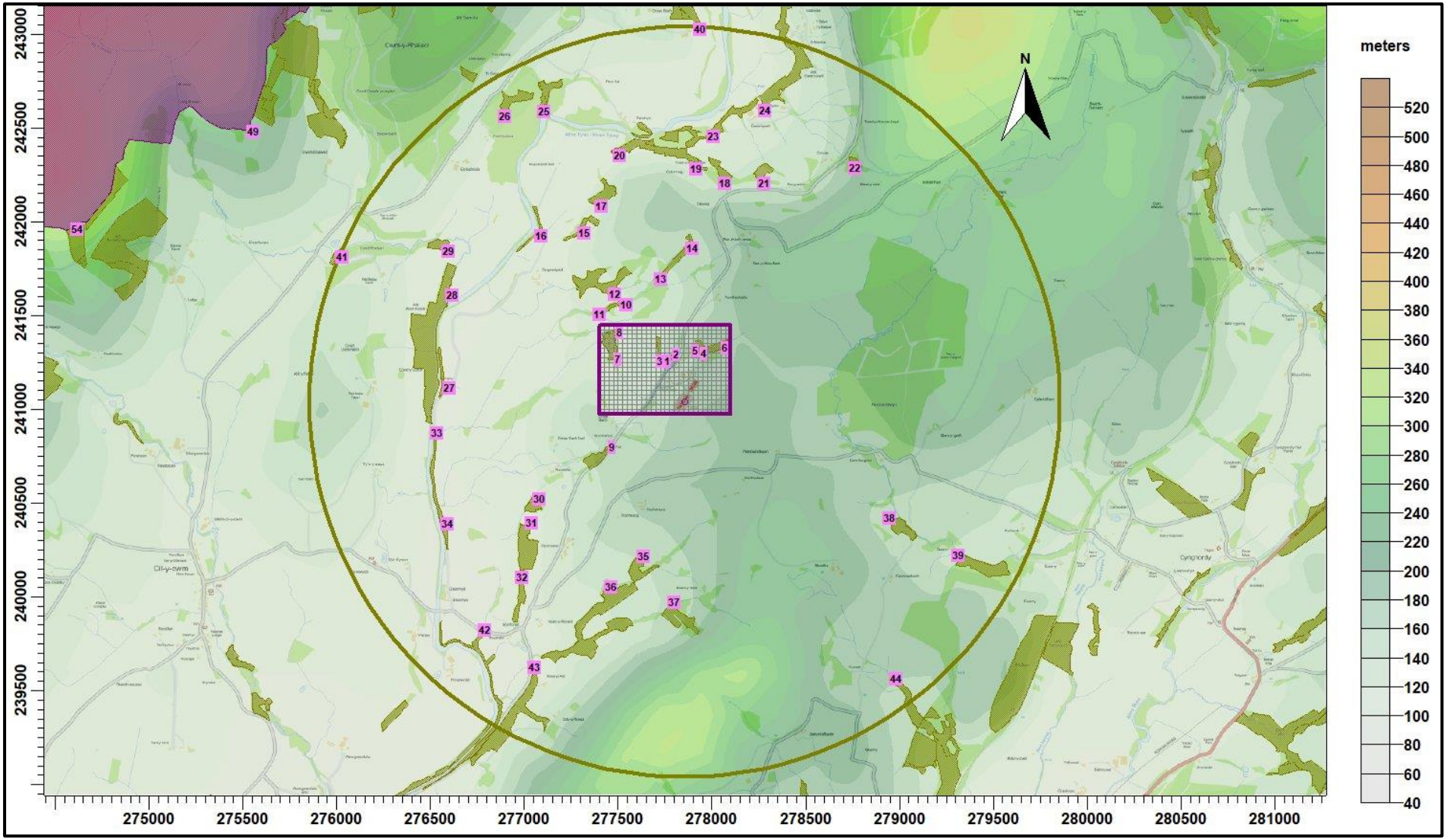


Figure 4b. The discrete receptors and high resolution (25 m) regular Cartesian grid – a closer view, focussing on the non-statutory sites



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/m³)	< 10	10 - 20	20 - 30	30 – 80	> 80
Deposition velocity – woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity – short vegetation (m/s)	0.02 (0.015 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity – arable farmland/rye grass (m/s)	0.005	0.005	0.005	0.005	0.003

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

Contour plots of the spatially varying deposition fields are provided in Figure 5a and Figure 5b.

Figure 5a. The spatially varying deposition field – low resolution detailed modelling

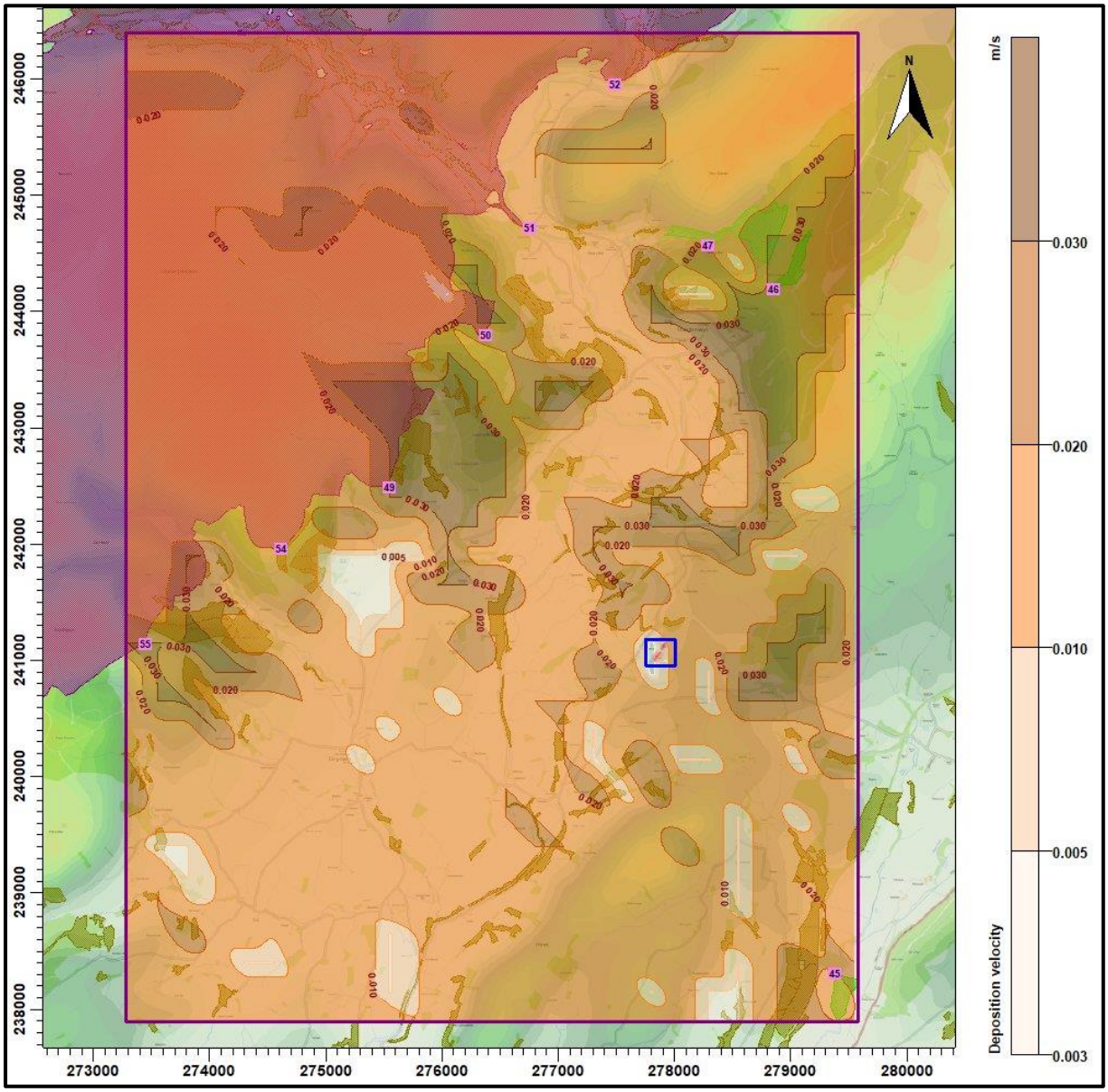
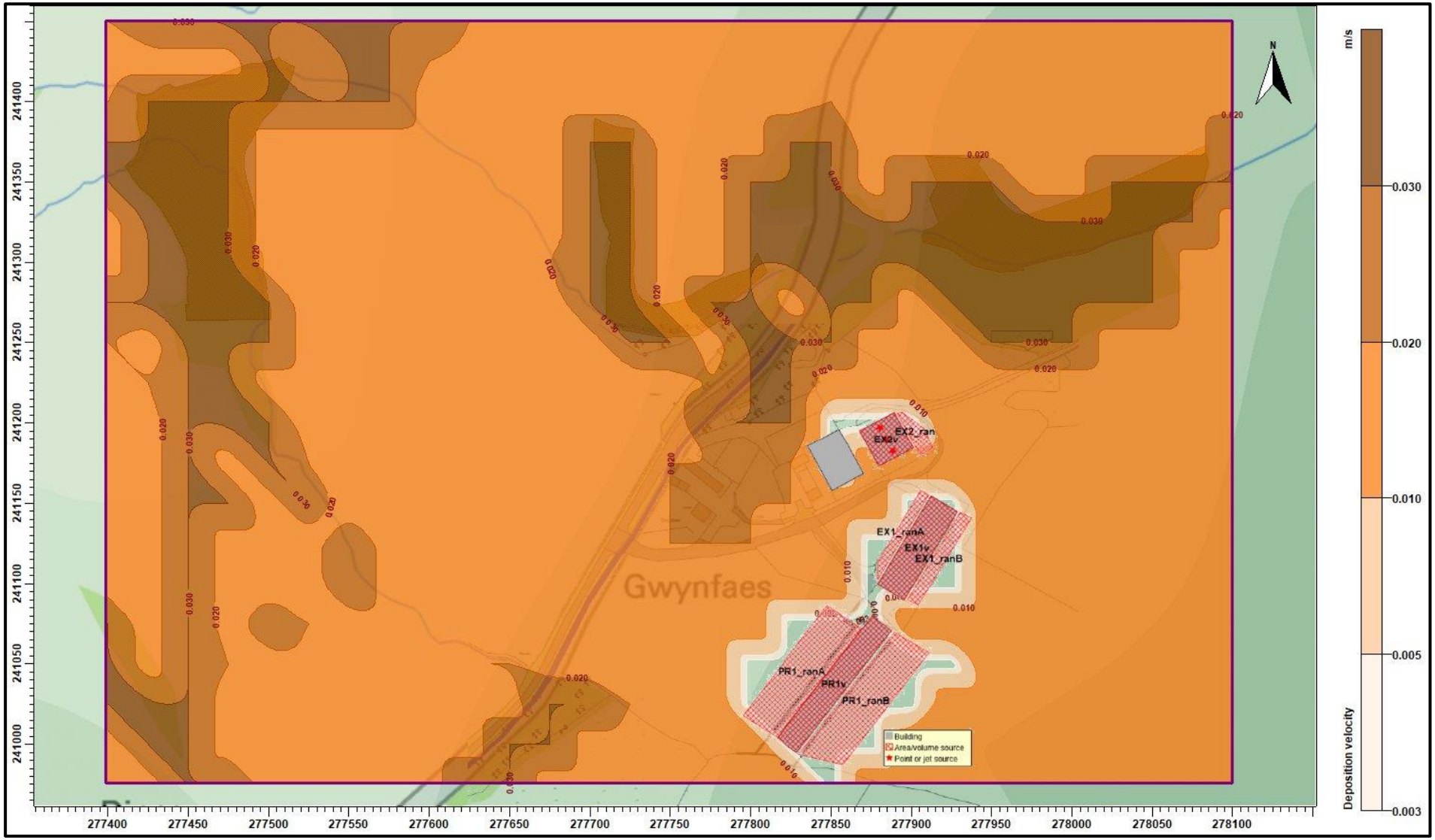


Figure 5b. The spatially varying deposition field – high resolution detailed modelling



5. Details of the Model Runs and Results

5.1 Preliminary modelling

ADMS was run a total of thirty-two times; once for each year of the meteorological record for the existing and proposed scenarios 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, a fixed deposition at 0.003 m/s (and with a correction to account for calms)– GFS data.

For each mode, statistics for the maximum annual mean ammonia concentration at each receptor were compiled. Equivalent ammonia concentrations and nitrogen deposition rates are shown in Table 5 below.

Details of the predicted annual mean ammonia concentrations at each receptor are provided in Table 6. 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 a Critical Level or Critical Load for a SSSI/SAC/SPA or 50% [1] 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, cells referring to the SSSIs are shaded green and cells referring to the SACs/SPA are shaded lilac.

1. The pre-February 2016 value is used.

Table 5. Equivalent ammonia concentrations

Deposition Velocity (m/s)	Concentration equivalent to X % of Critical Load of 10 kg/ha (µg/m^3)					
	100%	50%	20%	8%	4%	1%
0.03	1.284	0.642	0.257	0.103	**0.051**	0.013
0.02	1.925	0.963	0.385	0.154	0.077	0.019

Table 6. Predicted maximum annual mean ammonia concentration at the discrete receptors

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)							
				Existing				Proposed			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s
1	277763	241253	Unnamed AW	**3.745**	**4.432**	**3.884**	**3.449**	**2.322**	**2.591**	**2.388**	**2.052**
2	277809	241292	Unnamed AW	**3.463**	**4.207**	**3.377**	**3.140**	**2.251**	**2.509**	**2.349**	**2.101**
3	277720	241256	Unnamed AW	**2.713**	**3.181**	**2.869**	**2.448**	**1.788**	**1.999**	**1.858**	**1.549**
4	277955	241293	Unnamed AW	**7.397**	**8.015**	**8.577**	**7.721**	**4.981**	**5.181**	**5.533**	**4.614**
5	277910	241310	Unnamed AW	**6.312**	**6.925**	**7.141**	**6.297**	**3.693**	**3.884**	**4.284**	**3.561**
6	278071	241328	Unnamed AW	**2.527**	**2.795**	**2.674**	**2.332**	**2.126**	**2.241**	**2.144**	**1.780**
7	277500	241264	Unnamed AW	**0.870**	**1.003**	**0.915**	**0.693**	**0.703**	**0.781**	**0.737**	**0.556**
8	277511	241405	Unnamed AW	**0.566**	**0.675**	**0.518**	0.395	0.452	**0.513**	0.402	0.306
9	277467	240795	Unnamed AW	0.465	**0.526**	0.437	0.305	0.486	**0.530**	0.451	0.308
10	277544	241554	Unnamed AW	0.353	0.438	0.308	0.238	0.306	0.352	0.280	0.218
11	277400	241502	Unnamed AW	0.330	0.398	0.285	0.210	0.276	0.315	0.230	0.172
12	277481	241610	Unnamed AW	0.270	0.336	0.224	0.172	0.238	0.275	0.207	0.159
13	277729	241694	Unnamed AW	0.346	0.416	0.386	0.314	0.296	0.338	0.362	0.301
14	277898	241856	Unnamed AW	0.322	0.363	0.361	0.258	0.275	0.297	0.327	0.249
15	277317	241938	Unnamed AW	0.118	0.148	0.092	0.067	0.109	0.127	0.089	0.066
16	277089	241921	Unnamed AW	0.095	0.119	0.060	0.046	0.087	0.102	0.061	0.047
17	277413	242081	Unnamed AW	0.109	0.136	0.095	0.069	0.101	0.117	0.092	0.069
18	278070	242202	Unnamed AW	0.195	0.215	0.231	0.164	0.173	0.184	0.223	0.160
19	277918	242280	Unnamed AW	0.140	0.159	0.163	0.134	0.126	0.137	0.175	0.150
20	277508	242349	Unnamed AW	0.085	0.102	0.076	0.060	0.079	0.090	0.080	0.064
21	278278	242202	Unnamed AW	0.211	0.230	0.247	0.165	0.191	0.201	0.227	0.152
22	278762	242282	Unnamed AW	0.115	0.127	0.119	0.070	0.113	0.121	0.104	0.062
23	278007	242453	Unnamed AW	0.119	0.133	0.149	0.130	0.108	0.117	0.168	0.148
24	278281	242588	Unnamed AW	0.124	0.135	0.118	0.091	0.114	0.121	0.122	0.093
25	277107	242585	Unnamed AW	0.049	0.062	0.028	0.019	0.047	0.055	0.028	0.020

Table 6. (continued)

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)							
				Existing				Proposed			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s
26	276894	242562	Unnamed AW	0.043	0.055	0.023	0.015	0.042	0.049	0.024	0.016
27	276600	241112	Unnamed AW	0.138	0.154	0.186	0.104	0.132	0.143	0.181	0.101
28	276614	241605	Unnamed AW	0.100	0.117	0.098	0.055	0.094	0.105	0.093	0.052
29	276594	241838	Unnamed AW	0.079	0.094	0.059	0.035	0.074	0.084	0.054	0.034
30	277079	240518	Unnamed AW	0.159	0.180	0.151	0.104	0.159	0.173	0.154	0.107
31	277041	240394	Unnamed AW	0.133	0.151	0.123	0.086	0.134	0.146	0.120	0.083
32	276986	240103	Unnamed AW	0.092	0.105	0.092	0.061	0.093	0.102	0.091	0.060
33	276534	240873	Unnamed AW	0.121	0.133	0.136	0.081	0.117	0.126	0.139	0.082
34	276591	240385	Unnamed AW	0.093	0.103	0.082	0.057	0.097	0.103	0.083	0.058
35	277638	240215	Unnamed AW	0.147	0.172	0.160	0.098	0.151	0.168	0.189	0.118
36	277462	240051	Unnamed AW	0.114	0.131	0.129	0.076	0.116	0.128	0.142	0.085
37	277799	239970	Unnamed AW	0.085	0.105	0.109	0.062	0.087	0.101	0.125	0.072
38	278947	240420	Unnamed AW	0.134	0.151	0.132	0.092	0.136	0.147	0.137	0.097
39	279313	240221	Unnamed AW	0.084	0.095	0.083	0.054	0.086	0.093	0.085	0.057
40	277935	243023	Unnamed AW	0.058	0.065	0.070	0.058	0.055	0.060	0.085	0.072
41	276032	241810	Unnamed AW	0.052	0.062	0.052	0.026	0.051	0.058	0.051	0.025
42	276790	239820	Unnamed AW	0.062	0.072	0.056	0.039	0.063	0.070	0.059	0.040
43	277055	239624	Unnamed AW	0.060	0.069	0.065	0.039	0.060	0.067	0.067	0.040
44	278981	239564	Unnamed AW	0.064	0.071	0.060	0.036	0.064	0.068	0.062	0.038

Table 6. (continued)

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)							
				Existing				Proposed			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s
45	279379	238305	Rhos Dolau-Bran SSSI	**0.028**	**0.031**	**0.028**	**0.015**	**0.028**	**0.031**	**0.030**	**0.017**
46	278852	244190	Mwyngloddfa Nantymwyn SSSI	**0.035**	**0.038**	**0.023**	0.011	**0.035**	**0.037**	**0.023**	0.011
47	278291	244568	Mwyngloddfa Nantymwyn SSSI	**0.023**	**0.026**	**0.033**	**0.015**	**0.024**	**0.026**	**0.035**	**0.016**
48	281462	237710	Crychan Forest Tracks SSSI	0.012	0.014	0.013	0.006	0.013	0.014	0.014	0.007
49	275554	242481	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	**0.027**	**0.033**	**0.023**	**0.012**	**0.027**	**0.031**	**0.021**	**0.010**
50	276378	243796	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	**0.017**	**0.021**	**0.018**	0.010	**0.017**	**0.020**	**0.020**	0.010
51	276759	244715	Cwm Doethie - Mynydd Mallaen SAC	**0.013**	**0.016**	**0.021**	**0.012**	**0.014**	**0.016**	**0.021**	**0.013**
52	277488	245951	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	**0.011**	**0.013**	**0.013**	0.007	**0.011**	**0.013**	**0.014**	0.008
53	279183	247377	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	**0.010**	**0.011**	0.006	0.003	**0.011**	**0.012**	0.007	0.003
54	274620	241958	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	**0.022**	**0.026**	**0.023**	0.008	**0.023**	**0.025**	**0.021**	0.008
55	273447	241134	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	**0.017**	**0.019**	**0.023**	0.008	**0.018**	**0.020**	**0.021**	0.008
56	276166	234788	River Tywi SAC	0.006	0.007	0.008	0.004	0.006	0.007	**0.011**	0.005
57	285766	244771	River Wye SAC	0.005	0.006	0.004	0.002	0.006	0.007	0.004	0.003
58	285684	235198	Mynydd Epynt SAC	0.004	0.005	0.004	0.002	0.005	0.005	0.003	0.002

5.2 Detailed deposition modelling

The detailed modelling was carried out over two restricted domains; one that includes Rhos Dolau-Bran SSSI, Mwyngloddfa Nantmwyn SSSI and the closer parts of Cwm Doethie-Mynydd Mallaen SAC/Elenydd Mallaen SPA and one that includes the nearby AWs. These are the areas where the preliminary modelling run with a fixed deposition rate indicated that annual mean ammonia concentrations (or nitrogen deposition rates) could potentially exceed the Natural Resources Wales lower threshold of the relevant Critical Level or Critical Load. At the other receptors considered, the preliminary modelling run 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.

The preliminary modelling indicated that calms may have a significant effect. Spatially varying deposition and terrain cannot be modelled in conjunction with calms; therefore, to account for calms, a correction, based upon the difference between the basic and calms modes of the preliminary modelling, has been applied to the results of the detailed modelling.

The predicted maximum annual mean ground level ammonia concentrations and nitrogen deposition rates are shown in Tables 7 (low resolution) and 8 (high resolution). In these tables, 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/SAC/SPA 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/SAC/SPA and 50% [1] and 100% for a non-statutory site) are coloured blue.

Contour plots of the predicted ground level maximum annual mean ammonia concentrations and nitrogen deposition rates for the low resolution detailed modelling, for both the existing and proposed scenarios are shown in Figures 6a, 6b, 6c and 6d. Contour plots of the predicted ground level maximum annual mean ammonia concentrations and nitrogen deposition rates for the high resolution detailed modelling, for both the existing and proposed scenarios are shown in Figures 7a, 7b, 7c and 7d.

1. The pre-February 2016 value is used.

Table 7. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors – low resolution detailed modelling

Receptor number	X(m)	Y(m)	Site	Maximum annual mean ammonia concentration at ground level					Maximum annual mean nitrogen deposition rate					
				Critical Level (µg/m³)	Existing		Proposed		Deposition Velocity (m/s)	Critical Load (kg/ha)	Existing		Proposed	
					PC (µg/m³)	%age of Cle	PC (µg/m³)	%age of Cle			PC (kg/ha)	%age of Clo	PC (kg/ha)	%age of Clo
45	279379	238305	Rhos Dolau-Bran SSSI	3.0	0.007	0.2	0.009	0.3	0.03	10.0	0.06	0.57	0.07	0.7
46	278852	244190	Mwyngloddfa Nantymwyn SSSI	1.0	0.004	0.4	0.005	0.5	0.03	5.0	0.03	0.57	0.04	0.7
47	278291	244568	Mwyngloddfa Nantymwyn SSSI	1.0	0.005	0.5	0.007	0.7	0.02	5.0	0.03	0.55	0.04	0.7
49	275554	242481	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	1.0	0.005	0.5	0.005	0.5	0.02	8.0	0.03	0.32	0.02	0.3
50	276378	243796	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	1.0	0.003	0.3	0.004	0.4	0.02	8.0	0.02	0.22	0.02	0.3
51	276759	244715	Cwm Doethie - Mynydd Mallaen SAC	1.0	0.006	0.6	0.008	0.8	0.02	8.0	0.03	0.41	0.04	0.5
52	277488	245951	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	1.0	0.004	0.4	0.005	0.5	0.02	8.0	0.02	0.24	0.02	0.3
54	274620	241958	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	1.0	0.003	0.3	0.003	0.3	0.02	8.0	0.02	0.21	0.02	0.2
55	273447	241134	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	1.0	0.003	0.3	0.003	0.3	0.02	8.0	0.02	0.19	0.02	0.2

Table 8. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors – high resolution detailed modelling

Receptor number	X(m)	Y(m)	Site	Maximum annual mean ammonia concentration at ground level					Maximum annual mean nitrogen deposition rate					
				Critical Level (µg/m³)	Existing		Proposed		Deposition Velocity (m/s)	Critical Load (kg/ha)	Existing		Proposed	
					PC (µg/m³)	%age of Cle	PC (µg/m³)	%age of Cle			PC (kg/ha)	%age of Clo	PC (kg/ha)	%age of Clo
1	277763	241253	Unnamed AW	1.0	2.476	**247.6**	1.684	**168.4**	0.03	10.0	19.292	**192.9**	13.119	**131.2**
2	277809	241292	Unnamed AW	1.0	2.257	**225.7**	1.530	**153.0**	0.03	10.0	17.582	**175.8**	11.920	**119.2**
3	277720	241256	Unnamed AW	1.0	1.663	**166.3**	1.225	**122.5**	0.03	10.0	12.956	**129.6**	9.544	95.4
4	277955	241293	Unnamed AW	1.0	4.773	**477.3**	2.913	**291.3**	0.03	10.0	37.183	**371.8**	22.699	**227.0**
5	277910	241310	Unnamed AW	1.0	3.936	**393.6**	2.144	**214.4**	0.03	10.0	30.663	**306.6**	16.705	**167.1**
6	278071	241328	Unnamed AW	1.0	1.336	**133.6**	1.109	**110.9**	0.03	10.0	10.409	**104.1**	8.643	86.4
7	277500	241264	Unnamed AW	1.0	0.376	37.6	0.365	36.5	0.03	10.0	2.926	29.3	2.840	28.4
8	277511	241405	Unnamed AW	1.0	0.235	23.5	0.231	23.1	0.03	10.0	1.835	18.3	1.799	18.0

Figure 6a. Maximum annual ammonia concentration – existing, low resolution detailed modelling

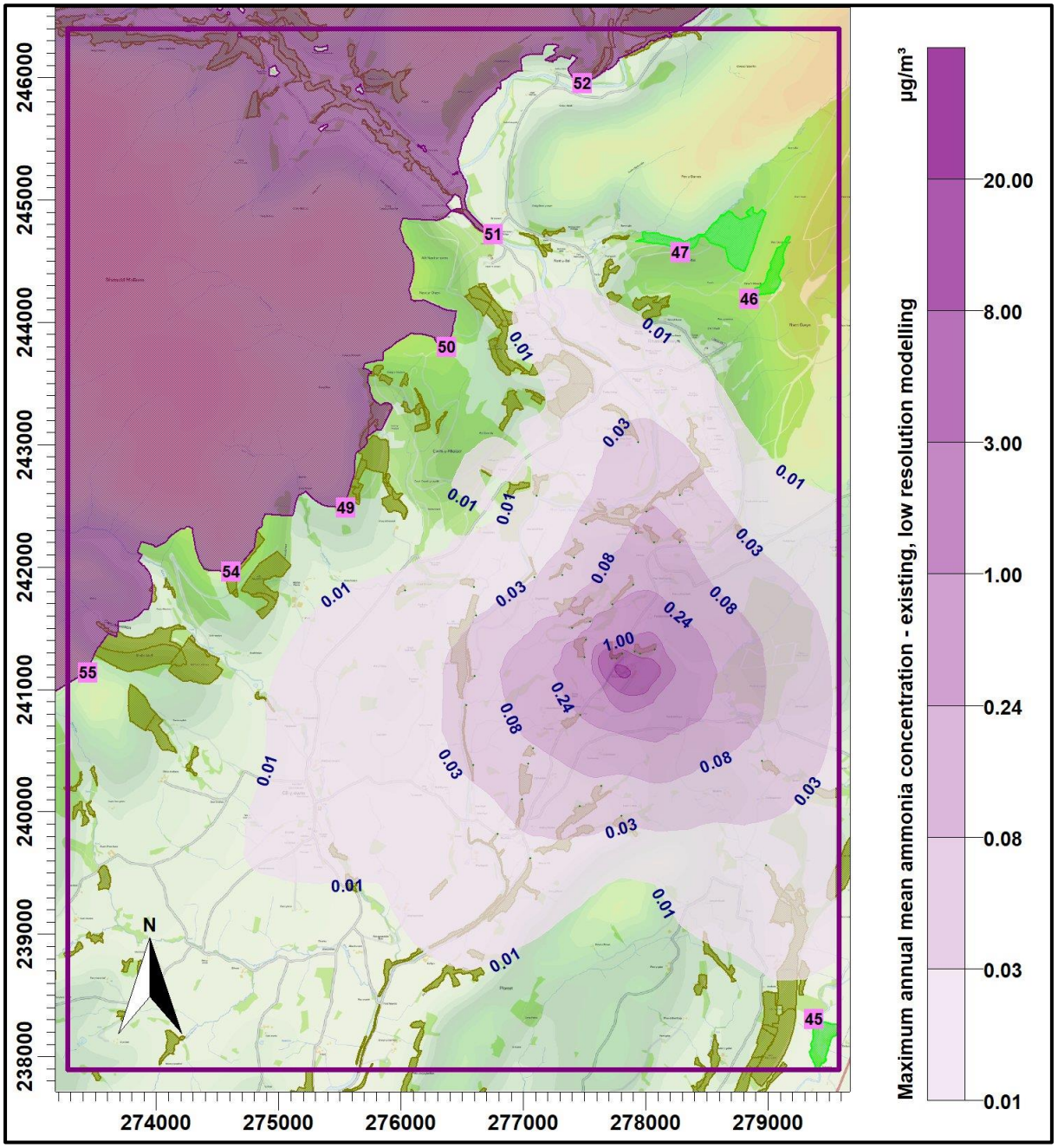


Figure 6b. Maximum annual ammonia concentration – proposed, low resolution detailed modelling

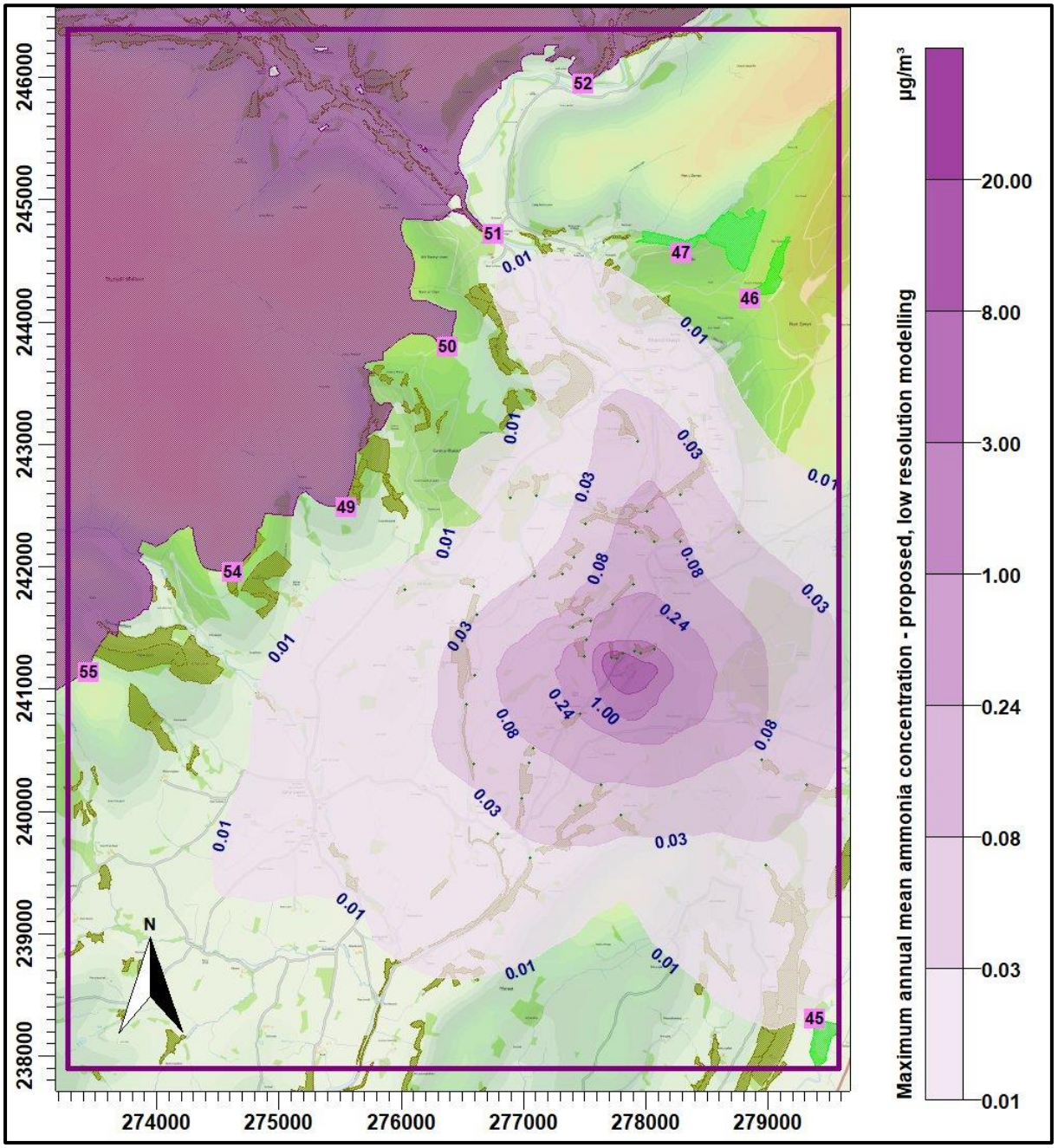


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Figure 6c. Maximum annual nitrogen deposition rates – existing, low resolution detailed modelling

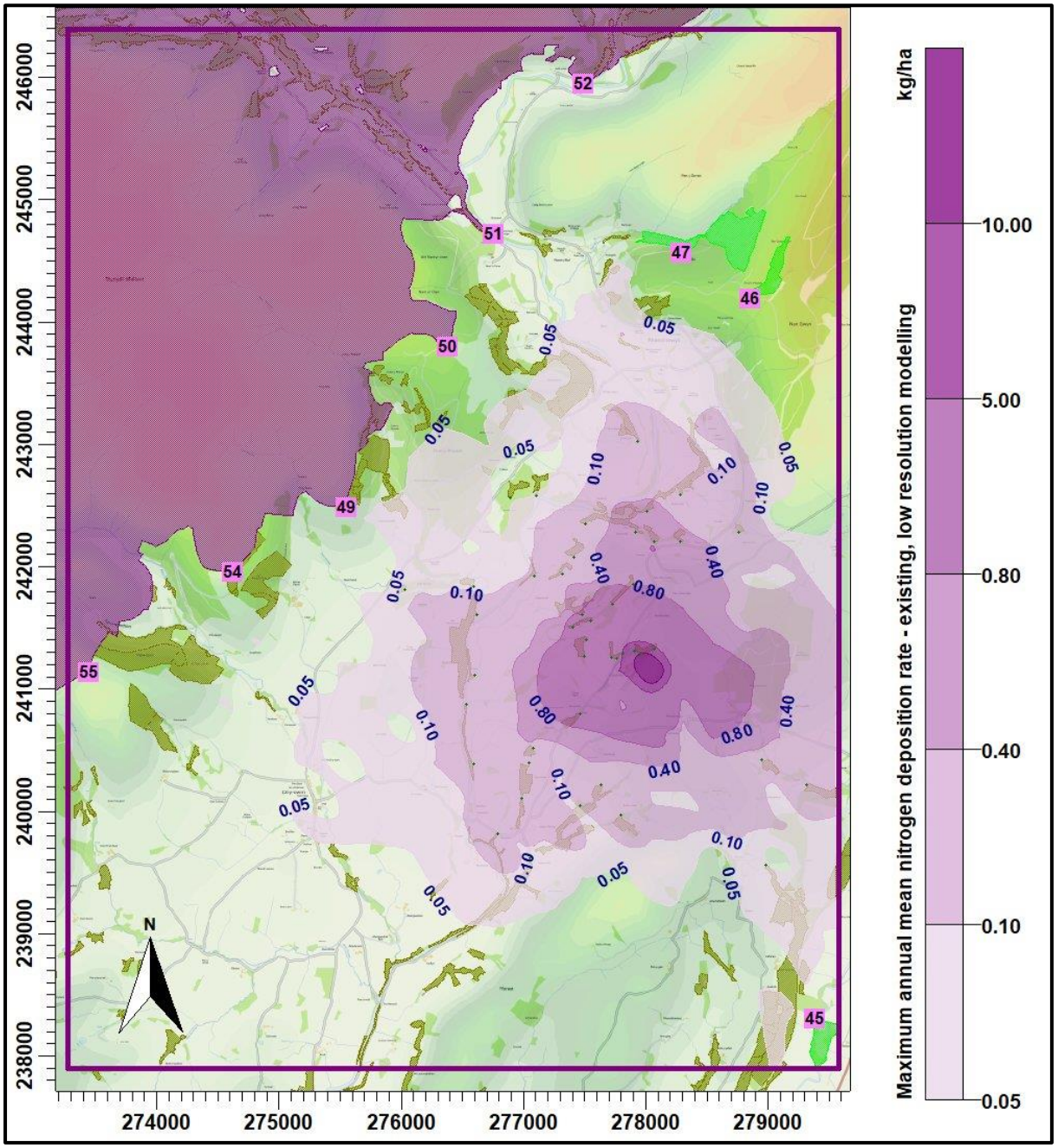


Figure 6d. Maximum annual nitrogen deposition rates – proposed, low resolution detailed modelling

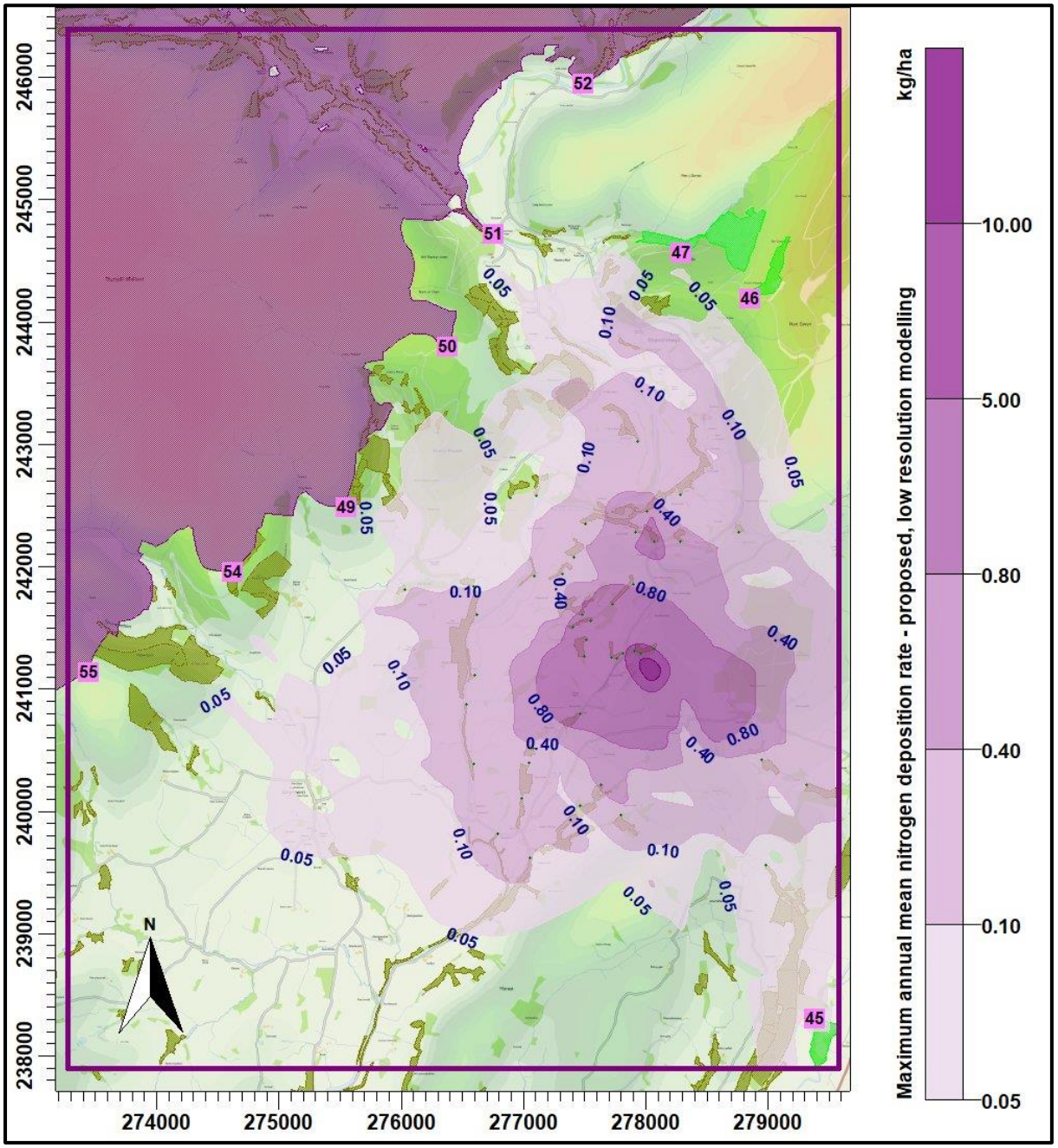


Figure 7a. Maximum annual ammonia concentration – existing, high resolution detailed modelling

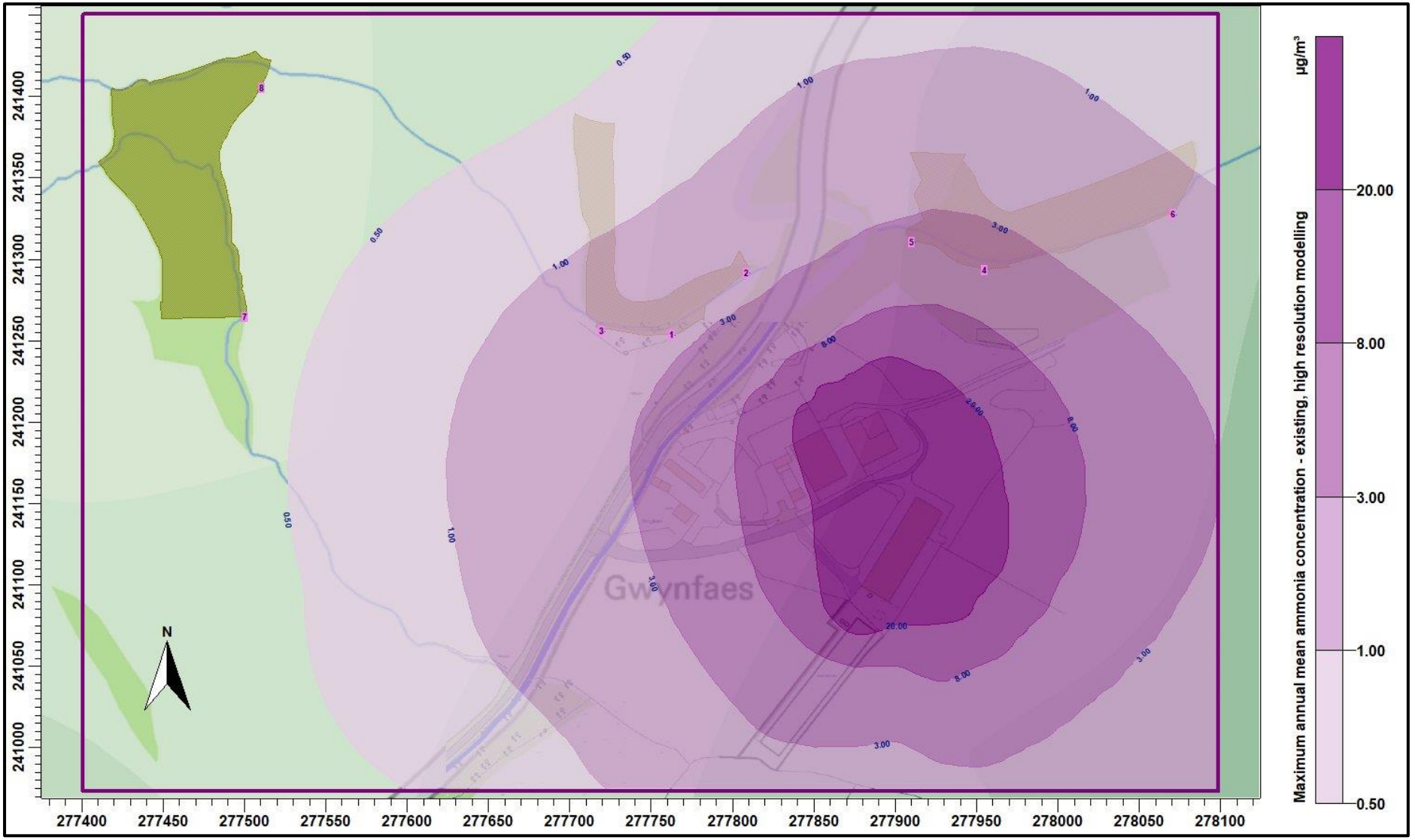


Figure 7b. Maximum annual ammonia concentration – proposed, high resolution detailed modelling

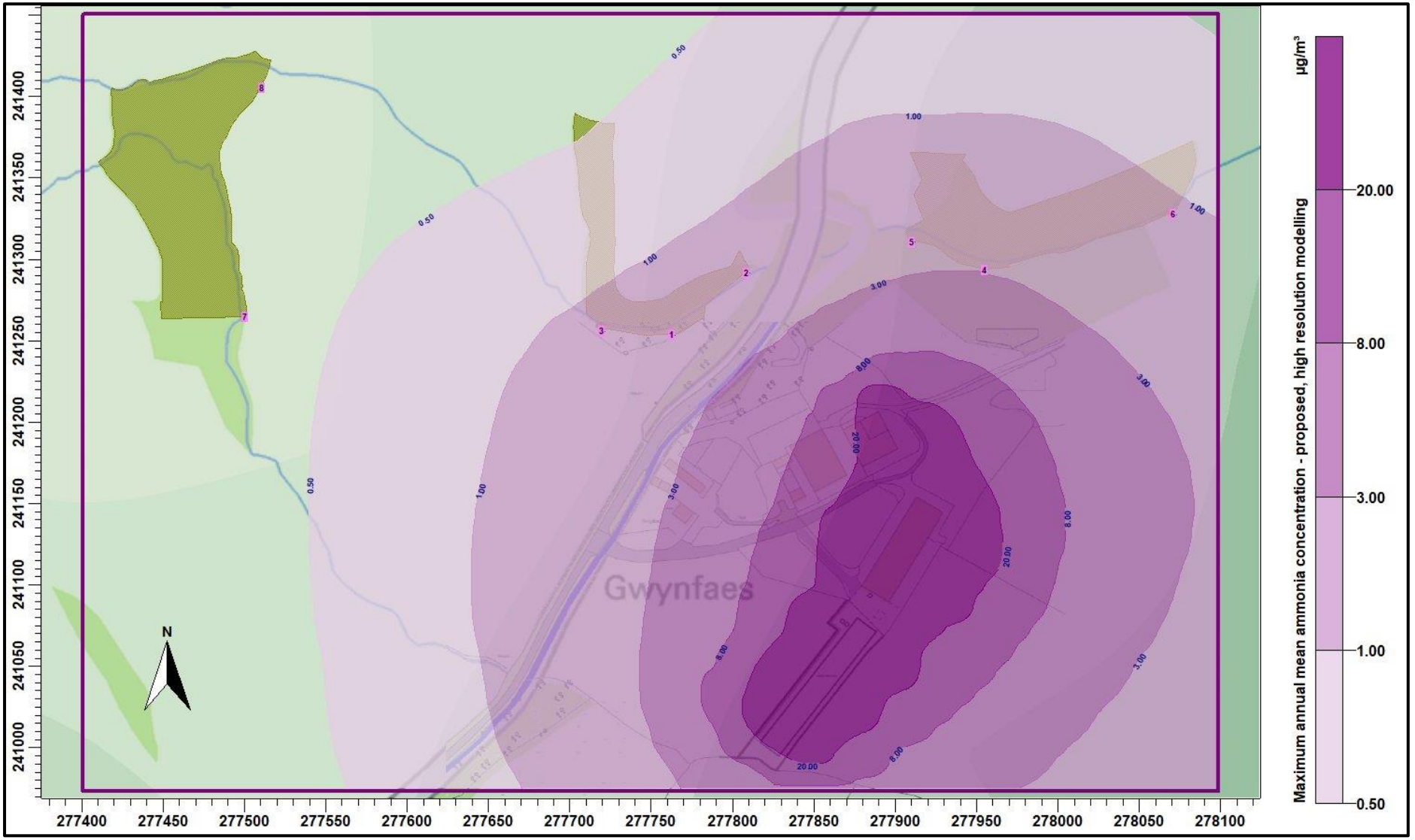


Figure 7c. Maximum nitrogen deposition – existing, high resolution detailed modelling

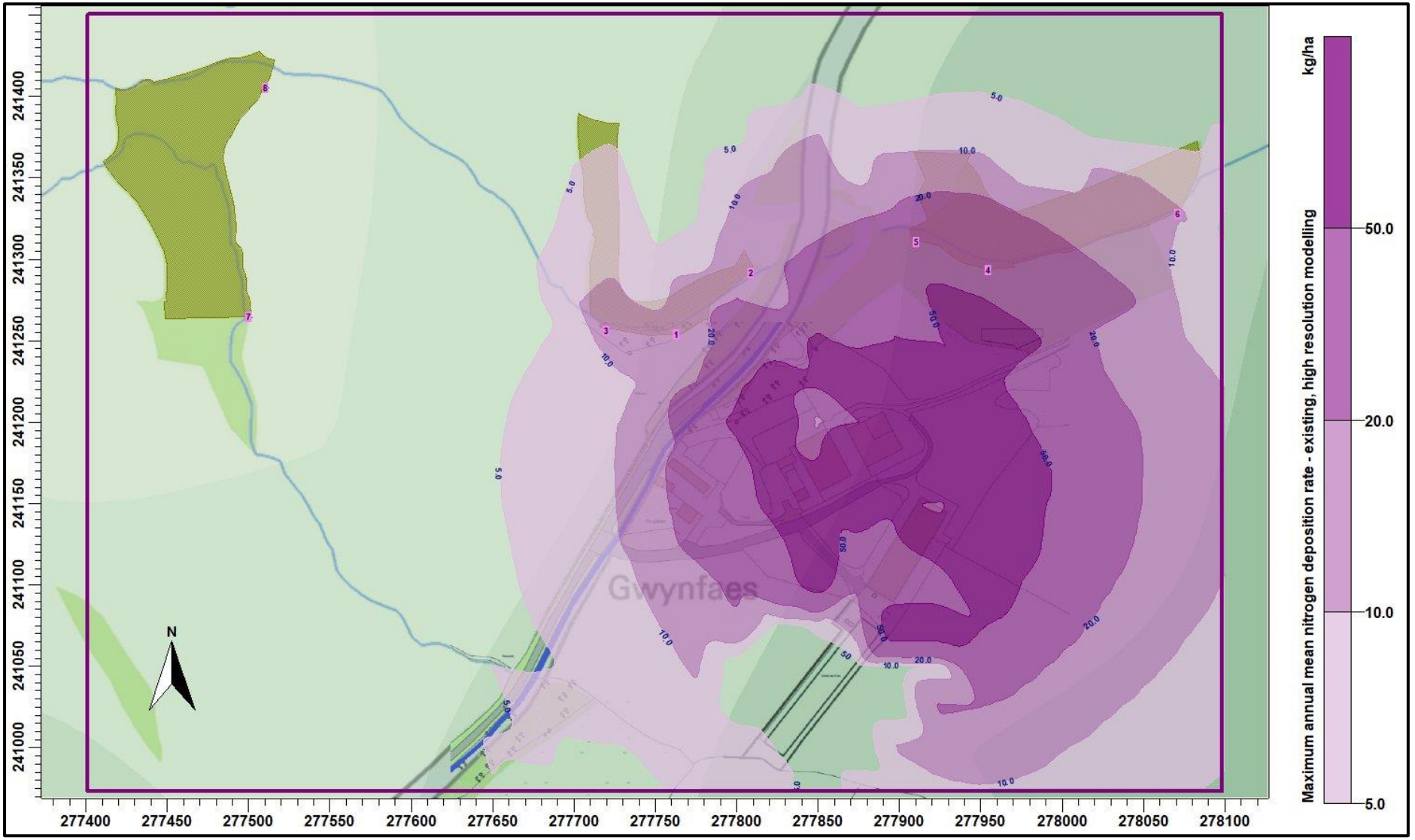
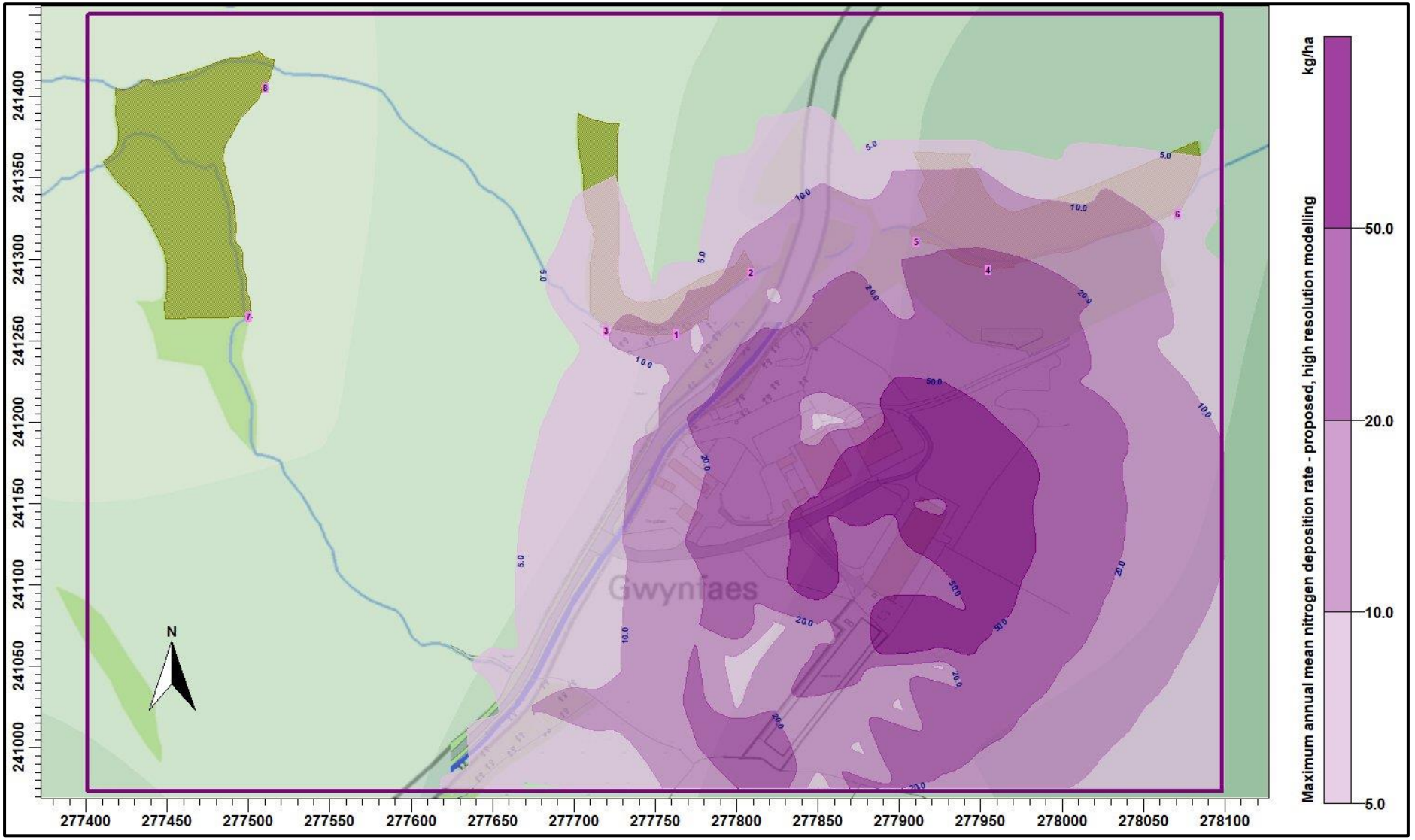


Figure 7d. Maximum nitrogen deposition - proposed, high resolution detailed modelling



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Gail Lewis, of Roger Parry & Partners LLP, on behalf of AS, S and ME Reah, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed free range egg-laying chicken houses at Gwynfaes, Rhandirmwyn, Landovery in Carmarthenshire. SA20 0NG.

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

Preliminary modelling

The preliminary modelling predicts that the process contribution of the existing and proposed poultry houses at Gwynfaes to annual mean ammonia concentrations and nitrogen deposition rates would potentially exceed the Natural Resources Wales lower threshold percentage of the relevant Critical Level or Critical Load at receptors located at: the closest AWs; Rhos Dolau-Bran SSSI; Mwyngloddfa Nantymwyn SSSI and closer parts of Cwm Doethie – Mynydd Mallaen SAC/Elenudd Mallarn SPA.

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

Low resolution detailed modelling

The detailed modelling conducted at a low resolution predicts that the process contribution of the existing and proposed poultry houses at Gwynfaes to annual mean ammonia concentrations and nitrogen deposition rates would not exceed the Natural Resources Wales lower threshold percentage of the relevant Critical Level or Critical Load at discrete receptors located at Rhos Dolau-Bran SSSI, Mwyngloddfa Nantymwyn SSSI or Cwm Doethie – Mynydd Mallaen SAC/Elenudd Mallarn SPA.

High resolution detailed modelling

The detailed modelling at a higher resolution predicts that the process contribution of the existing and proposed poultry houses at Gwynfaes to annual mean ammonia concentrations and nitrogen deposition rates would exceed the Natural Resources Wales higher threshold percentage of both the precautionary Critical Level of 1.0 µg/m³ and the Critical Load of 10.0 kg/ha at the discrete receptors located at two of the closest AWs.

For the process contribution to ammonia concentrations, the predicted exceedances are approximately 0.26 ha from the existing poultry houses and approximately 0.22 ha from the existing and proposed poultry houses at the western-most unnamed AW and 0.69 ha from the existing poultry houses and 0.67 ha from the existing and proposed poultry houses at the eastern-most unnamed AW.

For the process contribution to nitrogen deposition, the predicted exceedances are approximately 0.21 ha from the existing poultry houses and approximately 0.11 ha from the existing and proposed poultry houses at the western-most unnamed AW and 0.62 ha from the existing poultry houses and 0.50 ha from the existing and proposed poultry houses at the eastern-most unnamed AW.

In comparison to the existing poultry houses at Gwynfaes, the proposed poultry houses, including the changes to the ventilation for the northern-most poultry house, represent a reduction in impacts at the nearby non-statutory wildlife sites.

Mitigation

Where exceedances of the upper threshold are predicted at non-statutory sites, such as at the closest AWs (Coed Tylissa), then some form of mitigation is usually required. AS Modelling & Data Ltd. would recommend that, if available, to compensate for possible detrimental effects on the nearby AW, the wildlife site is actively managed for wildlife, and/or, that land of at least a similar area to the exceedance of 100% of the Critical Level is set aside for nature conservation and planted with native species. Alternatively, or additionally, unfertilised and only lightly grazed buffer zones and corridors could be set up around and between the AWs; such buffer zones and corridors can greatly enhance bio-diversity over time. Additionally, Beasley et al, 2013 (Defra project AC0201) have found that tree planting locally can be used as a measure to help protect downwind sensitive ecosystems from ammonia emissions from agricultural installations.

7. References

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http://www.apis.ac.uk/

ANNEX 1 – Modelling of Ammonia Emissions from Manure Storage and Manure Spreading

Ammonia emission from the poultry housing and ranging areas are as in the main body of this report (proposed scenario).

Emissions from the manure storage areas are represented by two volume sources within ADMS and are based upon the assumption that that there are 120 tonnes of fresh manure in storage with an emission factor of 2.38kg-NH3/tonne/y (the Environment Agency standard emission factor for poultry manures). The volume sources are 3.0 m in height with their bases at ground level.

Emissions from manure spreading are based upon the assumption that laying hens produce 0.8 kg of ammoniacal nitrogen per year. From this figure droppings to the ranging area and ammonia losses from housing and storage are subtracted. Additionally, 40% of manures is exported out of the area, this is also subtracted.

It is also assumed that 50% of the total ammoniacal nitrogen (TAN) is evolved as ammonia (NH_3).

Details of the calculation are as follows:

Total ammoniacal nitrogen (TAN) from 30,000 laying hens:

30,000 hens x 0.8 kg-N/hen/y =	**24,000 kg-N/y**
12% of droppings deposited on ranging areas:	
30,000 hens x 0.8 kg-N/hen/y x 12% =	-2,880 kg/N/y
Losses from housing (assumes 88% of droppings within housing):	
EX1 - 16,000 birds x 0.08 kg-NH3/bird/y x (14/17) x 88% =	-927.6 kg-N/y
EX2 - 6,000 birds x 0.08 kg-NH3/bird/y x (14/17) x 88% =	-1,261.0 kg-N/y
PR1 - 8,000 birds x 0.08 kg-NH3/bird/y x (14/17) x 88% = -	-463.8 kg-N/y
Losses from manure storage:	
120 tonnes x 2.38 kg NH3/tonne/y * (14/17) =	-235.2 kg-N/y
TAN remaining in manure =	**18,232.4 kg-N/y**
40% exported from the area:	
18,232.4 kg-N/y x 40% =	-7,293.0 kg-N/y
Total TAN remaining for spreading ar Gwynfaes and Clynmawr =	**10,939.4 kg-N/y**

Assuming 50% of TAN is evolved as ammonia (NH_3), then NH_3 produced from field spreading is:

10,939.4 kg-N/y * 50% * (17/14) = 6,641.8 kg NH_3/y

1/6th of the remaining manure (after export) is spread at Gwynfaes, so emission from the fields at Gwynfaes is:

6,641.8 x (1/6) = 1,107.0 kg NH_3/y

And 5/6th of the remaining manure (after export) is spread at Clynmawr, so emission from the fields at Clynmawr is:

6,641.8 x (5/6) = 5,534.8 kg NH_3/y

Emissions from field spreading of manure are characterised by a large emission directly from the manure immediately after spreading with and exponential decay over following days. However, lower level emissions of ammonia from soils may continue for weeks or months after application and nitrogen absorbed by plants in the fields may be emitted by the plants themselves, particularly during senescence of the plants, or decay of any dead plant matter left on the fields. It is not possible to model these characteristics of the emissions, chiefly because it cannot be known precisely when and where manure is spread. Therefore, emissions are modelled as a continuous average emission rate, which is of course considerably less than peak emissions, but also greater than the median emission rate. As the Critical Level is defined in terms of an annual mean ammonia concentration and the Critical Load is defined in terms of an annual nitrogen deposition rate, this is considered an acceptable compromise, at least for receptors some distance from the spreading operations.

Within ADMS, the emissions from the field spreading are represented by a series of point sources located at the centroids of the fields that are used for manure spreading. Emissions are divided equally among the point sources with no regard for field size or actual application rate of each field, again as the key receptors are some distance from the source this is considered an acceptable modelling compromise. The point sources are defined at 0.2 m above ground level, with a diameter of 2 m and an emission velocity of 0.1 m/s and an emission temperature at ambient conditions (from the meteorology file).

The modelling was carried out using all discrete receptors and with the low resolution deposition velocity field. Outside of the low resolution deposition velocity field domain, a fixed deposition velocity of 0.003 m/s is applied. The modelling was performed with a 20 km 20 km terrain file, and FLOWSTAR at a resolution of 64 x64 grid points; therefore, the resolution if the wind speed and direction field is approximately 300m. A correction factor of 1.1 was applied to the results ton account for calm and light winds, which cannot be modelled in conjunction with spatially varying deposition.

Results of the modelling are provided in Table A1, these results include emissions from housing (proposed scenario), manure storage and manure spreading). Contour plots of the predicted maximum annual ammonia concentrations and nitrogen deposition rates are provided in Figures A1a and A1b, respectively.

Please note that spreadsheets with details of the calculations and results for individual sources and all modelling files can be made available upon request.

Table A1. Predicted annual mean ammonia concentrations and nitrogen deposition rates in the surrounding area (all sources)

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	277763	241253	Unnamed AW	0.03	1.0	10.0	2.877	**287.7**	22.42	**224.2**
2	277809	241292	Unnamed AW	0.03	1.0	10.0	2.689	**268.9**	20.95	**209.5**
3	277720	241256	Unnamed AW	0.03	1.0	10.0	2.076	**207.6**	16.18	**161.8**
4	277955	241293	Unnamed AW	0.03	1.0	10.0	4.378	**437.8**	34.11	**341.1**
5	277910	241310	Unnamed AW	0.03	1.0	10.0	3.748	**374.8**	29.20	**292.0**
6	278071	241328	Unnamed AW	0.03	1.0	10.0	1.609	**160.9**	12.53	**125.3**
7	277500	241264	Unnamed AW	0.03	1.0	10.0	0.616	61.6	4.80	48.0
8	277511	241405	Unnamed AW	0.03	1.0	10.0	0.348	34.8	2.71	27.1
9	277467	240795	Unnamed AW	0.03	1.0	10.0	0.725	72.5	5.65	56.5
10	277544	241554	Unnamed AW	0.03	1.0	10.0	0.250	25.0	1.94	19.4
11	277400	241502	Unnamed AW	0.03	1.0	10.0	0.205	20.5	1.60	16.0
12	277481	241610	Unnamed AW	0.03	1.0	10.0	0.188	18.8	1.47	14.7
13	277729	241694	Unnamed AW	0.03	1.0	10.0	0.311	31.1	2.43	24.3
14	277898	241856	Unnamed AW	0.03	1.0	10.0	0.269	26.9	2.10	21.0
15	277317	241938	Unnamed AW	0.03	1.0	10.0	0.085	8.5	0.66	6.6
16	277089	241921	Unnamed AW	0.03	1.0	10.0	0.065	6.5	0.51	5.1
17	277413	242081	Unnamed AW	0.03	1.0	10.0	0.083	8.3	0.65	6.5
18	278070	242202	Unnamed AW	0.03	1.0	10.0	0.176	17.6	1.37	13.7
19	277918	242280	Unnamed AW	0.03	1.0	10.0	0.160	16.0	1.25	12.5

Table A1. (continued)

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
20	277508	242349	Unnamed AW	0.03	1.0	10.0	0.077	7.7	0.60	6.0
21	278278	242202	Unnamed AW	0.03	1.0	10.0	0.164	16.4	1.28	12.8
22	278762	242282	Unnamed AW	0.03	1.0	10.0	0.070	7.0	0.54	5.4
23	278007	242453	Unnamed AW	0.03	1.0	10.0	0.165	16.5	1.29	12.9
24	278281	242588	Unnamed AW	0.03	1.0	10.0	0.116	11.6	0.90	9.0
25	277107	242585	Unnamed AW	0.03	1.0	10.0	0.028	2.8	0.22	2.2
26	276894	242562	Unnamed AW	0.03	1.0	10.0	0.022	2.2	0.17	1.7
27	276600	241112	Unnamed AW	0.03	1.0	10.0	0.088	8.8	0.69	6.9
28	276614	241605	Unnamed AW	0.03	1.0	10.0	0.052	5.2	0.41	4.1
29	276594	241838	Unnamed AW	0.03	1.0	10.0	0.039	3.9	0.31	3.1
30	277079	240518	Unnamed AW	0.03	1.0	10.0	0.381	38.1	2.97	29.7
31	277041	240394	Unnamed AW	0.03	1.0	10.0	0.550	55.0	4.28	42.8
32	276986	240103	Unnamed AW	0.03	1.0	10.0	0.829	82.9	6.46	64.6
33	276534	240873	Unnamed AW	0.03	1.0	10.0	0.081	8.1	0.63	6.3
34	276591	240385	Unnamed AW	0.03	1.0	10.0	0.109	10.9	0.85	8.5
35	277638	240215	Unnamed AW	0.03	1.0	10.0	1.126	**112.6**	8.77	87.7
36	277462	240051	Unnamed AW	0.03	1.0	10.0	1.473	**147.3**	11.48	**114.8**
37	277799	239970	Unnamed AW	0.03	1.0	10.0	0.762	76.2	5.93	59.3
38	278947	240420	Unnamed AW	0.03	1.0	10.0	0.173	17.3	1.34	13.4

Table A1. (continued)

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
39	279313	240221	Unnamed AW	0.03	1.0	10.0	0.107	10.7	0.84	8.4
40	277935	243023	Unnamed AW	0.03	1.0	10.0	0.088	8.8	0.68	6.8
41	276032	241810	Unnamed AW	0.03	1.0	10.0	0.025	2.5	0.19	1.9
42	276790	239820	Unnamed AW	0.03	1.0	10.0	0.444	44.4	3.46	34.6
43	277055	239624	Unnamed AW	0.03	1.0	10.0	0.649	64.9	5.06	50.6
44	278981	239564	Unnamed AW	0.03	1.0	10.0	0.102	10.2	0.80	8.0
45	279379	238305	Rhos Dolau-Bran SSSI	0.03	3.0	10.0	0.029	1.0	0.23	**2.3**
46	278852	244190	Mwyngloddfa Nantymwyn SSSI	0.02	1.0	5.0	0.009	0.9	0.05	0.9
47	278291	244568	Mwyngloddfa Nantymwyn SSSI	0.02	1.0	5.0	0.013	**1.3**	0.07	**1.3**
48	281462	237710	Crychan Forest Tracks SSSI	0.02	1.0	10.0	0.009	0.9	0.05	0.5
49	275554	242481	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	0.02	1.0	8.0	0.009	0.9	0.05	0.6
50	276378	243796	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	0.02	1.0	8.0	0.008	0.8	0.04	0.5
51	276759	244715	Cwm Doethie - Mynydd Mallaen SAC	0.02	1.0	8.0	0.017	**1.7**	0.09	**1.1**
52	277488	245951	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	0.02	1.0	8.0	0.009	0.9	0.05	0.6
53	279183	247377	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	0.02	1.0	8.0	0.004	0.4	0.02	0.2
54	274620	241958	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	0.02	1.0	8.0	0.007	0.7	0.04	0.5
55	273447	241134	Cwm Doethie - Mynydd Mallaen SAC / Elenydd Mallaen SPA	0.02	1.0	8.0	0.006	0.6	0.03	0.4
56	276166	234788	River Tywi SAC	0.02	1.0	8.0	0.006	0.6	0.03	0.4
57	285766	244771	River Wye SAC	0.02	1.0	8.0	0.004	0.4	0.02	0.3
58	285684	235198	Mynydd Epynt SAC	0.02	1.0	8.0	0.002	0.2	0.01	0.1

Figure A1a Maximin annual mean ammonia concentration

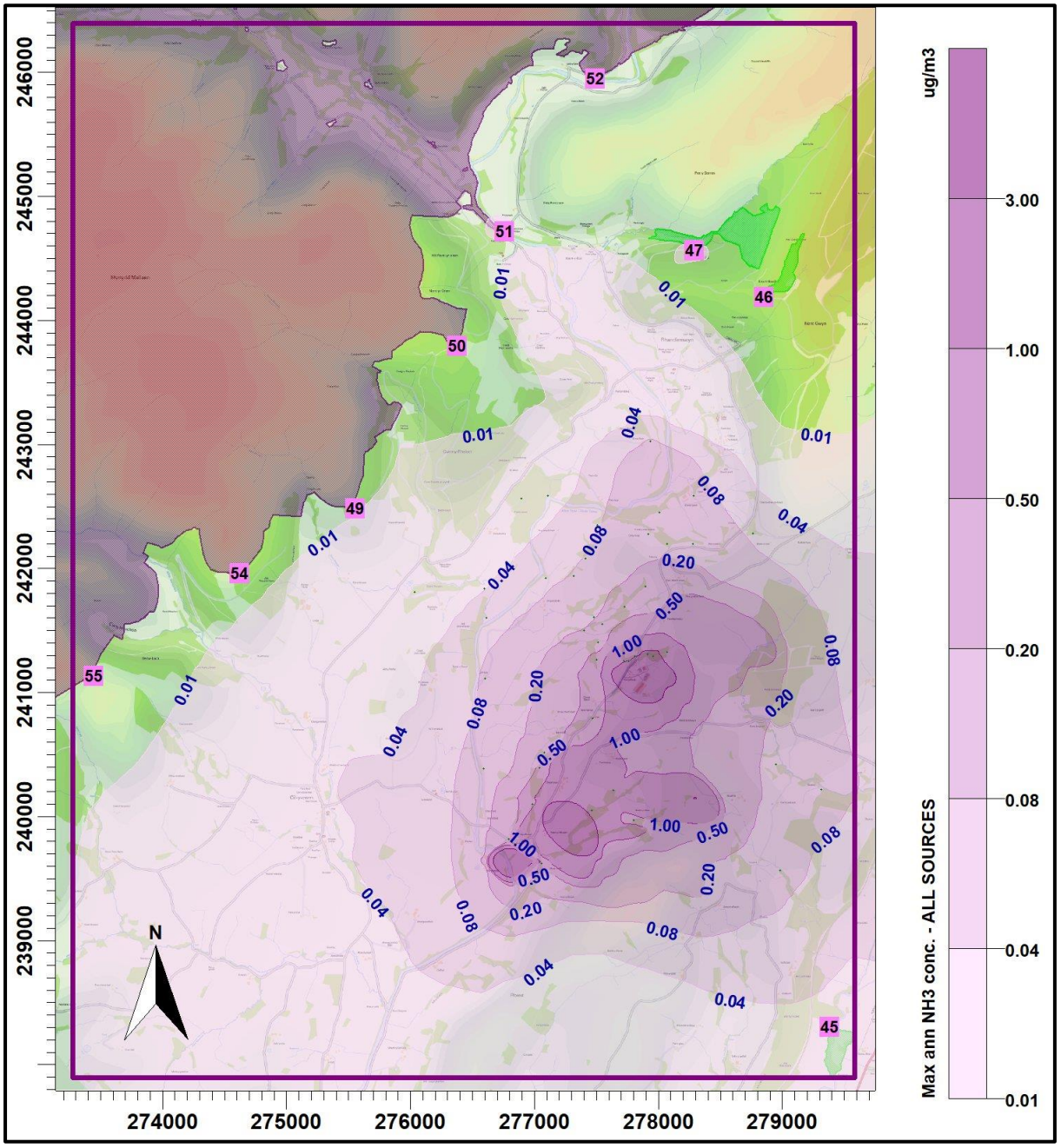

Figure A1a Maximin annual mean nitrogen deposition rate