A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing and Proposed Free Range Egg Laying Chicken Houses at Rhiwhiriaethr Isaf, near Llanfair Caereinion in Powys

Prepared by Steve Smith

AS Modelling & Data Ltd.

Email: stevesmith@asmodata.co.uk

Telephone: 01952 462500

10th September 2018

1. Introduction

AS Modelling & Data Ltd. has been instructed by Gerallt Davies of Roger Parry & Partners LLP, on behalf of the applicant Mr. G. Jones, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed free range egg laying chicken houses at Rhiwhiriaethr Isaf, Llanfair Caereinion, Welshpool, Powys. SY21 0DU.

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

This report is arranged in the following manner:

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

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

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

- Section 5 contains the results of the modelling.

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

2. Background Details

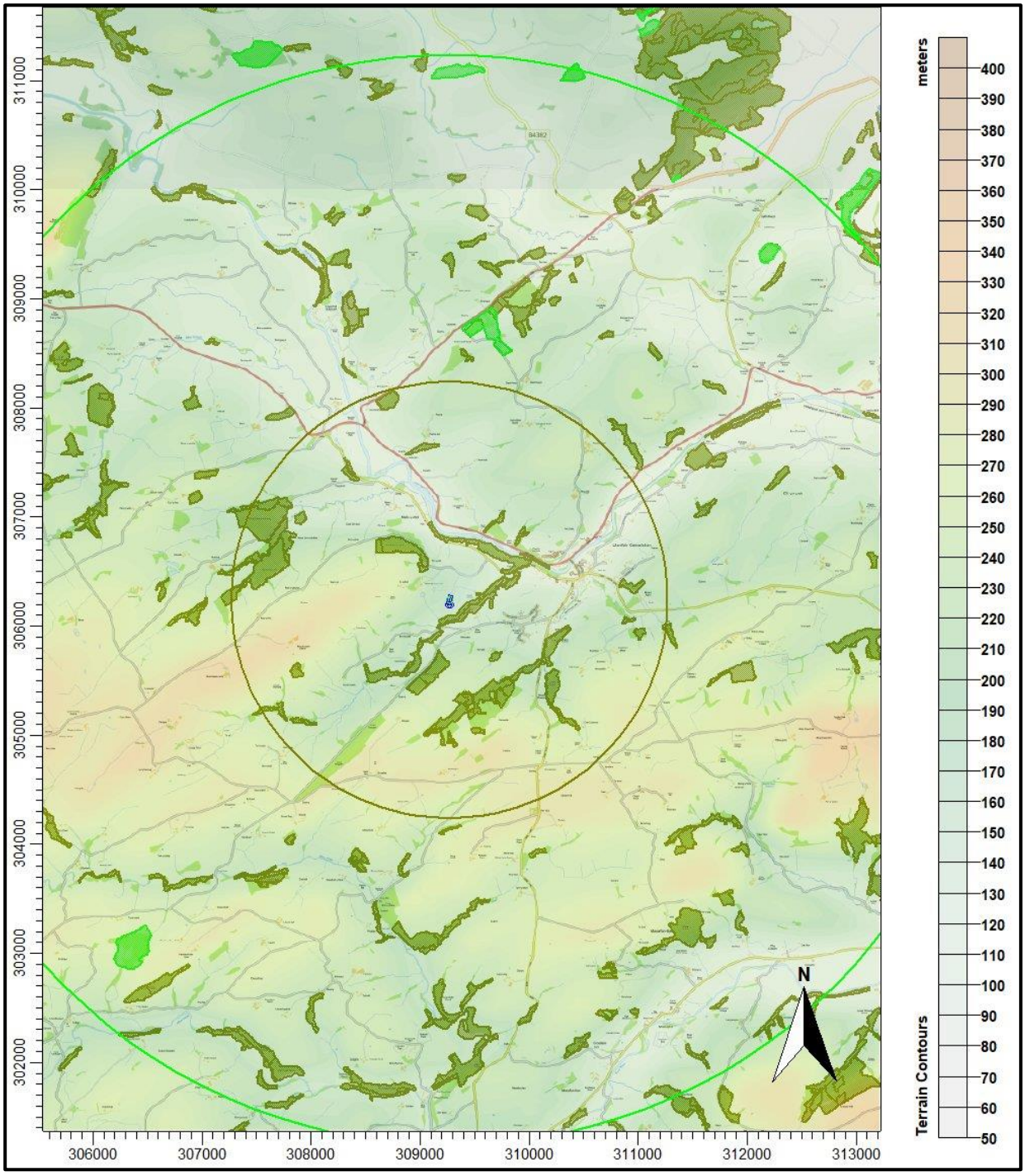
The site of the existing and proposed free range chicken houses at Rhiwhiriaethr Isaf is in a rural area, approximately 1 km to the west-south-west of the village of Llanfair Caereinion in Powys. The surrounding land is used predominantly for livestock farming, although there are some wooded areas. The site is at an altitude of around 183 m with the land falling towards a tributary of Afon Banwy neu Enion to the east and rising towards hills to the west.

The existing poultry house currently provides accommodation for up to 16,000 free range egg laying chickens. Under the proposal, a new poultry house would be constructed adjacent to the existing poultry house in order to provide accommodation for a further 16,000 birds. The existing and proposed poultry houses have/would have pop holes to provide the birds with daytime access to an outside ranging area. Under the proposal, in order to mitigate the ammonia emission from the ranging areas, concrete pads would be constructed adjacent to the houses; the concrete pads would extend 15 m from the housing and their purpose would be to intercept a proportion of birds' droppings, which would be removed by daily scraping/sweeping and stored temporarily on the farm, prior to being removed from site or spreading to land. The poultry house are/would be ventilated by ridge/roof mounted fans, each with a short chimney. Every four days, the birds' droppings are/would be removed from the housing by a belt collection system and stored temporarily on the farm, prior to being removed from site or spreading to land.

There are several areas of Ancient Woodlands (AWs) within 2 km of the site. There are also seven Sites of Special Scientific Interest (SSSIs) within 5 km of the site, namely: Gweunydd Ger Fronhaul SSSI to the north; Cors Cefn Llwyd SSSI to the north-east; Ffridd Mathrafal Track Section SSSI to the north-north-east; Gwaun Efail Wig SSSI and Cors Ty-Gwyn SSSI to the north; Coed Ty-Mawr SSSI to the north-east and Cors Llanllugan SSSI to the south-west. There are no internationally designated sites within 5 km of the farm.

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

Figure 1. The area surrounding the site – concentric circles radii at 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 site of the proposed poultry unit and the wildlife sites is 1.41 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 27.86 kg-N/ha/y and to short vegetation is 18.76 kg-N/ha/y. The background acid deposition rate to woodland is 2.15 keq/ha/y and to short vegetation is 1.49 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS, April 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. 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 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)
AWs	1.0 [1]	-	-
Gweunydd Ger Fronhaul SSSI, Cors Cefn Llwyd SSSI, Gwaun Efail Wig SSSI & Coed Ty-Mawr SSSI	1.0 [1]	10.0 [2]	-
Cors Ty-Gwyn SSSI & Cors Llanllugan SSSI	1.0 [1]	5.0 [2]	-
Ffridd Mathrafal Track Section SSSI	n/a [3]	n/a [3]	n/a [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 on the citation for the site and information obtained from the APIS website (April 2018).
3. Site designated for geological features only.

3.4 Guidance on the significance of ammonia emissions

3.4.1 Natural Resources Wales criteria

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%).

3.4.2 Environment Agency criteria

The following are obtained from the Environment Agency's horizontal guidance, H1 Environmental Risks Assessment, H1 Annex B - Intensive Farming.

"An emission is insignificant where Process Contribution (PC) is <4% of Critical Levels for SACs, SPAs and Ramsars, <20% for SSSIs, and <50% for local and national nature reserves (LNRs & NNRs), ancient woodland and local wildlife sites." And, "Where modelling predicts a process contribution >20% of the Critical Level/Load at a SAC, SPA or Ramsar, >50% at a SSSI or >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; 4% to 20% for SACs, SPAs and Ramsars; 20% to 50% for SSSIs and 100% to 100% for other non-statutory wildlife sites, whether or not the impact is deemed acceptable is at the discretion of the Environment Agency. In making their decision, the Environment Agency will consider whether other farming installations might act in-combination with the farm and the sensitivities of the wildlife sites. 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/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, in an aviary system, where manure is removed frequently using a belt system, the Environment Agency figure is 0.08 kg-NH_3/bird place/year.

3.6.2 Existing/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.

To mitigate the ammonia emission from the ranging area, sconcrete pads would be constructed adjacent to the houses; the concrete pads would extend 15 m from the housing and their purpose would be to intercept a proportion of birds' droppings, which would be removed by daily scraping/sweeping and stored temporarily on the farm, prior to being removed from site or spreading to land. It is estimated that these pads would intercept approximately 50% of the birds' droppings. This estimate is based upon observations of existing ranging areas, which suggest noticeably poached and soiled parts of the ranges do not normally extend much more than 50 m from the housing and that most useage and dunging occurs close to the housing and decreases approximately linearly with distance from the housing.

Details of the poultry numbers and types, the emission factors used and the calculated ammonia emission rates are provided in Table 2.

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.

Table 2. Details of poultry numbers and ammonia emission rates

Source	Animal numbers	Type or weight	Emission factor ($kg\text{-}NH_3/place/y$)	Emission rate ($g\text{-}NH_3/s$)
Existing House	16,000 (x 0.88)	Egg laying chickens, aviary system	0.08 (EA/BREF figure)	0.035693
Existing Range	16,000 (x 0.12)	Ranging areas	0.34 (AS Modelling & Data figure)	0.020686
Existing Range (with abatement)	16,000 (x 0.06)	Ranging areas	0.34 (AS Modelling & Data figure)	0.010343
Proposed House	16,000 (x 0.88)	Egg laying chickens, aviary system	0.08 (EA/BREF figure)	0.035693
Proposed Range	16,000 (x 0.12)	Ranging areas	0.34 (AS Modelling & Data figure)	0.020686
Proposed Range (with abatement)	16,000 (x 0.06)	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 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 wind rose for the raw GFS data is shown in Figure 2a.

Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and where terrain data is included in the modelling, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for the location at the poultry houses at Rhiwhiriaethr Isaf is shown in Figure 2b. It should be noted that 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 in terrain runs 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 52.646 N, 3.341 W, 2014-2017

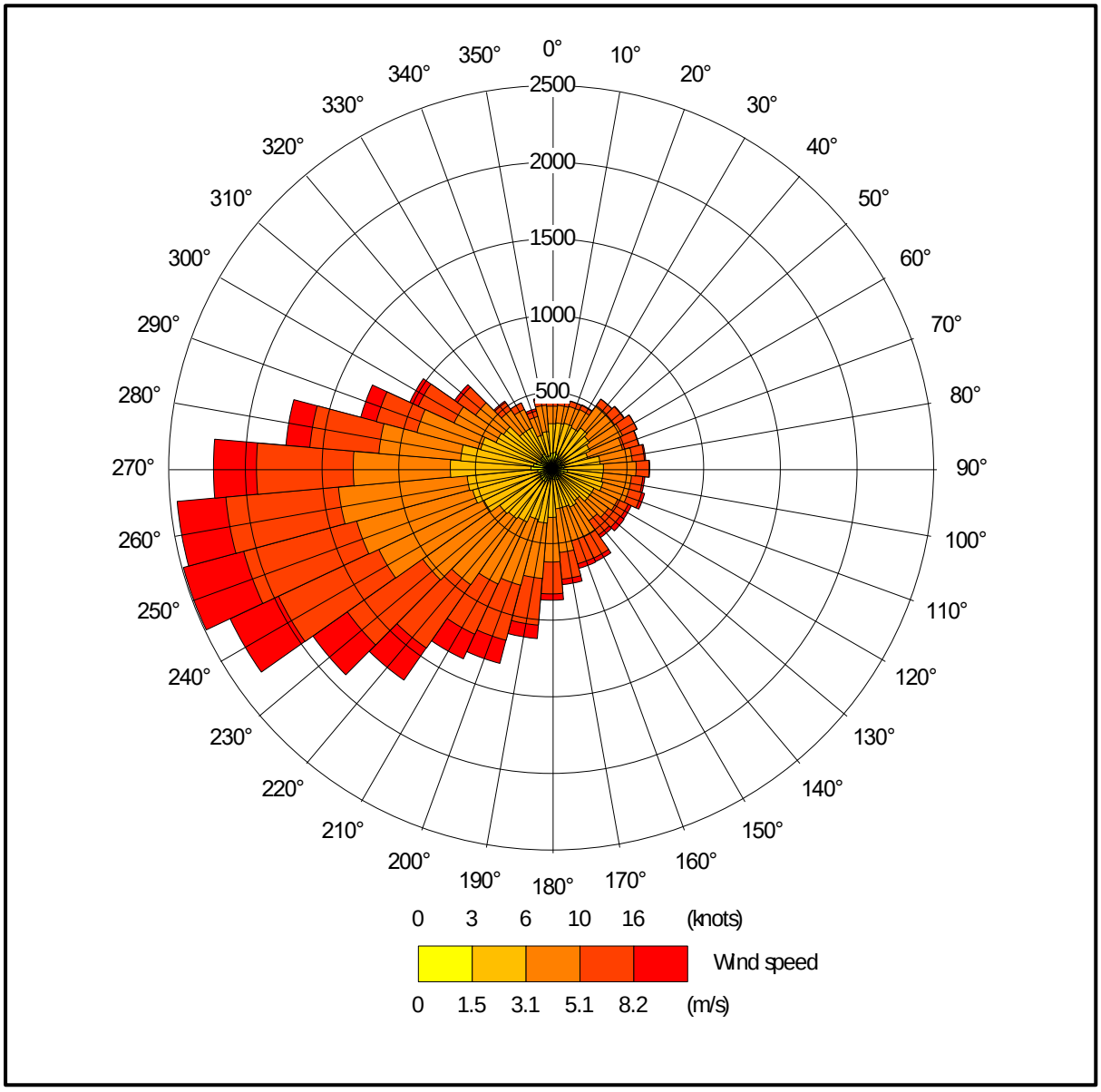
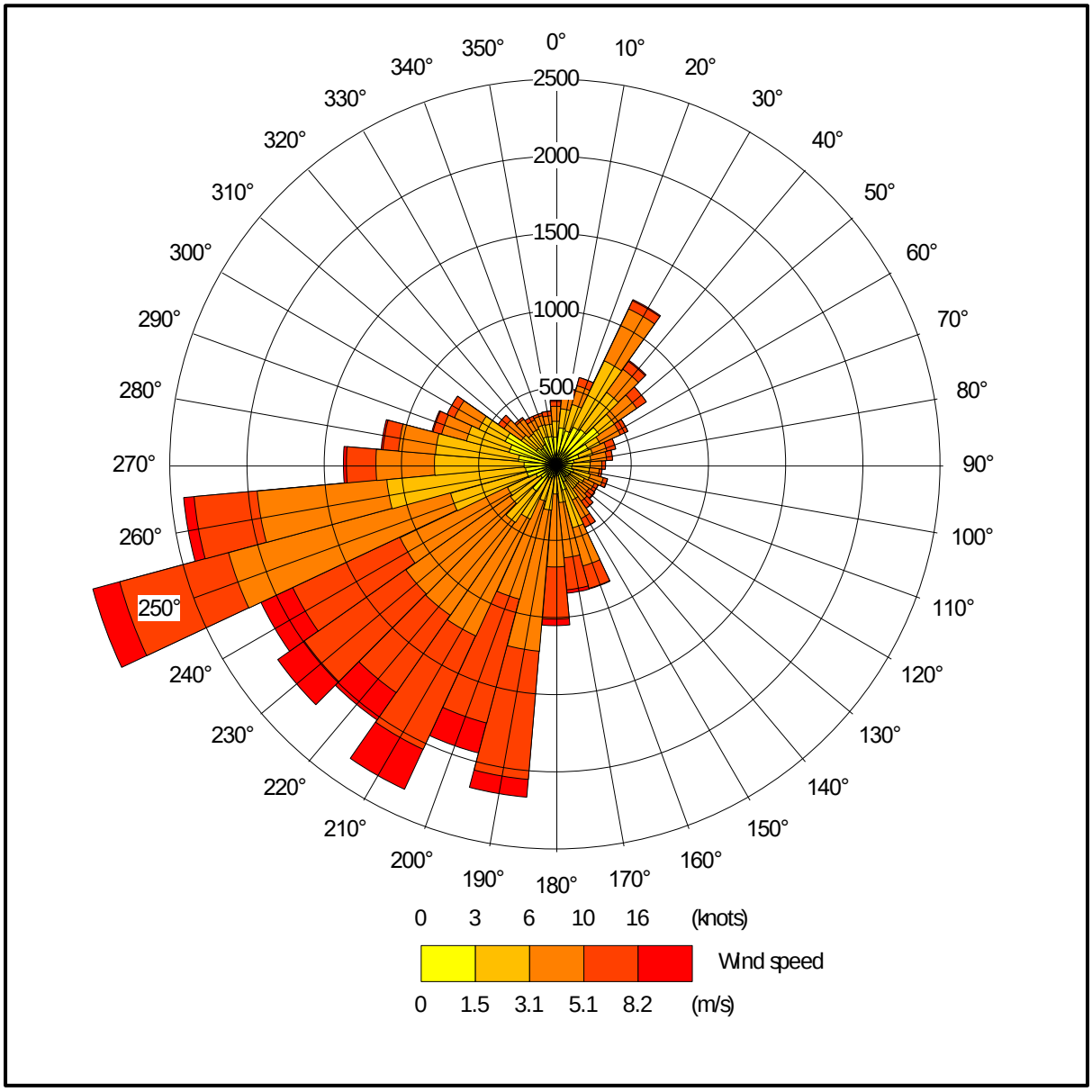


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 309300, 306200



4.2 Emission sources

Emissions from the high speed ridge/roof fans that are/would be used to ventilate the poultry houses are represented by three point sources per house within ADMS (EX1 a, b & c and PR1 a, b & c). Details of the point source parameters are shown in Table 3a. The positions of the point sources may be seen in Figure 3, where they are indicated by red star symbols.

Table 3a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source (g-NH_3/s)
EX1 a, b & c	6.5	0.8	11.0	21.0	0.011898
PR1 a, b & c	6.5	0.8	11.0	21.0	0.011898

The poultry houses have/would have ranging areas, which is represented by two area sources within ADMS (EX1_ran and PR1_ran). Note that the area sources cover the parts of the ranges most likely to be used frequently and not the whole ranging area. Details of the area source parameters are provided in Table 3b. The positions of the area sources are shown in Figure 3.

Table 3b. Area source parameters

Source ID	Area (m^2)	Base height (m)	Emission temperature (˚C)	Emission rate (g-NH_3/s)
EX_range	2,523.5	0.0	Ambient	0.020686
PR_range	2,276.6	0.0	Ambient	0.020686
EX_range (abated)	2,523.5	0.0	Ambient	0.010343
PR_range (abated)	2,276.6	0.0	Ambient	0.010343

4.3 Modelled buildings

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

4.4 Discrete receptors

Fifty-one discrete receptors have been defined: forty-two at the AWs (1 to 42) and nine at the SSSIs (43 to 51). These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figures 4a and 4b, where they are marked by enumerated pink rectangles.

4.5 Cartesian grid

To produce the contour plots presented in Section 5 of this report and to define the spatially varying deposition field used in the detailed modelling, two regular Cartesian grids have been defined at ground level within ADMS. The positions of the Cartesian grids may be seen in Figure 4a and 4b, where they are marked by grey lines.

4.6 Terrain data

Terrain has been considered in the modelling. The terrain data are based upon the Ordnance Survey 50 m Digital Elevation Model. A 12.0 km x 12.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS for the preliminary modelling and detailed modelling runs. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is approximately 180 m.

4.7 Roughness Length

A fixed surface roughness length of 0.325 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 0.275 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 3. The positions of the modelled buildings and sources

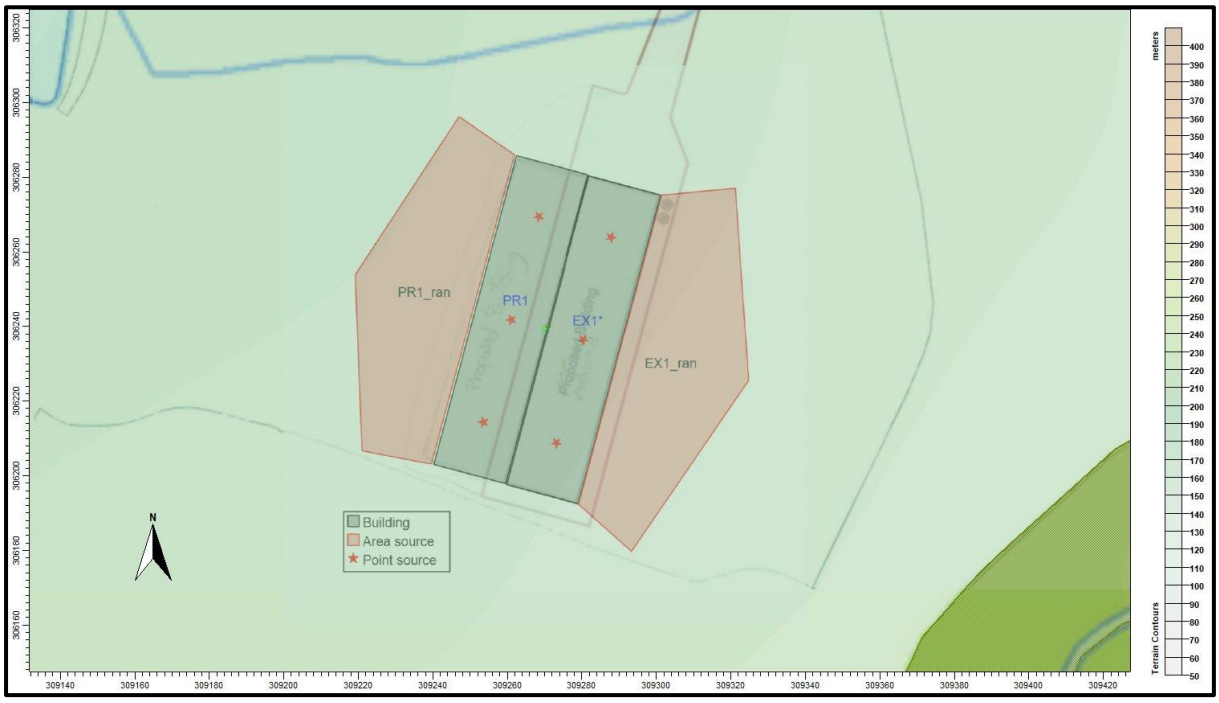


Figure 4a. The discrete receptors and low resolution regular Cartesian grid

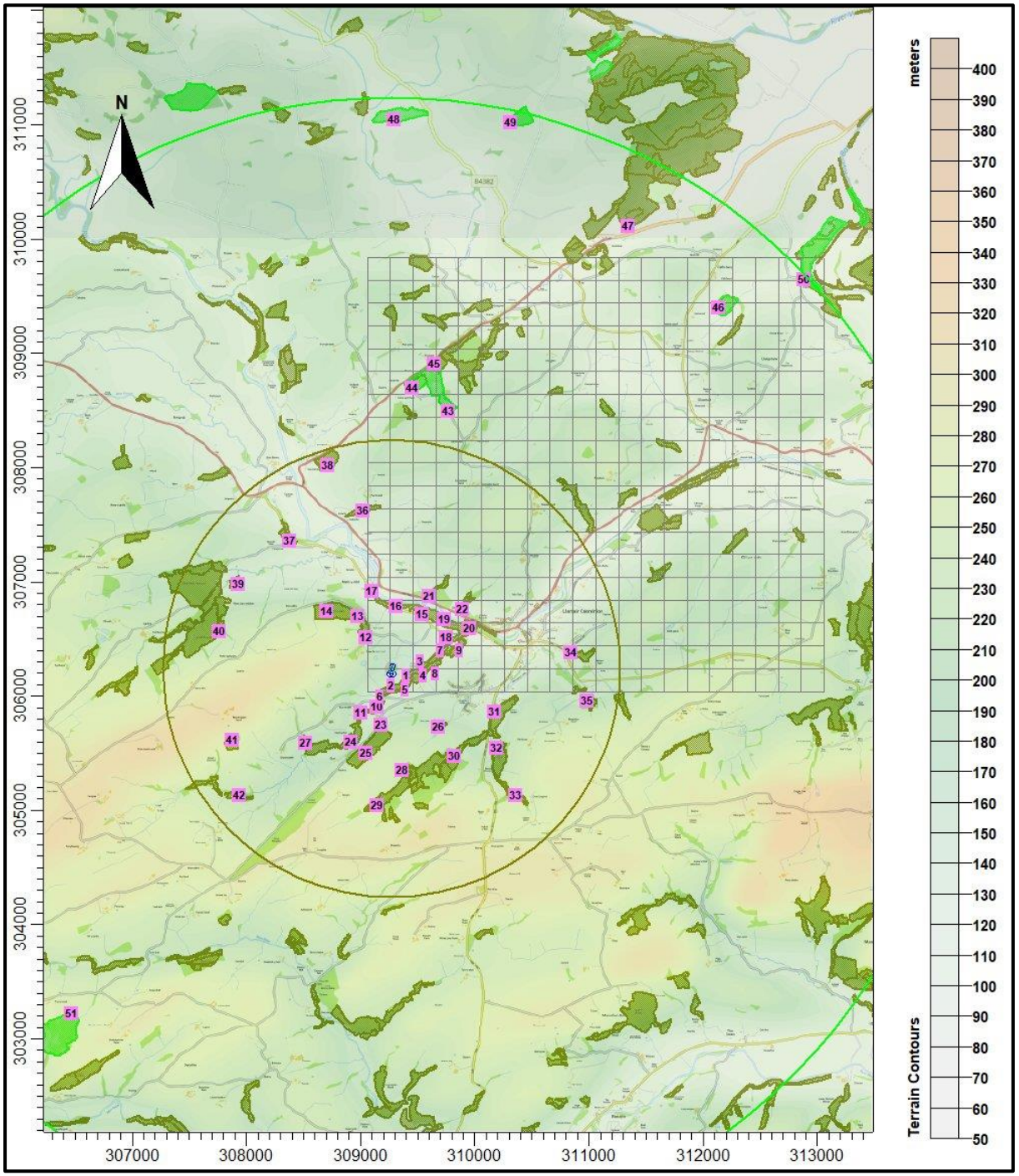
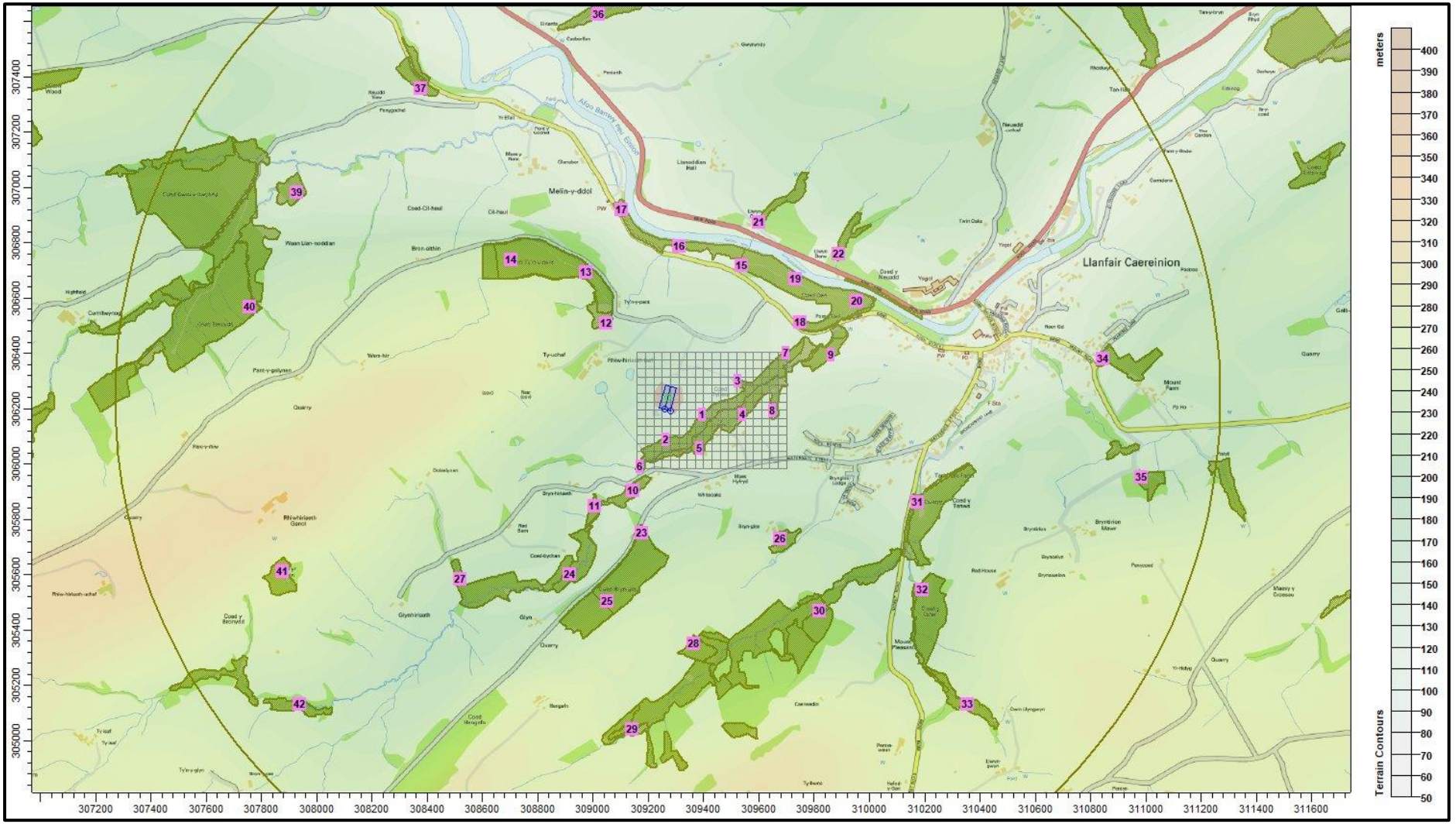


Figure 4b. The discrete receptors and high resolution regular Cartesian grid



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 (m/s)	0.005	0.005	0.005	0.005	0.003

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

In this case, spatially varying deposition fields have been defined at low resolution of a large domain encompassing the SSSIs and also over a high resolution domain encompassing the nearer AWs. Contour plots of the spatially varying deposition fields are provided in Figures 5a and 5b.

Figure 5a. The low resolution spatially varying deposition field

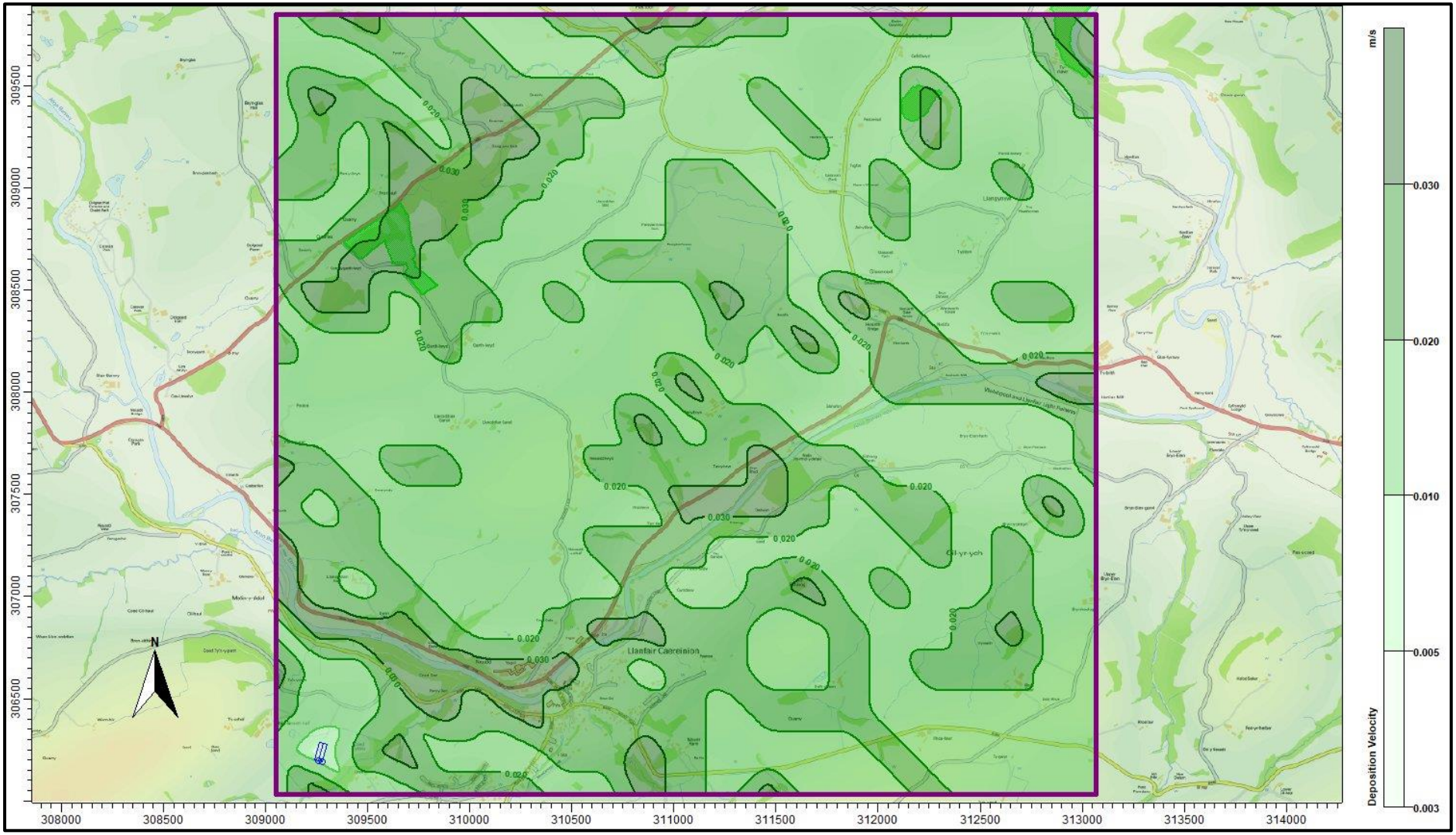
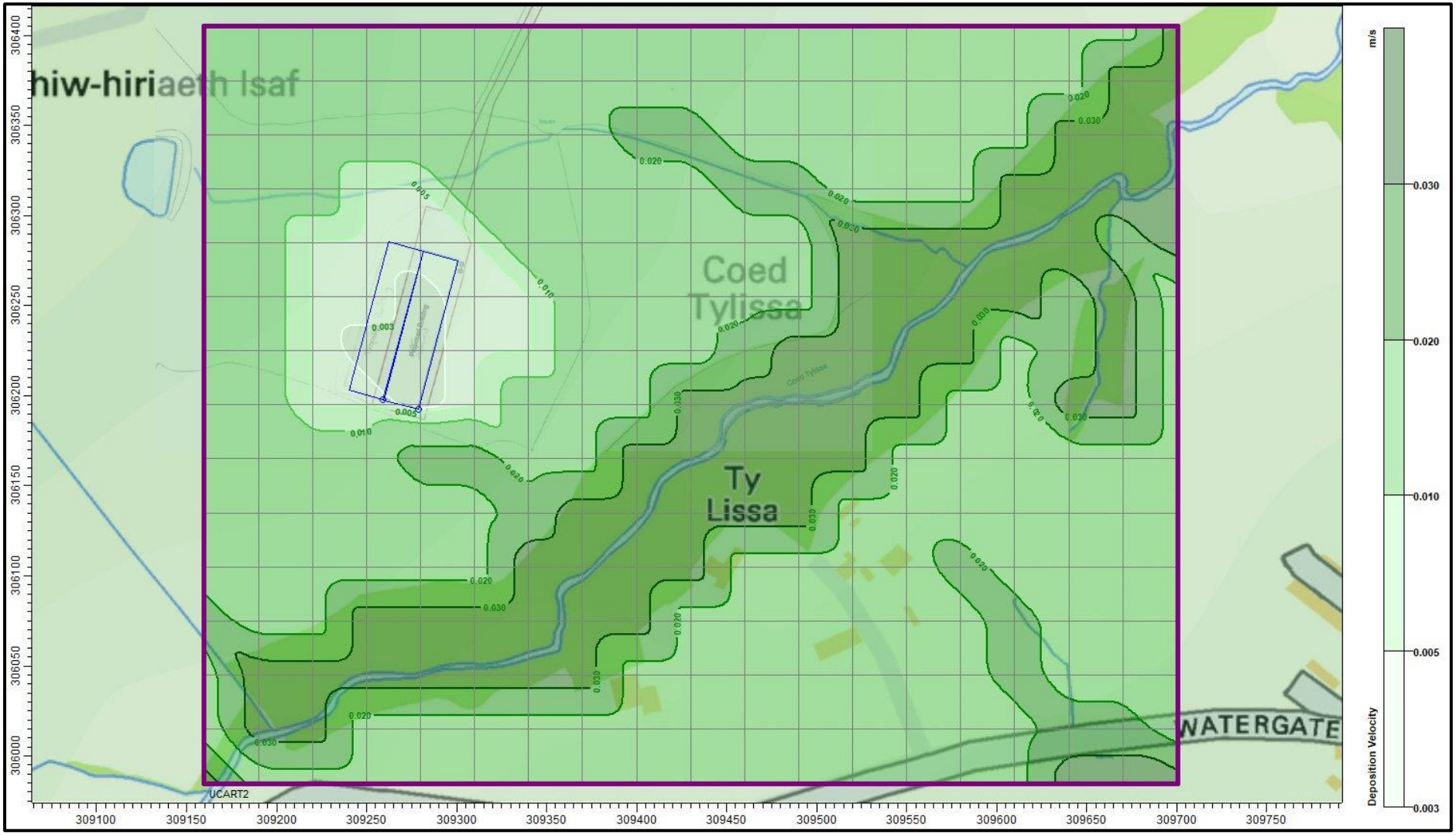


Figure 5b. The high resolution spatially varying deposition field



5. Details of the Model Runs and Results

5.1 Preliminary modelling

ADMS was run a total of sixteen times; once for each year of the meteorological record and in the following four modes for the unabated range emission scenarios:

- 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 a 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.

Details of the predicted annual mean ammonia concentrations at each receptor are provided in Table 5. In the Table, predicted ammonia concentrations, including those that would lead to a nitrogen deposition rate, that are in excess of the Natural Resources Wales upper threshold (8% of Critical Level or Load for a SSSI and 100% of a Critical Level or Load for an AW) are coloured red. Concentrations in the range between the Natural Resources Wales upper threshold and lower threshold (1% to 8% for a SSSI and 50%[1] to 100% for an AW) are coloured blue. For convenience, cells referring to the SSSIs are shaded green and cells referring to the AWs are shaded olive.

1. The Pre-February 2016 figure is retained.

Table 5. Predicted maximum annual mean ammonia concentration at the discrete receptors – unabated range emissions

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 No Calms Terrain Fixed depo 0.003 m/s
1	309396	306177	Coed Tylissa AW	**5.430**	**5.430**	**5.802**	**4.059**
2	309263	306088	Coed Tylissa AW	**2.375**	**2.375**	**3.420**	**2.231**
3	309523	306300	Coed Tylissa AW	**2.448**	**2.448**	**2.476**	**1.855**
4	309543	306177	Coed Tylissa AW	**2.034**	**2.034**	**1.939**	**1.245**
5	309385	306055	Coed Tylissa AW	**1.165**	**1.165**	**1.472**	0.864
6	309170	305992	Coed Tylissa AW	0.944	0.944	**1.414**	0.888
7	309696	306400	Coed Tylissa AW	0.869	0.869	0.908	0.687
8	309649	306191	Coed Tylissa AW	**1.285**	**1.285**	**1.202**	0.768
9	309863	306394	AW	0.554	0.554	0.581	0.438
10	309144	305905	AW	0.576	0.576	0.845	0.502
11	309006	305849	AW	0.348	0.348	0.543	0.379
12	309046	306510	AW	0.513	0.513	0.530	0.320
13	308974	306693	Coed Ty'n-y-pant AW	0.251	0.251	0.278	0.183
14	308701	306737	Coed Ty'n-y-pant AW	0.146	0.146	0.135	0.079
15	309537	306716	Coed Deri AW	0.384	0.384	0.392	0.263
16	309312	306788	Coed Deri AW	0.305	0.305	0.406	0.311
17	309102	306919	Coed Deri AW	0.177	0.177	0.252	0.200
18	309751	306512	Coed Deri AW	0.563	0.563	0.634	0.464
19	309733	306669	Coed Deri AW	0.366	0.366	0.416	0.279
20	309954	306589	Coed Deri AW	0.332	0.332	0.351	0.247
21	309599	306874	AW	0.237	0.237	0.214	0.135
22	309889	306758	AW	0.247	0.247	0.264	0.166
23	309175	305749	Coed Bryn-glas AW	0.343	0.343	0.430	0.218
24	308916	305599	AW	0.162	0.162	0.239	0.137
25	309049	305502	Coed Bryn-glas AW	0.167	0.167	0.221	0.099
26	309676	305728	AW	0.179	0.179	0.192	0.087
27	308518	305584	AW	0.108	0.108	0.191	0.118
28	309364	305352	AW	0.094	0.094	0.103	0.043
29	309140	305041	AW	0.082	0.082	0.085	0.032
30	309821	305470	AW	0.096	0.096	0.125	0.051
31	310175	305863	Coed y Tanws AW	0.185	0.185	0.194	0.101
32	310191	305544	Coed y Goat AW	0.095	0.095	0.112	0.053
33	310356	305131	AW	0.050	0.050	0.055	0.022
34	310844	306379	AW	0.130	0.130	0.138	0.086
35	310985	305954	AW	0.101	0.101	0.098	0.049
36	309020	307624	AW	0.055	0.055	0.055	0.038
37	308376	307359	AW	0.048	0.048	0.056	0.039
38	308707	308014	AW	0.038	0.038	0.039	0.024
39	307928	306981	AW	0.059	0.059	0.054	0.028
40	307757	306568	Coed Newydd AW	0.066	0.066	0.065	0.032
41	307875	305611	Coed Yr Ychain AW	0.047	0.047	0.050	0.023
42	307940	305133	AW	0.045	0.045	0.064	0.036
43	309764	308492	Gweunydd Ger Fronhaul SSSI	**0.030**	**0.030**	**0.025**	**0.017**
44	309451	308698	Gweunydd Ger Fronhaul SSSI	**0.025**	**0.025**	**0.026**	**0.018**
45	309640	308905	Gweunydd Ger Fronhaul SSSI	**0.023**	**0.023**	**0.022**	**0.015**
46	312136	309396	Cors Cefn Llwyd SSSI	**0.016**	**0.016**	**0.020**	0.010
47	311338	310115	Ffridd Mathrafal Track Section SSSI	0.013	0.013	0.015	0.008
48	309289	311046	Gwaun Efail Wig SSSI	0.009	0.009	**0.010**	0.006
49	310313	311019	Cors Ty-Gwyn SSSI	**0.010**	**0.010**	**0.010**	0.006
50	312881	309649	Coed Ty-Mawr SSSI	**0.014**	**0.014**	**0.020**	0.010
51	306469	303223	Cors Llanllugan SSSI	**0.013**	**0.013**	**0.015**	0.007

5.2 Detailed deposition modelling

The detailed modelling was carried out over two restricted domains where the preliminary modelling of the unabated scenario indicated that annual mean ammonia concentrations could potentially exceed the relevant lower threshold percentage of the Critical Level or Critical Load. The low resolution domain covers the poultry houses and range and the SSSIs; the high resolution domain covers the poultry houses and range and nearby AWs. At all other receptors considered, the preliminary modelling of the unabated scenario 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 proposed scenario was run with unabated range emissions and with abated range emissions.

The predicted maximum annual mean ground level ammonia concentrations and nitrogen deposition rates at the discrete receptors are shown in Tables 6a and 6b (unabated range emissions) and Tables 7a and 7b (abated range emissions). In these tables, predicted ammonia concentrations and nitrogen deposition rates that are in excess of the Natural Resources Wales upper threshold (8% of Critical Level or Load for a SSSI and 100% of Critical Level or Load for an AW) are coloured red. Concentrations that are in the range between the Natural Resources Wales lower and upper thresholds (1% to 8% for a SSSI and 50%[1] to 100% for an AW) are coloured blue.

Contour plots of the predicted ground level maximum annual mean ammonia and the maximum nitrogen deposition rate for the abated range emissions scenario are shown in Figures 6a and 6b (low resolution domain) and in Figures 7a and 7b (high resolution domain).

1. The pre-February 2016 figure is retained.

Table 6a. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors – low resolution domain – unabated range emissions

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
43	309764	308492	Gweunydd Ger Fronhaul SSSI	0.020	1.0	10.0	0.011	**1.1**	0.06	0.6
44	309451	308698	Gweunydd Ger Fronhaul SSSI	0.030	1.0	10.0	0.011	**1.1**	0.09	0.9
45	309640	308905	Gweunydd Ger Fronhaul SSSI	0.030	1.0	10.0	0.009	0.9	0.07	0.7
46	312136	309396	Cors Cefn Llwyd SSSI	0.030	1.0	10.0	0.005	0.5	0.04	0.4
50	312881	309649	Coed Ty-Mawr SSSI	0.030	1.0	10.0	0.005	0.5	0.04	0.4

Table 6b. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors – high resolution domain – unabated range emissions

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	309396	306177	Coed Tylissa AW	0.030	1.0	10.0	2.442	**244.2**	19.03	**190.3**
2	309263	306088	Coed Tylissa AW	0.030	1.0	10.0	1.397	**139.7**	10.89	**108.9**
3	309523	306300	Coed Tylissa AW	0.030	1.0	10.0	1.254	**125.4**	9.77	**97.7**
4	309543	306177	Coed Tylissa AW	0.030	1.0	10.0	0.653	**65.3**	5.09	**50.9**
5	309385	306055	Coed Tylissa AW	0.030	1.0	10.0	0.393	39.3	3.06	30.6
6	309170	305992	Coed Tylissa AW	0.030	1.0	10.0	0.538	**53.8**	4.19	41.9
7	309696	306400	Coed Tylissa AW	0.030	1.0	10.0	0.474	47.4	3.69	36.9
8	309649	306191	AW	0.030	1.0	10.0	0.404	40.4	3.15	31.5

Table 7a. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors – low resolution domain – abated range emissions

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
43	309764	308492	Gweunydd Ger Fronhaul SSSI	0.020	1.0	10.0	0.009	0.9	0.05	0.5
44	309451	308698	Gweunydd Ger Fronhaul SSSI	0.030	1.0	10.0	0.009	0.9	0.07	0.7
45	309640	308905	Gweunydd Ger Fronhaul SSSI	0.030	1.0	10.0	0.008	0.8	0.06	0.6
46	312136	309396	Cors Cefn Llwyd SSSI	0.030	1.0	10.0	0.005	0.5	0.04	0.4
50	312881	309649	Coed Ty-Mawr SSSI	0.030	1.0	10.0	0.004	0.4	0.03	0.3

Table 7b. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors – high resolution domain – abated range emissions

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	309396	306177	Coed Tylissa AW	0.030	1.0	10.0	1.478	**147.8**	11.51	**115.1**
2	309263	306088	Coed Tylissa AW	0.030	1.0	10.0	0.828	**82.8**	6.45	**64.5**
3	309523	306300	Coed Tylissa AW	0.030	1.0	10.0	0.900	**90.0**	7.01	**70.1**
4	309543	306177	Coed Tylissa AW	0.030	1.0	10.0	0.458	**45.8**	3.57	35.7
5	309385	306055	Coed Tylissa AW	0.030	1.0	10.0	0.250	25.0	1.95	19.5
6	309170	305992	Coed Tylissa AW	0.030	1.0	10.0	0.356	35.6	2.77	27.7
7	309696	306400	Coed Tylissa AW	0.030	1.0	10.0	0.347	34.7	2.70	27.0
8	309649	306191	AW	0.030	1.0	10.0	0.300	30.0	2.33	23.3

Figure 6a. Maximum annual ammonia concentration – low resolution domain – abated range emissions

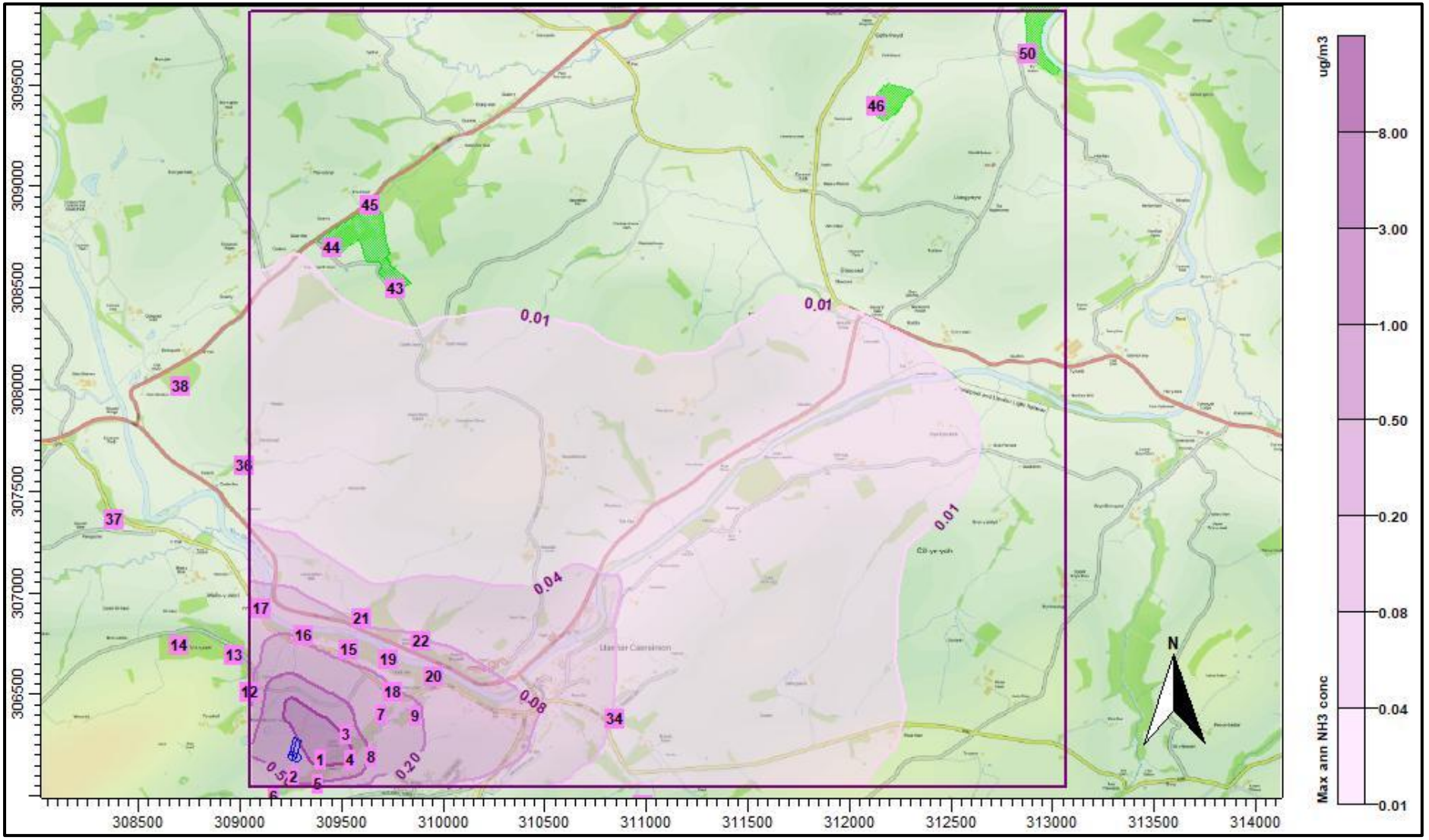


Figure 6b. Maximum annual nitrogen deposition rate – low resolution domain – abated range emissions

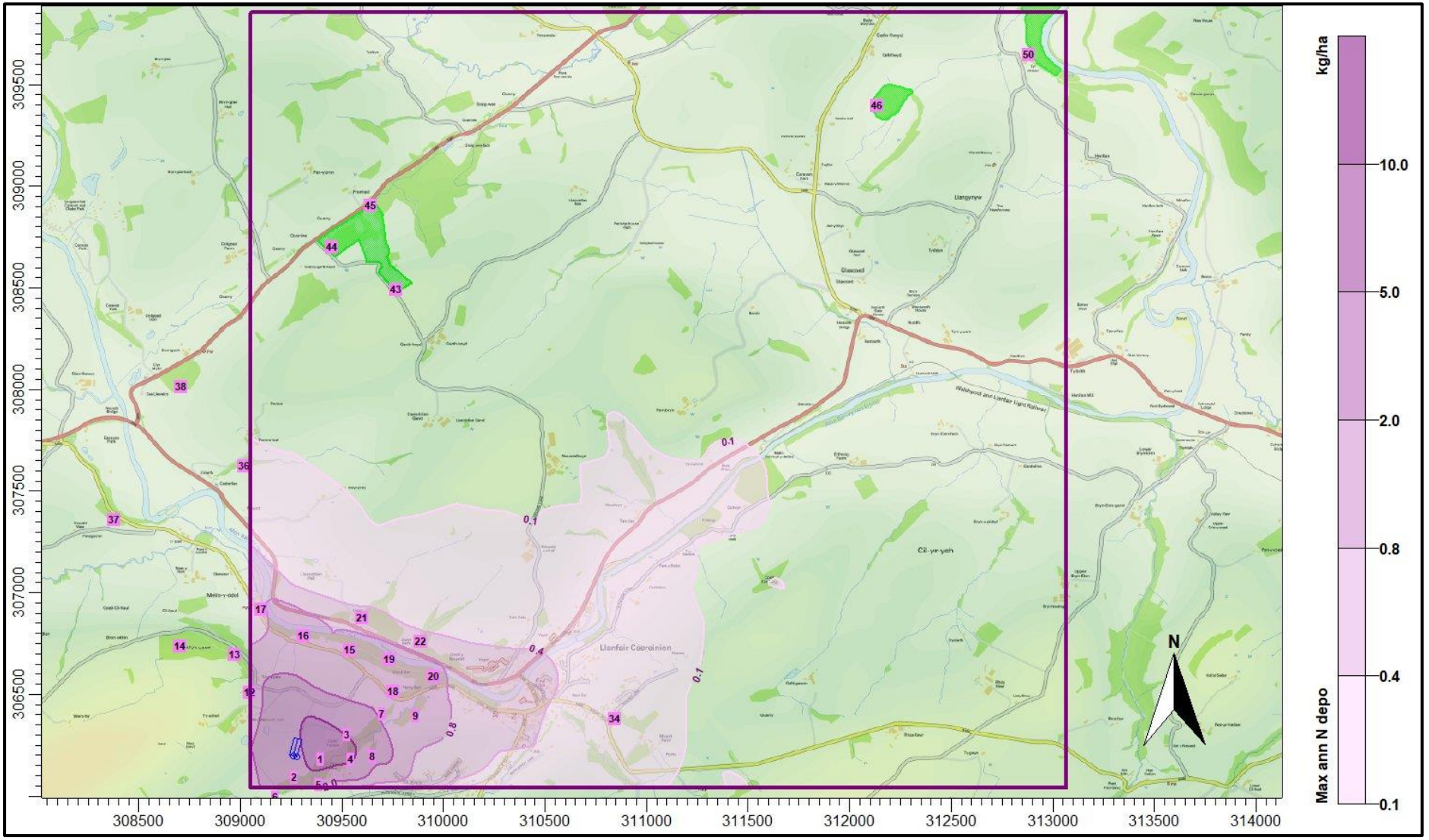


Figure 7a. Maximum annual ammonia concentration – high resolution domain – abated range emissions

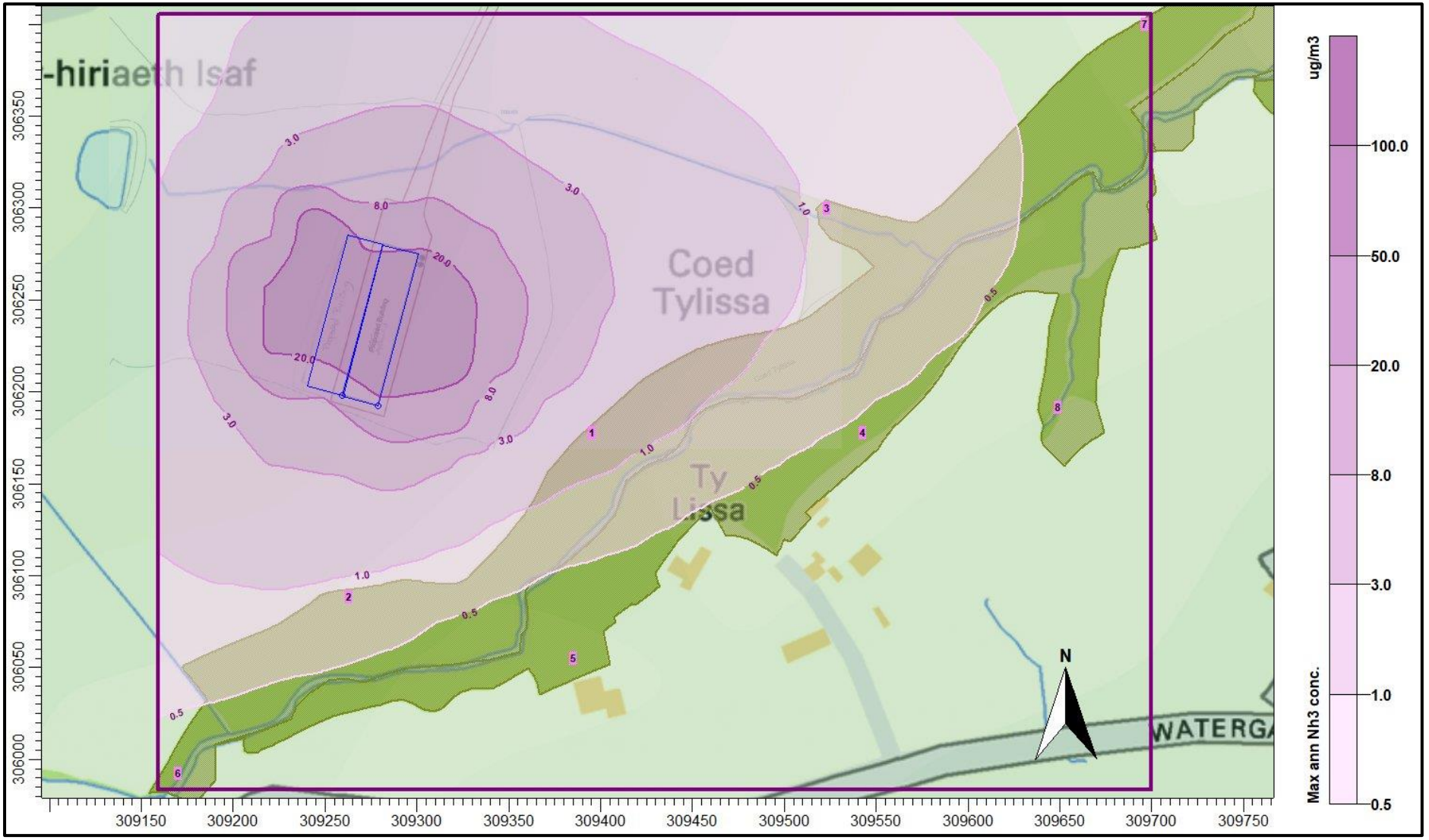
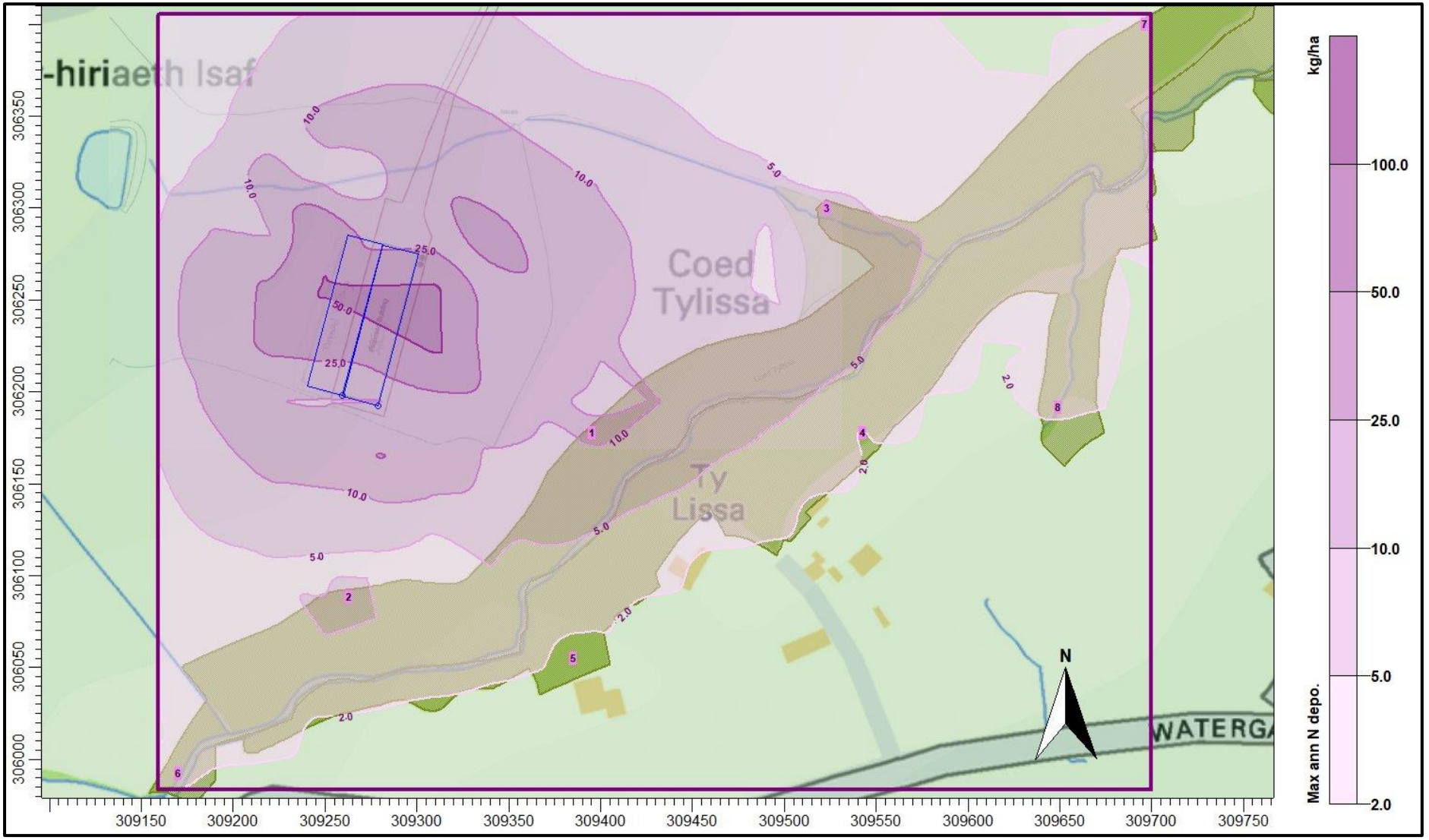


Figure 7b. Maximum annual nitrogen deposition rate – high resolution domain – abated range emissions



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Geraint Davies of Richard Parry & Partners LLP, on behalf of the applicant Mr. G. Jones, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed free range egg laying chicken houses at Rhiwhiriaethr Isaf, Llanfair Caereinion, Welshpool, Powys. SY21 0DU.

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:

- At Gweunydd Ger Fronhaul SSSI, the process contribution to annual ammonia concentrations would potentially exceed Natural Resources Wales lower threshold (1% for a SSSI) of the Critical Level of 1.0 µg-NH_3/m^3.

- At nearby AWs, the process contribution to annual ammonia concentrations would potentially exceed Natural Resources Wales upper and lower threshold (100% for an AW) of the Critical Level of 1.0 µg-NH_3/m^3.

- At all other sites considered, the preliminary modelling predicts that the process contribution to the annual ammonia concentration and the nitrogen deposition rate would be below Natural Resources Wales lower threshold percentage of Critical Level for the site (1% for a SSSI and 100% for non-statutory sites).

Detailed deposition modelling

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

- At Gweunydd Ger Fronhaul SSSI the process contributions to the annual mean ammonia concentration and the nitrogen deposition rate would be below Natural Resources Wales lower threshold percentage of Critical Level or Load (1% for a SSSI).

- At one nearby AW (Coed Tylissa), the process contribution to ammonia concentration is predicted to be above the Natural Resources Wales upper and lower threshold percentage (100%) of the Critical Level of 1.0 µg-NH_3/m^3. The area of this exceedance is approximately 0.35 ha.

Where exceedances of the upper threshold are predicted at non statutory sites, such as at the closest AW (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

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/