A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing and Proposed Broiler Chicken Rearing Houses at Meadowlands, Sleap, near Wem in Shropshire

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Ian Pick of Ian Pick Associates Ltd., on behalf of D. V. & K. J. Grocott, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed broiler chicken rearing houses at Meadowlands, Sleap, near Wem in Shropshire. SY4 3HE.

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 and also upon an emissions model that estimates emissions from the Inno+ ammonia scrubbing equipment that would be fitted to some of the poultry houses. 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 broiler rearing houses at Meadowlands is in a rural area, approximately 650 m to the south-east of Sleap Airfield and approximately 1.9 km to the south-west of the market town of Wem in Shropshire. The surrounding land is used largely for arable farming, but there is also an active airfield nearby and several isolated areas of woodland. The site is on an area of relatively flat land at an altitude of around 80 m, with terrain rising steeply towards the peak of several hills to the south and south-east and falling gently towards Sleap Brook to the north.

There are currently six poultry houses at Meadowlands which provide accommodation for up to 318,000 broiler chickens. The existing poultry houses are ventilated by high speed roof fans, each with a short chimney. The chickens are reared from day old chicks up to 38 days old and there are approximately 7.5 flocks per annum. Manure and spent litter collects within the housing throughout the flock and is cleared and removed from the site at the end of each flock cycle.

Under the proposal, three new poultry houses would be constructed approximately 85 m to the north-east of the existing buildings, these houses would provide accommodation for an additional 142,500 broiler chickens. The proposed poultry houses and the northern most of the existing poultry house would be ventilated by Inno+ air scrubber units, which would provide the majority of the ventilation, for the majority of the time. Backup ventilation in case of scrubber failure and for supplementary ventilation which would be required at the end of crops in warm weather, would be provided by high speed ridge or roof fans, each with a short chimney. The chickens would be reared from day old chicks up to 38 days old and there would be approximately 7.5 flocks per annum.

There is one site designated as a Local Wildlife Site (LWS) within 2 km of the poultry unit (the normal screening distance for non-statutory sites) and although outside normal screening distances for non-statutory sites, six areas designated as Ancient Woodlands (AWs) that are within 5 km have also been considered. There are also eleven Sites of Special Scientific Interest (SSSIs) within 10 km (the normal screening distance for statutory sites), some of which are also designated as Special Areas of Conservation (SACs) and Ramsar sites.

Maps of the surrounding area showing the positions of the existing and proposed poultry houses and the nearby wildlife sites are provided in Figures 1a and 1b. In the figures, the LWS is shaded in yellow, the SSSIs are shaded in green, the SACs are shaded in purple, the Ramsar sites are shaded in blue, the site of the existing poultry houses is outlined in red and the site of the proposed poultry houses is outlined in blue.

Figure 1a. The area surrounding Meadowlands, with circles radii at 2.2km (olive), 5.2 km (green) and 10.2 km (purple)

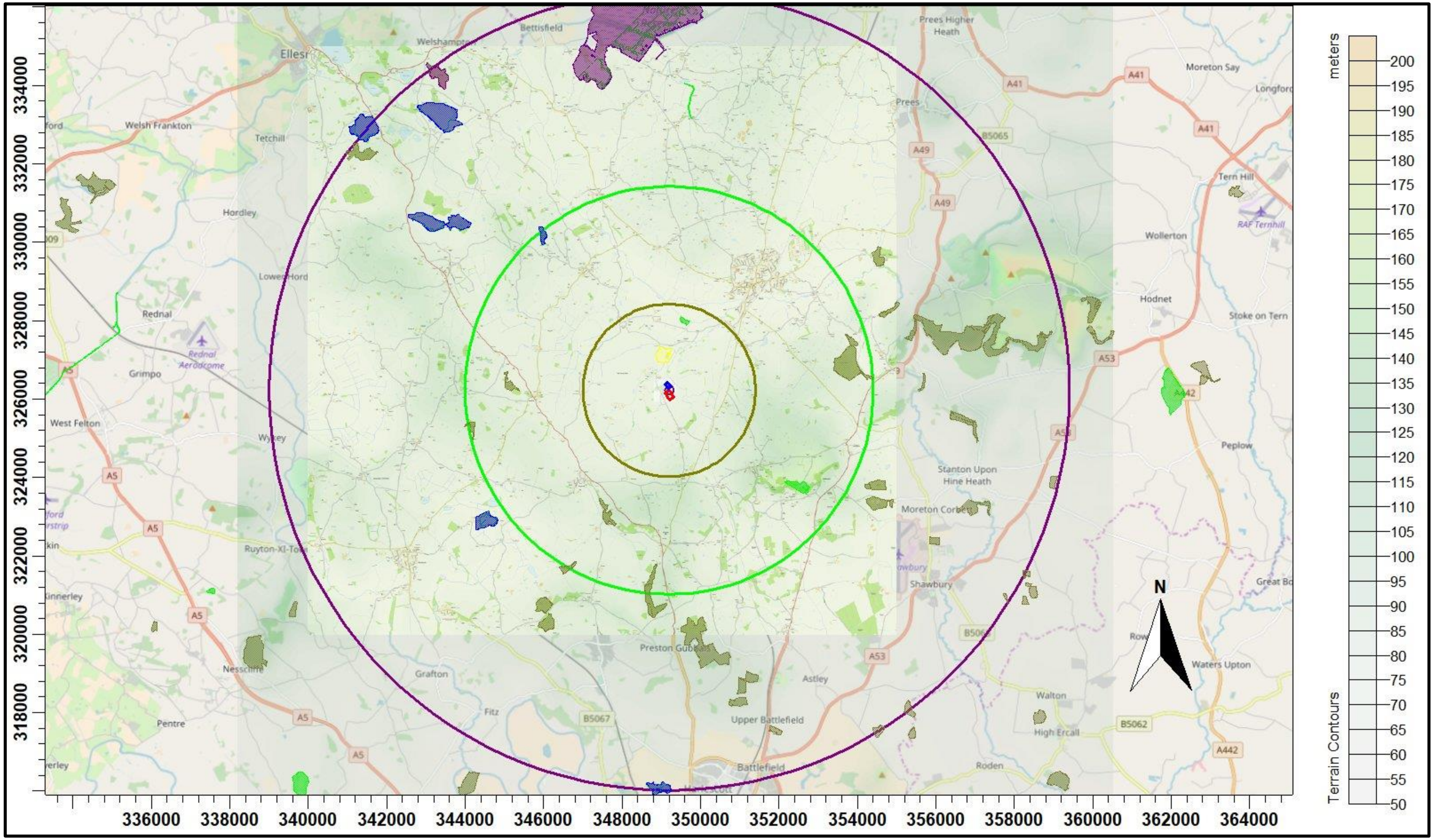
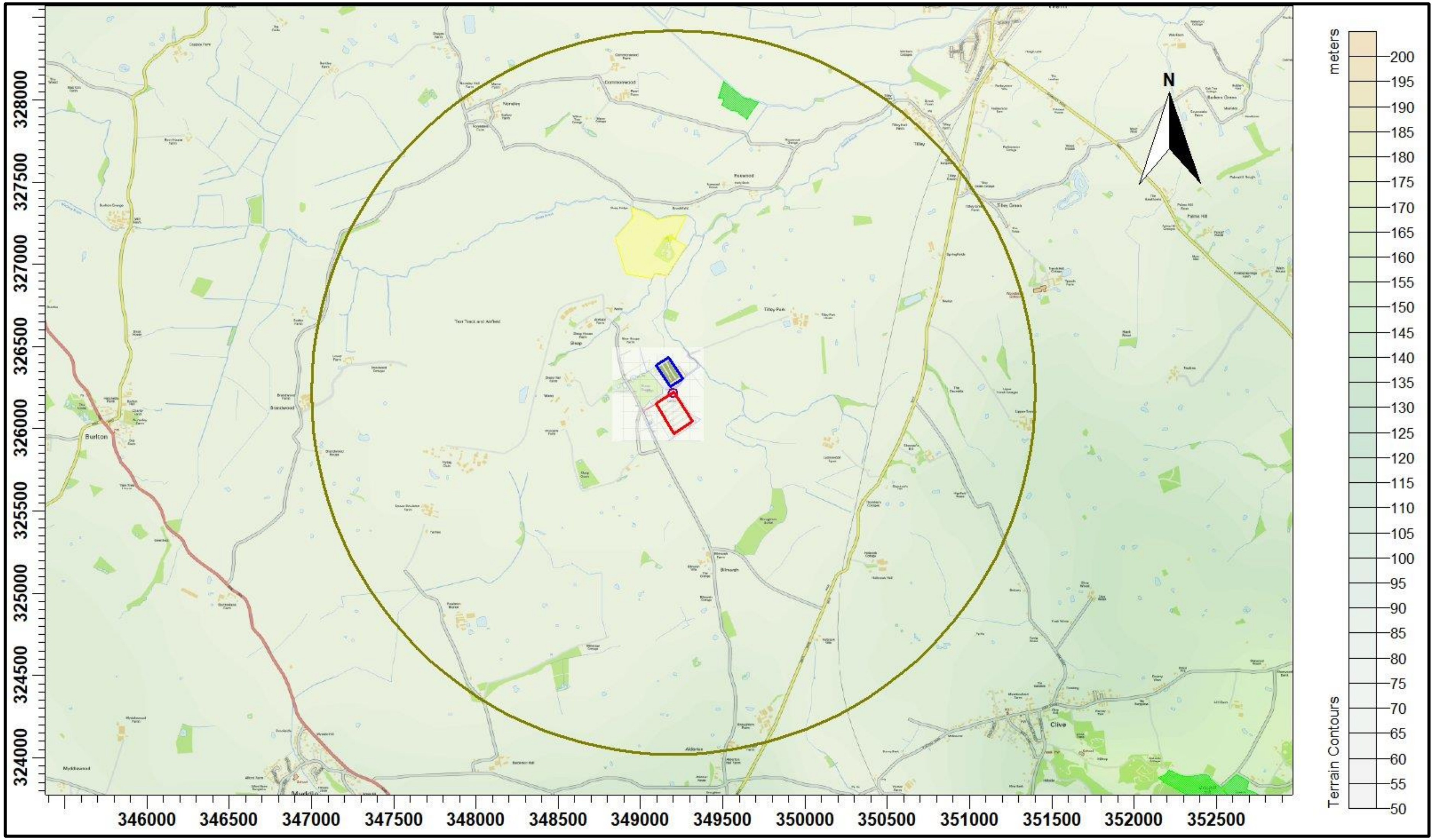


Figure 1b. The area surrounding Meadowlands - a closer view



3. Ammonia, Background Levels, Critical Levels & Loads & Emission Rates

3.1 Ammonia concentration and nitrogen and acid deposition

When assessing potential impact on ecological receptors, ammonia concentration is usually expressed in terms of micrograms of ammonia per metre cubed of air ($\mu g\text{-}NH_3/m^3$) 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 poultry unit and the wildlife sites is 3.46 $\mu g\text{-}NH_3/m^3$. The background nitrogen deposition rate to woodland is 44.38 kg-N/ha/y and to short vegetation is 25.62 kg-N/ha/y. The background acid deposition rate to woodland is 3.21 keq/ha/y and to short vegetation is 1.86 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS, February 2022).

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 $\mu g\text{-}NH_3/m^3$ 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 $\mu g\text{-}NH_3/m^3$ 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.

Table 1. Critical Levels and Critical Loads at the wildlife sites

Site	Critical Level (µg-NH_3/m^3)	Critical Load Nitrogen Deposition (kg-N/ha/y)	Critical Load Acid Deposition (keq/ha/y)
Ruewood Pools LWS	1.0 [1]	-	-
Ruewood Pastures SSSI	1.0 [1 & 2]	15.0 [2 & 3]	-
Grinshill Quarries SSSI & Prees Branch Canal SSSI	n/a [4]	n/a [4]	-
Fenemere SSSI	3.0 [2, 3 & 5]	10.0 [2 & 3]	
Brownheath Moss SSSI; Sweat Mere and Crose Mere SSSI; Cole Mere SSSI; White Mere SSSI; Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses SSSI/SAC; Fenemere SSSI; Hencott Pool SSSI; West Midland Mosses SAC; Midland Meres & Mosses Phase 1 Ramsar & Midland Meres & Mosses Phase 2 Ramsar	1.0 [1 & 2]	10.0[2 & 3]	-

1. A precautionary figure used where no details of the ecology of the site are available, or the citation for the site contains reference to sensitive lichens and/or bryophytes.
2. Based upon the citation for the site and information listed on APIS (February 2022).
3. The lower bound of the range of Critical Loads for the site/species, obtained from APIS (February 2022).
4. No information on Critical Level/Load given.
5. Based upon site inspections.

3.4 Guidance on the significance of ammonia emissions

3.4.1 Environment Agency Criteria

The Environment Agency web-page titled "Intensive farming risk assessment for your environmental permit", contains a set of criteria, with thresholds defined by percentages of the Critical Level or Critical Load, for: internationally designated wildlife sites (Special Protection Areas (SPAs), Special Areas of Conservation (SACs) and Ramsar sites); Sites of Special Scientific Interest (SSSIs) and other non-statutory wildlife sites. The lower and upper thresholds are: 4% and 20% for SACs, SPAs and Ramsar sites; 20% and 50% for SSSIs and 100% and 100% for non-statutory wildlife sites. If the predicted process contributions to Critical Level or Critical Load are below the lower threshold percentage, the impact is usually deemed acceptable.

If the predicted process contributions to Critical Level or Critical Load are in the range between the lower and upper thresholds; 4% to 20% for SACs, SPAs and Ramsar sites; 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. 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 Natural England advisory criterion

Natural England are a statutory consultee at planning and usually advise that, if predicted process contributions exceed 1% of Critical Level or Critical Load at a SSSI, SAC, SPA or Ramsar site, then the local authority should consider whether other farming installations[1] might act in-combination or cumulatively with the farm and the sensitivities of the wildlife sites. This advice is based primarily upon the Habitats Directive, EIA Directive and the Countryside and Rights of Way Act.

1. The process contribution from most farming installations is already included in the background ammonia concentrations and nitrogen and acid deposition rates. Therefore, it is normally only necessary to consider new installations and installations with extant planning permission and proposed developments when understanding the additional impact of a proposal upon nearby ecologies. However, established farms in close proximity may need to be considered given the background concentrations and deposition rates are derived as an average for a 5 km by 5 km grid.

3.4.3 Joint Nature Conservancy Committee - Guidance on Decision-making Thresholds for Air Pollution

In December 2021, the Joint Nature Conservancy Committee (JNCC) published a report titled, "Guidance on Decision-making Thresholds for Air Pollution" This report provides decision-making criteria to inform the assessment of air quality impacts on designated conservation sites. The criteria are intended to be applied to individual sources to identify those for which a decision can be taken without the need for further assessment effort.

The Decision-making thresholds (DMT) for on-site emission sources provided in the JNCC report are reproduced below:

- For lichens and bryophytes - 0.08%, 0.20%, 0.34% and 0.75% of the Critical Level for high, medium, low and very low development density areas, respectively.
- For higher plants - 0.08%, 0.20%, 0.34% and 0.75% of the Critical Level for high, medium, low and very low development density areas, respectively.
- For nitrogen deposition to woodland (Critical Load 10 kg-N/ha/y) - 0.13%, 0.34%, 0.57% and 1.30% of the Critical Level for high, medium, low and very low development density areas, respectively.
- For nitrogen deposition to grassland (Critical Load 10 kg-N/ha/y) 0.09%, 0.24%, 0.40% and 0.88% of the Critical Level for high, medium, low and very low development density areas, respectively.

Note that 'development density' is defined as, the assumed number of additional new sources below the DMT within 5 km of the proposed development over 13 years: very low density being 1 development; low 5 developments; medium 10 developments and high 30 developments.

Subject to some exceptions, where the process contribution from an on-site source is below the DMT, no further assessment is required. Where the process contribution exceeds the DMT there are two possible outcomes:

- Where site-relevant thresholds have been derived these can be applied to see if it is possible to avoid further assessment effort on the basis of site specific circumstances.
- If site-relevant thresholds have not yet been derived, further assessment in combination with other plans and projects is required.

3.4.4 Shropshire Council Guidance

In April 2018, Shropshire Council published Interim Guidance Note GN2 (Version 1, April 2018), "Assessing the impact of ammonia and nitrogen on designated sites and Natural Assets from new and expanding livestock units (LSUs)".

AS Modelling & Data Ltd. are currently assessing this guidance; however, in summary, it appears that the following criteria are applicable:

If the sum of the Process Contribution from the application site and other nearby livestock units is less than 1% of the relevant Critical Level or Critical Load (at a wildlife site) then:

- The application can be determined providing avoidance and mitigation measures can be conditioned. It should be noted that it is extremely unlikely that this condition could ever be achieved.

- If the Process Contribution from the application site and other nearby livestock units is greater than 1% of the relevant Critical Level or Critical Load (at a wildlife site) then:

- If the modelled Process Contribution, including BAT (Best Available Techniques) or other avoidance/mitigation measures leads to either; no additional nitrogen deposition or a reduction in background nitrogen deposition (it is assumed this also means no increase in ammonia concentration, or a reduction in concentration), then the application can be determined providing avoidance and mitigation measures can be conditioned. Furthermore, the guidance states that a) new sites would have to be nitrogen neutral (please note that, without some form of nitrogen offset elsewhere, this is not possible) and b) extensions to existing sites would need to add no extra nitrogen deposition or, ideally, achieve a reduction in the nitrogen background level, by use of Best Available Techniques (BAT) or other mitigation measures.

- If the modelled Process Contribution, including BAT, or other avoidance/mitigation measures is not neutral or do not lead to a reduction in nitrogen deposition (it is assumed this also means ammonia concentration), then if the Predicted Environmental Concentration (sum of process contribution and background levels/loads) leads to an exceedance of the relevant Critical Level or Load at a receptor, then, assessments will be made on a case by case basis.

- In the case of nationally, or internationally designated wildlife sites: If the Predicted Environmental Concentration can be reduced to avoid the exceedance, or it can be demonstrated that there would be no adverse effect on an international site, or no damage to the scientific interest of a national site: then the application can be potentially approved with conditioned control measures; otherwise, the application will be potentially refused when all avenues to reduce the contributions are exhausted and it cannot be shown that damage to the sensitive receptors will not occur.

- In the case of a locally designated site: if control measures are available that can reduce the Predicted Environmental Concentration to avoid exceedance of the ammonia Critical Level or nitrogen Critical Load or it can be demonstrated that there would be no adverse effects then: the application can be potentially approved with conditioned control measures; otherwise, a balanced planning decision will be taken based on the information provided, other material considerations and planning policy.

3.5 Quantification of ammonia emissions

Ammonia emission rates from poultry houses 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 annual statistics it is not usually necessary to model short term temporal variations and a steady continuous emission rate can be assumed. However, in this case, where ammonia scrubbing equipment is used it is necessary to model the variations for both the houses where ammonia scrubbers are fitted and to provide a comparison, the existing houses with standard ventilation. Such temporal variations might introduce rather more uncertainty than modelling continuous emissions; therefore, to counter this possibility and to provide robust annual mean statistics, three separate sets of calculations were performed; the first with the first day of the meteorological record coinciding with day 1 of the crop cycle, the second coinciding with day 16 of the crop cycle and the third coinciding with day 32 of the crop cycle.

Explanations of the calculations used to estimate ammonia emissions are provided in Sections 3.5.1 to 3.5.5. Graphs showing the calculated emission rates for the standard ventilation systems and the air scrubber systems over the first year of the meteorological record are provided in Figures 2a and 2b (note that graphs for other years would be similar, but not identical).

3.5.1 Calculation of ventilation rates

To calculate emission rates, it is necessary to know the ventilation rates of the poultry house. The ventilation rates used in the calculations are based on industry practices and standard bird growth factors. Minimum ventilation rates are as those of an operational poultry house and maximum ventilation rates are based on Defra guidelines. Target internal temperature is 33 Celsius at the beginning of the crop and is decreased to 22 Celsius by day 34 of the crop. If the external temperature is 7 Celsius, or more, lower than the target temperature, minimum ventilation only is assumed for the calculation. Above this, ventilation rates are increased in proportion to the difference between ambient temperature and target internal temperature. A maximum transitional ventilation rate (35% of the maximum possible ventilation rate) is reached when the ambient temperature is equal to the target temperature. A high ventilation rate (70% maximum possible ventilation rate) is reached when the temperature is 4 degrees above target and if external temperature is above 33 Celsius the maximum ventilation rate is assumed. This ventilation model is validated/calibrated against ventilation rate records from several operational broiler rearing houses that are available to AS Modelling & Data Ltd.

3.5.2 Emissions from the existing houses with standard ventilation

The calculation of the emission rates from the standard ventilation systems, the internal ammonia concentration is assumed to be function of the age of the flock. The internal ammonia concentration in the model is set at 1,000 $\mu g/m^3$ at the start of the crop cycle and rises to a maximum of 7,200 $\mu g/m^3$ by day 26 of the crop. These figures are based upon records from several operational broiler rearing houses that are available to AS Modelling & Data Ltd. It should be noted that these figures are adjusted (upwards) so that the model provides emission rates that are approximately equivalent to the Environment Agency's standard emission factor of 0.034 kg-NH_3/bird/y and that in this case, when all the variable emission rates are averaged, the emission factor obtained is 0.0349 kg-NH_3/bird/y.

An ammonia emission rate for each hour of the period modelled is calculated by multiplying the outlet concentration by the modelled ventilation rate.

3.5.3 Emissions from the air scrubbing equipment

Where fitted, the air scrubbers would provide up to 350,000 m^3/h (97.22 m^3/h) of ventilation. For the calculation of the emission rates from the air scrubbers, the outlet ammonia concentration is assumed to be a constant 1.5 ppm (1,053.3 $\mu g/m^3$). This figure is based upon the guaranteed maximum outlet concentration from the manufacturers of the ammonia scrubbing equipment. It should be noted that, typically, an agricultural wet chemical scrubber can achieve 1 to 1.5 ppm outlet ammonia concentration; therefore, the 1.5 ppm assumed is at the upper end of the range and is precautionary.

An ammonia emission rate for each hour of the period modelled is calculated by multiplying the outlet concentration by the modelled ventilation rate.

3.5.4 Emissions from the bypass ventilation systems on the houses fitted with air scrubbers

The capacities of the air scrubbers would be 350,000 m^3/h (97.22 m^3/h); if the modelled ventilation rate exceeds the scrubber capacity, additional ventilation would be provided by standard ridge mounted fans. The concentration is based upon long term, high temporal resolution monitoring of broiler rearing houses elsewhere and is dependent upon the crop stage. The internal ammonia concentrations assumed are then set so as to give approximately the same overall emission factor as the regulatory standard emission factor (see Section 3.5.1). Similarly, to the scrubber emissions, an emission rate from the bypass ventilation system is calculated by multiplying the internal concentration by the bypass ventilation rate.

3.5.5 The overall abatement of ammonia provided by the air scrubbers

The annual emission rates are variable, as they depend on ambient temperature and for example how often bypass ventilation is used. However, the average emission rate over the four year meteorological record is equivalent to an emission factor of 0.0077 kg-NH_3/bird place/y, which is approximately 23% of the Environment Agency’s standard emission factor of 0.034 kg-NH_3/bird place/y, i.e. assuming an outlet concentration of 1.5 ppm, the use of scrubbers would reduce housing emissions by approximately 77% from regulatory emission figures.

Figure 2a. Emission rates over the first year of the meteorological record for one house with standard ventilation system and 53,000 birds.

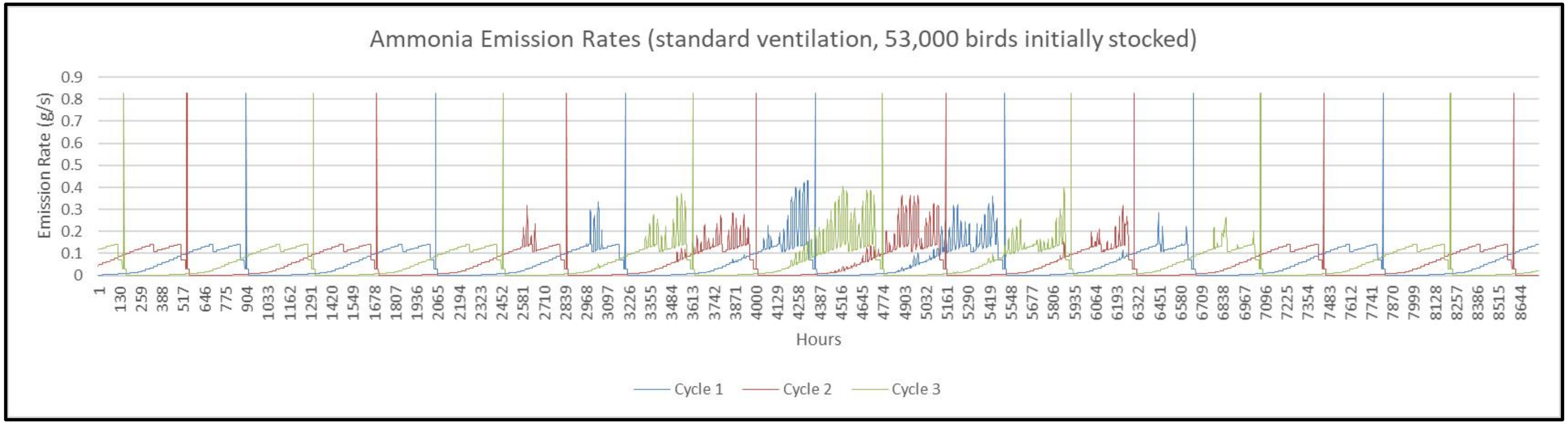
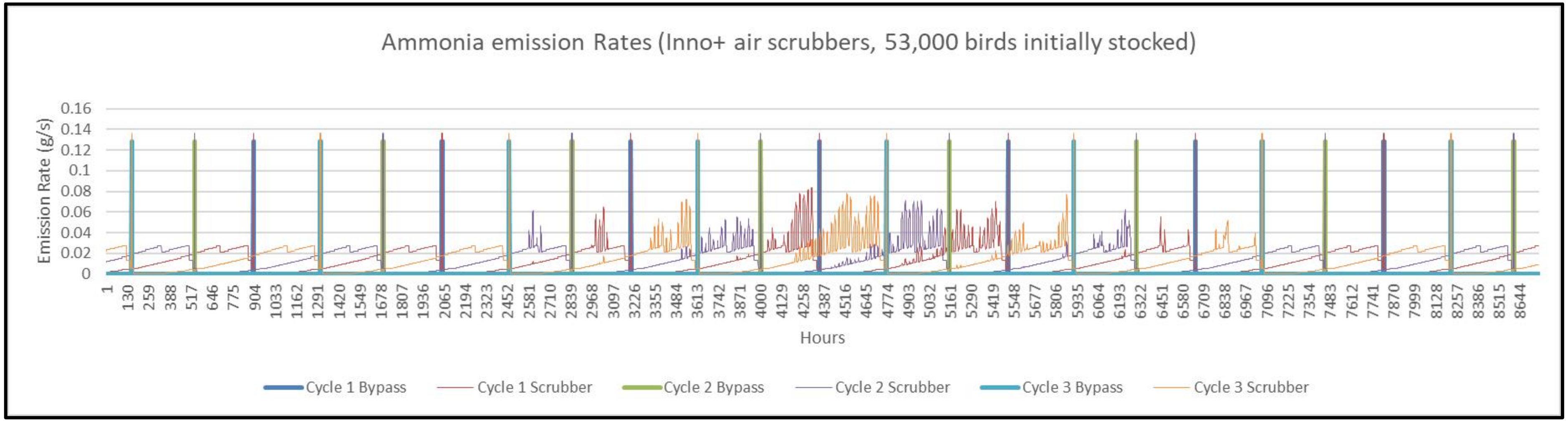


Figure 2b. Emission rates over the first year of the meteorological record for one house with Inno+ ammonia scrubbers and 53,000 birds.



4. The Atmospheric Dispersion Modelling System (ADMS) and Model Parameters

The Atmospheric Dispersion Modelling System (ADMS) ADMS 5 is a new generation Gaussian plume air dispersion model, which means that the atmospheric boundary layer properties are characterised by two parameters; the boundary layer depth and the Monin-Obukhov length rather than in terms of the single parameter Pasquill-Gifford class.

Dispersion under convective meteorological conditions uses a skewed Gaussian concentration distribution (shown by validation studies to be a better representation than a symmetrical Gaussian expression).

ADMS has a number of model options that include: dry and wet deposition; NO_x chemistry; impacts of hills; variable roughness; buildings and coastlines; puffs; fluctuations; odours; radioactivity decay (and γ-ray dose); condensed plume visibility; time varying sources and inclusion of background concentrations.

ADMS has an in-built meteorological pre-processor that allows flexible input of meteorological data both standard and more specialist. Hourly sequential and statistical data can be processed and all input and output meteorological variables are written to a file after processing.

The user defines the pollutant, the averaging time (which may be an annual average or a shorter period), which percentiles and exceedance values to calculate, whether a rolling average is required or not and the output units. The output options are designed to be flexible to cater for the variety of air quality limits which can vary from country to country and are subject to revision.

4.1 Meteorological data

Computer modelling of dispersion requires hourly sequential meteorological data and to provide robust statistics the record should be of a suitable length; preferably four years or longer.

The meteorological data used in this study is obtained from assimilation and short term forecast fields of the Numerical Weather Prediction (NWP) system known as the Global Forecast System (GFS)[1].

The GFS is a spectral model: the physics/dynamics model has an equivalent resolution of approximately 9 km (latterly 6 km) over the UK. Terrain is understood to be resolved at a resolution of approximately 2 km, with sub-9/6 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[2]). 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.

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 3a. 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 of the poultry houses at Meadowlands is shown in Figure 3b. The resolution of the wind field in terrain runs is approximately 340 m. Please also note that FLOWSTAR[2] 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[3].

1. The GFS data used is derived from the high resolution operational GFS datasets, the data is not obtained from the lower resolution (0.5 degree) long-term archive.
2. Note that FLOWSTAR requirements are for meteorological data representative of the upwind flow over the modelling domain and that single site meteorological data (observational or from high resolution modelled data) that is representative of the application site is not generally suitable (personal correspondence: CERC 2019 and UK Met O 2015). If data are deemed representative of a particular application site, either wholly or partially, then

these data cannot also be representative of the upstream flow over the modelling domain. Furthermore, it would be extremely poor practice to use such data as the boundary conditions for a flow-solver, such as FLOWSTAR.

3. When modelling complex terrain with ADMS, by default, the minimum turbulence length has 0.1 m added to the flat terrain value (calculated from the Monin-Obukhov length). Whilst this might be appropriate over hill/mountain tops in terrain with slopes > 1:10 (and quite possibly only in certain wind directions) in lesser terrain it introduces model behaviour that is not desirable where FLOWSTAR is simply being used to modify the upwind flow. Specifically, the parameter sigma z of the Gaussian plume model is overly constrained, which for elevated point sources emissions, may on occasion cause over prediction of ground level concentrations in stable weather conditions and light winds (Steven R. Hanna & Biswanath Chowdhury, 2013), conversely for low level emission sources, this will cause gross under prediction. Note that this becomes particularly important overnight and if calm and light wind conditions are not being ignored, as they often are when using traditional observational meteorological datasets. To reduce this behaviour, where terrain is modelled, AS Modelling & Data Ltd. have set a minimum turbulence length of 0.025 m in ADMS. This approximates the normal behaviour of ADMS with flat terrain.

Figure 3a. The wind rose. Raw GFS derived data for 52.829 N, 2.754 W, 2018 - 2021

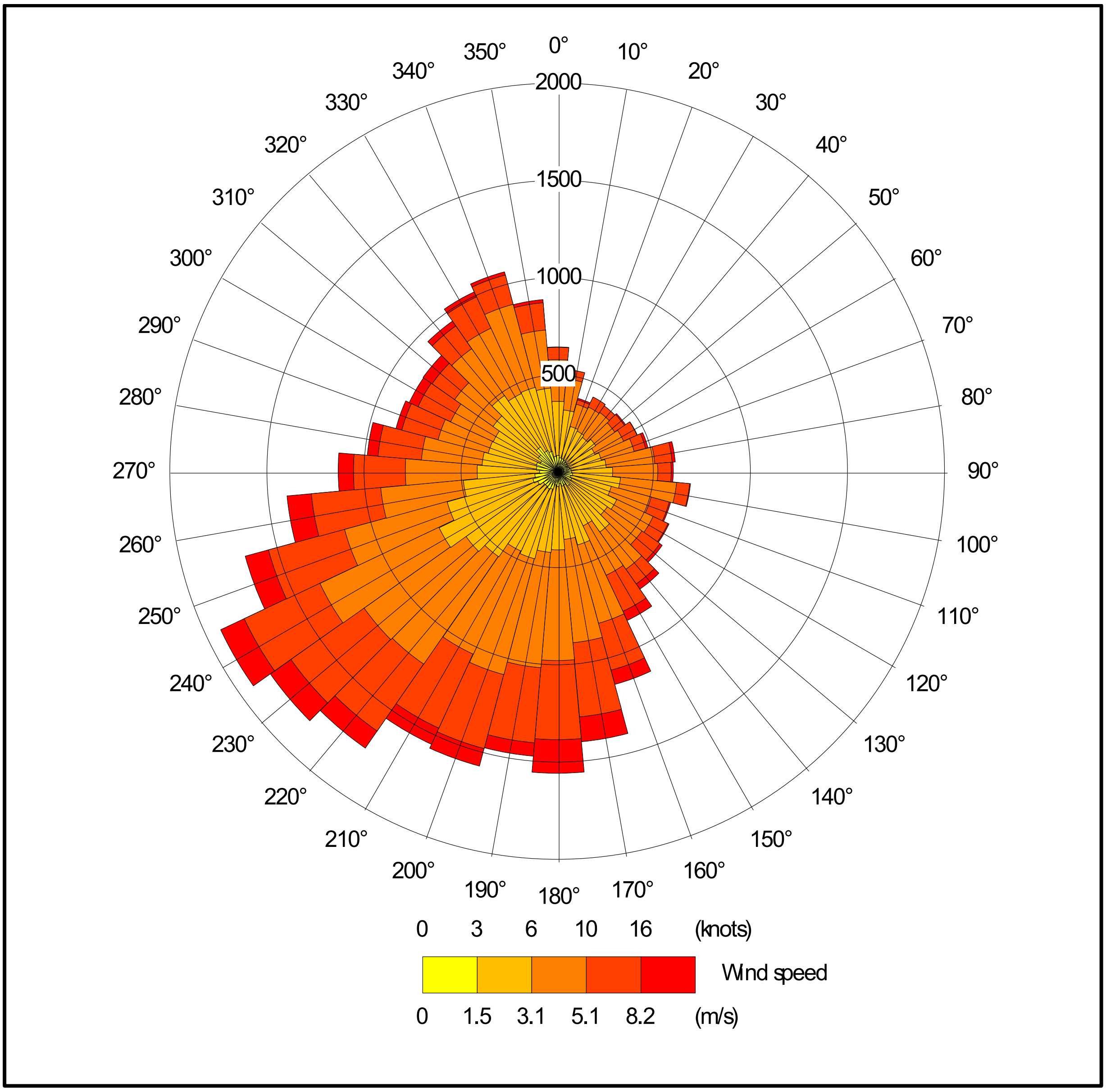
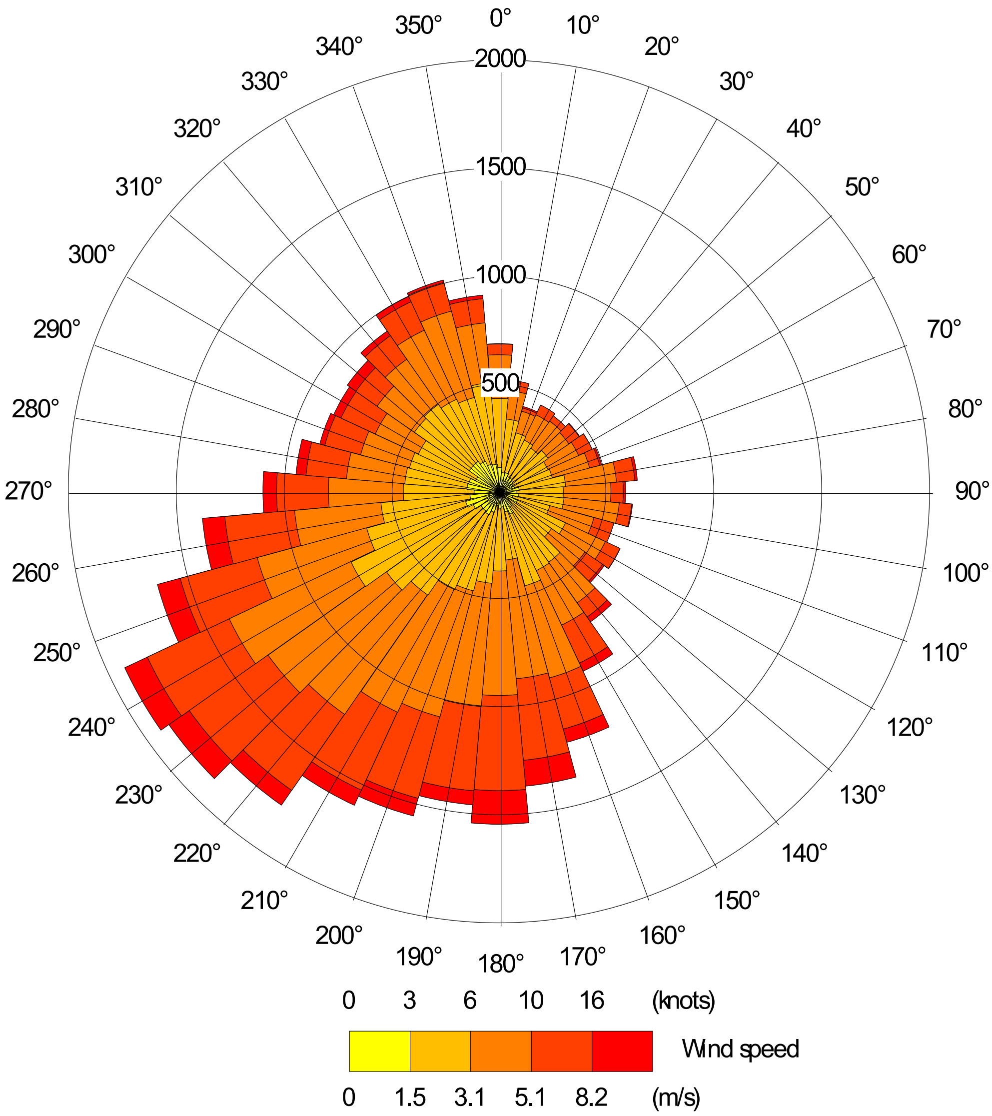


Figure 3b. The wind rose. FLOWSTAR modified GFS derived data for NGR 349200, 326200, 2018-2021



4.2 Emission sources

Emissions from the chimneys of the uncapped high speed roof fans that are used for the ventilation of the existing poultry houses are represented by three point sources per house within ADMS (EX1 1, 2 & 3 to EX6 1, 2 & 3).

Emissions from the air scrubbers and the high speed ridge/roof fans that would be used as bypass/backup ventilation are represented by six point sources per house within ADMS (EX6_BYP 1, 2 & 3 and EX6_SCR 1, 2 & 3; PR1_BYP 1, 2 & 3 and PR1_SCR 1, 2 & 3 to PR3_BYP 1, 2 & 3 and PR3_SCR 1, 2 & 3).

Details of the point source parameters are shown in Table 2. The positions of the point sources may be seen in Figure 4 (marked by green circles).

Table 2. 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 1, 2 & 3 to EX6 1, 2 & 3	6.0	0.8	11.0	Variable [1]	Variable [1]
EX6_BYP 1, 2 & 3	6.0	0.8	11.0	Variable [1]	Variable [1]
EX6_SCR 1, 2 & 3	6.1 to 7.3	0.8	12.0 [2]	Variable [1]	Variable [1]
PR1_BYP 1, 2 & 3 to PR3_BYP 1, 2 & 3	6.7	0.8	11.0	Variable [1]	Variable [1]
PR1_SCR 1, 2 & 3 and PR3_SCR 1, 2 & 3	6.1 to 7.3	0.8	12.0 [2]	Variable [1]	Variable [1]

1. Dependent on crop stage and ambient temperature.
2. The modelling assumes that Inno+ air scrubber is fitted with fixed velocity high speed fans and not any other configuration.

4.3 Modelled buildings

The structure of the existing and proposed poultry houses may affect the plumes from the point sources. Therefore, the buildings are modelled within ADMS. The positions of the modelled buildings may be seen in Figure 4 (marked by grey rectangles).

4.4 Discrete receptors

Twenty-one discrete receptors have been defined at the statutory and non-statutory wildlife sites. These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figures 5a and 5b (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 velocity fields, a nested Cartesian grid has been defined within ADMS. The grid receptors are defined at ground level within ADMS. The position of the nested Cartesian grid receptors may be seen in Figures 5a and 5b (marked by green crosses).

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 22.0 km x 22.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is approximately 340 m.

4.7 Roughness Length

A fixed surface roughness length of 0.275 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 0.25 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 4. The positions of the modelled buildings and sources

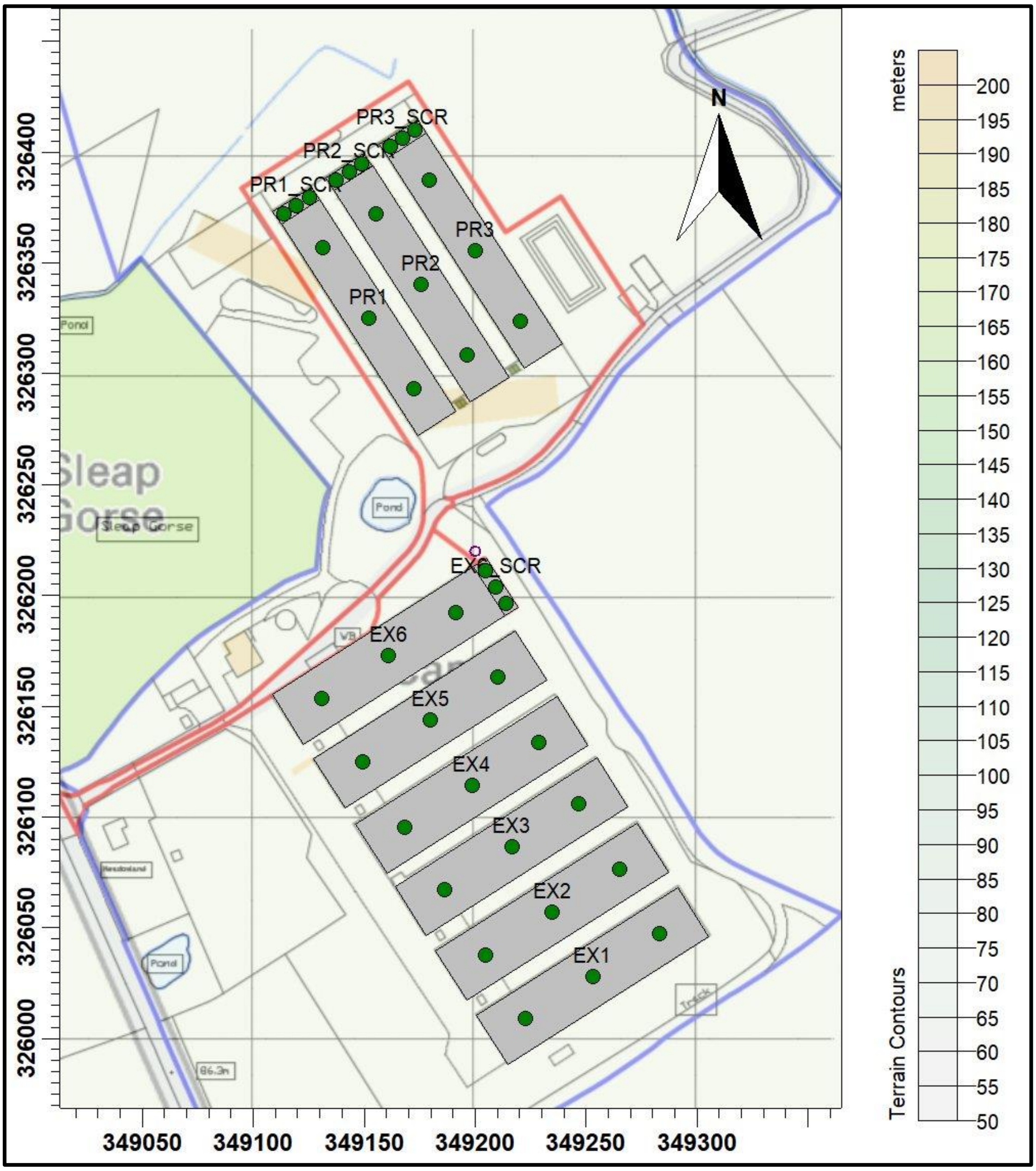


Figure 5a. The discrete receptors - with circles radii at 2.2 km (olive), 5.2 km (green) and 10.2 km (purple)

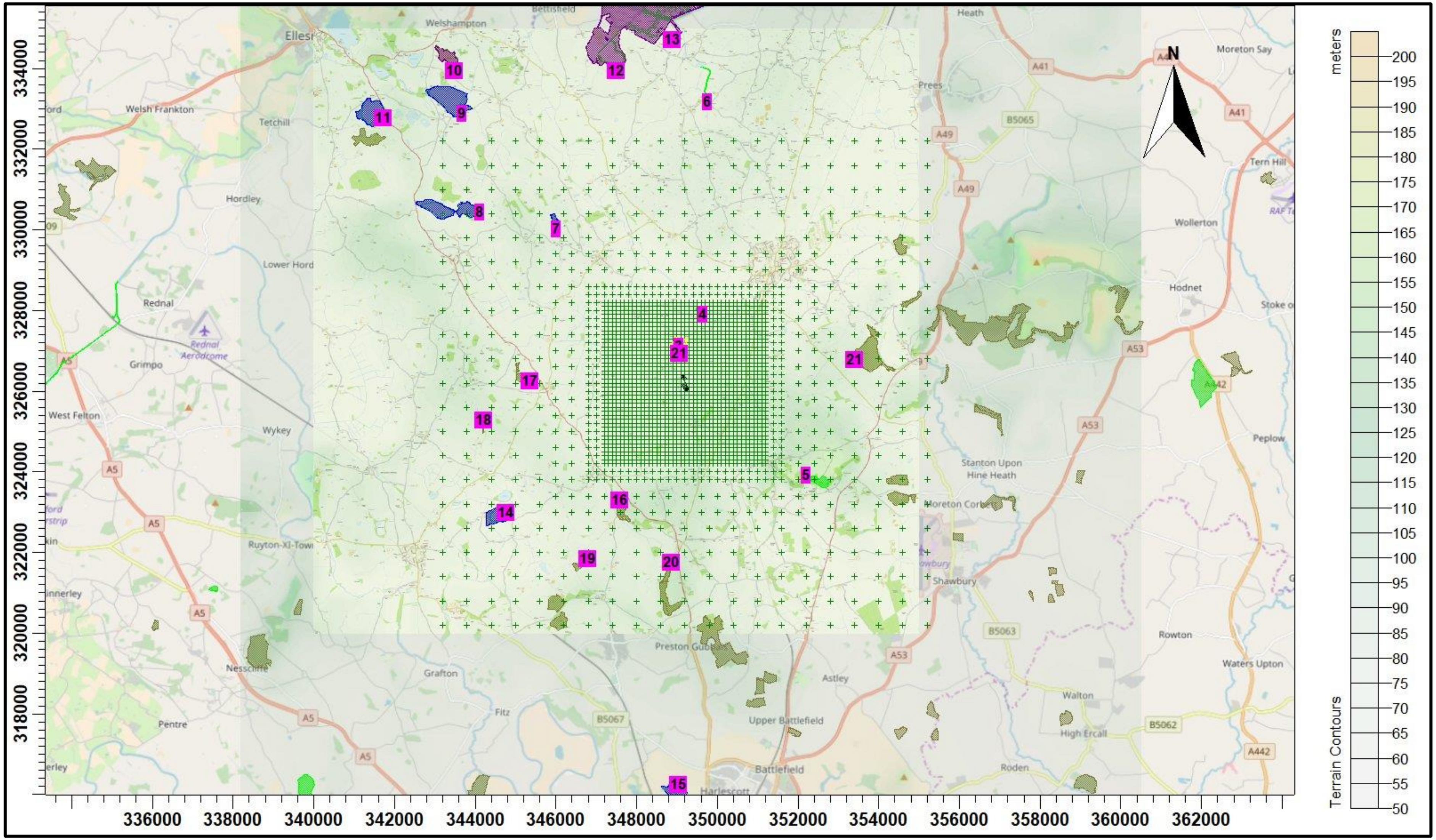
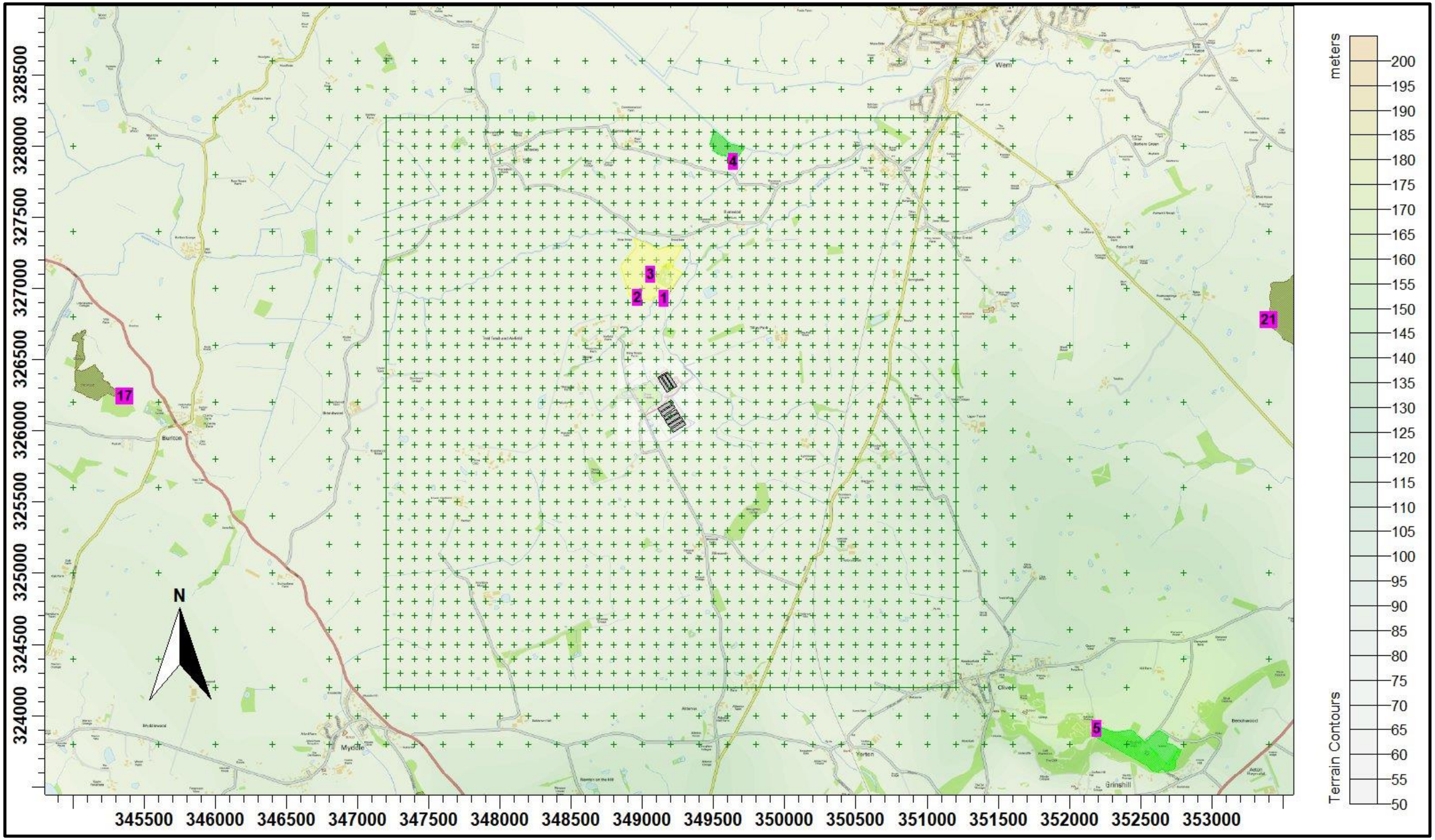


Figure 5b. The discrete receptors and regular Cartesian grid - a closer view



4.8 Deposition

The method used to model deposition of ammonia and consequent plume depletion is based primarily upon Frederik Schrader and Christian Brümmer. Land Use Specific Ammonia Deposition Velocities: a Review of Recent Studies (2004-2013). AS Modelling & Data Ltd. has restricted deposition over arable farmland and heavily grazed and fertilised pasture; this is to compensate for possible saturation effects due to fertilizer application and to allow for periods when fields are clear of crops (Sutton), the deposition is also restricted over areas with little or no vegetation and the deposition velocity is set to 0.002 m/s where grid points are over the poultry housing and 0.010 m/s to 0.015 m/s over heavily grazed grassland. Where deposition over water surfaces is calculated, a deposition velocity of 0.005 m/s is used.

In summary, the method is as follows:

- A preliminary run of the model without deposition is used to provide an ammonia concentration field.
- The preliminary ammonia concentration field, along with land usage, has been used to define a deposition velocity field. The deposition velocities used are provided in Table 3.

Table 3. Deposition velocities

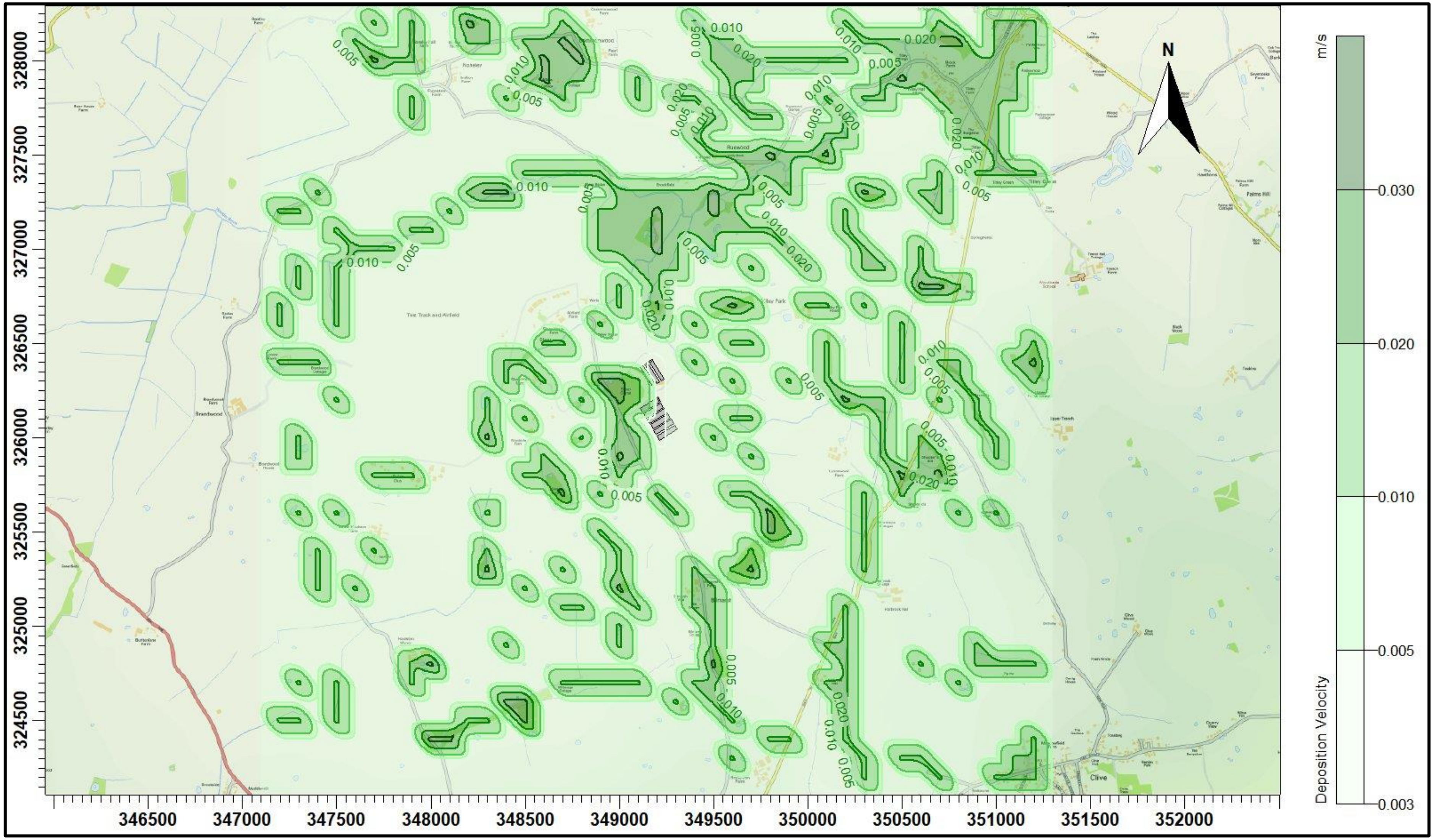
NH_3 concentration (PC + background) (µg/m^3)	< 10	10 - 20	20 - 30	30 - 80	> 80
Deposition velocity - woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity - short vegetation (m/s)	0.02 (0.010 to 0.015 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity - arable farmland/rye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

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

A contour plot of the spatially varying deposition field is provided in Figure 6.

Please note that, outside of the central 4 km x 4 km grid, a fixed deposition at 0.005 m/s is applied and similarly to not modelling deposition at all, the predicted ammonia concentrations (and nitrogen and acid deposition rates) are always equal to, or higher than if spatially varying deposition were modelled explicitly, particularly where there is some distance between the source and a receptor.

Figure 6. The spatially varying deposition field



5. Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

Not conducted/reported. In this case normal sensitivity tests for meteorological data, treatment of calms and treatment of terrain has been conducted previously. Added tests on effects of stack heights and scrubber ventilation configuration were conducted, these are not reported upon, but are available upon request.

5.2 Detailed deposition modelling

Detailed modelling has been carried out over a 4 km x 4 km domain around the existing and proposed poultry houses at Meadowlands. Outside of this domain, a fixed deposition velocity of 0.005 m/s is assumed.

The predicted process contribution to maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors are shown in Table 4a for the existing scenario and Table 4b for the proposed scenario. In the Tables, predicted ammonia concentrations and deposition rates that are in excess of 1% of the relevant Critical Level/Load are highlighted in bold text. The predicted changes in mean ammonia concentrations and nitrogen deposition rates at the discrete receptors are shown in Table 5.

Contour plots of the predicted process contributions to ground level maximum annual mean ammonia concentrations and nitrogen deposition rates are shown in Figures 7a and 7b for the existing scenario and Figures 8a and 8b for the proposed scenario. Contour plots of the predicted changes in mean ammonia concentrations and nitrogen deposition rates are shown in Figures 9a and 9b.

Table 4a. Predicted process contribution to maximum annual mean ammonia and nitrogen deposition at the discrete receptors - existing scenario

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	349150	326930	Ruewood Pools LWS	0.02	1	10	0.249	**24.95**	1.30	**12.96**
2	348965	326935	Ruewood Pools LWS	0.02	1	10	0.242	**24.15**	1.25	**12.55**
3	349056	327095	Ruewood Pools LWS	0.02	1	10	0.175	**17.53**	0.91	**9.10**
4	349640	327892	Ruewood Pastures SSSI	0.03	1	15	0.071	**7.15**	0.56	**3.71**
5	352194	323907	Grinshill Quarries SSSI	0.03	n/a	n/a	0.015	-	0.12	-
6	349742	333163	Prees Branch Canal SSSI	0.03	n/a	n/a	0.007	-	0.06	-
7	346004	330009	Brownheath Moss SSSI/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	0.012	**1.22**	0.10	0.95
8	344103	330441	Sweat Mere and Crose Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	0.007	0.70	0.05	0.54
9	343671	332882	Cole Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	0.006	0.57	0.04	0.44
10	343476	333941	Clarepool Moss SSSI/West Midlands Mosses SAC/Midland Meres & Mosses Phase 1 Ramsar	0.03	1	10	0.005	0.50	0.04	0.39
11	341727	332774	White Mere SSSI/Midland Meres & Mosses Phase 1 Ramsar	0.03	1	10	0.004	0.39	0.03	0.31
12	347495	333941	Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses SSSI/SAC/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	0.007	0.67	0.05	0.53
13	348877	334719	Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses SSSI/SAC/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	0.006	0.57	0.04	0.44
14	344751	322988	Fenemere SSSI/Midland Meres & Mosses Phase 1 Ramsar	0.03	3	10	0.007	0.25	0.06	0.58
15	349029	316247	Hencott Pool SSSI/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	0.004	0.39	0.03	0.30
16	347587	323292	AW	0.03	1	10	0.013	**1.28**	0.10	1.00
17	345365	326243	AW	0.03	1	10	0.013	**1.35**	0.10	**1.05**
18	344210	325283	AW	0.03	1	10	0.007	0.72	0.06	0.56
19	346787	321834	AW	0.03	1	10	0.007	0.74	0.06	0.58
20	348849	321746	AW	0.03	1	10	0.012	**1.20**	0.09	0.94
21	353399	326776	AW	0.03	1	10	0.018	**1.81**	0.14	**1.41**

Table 4b. Predicted process contribution to maximum annual mean ammonia and nitrogen deposition at the discrete receptors - proposed scenario

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	349150	326930	Ruewood Pools LWS	0.02	1	10	0.247	**24.68**	1.28	**12.82**
2	348965	326935	Ruewood Pools LWS	0.02	1	10	0.236	**23.64**	1.23	**12.28**
3	349056	327095	Ruewood Pools LWS	0.02	1	10	0.171	**17.07**	0.89	**8.87**
4	349640	327892	Ruewood Pastures SSSI	0.03	1	15	0.068	**6.79**	0.53	**3.53**
5	352194	323907	Grinshill Quarries SSSI	0.03	n/a	n/a	0.014	-	0.11	-
6	349742	333163	Prees Branch Canal SSSI	0.03	n/a	n/a	0.007	-	0.05	-
7	346004	330009	Brownheath Moss SSSI/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	0.011	**1.14**	0.09	0.89
8	344103	330441	Sweat Mere and Crose Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	0.007	0.65	0.05	0.51
9	343671	332882	Cole Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	0.005	0.53	0.04	0.41
10	343476	333941	Clarepool Moss SSSI/West Midlands Mosses SAC/Midland Meres & Mosses Phase 1 Ramsar	0.03	1	10	0.005	0.46	0.04	0.36
11	341727	332774	White Mere SSSI/Midland Meres & Mosses Phase 1 Ramsar	0.03	1	10	0.004	0.37	0.03	0.29
12	347495	333941	Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses SSSI/SAC/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	0.006	0.64	0.05	0.50
13	348877	334719	Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses SSSI/SAC/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	0.005	0.54	0.04	0.42
14	344751	322988	Fenemere SSSI/Midland Meres & Mosses Phase 1 Ramsar	0.03	3	10	0.007	0.23	0.05	0.54
15	349029	316247	Hencott Pool SSSI/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	0.004	0.36	0.03	0.28
16	347587	323292	AW	0.03	1	10	0.012	**1.19**	0.09	0.93
17	345365	326243	AW	0.03	1	10	0.013	**1.26**	0.10	0.98
18	344210	325283	AW	0.03	1	10	0.007	0.67	0.05	0.53
19	346787	321834	AW	0.03	1	10	0.007	0.69	0.05	0.54
20	348849	321746	AW	0.03	1	10	0.011	**1.12**	0.09	0.87
21	353399	326776	AW	0.03	1	10	0.017	**1.70**	0.13	**1.32**

Table 5. Predicted changes in process contribution to maximum annual mean ammonia and nitrogen deposition at the discrete receptors

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	349150	326930	Ruewood Pools LWS	0.02	1	10	-0.0027	-0.27	-0.014	-0.14
2	348965	326935	Ruewood Pools LWS	0.02	1	10	-0.0051	-0.51	-0.026	-0.26
3	349056	327095	Ruewood Pools LWS	0.02	1	10	-0.0045	-0.45	-0.024	-0.24
4	349640	327892	Ruewood Pastures SSSI	0.03	1	15	-0.0035	-0.35	-0.028	-0.18
5	352194	323907	Grinshill Quarries SSSI	0.03	n/a	n/a	-0.0010	-	-0.008	-
6	349742	333163	Prees Branch Canal SSSI	0.03	n/a	n/a	-0.0004	-	-0.003	-
7	346004	330009	Brownheath Moss SSSI/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	-0.0008	-0.08	-0.006	-0.06
8	344103	330441	Sweat Mere and Crose Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	-0.0005	-0.05	-0.004	-0.04
9	343671	332882	Cole Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	-0.0004	-0.04	-0.003	-0.03
10	343476	333941	Clarepool Moss SSSI/West Midlands Mosses SAC/Midland Meres & Mosses Phase 1 Ramsar	0.03	1	10	-0.0003	-0.03	-0.002	-0.02
11	341727	332774	White Mere SSSI/Midland Meres & Mosses Phase 1 Ramsar	0.03	1	10	-0.0003	-0.03	-0.002	-0.02
12	347495	333941	Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses SSSI/SAC/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	-0.0004	-0.04	-0.003	-0.03
13	348877	334719	Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses SSSI/SAC/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	-0.0003	-0.03	-0.003	-0.03
14	344751	322988	Fenemere SSSI/Midland Meres & Mosses Phase 1 Ramsar	0.03	3	10	-0.0005	-0.02	-0.004	-0.04
15	349029	316247	Hencott Pool SSSI/Midland Meres & Mosses Phase 2 Ramsar	0.03	1	10	-0.0002	-0.02	-0.002	-0.02
16	347587	323292	AW	0.03	1	10	-0.0009	-0.09	-0.007	-0.07
17	345365	326243	AW	0.03	1	10	-0.0009	-0.09	-0.007	-0.07
18	344210	325283	AW	0.03	1	10	-0.0005	-0.05	-0.004	-0.04
19	346787	321834	AW	0.03	1	10	-0.0005	-0.05	-0.004	-0.04
20	348849	321746	AW	0.03	1	10	-0.0008	-0.08	-0.006	-0.06
21	353399	326776	AW	0.03	1	10	-0.0011	-0.11	-0.009	-0.09

Figure 7a. Predicted process contribution to maximum annual mean ammonia concentration - existing scenario

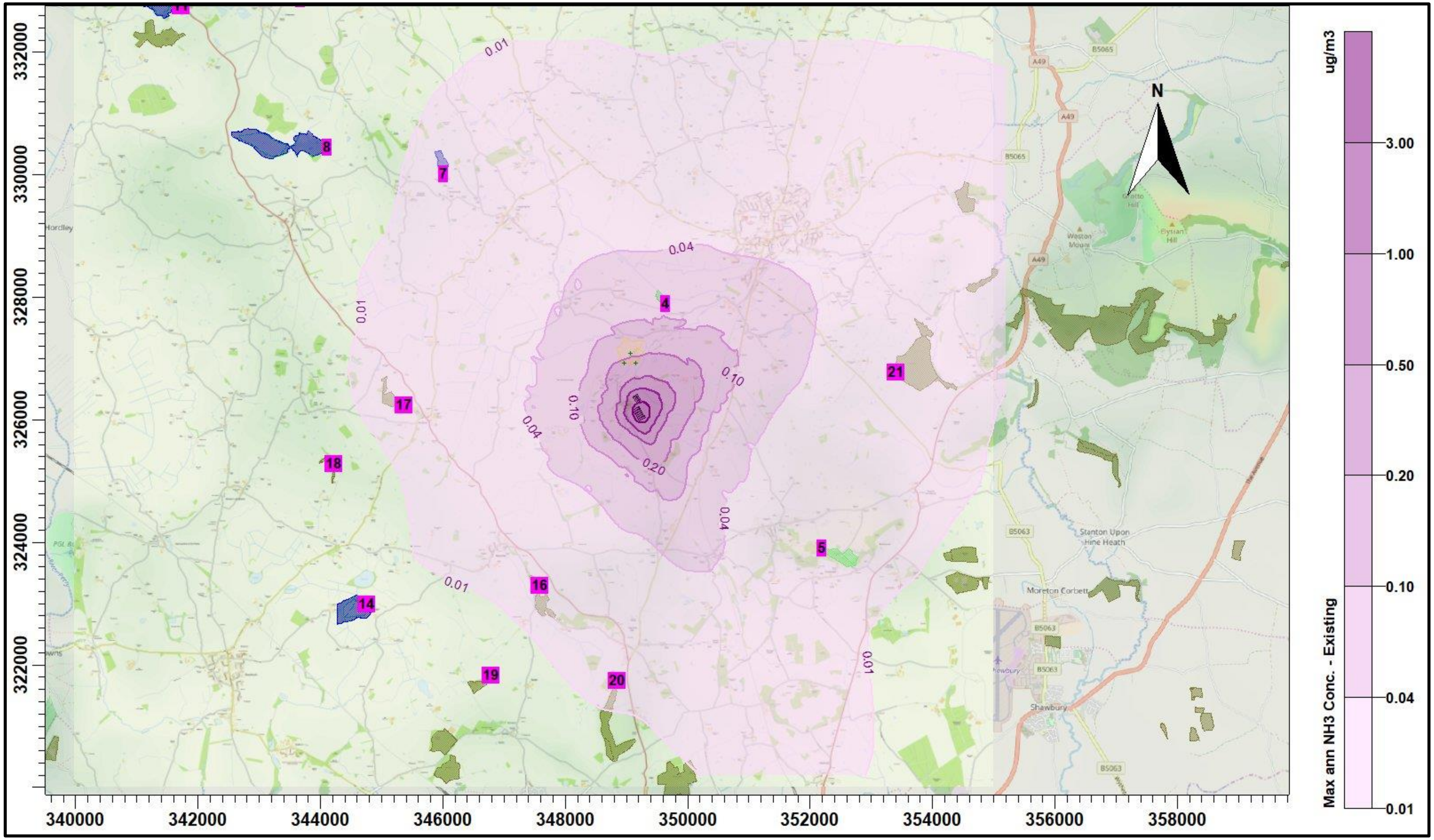


Figure 7b. Predicted process contribution to maximum annual nitrogen deposition rates - existing scenario

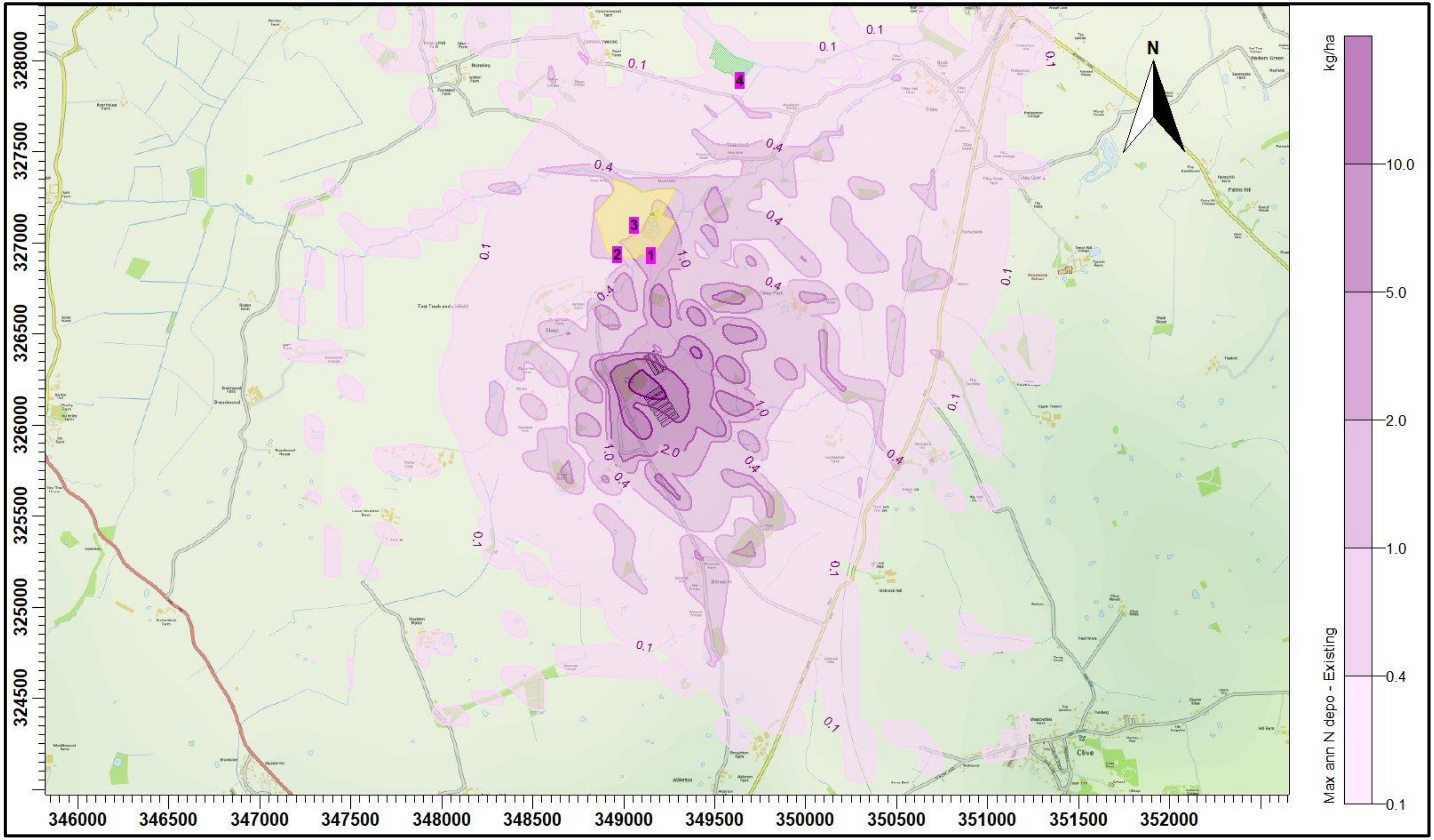


Figure 8a. Predicted process contribution to maximum annual mean ammonia concentration - proposed scenario

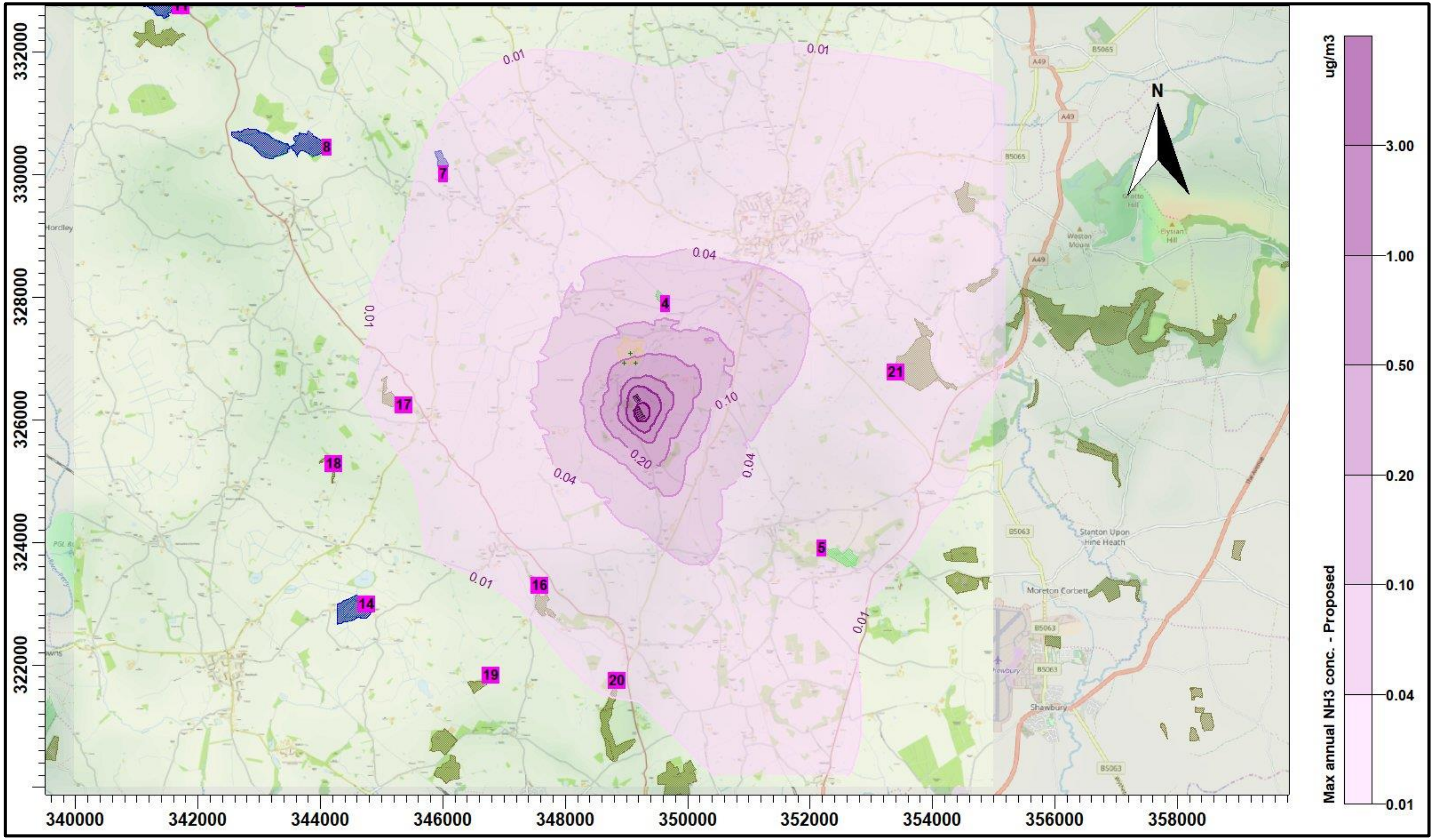


Figure 8b. Predicted process contribution to maximum annual nitrogen deposition rates - proposed scenario

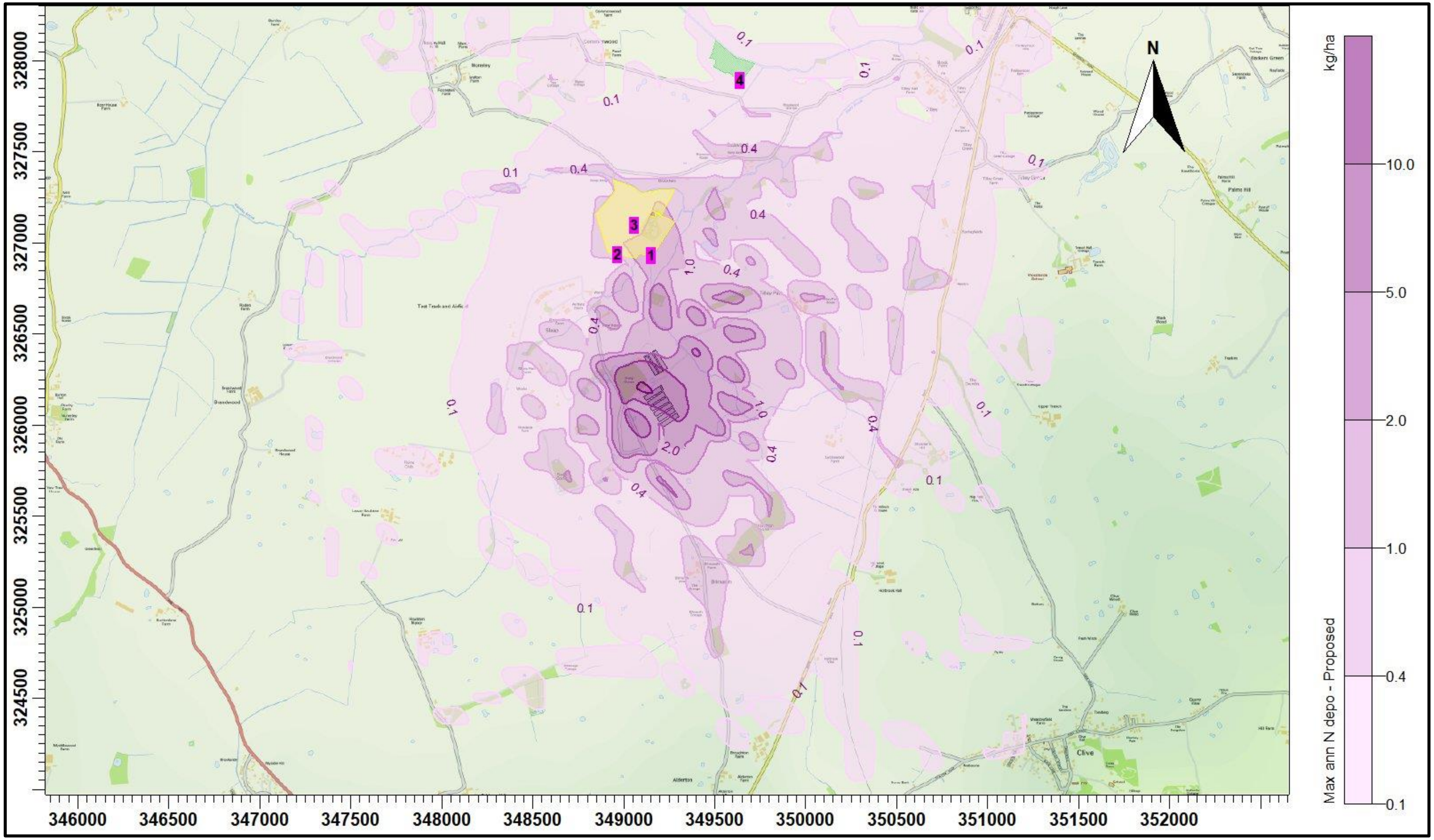


Figure 9a. Predicted change in process contribution to maximum annual mean ammonia concentration

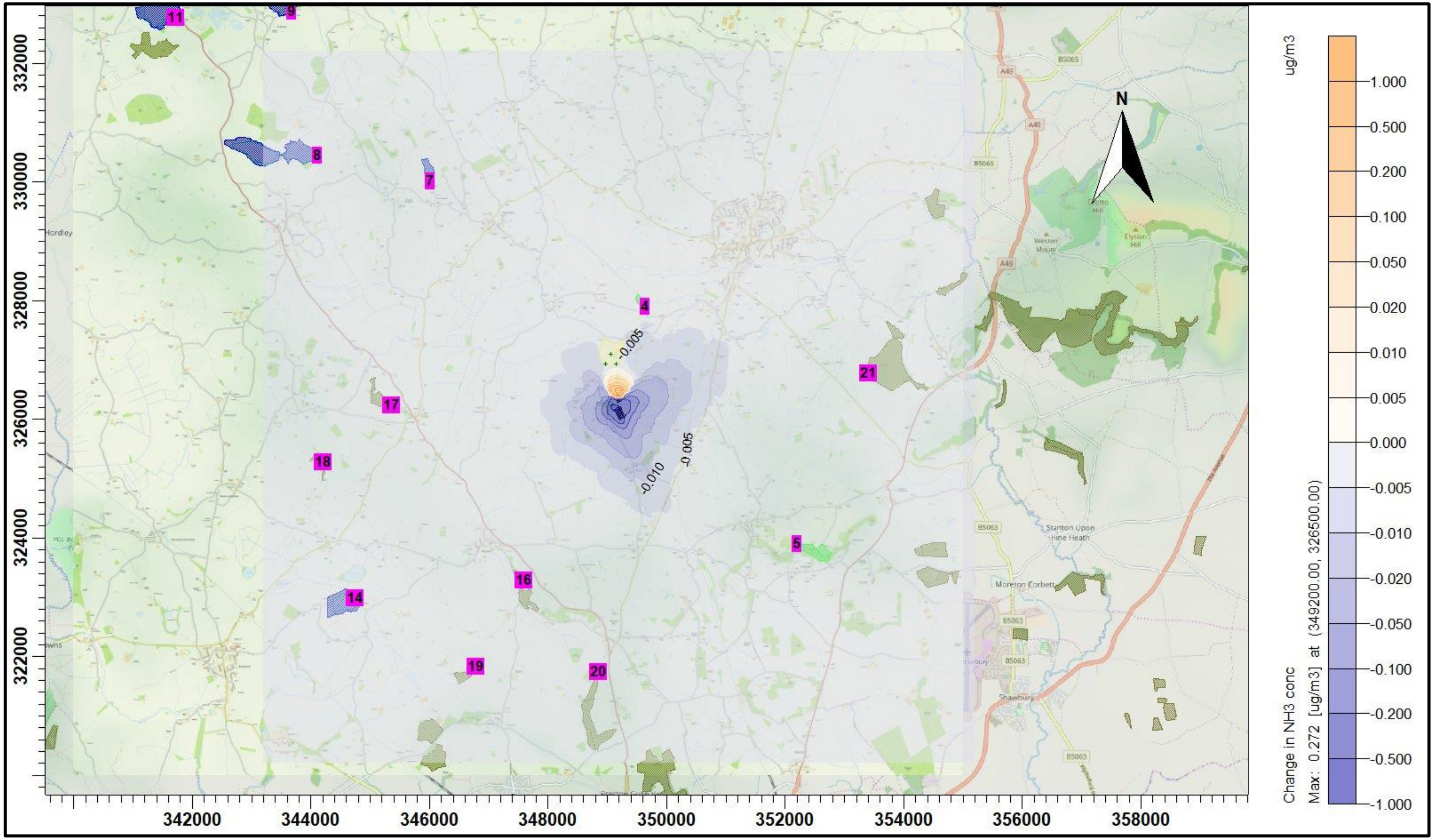
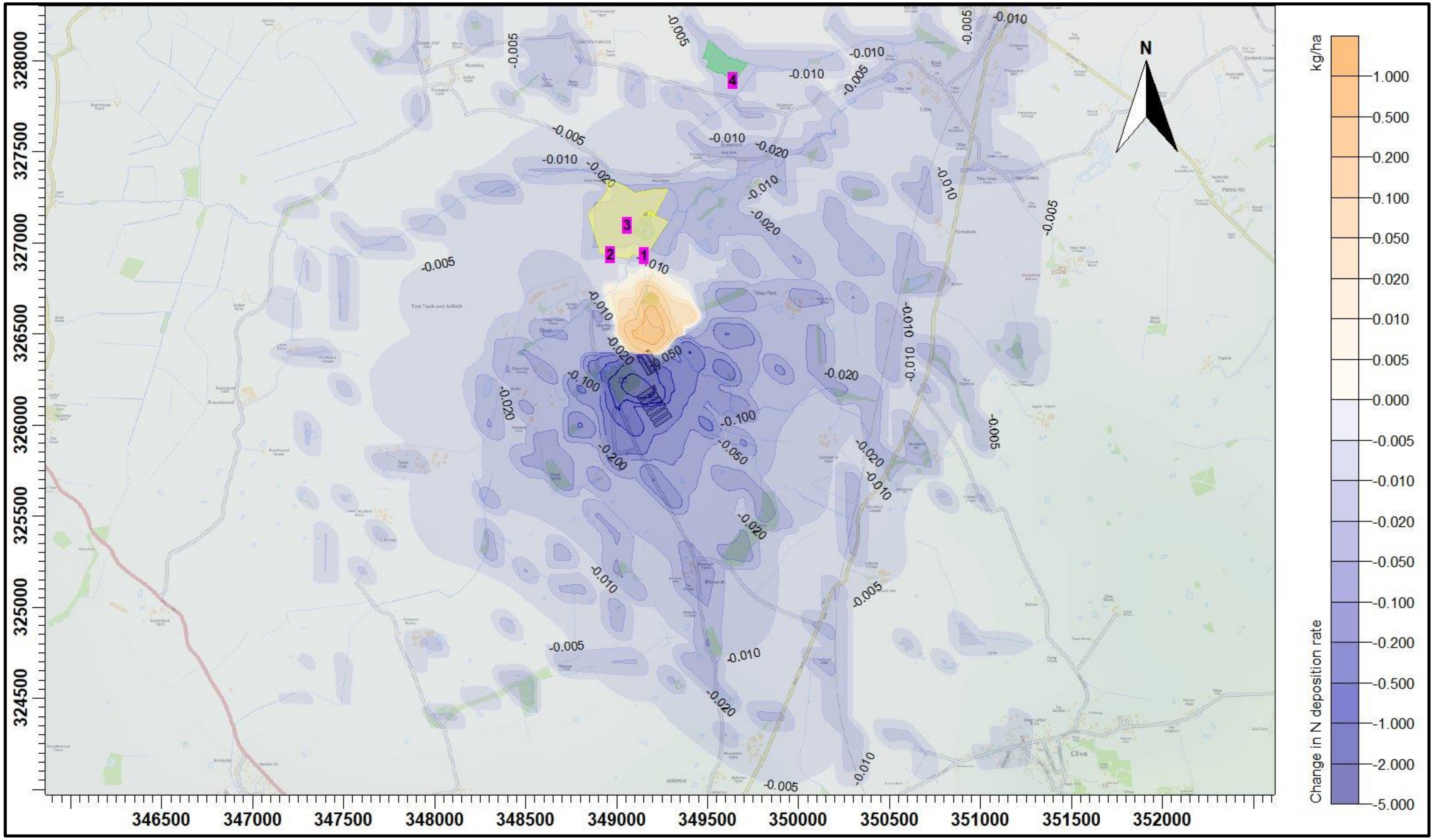


Figure 9b. Predicted change in process contribution to maximum annual nitrogen deposition rates



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Ian Pick of Ian Pick Associates Ltd., on behalf of D. V. & K. J. Grocott, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed broiler chicken rearing houses at Meadowlands, Sleap, near Wem in Shropshire. SY4 3HE.

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 and also upon an emissions model that estimates emissions from the Inno+ ammonia scrubbing equipment that would be fitted to some of the poultry houses. 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.

It should be noted that the modelling is for Inno+ ammonia scrubbing equipment to the specification described in this report and is unlikely to be representative of other scrubber designs or specifications.

The modelling predicts that:

- At all wildlife sites, the process contribution to annual mean ammonia concentrations and nitrogen deposition rates would be below the Environment Agency's lower threshold percentages (4% for an internationally designated site, 20% for a SSSI and 100% for a non-statutory site) of the relevant Critical Level/Load for the site. In all cases, the process contributions are reduced in the proposed scenario.

- At Ruewood Pools LWS, four of the AWs, the predicted process contribution to the annual mean concentration currently exceeds 1% of the Critical Level of 1.0 µg-NH_3/m^3; however, the magnitude of these exceedances would be reduced in the proposed scenario.

- The predicted process contribution to annual mean ammonia concentrations at Ruewood Pastures SSSI, currently exceeds 1% of the Critical Level of 1.0 µg-NH_3/m^3; however, the magnitude and extent of these exceedances would be reduced in the proposed scenario.

- The predicted process contribution to annual mean ammonia concentrations at Brownheath Moss SSSI/Midland Meres & Mosses Phase 2 Ramsar, currently exceeds 1% of the Critical Level of 1.0 µg-NH_3/m^3; however, the magnitude and extent of these exceedances would be reduced in the proposed scenario.

- At all other sites considered, the process contribution to annual mean ammonia concentrations and nitrogen deposition rates would be below 1% of the relevant Critical Level/Load for the site and would be lower than the existing process contribution.

- At all wildlife sites considered, the change in process contribution to annual mean ammonia concentrations and nitrogen deposition rates would be negative.

7. References

Cambridge Environmental Research Consultants (CERC) (website).

Environment Agency H1 Risk Assessment (website).

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