A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Dairy Farm and the Proposed Broiler Chicken Rearing Houses at Ditchford Bank Farm, near Hanbury in Worcestershire

AS Modelling & Data Ltd.

01952 462500

www.asmodata.co.uk

Prepared by Phil Edgington

philedgington@asmodata.co.uk
07483 340262
19th March 2021

Reviewed by Steve Smith

sally@asmodata.co.uk
07483 345124
19th March 2021

1. Introduction

AS Modelling & Data Ltd. has been instructed by Mr. Ian Pick of Ian Pick Associates, on behalf of G. O. Few & Sons, to use computer modelling to assess the impact of ammonia emissions from the dairy farm and the proposed broiler chicken rearing houses at Ditchford Bank Farm, Hanbury, Bromsgrove, Worcestershire. B60 4HS.

Ammonia emission rates from the dairy farm have been assessed and quantified based upon figures obtained from "Ammonia emission factors for UK agriculture", Misselbrook, *et al*. Ammonia emission rates from the proposed poultry houses have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors. The ammonia emission rates have then been used as inputs to an atmospheric dispersion and deposition model which calculates ammonia exposure levels and nitrogen and acid deposition rates in the surrounding area.

This report is arranged in the following manner:

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

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

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

- Section 5 contains the results of the modelling.

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

2. Background Details

Ditchford Bank Farm is approximately 1.9 km to the east of the village of Hanbury in Worcestershire. The surrounding land is used primarily for arable farming although there are some isolated wooded areas and some pastures. The farm is at an altitude of around 70 m, with the land falling along the Seeley Brook to the south and rising gently in other directions.

Currently, Ditchford Bank Farm operates a dairy enterprise and 933 cattle are accommodated, comprising milking and other mature cows and associated young stock. The animals are housed in a mixture of slatted cubicle sheds, pens and straw accommodation that are ventilated either naturally or by side fans.

Under the proposals, four new poultry houses would be constructed on land to the south-east of the existing farm buildings at Ditchford Bank Farm. These new buildings would house up to 200,000 broiler chickens, which would be reared from day old chicks to around 38 days old. The proposed houses would be ventilated by uncapped high speed ridge mounted fans, each with a short chimney. Manure and spent litter would collect within the houses during the rearing period and would be cleared and removed from the farm at the end of each flock cycle.

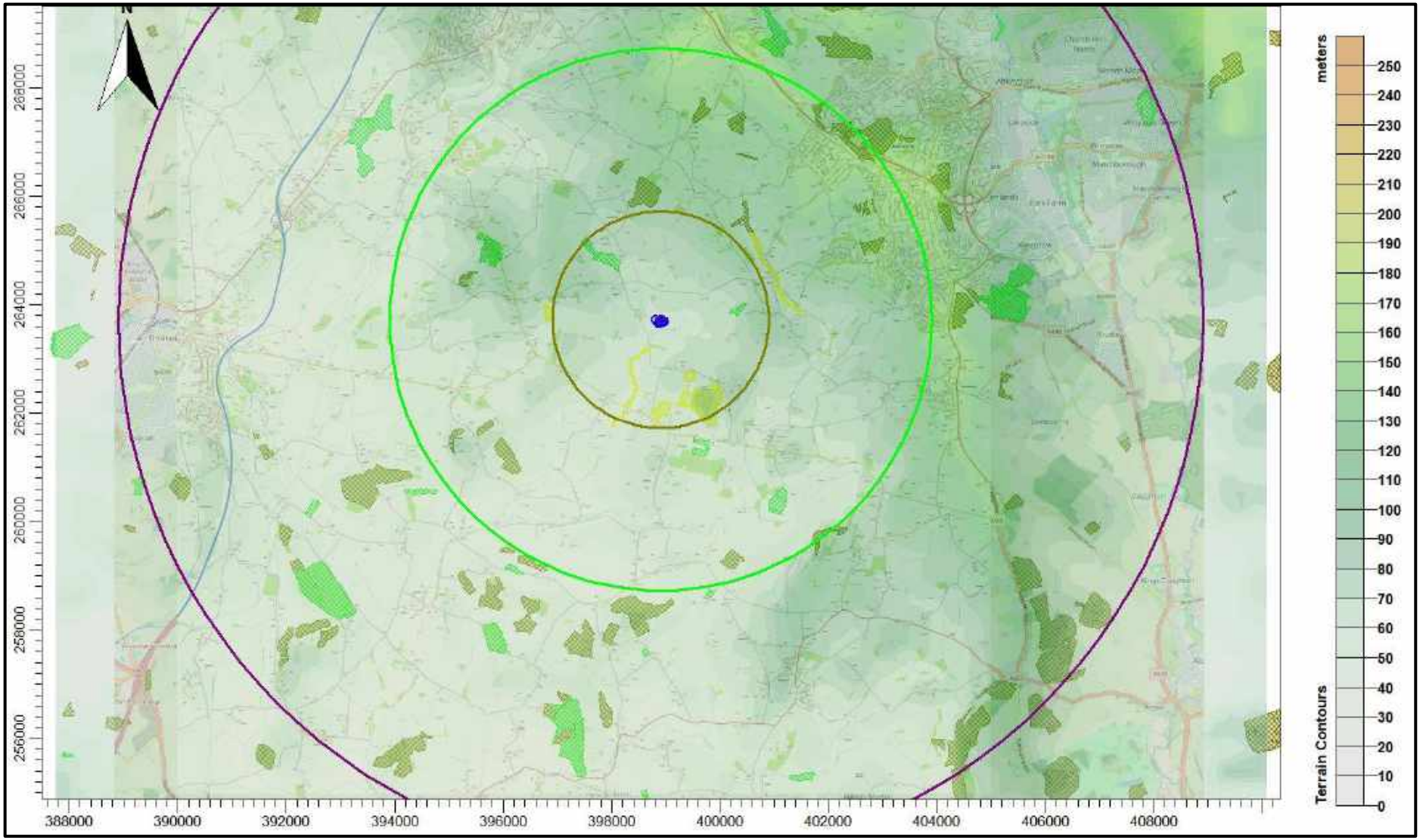
There are six areas designated as County Wildlife Sites (CWSs) and one area of Ancient Woodland (AW) that might be adversely affected by ammonia emissions within 2 km (the normal screening distance for non-statutory sites) of the poultry unit at Ditchford Bank Farm. There are also twenty-two Sites of Special Scientific Interest (SSSIs) within 10 km (the normal screening distance for statutory sites) of the farm. There are no internationally designated sites within 10 km of the site. Some further details of the SSSIs are provided below:

- Trickses Hole SSSI - Approximately 1.2 km to the east - The special interest of this site lies in the diversity of the semi-natural mesotrophic (neutral) grassland.
- Foster's Green Meadows SSSI - Approximately 1.0 km to the north-west - A nationally important complex of ancient meadows.
- Rookery Cottage Meadows SSSI - Approximately 2.1 km to the south-south-east - The special interest of the site lies in the diversity of the semi-natural grassland sward with its rich assemblage of herbs and grasses.
- Wylde Moor, Feckenham SSSI - Approximately 3.6 km to the south-east - A nationally important complex of ancient meadows. The deep fen peat and associated marsh and fen vegetation is of special interest because this habitat is very rare in Worcestershire.
- Pipershill Common SSSI - Approximately 3.0 km to the north-west - One of the few remaining areas of ancient wood pasture in Worcestershire.
- Upton Warren Pools SSSI - Approximately 5.8 km to the north-west - The principal importance of the site is its ornithological interest and a series of shallow pools of different origins provide an important habitat for wintering and passage waterfowl and wader species. However, the site also has considerable botanical importance.
- Burcot Lane Cutting SSSI - Approximately 8.0 km to the north-north-west - Geological.
- Hewell Park Lake SSSI - Approximately 5.1 km to the north-north-east - A shallow artificial lake surrounded by ornamental woodland lying in the grounds of Hewell Grange.
- Dagnell End Meadow SSSI - Approximately 7.9 km to the north-east - An area of ancient permanent pasture lying in the valley of the River Arrow. It represents one of the last surviving areas of such pasture in this part of Worcestershire.

- Ipsley Alders Marsh SSSI - Approximately 9.6 km to the east-north-east - A meadow within which is a marsh receiving calcium-rich water from springs arising from the underlying Triassic Keuper Mails. This is an unusual habitat and Ipsley Alders Marsh is the only sizeable area that now exists in the West Midlands.
- Rough Hill & Wirehill Woods SSSI - Approximately 5.6 km to the east - Two contiguous areas of ancient woodland, the varied soil conditions have given rise to six woodland types which are nationally restricted in their distribution.
- Stock Wood Meadows SSSI - Approximately 4.9 km to the east-south-east - The special interest of the site lies in the diversity of the damp semi-natural mesotrophic (neutral) grassland sward.
- Dormston Church Meadow SSSI - Approximately 5.9 km to the south - The meadow conforms with the mesotrophic (neutral) community, with a calcareous influence and some unusual woodland elements.
- Long Meadow, Thorn SSSI - Approximately 8.6 km to the east-south-east - A species rich neutral grassland.
- Portway Farm Meadows SSSI - Approximately 8.4 km to the south - The special interest lies in the diversity of the semi-natural grassland sward with its rich assemblage of herbs and grasses.
- Grafton Wood SSSI - Approximately 7.0 km to the south-south-west - Grafton Wood originally formed part of the ancient royal forest of Feckenham. The principal tree species are pedunculate oak, ash and birch. The site also includes areas of unimproved neutral grassland and a pond, which contribute greatly to its overall biological value. The site is noted for its lepidoptera.
- Salt Meadow, Earl's Common SSSI - Approximately 5.0 km to the south-south-west - An ancient hay meadow that contains a variety of grasses representative of neutral hay meadows.
- Rabbit Wood SSSI - Approximately 6.1 km to the south-south-west - An area of ancient primary woodland, whose recorded history goes back to the Norman period when it formed part of the Royal Forest of Feckenham.
- Dean Brook Valley Pastures SSSI - Approximately 5.0 km to the south-west - The special interest lies in the diversity of the semi-natural grassland sward.
- Lower Saleway Farm Meadows SSSI - Approximately 7.4 km to the south-west - Of special interest as a large, botanically diverse, semi-natural lowland grassland.
- Trench Wood SSSI - Approximately 7.0 km to the south-west - Selected because of its invertebrate and ornithological interest.
- Oakley Pool SSSI - Approximately 9.8 km to the west-south-west - The site consists of a pool surrounded by reedswamp, fen and grassland.

A map of the surrounding area showing the position of the proposed poultry houses, the LWSs, the AW and the SSSIs is provided in Figure 1. In the figure, the AW is shaded in olive, the LWSs are shaded in yellow, the SSSIs are shaded in green and the positions of the proposed poultry houses are outlined in blue.

Figure 1. The area surrounding Ditchford Bank Farm – with concentric circle radii at 2.0 km (olive), 5.0 km (green) and 10.0 km (purple)



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

3.1 Ammonia concentration and nitrogen and acid deposition

When assessing potential impact on ecological receptors, ammonia concentration is usually expressed in terms of micrograms of ammonia per metre cubed of air (µg-NH_3/m^3) as an annual mean. Ammonia in the air may exert direct effects on the vegetation, or indirectly affect the ecosystem through deposition which causes both hyper-eutrophication (excess nitrogen enrichment) and acidification of soils. Nitrogen deposition, specifically in this case the nitrogen load due to ammonia deposition/absorption, is usually expressed in kilograms of nitrogen per hectare per year (kg-N/ha/y). Acid deposition is expressed in terms of kilograms equivalent (of H^+ ions) per hectare per year (keq/ha/y).

3.2 Background ammonia levels and nitrogen and acid deposition

The background ammonia concentration (annual mean) in the area around Ditchford Bank Farm is 1.96 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 29.40 kg-N/ha/y and to short vegetation is 16.94 kg-N/ha/y. The background acid deposition rate to woodland is 1.99 keq/ha/y and to short vegetation is 1.20 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS, March 2021).

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. 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)
CWSs and AW	1.0 [1]	-	-
Trickses Hole SSSI, Foster's Green Meadows SSSI, Stock Wood Meadows SSSI, Dormston Church Meadow SSSI, Long Meadow, Thorn SSSI, Portway Farm Meadows SSSI, Salt Meadow, Earl's Common SSSI, Dean Brook Valley Pastures SSSI and Lower Saleway Farm Meadows SSSI	3.0 [4]	20.0 [2]	-
Burcot Lane Cutting SSSI and Hewell Park Lake SSSI	n/a [3]	n/a [3]	-
Rookery Cottage Meadows SSSI, Dagnell End Meadow SSSI, Ipsley Alders Marsh SSSI and Oakley Pool SSSI, Upton Warren Pools SSSI	3.0 [4]	15.0 [2]	-
Wylde Moor, Feckenham SSSI, Pipershill Common SSSI and Rough Hill & Wirehill Woods SSSI	1.0 [1 & 4]	10.0 [2]	-
Grafton Wood SSSI, Rabbit Wood SSSI and Trench Wood SSSI	1.0 [1 & 4]	15.0 [2]	-

1. A precautionary figure used where no details of the ecology of the site are available, or the citation for the sites indicates that sensitive lichens and/or bryophytes are present.
2. The lower bound of the range of Critical Loads for the site/species, obtained from APIS (January 2021).
3. The designation for these sites is geological/ornithological and they therefore have no assigned Critical Level or Critical Load.
4. Based upon the citation for the site and information obtained from APIS (January 2021).

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 criteria

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. Additionally, this advice is primarily for combustion processes.

Note that a process contribution of 1% of Critical Level or Critical Load would normally be considered insignificant. A process contribution that is above 1% of Critical Level or Critical Load should be regarded as potentially significant; however, 1% of Critical Level or Critical Load should not be used as a threshold above which damage is implied.

Recent advice from Natural England[2] states that "At the screening assessment stage for agricultural proposals acting alone, the threshold is 4% for both SSSI and N2K sites" and "At the detailed assessment stage where there is an in-combination assessment, the threshold for agricultural proposals is 20% for N2K sites and 50% for SSSIs".

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.
2. Hack, Richard M. "NE guideline screening thresholds for air pollution". Message to Nicola Stone, cc Ian Pick. 2nd October 2020. E-mail.

3.5 Quantification of Ammonia Emissions

Ammonia emission rates from farming 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.

For the dairy operation at Ditchford Bank Farm, all cattle housing emissions are based upon figures obtained from "Ammonia emission factors for UK agriculture", Misselbrook *et al*.

For the proposed poultry housing, the Environment Agency provides an Intensive farming guidance note which lists standard ammonia emission factors for a variety of livestock, including broiler chickens. The emission factor for broiler chickens is 0.034 kg-NH_3/bird place/y; this figure is used to calculate the emissions from the proposed poultry houses.

Details of the animal numbers and types and emission factors used and calculated ammonia emission rates are provided in Table 2a, for the dairy operation and in Table 2b, for the proposed poultry housing at Ditchford Bank Farm.

Table 2a. Details of cattle numbers and ammonia emission rate

Source	Animal numbers	Animal types; age	Animal weight	Housing	Emission factor (kg-NH_3/place/yr)	Total emission rate (g/s)
D1	240	Milking cows; 25 months+	550 kg	Cubicles	16.734	0.127265
D4	50	Calves; 0 to 3 months	40 to 90 kg	Pens	1.332	0.002110
D5	50	Calves; 3 to 6 months	90 to 175 kg	Pens	2.715	0.004302
D6	30	Cows; 26 months+	550 kg	Straw	11.270	0.010714
D7	60	Cows; 26 months+	550 kg	Straw	11.270	0.021427
D8	30	Cows; 26 months+	550 kg	Cubicles	16.734	0.015908
D9	60	Calving cows; 26 months+	550 kg	Straw	11.270	0.021427
D10	90	Young stock; 16 to 22 months	370 to 470 kg	Cubicles	12.779	0.036444
D11	28	Calves; 3 to 8 months	90 to 220 kg	Straw	3.176	0.002818
D12	50	Heiffers; 6 to 12 months	175 to 310 kg	Straw	4.970	0.007873
D12	150	Heiffers; 12 to 26 months	310 to 530 kg	Straw	8.606	0.040906
D12	50	Heiffers; 26 months+	550 kg	Straw	11.270	0.017856
D14	45	Cows s; 26 months+	550 kg	Cubicles	16.734	0.023862
					TOTAL	0.332910

Table 2b. Details of poultry numbers and ammonia emission rate

Source	Animal numbers	Type or weight	Emission factor (kg-NH_3/place/y)	Emission rate (g-NH_3/s)
Proposed Housing	200,000	Broiler Chickens	0.034	0.215479

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).

The GFS is a spectral model: the physics/dynamics model has an equivalent resolution of approximately 13 km (latterly 9km); terrain is understood to be resolved at a resolution of approximately 2 km, with sub-13/9 km terrain effects parameterised. Site specific data may be extrapolated from nearby archive grid points or a most representative grid point chosen. The GFS resolution adequately captures major topographical features and the broad-scale characteristics of the weather over the UK. Smaller scale topological features may be included in the dispersion modelling by using the flow field module of ADMS (FLOWSTAR). The use of NWP data has advantages over traditional meteorological records because:

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

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

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

The raw GFS wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and where terrain data is included in the modelling, wind speeds and directions will be further modified. The raw GFS wind rose is shown in Figure 2a and the terrain and roughness length modified wind rose for the location of the poultry unit at Ditchford Bank Farm is shown in Figure 2b. Note that elsewhere in the modelling domain, the modified wind roses may differ more markedly and that the resolution of the wind field in terrain runs is approximately 340 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. GFS derived data for 52.271 N, 2.016 W, 2017-2020

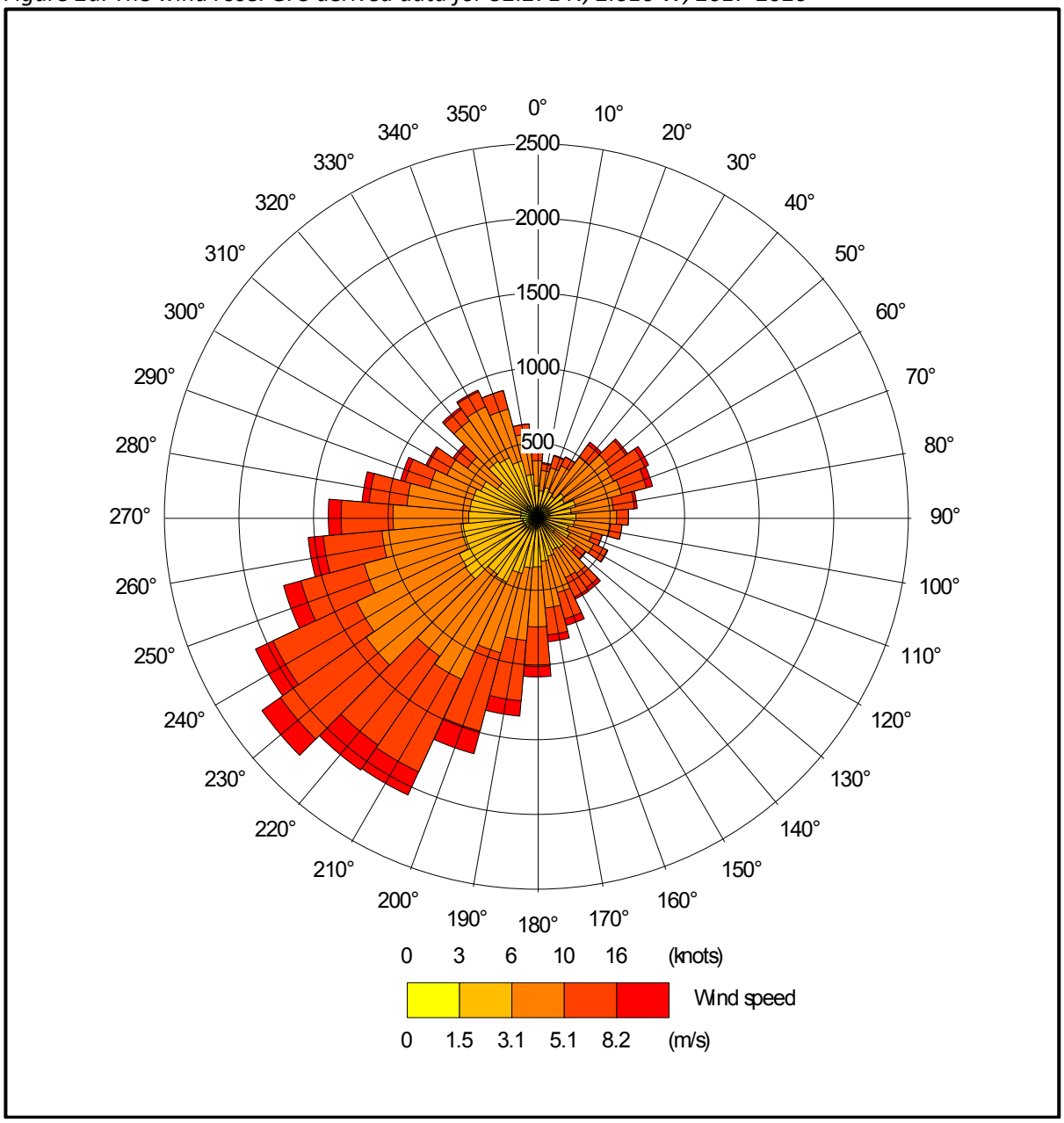
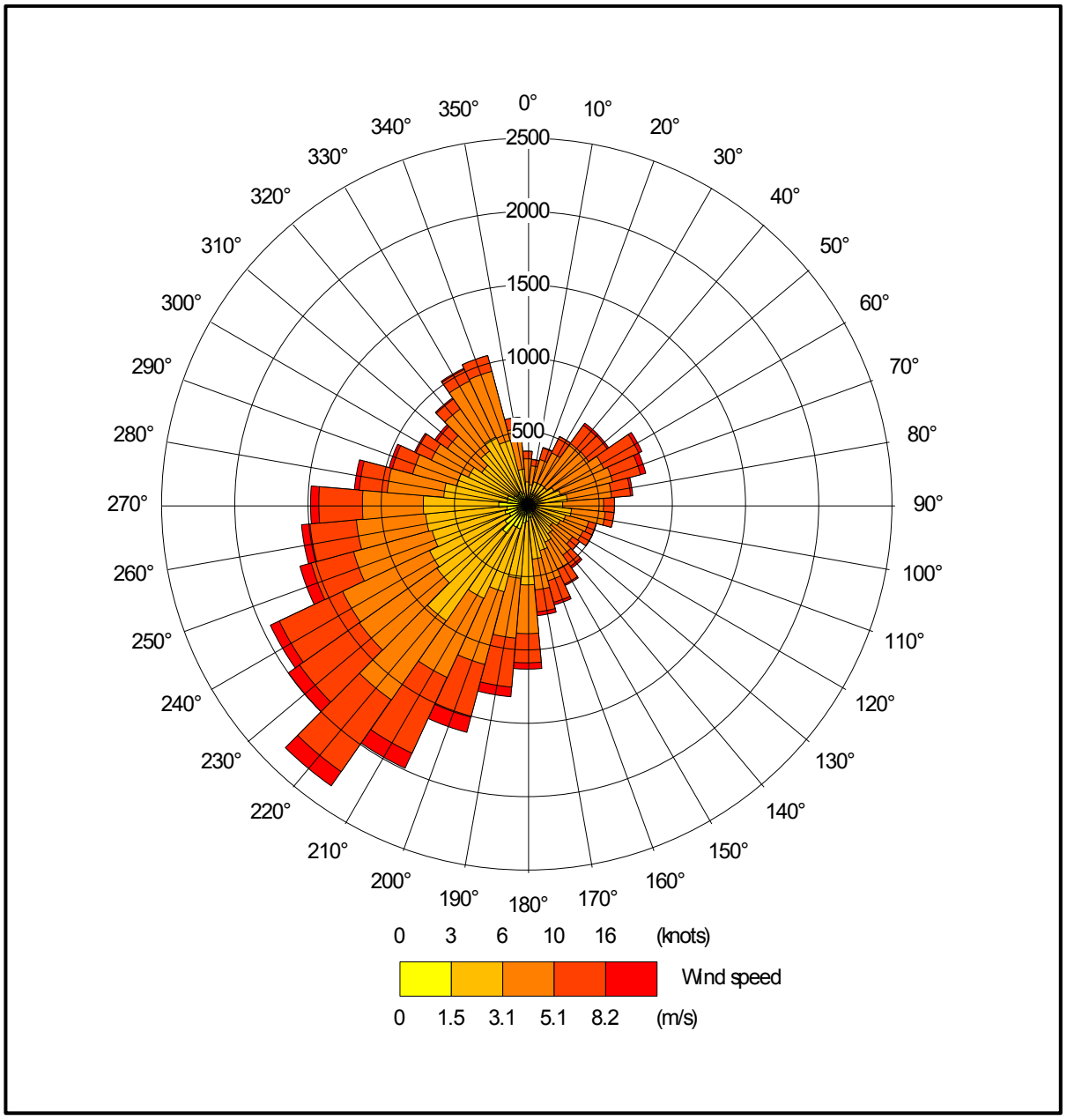


Figure 2b. The wind rose. FLOWSTAR derived data for NGR 398900, 263700



4.2 Emission sources

Emissions from the naturally, or side fan, ventilated cattle housing have been represented by volume sources within ADMS (D1v, D4v to D12v, D14v). Emissions from the uncapped chimneys of the ridge mounted fans that would be used to ventilate the proposed poultry houses are represented by three point sources per house within ADMS (PR1 to PR4; 1, 2 & 3). Details of the source parameters are shown in Table 3a, for the volume sources and Table 3b, for the point sources. The positions of the sources may be seen in Figure 3.

Table 3a. Volume source parameters

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
D1v	45.0	33.0	4.0	0.0	Ambient	0.127264
D4v	18.0	16.0	4.0	0.0	Ambient	0.002110
D5v	3.0	20.0	4.0	0.0	Ambient	0.004302
D6v	21.0	17.0	4.0	0.0	Ambient	0.010714
D7v	21.0	37.0	4.0	0.0	Ambient	0.021427
D8v	27.5	12.0	4.0	0.0	Ambient	0.015908
D9v	27.5	20.0	4.0	0.0	Ambient	0.021427
D10v	27.5	12.0	4.0	0.0	Ambient	0.036444
D11v	10.5	10.5	4.0	0.0	Ambient	0.002818
D12v	72.5	22.6	4.0	0.0	Ambient	0.066635
D14v	39.3	3.0	4.0	0.0	Ambient	0.023862

Table 3b. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (°C)	Emission rate per source (g-NH_3/s)
PR1 to PR4; 1, 2 & 3	8.0	0.8	11.0	22.0	0.017957

4.3 Modelled buildings

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

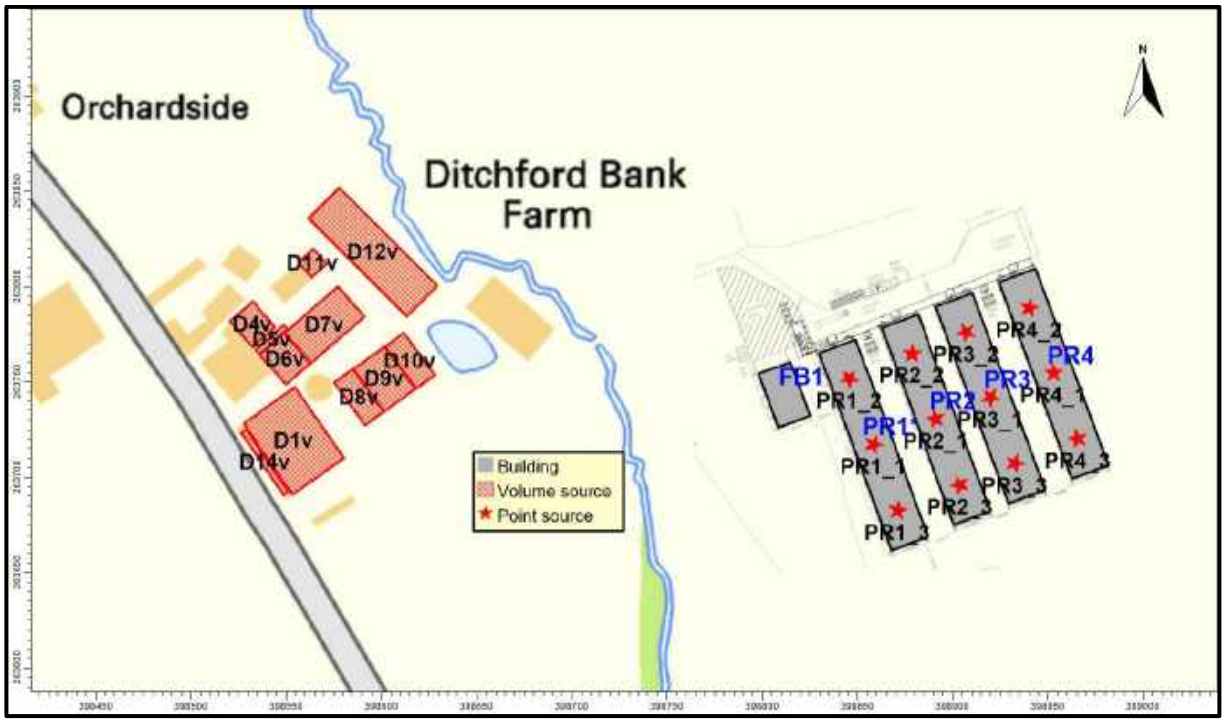
4.4 Discrete receptors

Thirty-six discrete receptors have been defined at the LWSs, the AW and the SSSIs. These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figure 4, where they are marked by enumerated pink rectangles.

4.5 Cartesian grid

To produce the contour plot presented in Section 5 of this report, a regular Cartesian grid has been defined within ADMS. The individual grid receptors are defined at ground level within ADMS. The position of the Cartesian grid may be seen in Figure 4, where it is marked by grey lines.

Figure 3. The positions of modelled sources and buildings



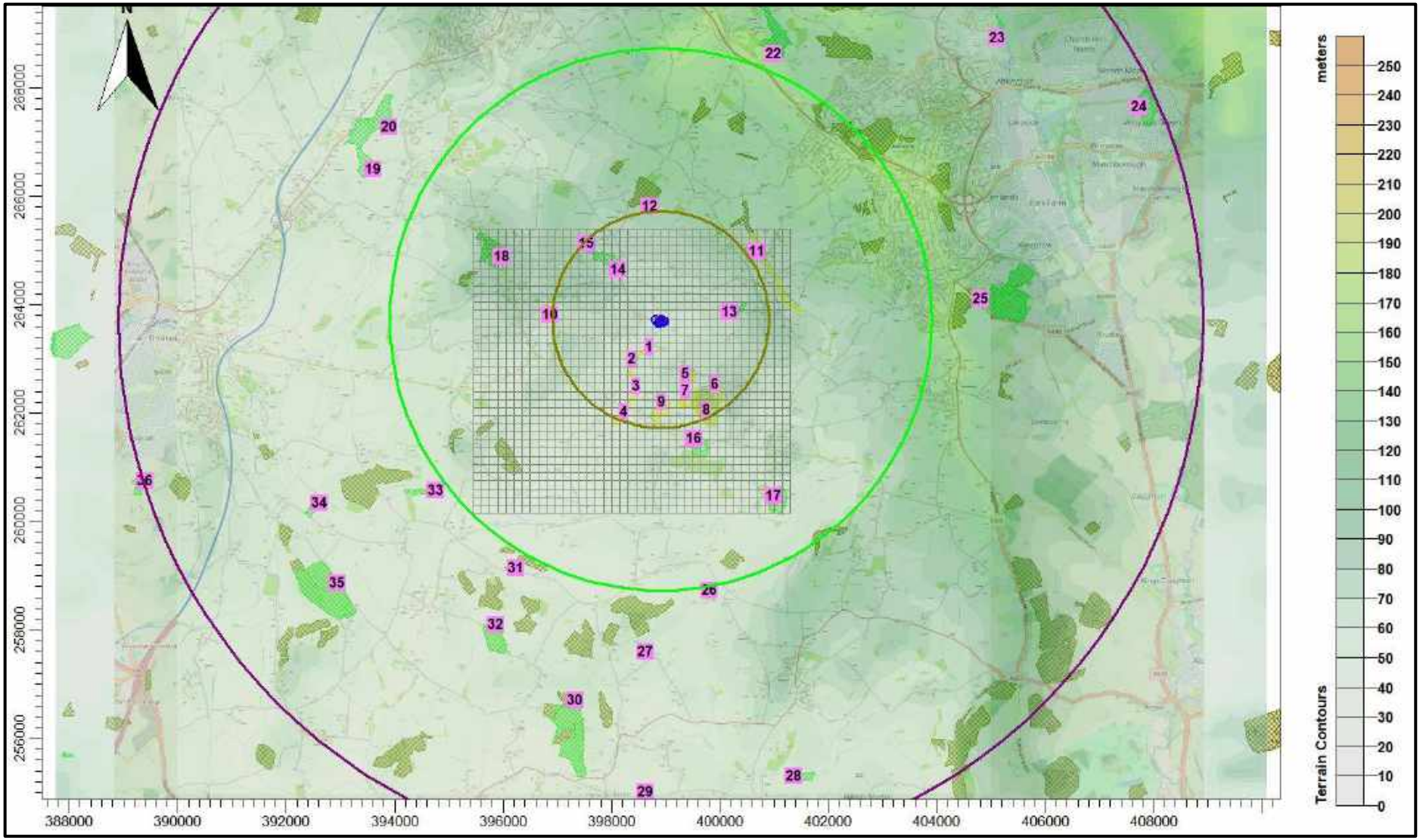
4.6 Terrain data

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

4.7 Roughness Length

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

Figure 4. The discrete receptors and Cartesian grids



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 is used to define a deposition velocity field. The deposition velocities used are provided in Table 4.

Table 4. Deposition velocities

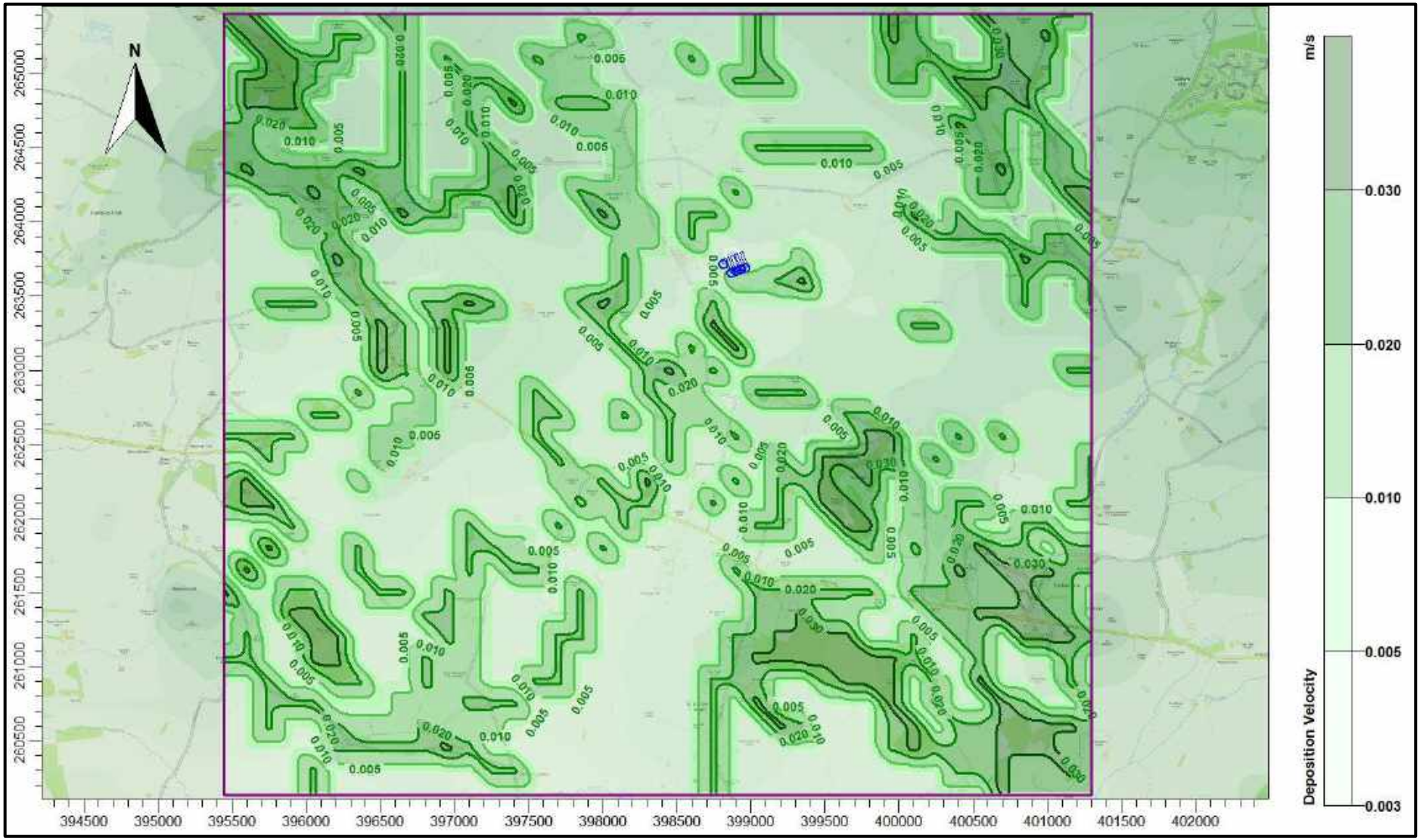
NH_3 concentration (PC + background) (µg/m^3)	< 10	10 - 20	20 - 30	30 – 80	> 80
Deposition velocity – woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity – short vegetation (m/s)	0.02 (0.010 to 0.015 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity – arable farmland/rye 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 5.

In this case, the model has also been run with a fixed deposition at 0.003 m/s and similarly to not modelling deposition at all, the predicted ammonia concentrations (and nitrogen and acid deposition rates) are always higher than if spatially varying deposition were modelled explicitly, particularly where there is some distance between the source and a receptor.

Figure 5. The spatially varying deposition



5. Details of the Model Runs and Results

5.1 Preliminary modelling

ADMS was run a total of thirty-two times; once for each year of the meteorological record, for the dairy houses and for the proposed poultry houses and in the following four modes:

- In basic mode without calms or terrain – GFS data.
- With calms and without terrain – GFS data.
- Without calms and with terrain – GFS data.
- Without calms, with terrain and fixed deposition at 0.003 m/s – GFS data.

For each mode, statistics for the maximum annual mean ammonia concentration at each receptor were compiled.

Details of the predicted process contribution, by the dairy houses and the proposed poultry houses, to annual mean ammonia concentrations at each receptor are provided in Table 5. In the Table, predicted ammonia concentrations (or those equivalent to nitrogen deposition rates) that are in excess of the Environment Agency's upper percentage threshold of the relevant Critical Level or Critical Load (50% for a SSSI and 100% for a non-statutory site) are coloured red. Predicted ammonia concentrations (or those equivalent to nitrogen deposition rates) that are in the range between the Environment Agency's upper percentage threshold and lower percentage threshold of the relevant Critical Level or Critical Load (20% to 50% for a SSSI and 100% to 100% for a non-statutory site) are coloured blue. Additionally, predicted ammonia concentrations (or concentrations equivalent to nitrogen deposition rates) that are in excess of 1% at statutory sites are highlighted in bold text. For convenience, cells referring to the AW are shaded olive, the LWSs are shaded yellow and the SSSIs are shaded green.

Table 5. Predicted maximum annual mean ammonia concentration at the discrete receptors

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)							
				Dairy houses				Poultry houses			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s [1]	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s
1	398685	263214	LWS	**1.517**	**2.080**	**1.588**	**1.338**	0.190	0.189	0.180	0.164
2	398370	262998	LWS	0.555	0.815	0.549	0.448	0.110	0.109	0.107	0.097
3	398447	262502	LWS	0.215	0.355	0.210	0.161	0.051	0.051	0.046	0.039
4	398228	262033	LWS	0.126	0.195	0.122	0.087	0.032	0.032	0.029	0.023
5	399355	262733	LWS	0.488	0.620	0.514	0.354	0.101	0.101	0.106	0.085
6	399905	262525	LWS	0.257	0.331	0.260	0.165	0.069	0.069	0.067	0.052
7	399362	262418	LWS	0.356	0.450	0.374	0.249	0.071	0.070	0.074	0.058
8	399751	262064	LWS	0.222	0.280	0.209	0.133	0.051	0.050	0.053	0.038
9	398920	262206	LWS	0.245	0.337	0.250	0.179	0.040	0.040	0.032	0.026
10	396865	263818	LWS	0.221	0.294	0.219	0.143	0.035	0.035	0.032	0.024
11	400680	264986	LWS	0.214	0.245	0.227	0.140	0.072	0.072	0.069	0.055
12	398704	265808	AW	0.243	0.296	0.291	0.169	0.044	0.044	0.043	0.030
13	400184	263871	Trickses Hole SSSI	**0.410**	**0.477**	**0.489**	**0.290**	**0.116**	**0.116**	**0.123**	**0.104**
14	398115	264645	Foster's Green Meadows SSSI	**0.671**	**0.865**	**0.712**	**0.492**	**0.070**	**0.069**	**0.065**	**0.050**
15	397535	265137	Foster's Green Meadows SSSI	**0.243**	**0.321**	**0.251**	**0.156**	**0.036**	**0.035**	**0.032**	0.023
16	399517	261519	Rookery Cottage Meadows SSSI	**0.147**	**0.191**	**0.148**	**0.096**	**0.036**	**0.035**	**0.037**	0.027
17	400987	260475	Wylde Moor, Feckenham SSSI	**0.071**	**0.089**	**0.073**	**0.041**	**0.022**	**0.022**	**0.024**	**0.014**
18	395964	264887	Pipershill Common SSSI	**0.088**	**0.122**	**0.078**	**0.045**	**0.018**	**0.017**	**0.018**	**0.011**
19	393601	266501	Upton Warren Pools SSSI	0.027	**0.038**	0.027	0.014	0.008	0.008	0.009	0.005
20	393890	267266	Upton Warren Pools SSSI	0.024	**0.035**	0.025	0.013	0.007	0.007	0.008	0.004
21	397040	271617	Burcot Lane Cutting SSSI	0.022	0.028	0.021	0.010	0.008	0.008	0.007	0.003
22	400986	268621	Hewell Park Lake SSSI	0.050	0.061	0.042	0.024	0.018	0.018	0.018	0.010
23	405110	268917	Dagnell End Meadow SSSI	0.028	**0.033**	0.027	0.016	0.011	0.011	0.012	0.007
24	407721	267642	Ipsley Alders Marsh SSSI	0.021	0.024	0.021	0.011	0.010	0.010	0.010	0.005

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)							
				Dairy houses				Poultry houses			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s [1]	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s
25	404814	264111	Rough Hill & Wirehill Woods SSSI	**0.042**	**0.050**	**0.033**	**0.018**	**0.016**	**0.016**	**0.016**	0.009
26	399805	258739	Stock Wood Meadows SSSI	**0.035**	**0.047**	**0.039**	0.022	0.011	0.011	0.011	0.007
27	398614	257602	Dormston Church Meadow SSSI	0.017	0.027	0.018	0.009	0.006	0.006	0.004	0.003
28	401367	255300	Long Meadow, Thorn SSSI	0.016	0.021	0.017	0.009	0.006	0.006	0.007	0.004
29	398614	255013	Portway Farm Meadows SSSI	0.010	0.015	0.011	0.005	0.004	0.004	0.003	0.002
30	397312	256698	Grafton Wood SSSI	**0.012**	**0.019**	**0.012**	0.006	0.005	0.005	0.004	0.002
31	396230	259136	Salt Meadow, Earl's Common SSSI	0.026	**0.035**	0.029	0.018	0.009	0.009	0.008	0.006
32	395860	258095	Rabbit Wood SSSI	**0.019**	**0.025**	**0.021**	**0.012**	0.007	0.007	0.006	0.004
33	394751	260560	Dean Brook Valley Pastures SSSI	0.025	**0.038**	0.025	0.016	0.008	0.008	0.007	0.005
34	392614	260341	Lower Saleway Farm Meadows SSSI	0.017	0.025	0.018	0.010	0.006	0.006	0.005	0.004
35	392943	258862	Trench Wood SSSI	**0.013**	**0.020**	**0.015**	0.009	0.005	0.005	0.004	0.003
36	389395	260752	Oakley Pool SSSI	0.012	0.016	0.013	0.007	0.005	0.005	0.005	0.003

[1] Modelling results increased by a factor of 1.35 to correct for the influence of calms.

5.2 Detailed deposition modelling

The detailed modelling, which includes nitrogen deposition and the consequent plume depletion, was carried out for all of the discrete receptors included in the preliminary modelling. A spatially varying deposition field has been applied to a smaller domain covering the poultry houses and closer SSSIs, where the preliminary modelling shows that the process contributions to the annual mean ammonia concentrations (or concentrations equivalent to deposition rates) would potentially exceed 1% of the Critical Level or Critical Load. Outside of this smaller modelling domain where a spatially varying deposition field has been applied, the deposition velocity is set to 0.003 m/s.

Terrain effects may be significant at some receptors; therefore, the detailed deposition runs were made with terrain included. Calms cannot be used with terrain or spatially varying deposition and have not been included in the detailed modelling; however, the results of the preliminary modelling indicate that the effects of calms are significant for the modelling of ammonia emissions from the dairy buildings. Therefore, for emissions from the dairy houses, the results of the modelling have been increased by a factor of 1.35, which is the average of the ratio of the results from the calms-no terrain modelling to the no calms-no terrain modelling runs.

The results of the detailed deposition modelling for the dairy houses and the proposed poultry houses are shown in Table 6. In the Table, the predicted process contribution to maximum annual mean ground level ammonia concentrations and nitrogen deposition rates that are in excess of the Environment Agency upper threshold percentage of the relevant Critical Level or Critical Load (50% for a SSSI) are coloured red. Ammonia concentrations and nitrogen deposition rates that are in the range between the Environment Agency's lower and upper threshold percentage of the relevant Critical Level or Critical Load (20% and 50% for a SSSI) are coloured blue. Additionally, predicted ammonia concentrations and nitrogen deposition rates that are in excess of 4% of the relevant Critical Level or Critical Load are coloured magenta and ammonia concentrations and nitrogen deposition rates that are in excess of 1% of the relevant Critical Level or Critical Load are highlighted in bold text. Note, the abbreviations PC, CLe and CLo in Table 6 refer to Process Contribution, Critical Level and Critical Load, respectively.

Contour plots, for the smaller domain where a spatially varying deposition rate has been applied, of the predicted process contribution of the dairy houses and the proposed poultry houses to ground level maximum annual mean ammonia concentration and the maximum nitrogen deposition rate are shown in Figure 6a and Figure 6b for the dairy houses and in Figure 7a and Figure 7b for the proposed poultry houses.

Table 6. Predicted process contribution to annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration				Maximum annual nitrogen deposition rate			
							Dairy houses		Poultry houses		Dairy houses		Poultry houses	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	PC (µg/m³)	%age of CLe	PC (µg/m³)	%age of CLe	PC (kg/ha)	%age of CLo	PC (kg/ha)	%age of CLo
1	398685	263214	LWS	0.03	1.0	10.0	0.964	96.4	0.2	15.5	7.51	75.1	1.2	12.1
2	398370	262998	LWS	0.03	1.0	10.0	0.340	34.0	0.1	7.9	2.65	26.5	0.6	6.2
3	398447	262502	LWS	0.03	1.0	10.0	0.123	12.3	0.0	3.0	0.95	9.5	0.2	2.3
4	398228	262033	LWS	0.03	1.0	10.0	0.069	6.9	0.0	1.8	0.54	5.4	0.1	1.4
5	399355	262733	LWS	0.03	1.0	10.0	0.265	26.5	0.1	7.8	2.07	20.7	0.6	6.1
6	399905	262525	LWS	0.03	1.0	10.0	0.097	9.7	0.0	3.8	0.76	7.6	0.3	2.9
7	399362	262418	LWS	0.03	1.0	10.0	0.140	14.0	0.1	5.3	1.09	10.9	0.4	4.2
8	399751	262064	LWS	0.03	1.0	10.0	0.066	6.6	0.0	2.8	0.52	5.2	0.2	2.2
9	398920	262206	LWS	0.03	1.0	10.0	0.103	10.3	0.0	2.0	0.80	8.0	0.2	1.5
10	396865	263818	LWS	0.03	1.0	10.0	0.092	9.2	0.0	2.1	0.72	7.2	0.2	1.7
11	400680	264986	LWS	0.03	1.0	10.0	0.090	9.0	0.0	4.1	0.70	7.0	0.3	3.2
12	398704	265808	AW	0.03	1.0	10.0	0.078	7.8	0.0	2.7	0.61	6.1	0.2	2.1
13	400184	263871	Trickses Hole SSSI	0.02	3.0	20.0	0.187	**6.2**	0.1	**2.8**	0.97	**4.9**	0.4	**2.2**
14	398115	264645	Foster's Green Meadows SSSI	0.02	3.0	20.0	0.264	**8.8**	0.0	**1.4**	1.37	**6.9**	0.2	**1.1**
15	397535	265137	Foster's Green Meadows SSSI	0.02	3.0	20.0	0.082	**2.7**	0.0	0.6	0.42	**2.1**	0.1	0.5
16	399517	261519	Rookery Cottage Meadows SSSI	0.02	3.0	15.0	0.051	**1.7**	0.0	0.7	0.26	**1.8**	0.1	0.7
17	400987	260475	Wylde Moor, Feckenham SSSI	0.02	1.0	10.0	0.018	**1.8**	0.0	0.9	0.09	0.9	0.0	0.5
18	395964	264887	Pipershill Common SSSI	0.03	1.0	10.0	0.021	**2.1**	0.0	0.8	0.16	**1.6**	0.1	0.7
19	393601	266501	Upton Warren Pools SSSI	0.03	3.0	15.0	0.005	0.2	0.0	0.1	0.04	0.3	0.0	0.2
20	393890	267266	Upton Warren Pools SSSI	0.03	3.0	15.0	0.005	0.2	0.0	0.1	0.04	0.3	0.0	0.1
21	397040	271617	Burcot Lane Cutting SSSI	0.03	n/a	n/a	0.006	n/a	0.0	n/a	0.04	n/a	0.0	n/a
22	400986	268621	Hewell Park Lake SSSI	0.03	n/a	n/a	0.012	n/a	0.0	n/a	0.09	n/a	0.1	n/a
23	405110	268917	Dagnell End Meadow SSSI	0.02	3.0	15.0	0.010	0.3	0.0	0.2	0.05	0.3	0.0	0.2
24	407721	267642	Ipsley Alders Marsh SSSI	0.02	3.0	15.0	0.006	0.2	0.0	0.1	0.03	0.2	0.0	0.2
25	404814	264111	Rough Hill & Wirehill Woods SSSI	0.03	1.0	10.0	0.009	0.9	0.0	0.6	0.07	0.7	0.0	0.5
26	399805	258739	Stock Wood Meadows SSSI	0.00	3.0	20.0	0.011	0.4	0.0	0.2	0.01	0.0	0.0	0.0

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration				Maximum annual nitrogen deposition rate			
							Dairy houses		Poultry houses		Dairy houses		Poultry houses	
				Deposition Velocity	Critical Level ($\mu g/m^3$)	Critical Load (kg/ha)	PC ($\mu g/m^3$)	%age of CLe	PC ($\mu g/m^3$)	%age of CLe	PC (kg/ha)	%age of CLo	PC (kg/ha)	%age of CLo
27	398614	257602	Dormston Church Meadow SSSI	0.03	3.0	20.0	0.006	0.2	0.0	0.1	0.05	0.2	0.0	0.1
28	401367	255300	Long Meadow, Thorn SSSI	0.03	3.0	20.0	0.005	0.2	0.0	0.1	0.04	0.2	0.0	0.1
29	398614	255013	Portway Farm Meadows SSSI	0.03	3.0	20.0	0.003	0.1	0.0	0.0	0.02	0.1	0.0	0.1
30	397312	256698	Grafton Wood SSSI	0.03	1.0	15.0	0.005	0.5	0.0	0.2	0.04	0.2	0.0	0.1
31	396230	259136	Salt Meadow, Earl's Common SSSI	0.02	3.0	20.0	0.014	0.5	0.0	0.2	0.07	0.4	0.0	0.1
32	395860	258095	Rabbit Wood SSSI	0.03	1.0	15.0	0.008	0.8	0.0	0.4	0.06	0.4	0.0	0.2
33	394751	260560	Dean Brook Valley Pastures SSSI	0.03	3.0	20.0	0.012	0.4	0.0	0.2	0.09	0.5	0.0	0.2
34	392614	260341	Lower Saleway Farm Meadows SSSI	0.03	3.0	20.0	0.007	0.2	0.0	0.1	0.06	0.3	0.0	0.1
35	392943	258862	Trench Wood SSSI	0.03	1.0	15.0	0.007	0.7	0.0	0.3	0.05	0.4	0.0	0.1
36	389395	260752	Oakley Pool SSSI	0.03	3.0	15.0	0.005	0.2	0.0	0.1	0.04	0.2	0.0	0.1

Figure 6a. Process contribution to maximum annual mean ammonia concentrations – dairy houses

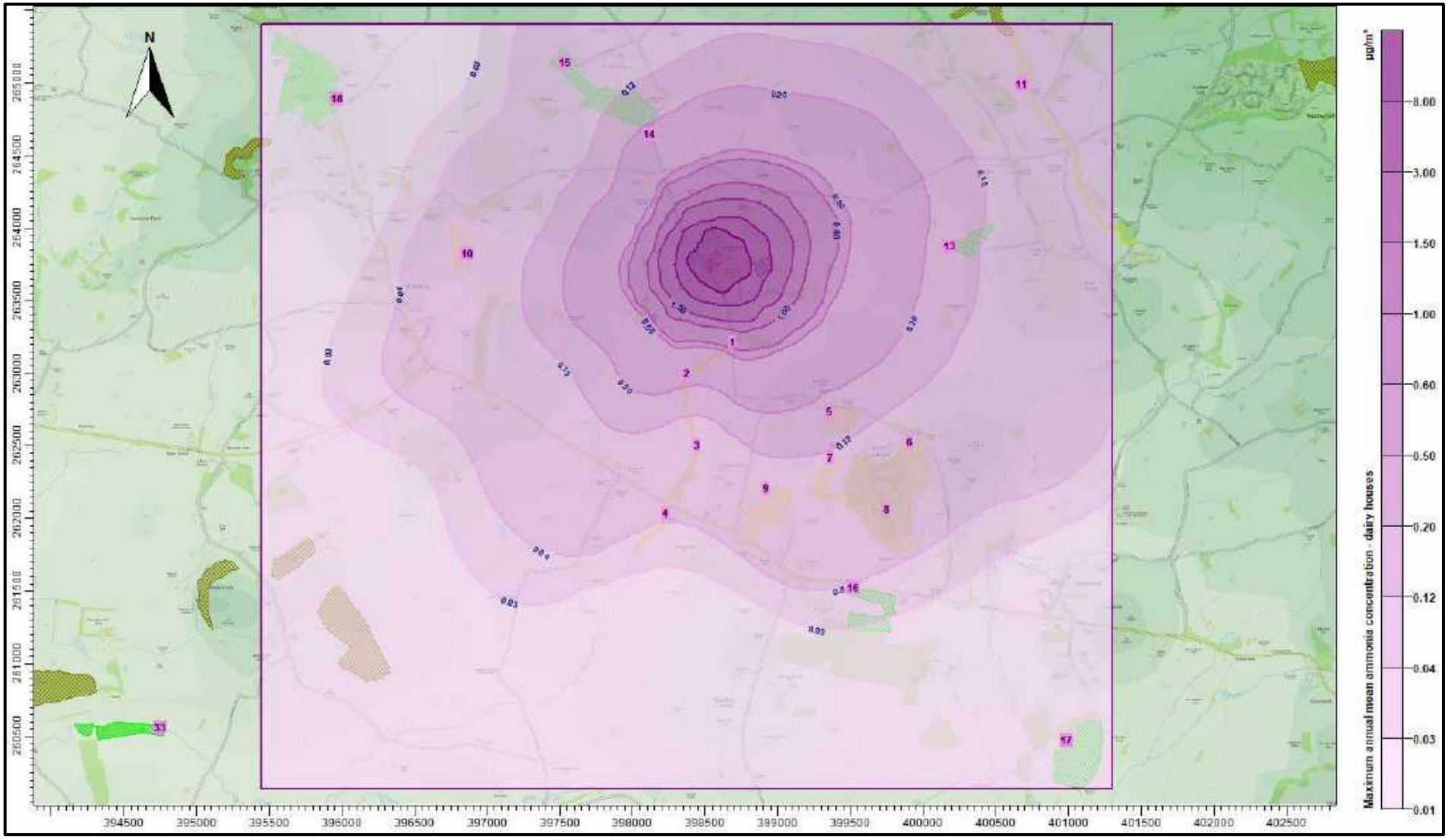


Figure 6b. Process contribution to maximum annual mean nitrogen deposition rate – dairy houses

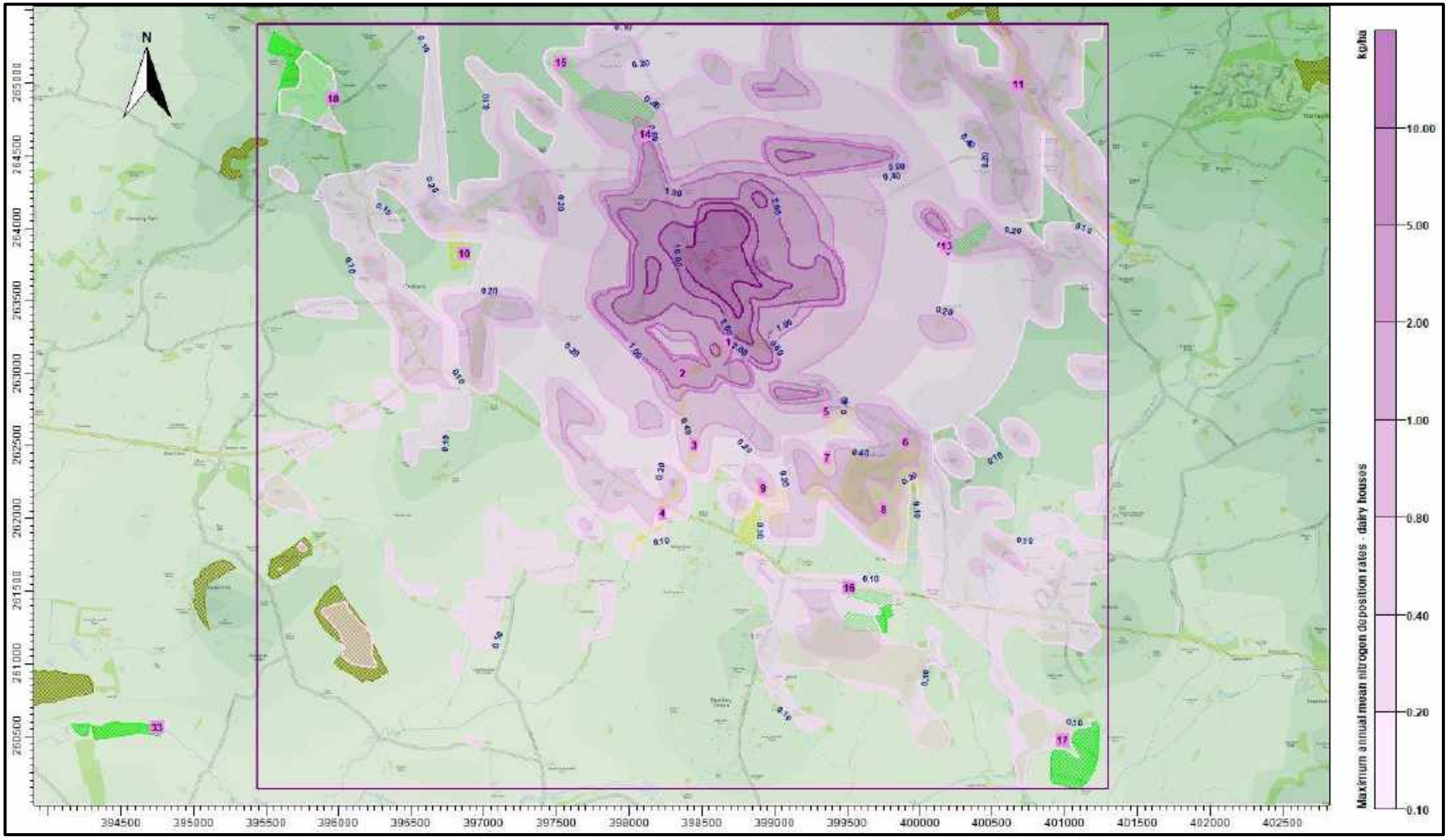


Figure 7a. Process contribution to maximum annual mean ammonia concentrations – poultry houses

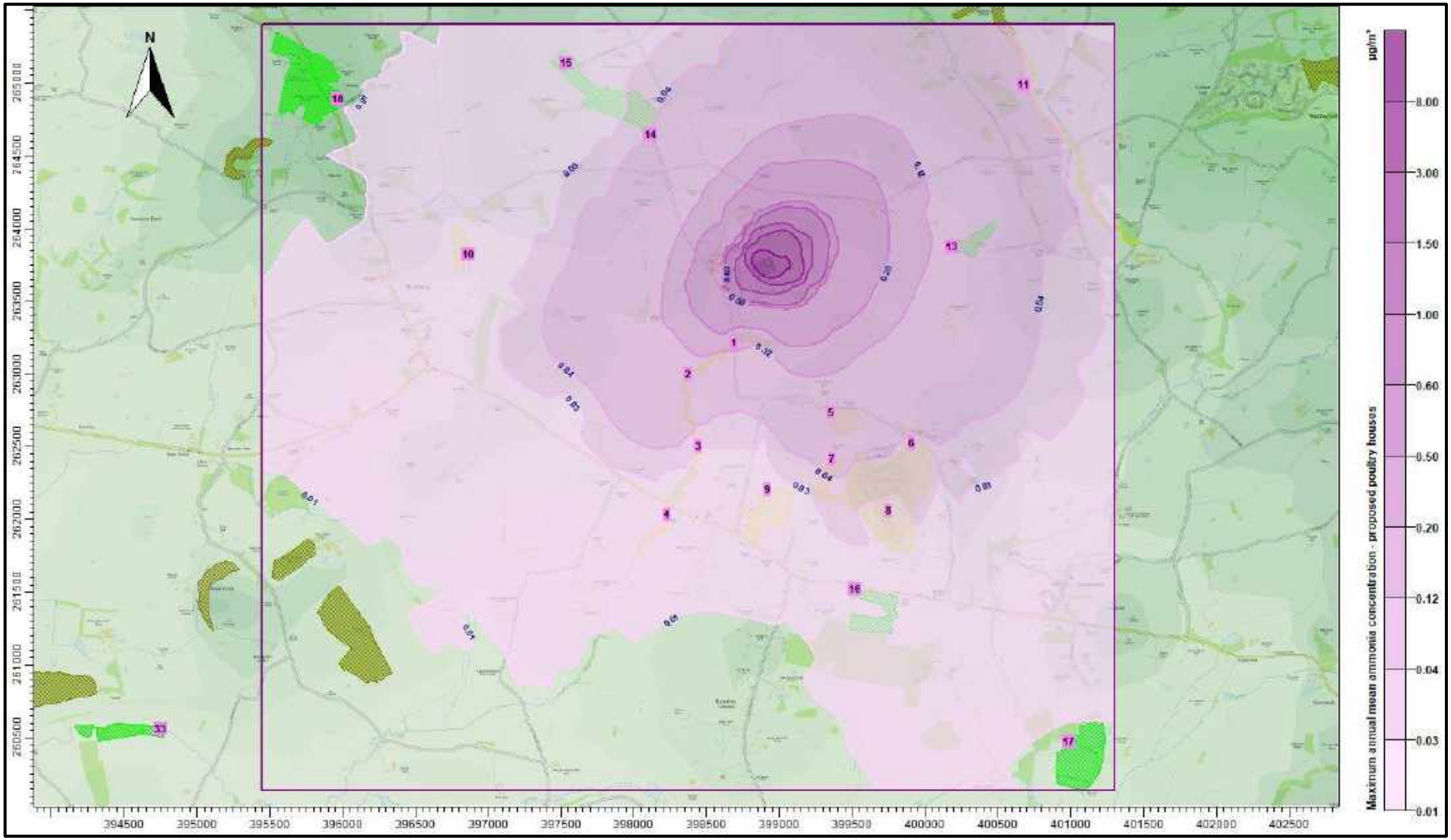
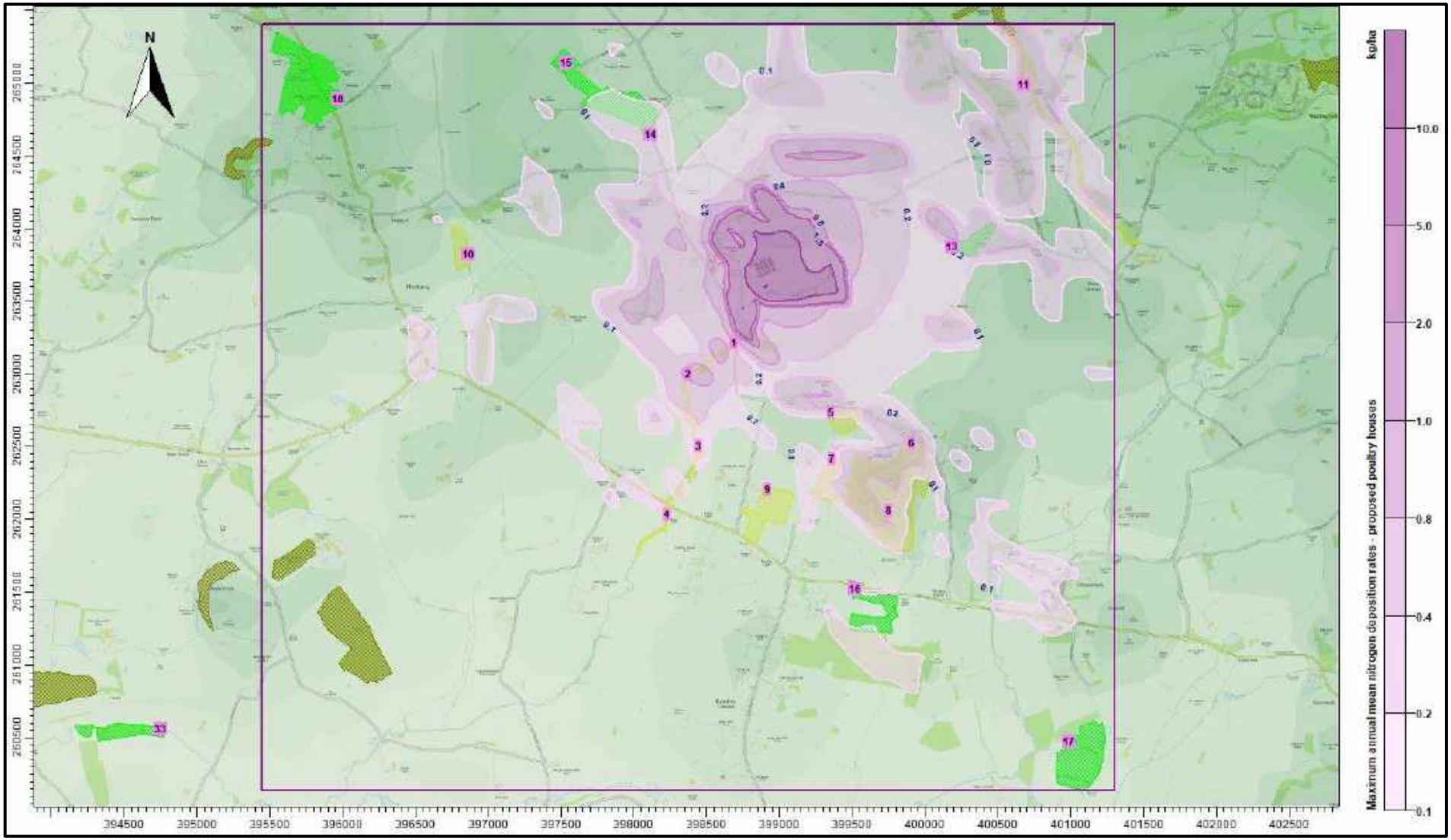


Figure 7b. Process contribution to maximum annual mean nitrogen deposition rate – poultry houses



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Mr. Ian Pick of Ian Pick Associates, on behalf of G. O. Few & Sons, to use computer modelling to assess the impact of ammonia emissions from the dairy farm and the proposed broiler chicken rearing houses at Ditchford Bank Farm, Hanbury, Bromsgrove, Worcestershire. B60 4HS.

Ammonia emission rates from the dairy farm have been assessed and quantified based upon figures obtained from "Ammonia emission factors for UK agriculture", Misselbrook, et al. Ammonia emission rates from the proposed poultry houses have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors. The ammonia emission rates have then been used as inputs to an atmospheric dispersion and deposition model which calculates ammonia exposure levels and nitrogen and acid deposition rates in the surrounding area.

The modelling predicts that:

- At all of the SSSIs, the process contributions of both the dairy houses and the proposed poultry houses to annual mean ammonia concentrations and nitrogen deposition rates would be well below the Environment Agency's lower threshold percentage (20% for SSSIs) of the Critical Level and Critical Load.

- At all of the LWSs and the AW, the process contributions of both the dairy houses and the proposed poultry houses to annual mean ammonia concentrations and nitrogen deposition rates would be below the Environment Agency's lower threshold percentage (100% for non-statutory sites) of the Critical Level and Critical Load.

- The process contribution of the dairy houses to annual mean ammonia concentrations and nitrogen deposition rates is predicted to exceed 4% of the relevant Critical Level and Critical Load over parts of Trickses Hole SSSI and Foster's Green Meadows SSSI.

- In addition, the process contributions of the dairy houses to ammonia concentrations and nitrogen deposition rates is predicted to exceed 1% of the relevant Critical Level and Critical Load at Rookery Cottage Meadows SSSI, Wylde Moor, Feckenham SSSI and Pipershill Common SSSI.

- The process contribution by the proposed poultry houses to annual mean ammonia concentration would exceed 1% of the Critical Level and the Critical Load at Trickses Hole SSSI and Foster's Green Meadows SSSI.

- At all other SSSIs included in the modelling, the process contribution of both the dairy houses and the proposed poultry houses to annual mean ammonia concentrations and nitrogen deposition rates is below 1% of the relevant Critical Level or Critical Load.

- Should the proposed changes be undertaken and poultry rearing replace dairy farming at Ditchford Bank Farm, at all of the discrete receptors included in the modelling there would be a reduction in the process contribution to ammonia concentrations and nitrogen deposition rates.

7. References

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Environment Agency H1 Risk Assessment (website).

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Misselbrook, et al. Ammonia emission factors for UK agriculture.

United Nations Economic Commission for Europe (UNECE) (website).

UK Air Pollution Information System (APIS) (website).