A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Proposed Egg Laying Chicken Houses at Methwold Airfield Poultry Unit, off Brandon Road, near Methwold in Norfolk

Prepared by Steve Smith

AS Modelling & Data Ltd.

Email: stevesmith@asmodata.co.uk

Telephone: 01952 462500

12th August 2019

1. Introduction

AS Modelling & Data Ltd. has been instructed by Annyalla Chicks Limited and I.P.T. Technology Limited, to use computer modelling to assess the impact of ammonia emissions from the proposed egg laying chicken houses at Methwold Airfield Poultry Unit, off Brandon Road, near Methwold in Norfolk. IP26 4DU.

Ammonia emission rates from the proposed poultry houses have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors and calculations based upon guaranteed outlet ammonia concentrations from the ammonia scrubbing systems that would be fitted to the poultry houses and known ventilation rates of egg laying chicken houses. The ammonia emission rates so obtained have then been used as inputs to an atmospheric dispersion and deposition model which calculates ammonia exposure levels and nitrogen deposition rates in the surrounding area.

This report is arranged in the following manner:

- Section 2 provides relevant details of the farm and potentially sensitive receptors in the area.
- Section 3 provides some general information on ammonia; details of the method used to estimate ammonia emissions, relevant guidelines and legislation on exposure limits and where relevant, details of likely background levels of ammonia.
- Section 4 provides some information about ADMS, the dispersion model used for this study and details the modelling procedure.
- Section 5 contains the results of the modelling.
- Section 6 provides a discussion of the results and conclusions.

2. Background Details

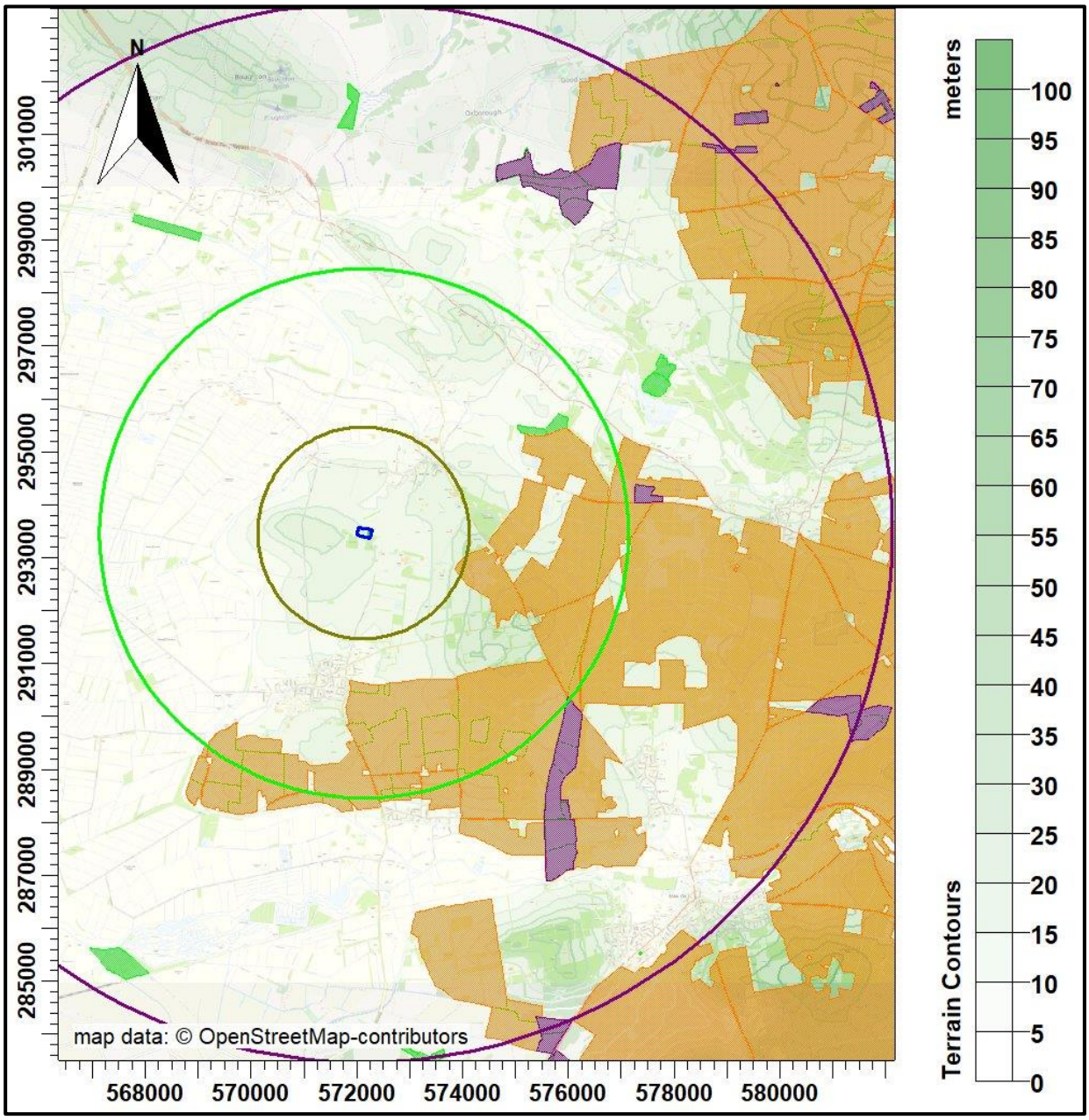
The site of the proposed egg laying chicken houses at Methwold Airfield is in a rural area, approximately 1.1 km to the south-south-west of the village of Methwold in Norfolk. The surrounding land is used largely for arable farming, although there are other intensive poultry and pig rearing sites and extensive wooded areas and some semi-natural grasslands and heathland in the Breckland Forest and The Brecklands to the east. The site is at an altitude of around 15 m with the land rising towards slightly higher ground to the south-west and falling towards Methwold and the fens to the north.

There is currently permission for six broiler chicken rearing houses at Methwold Airfield Poultry Unit, which are permitted to stock up to 300,000 broiler chickens. It is proposed that, rather than 300,000 broiler chickens, the poultry rearing houses be used to house up to 80,000 chickens, the majority of which would be egg laying chickens with a small proportion of cockerels. The hens (and cockerels) would produce fertilised eggs which would be transferred to hatcheries elsewhere. Ventilation for the houses, as currently permitted, is provided by uncapped high speed ridge/roof mounted fans, each with a short chimney with gable end fans to provide supplementary ventilation in hot weather conditions. Under the proposal, to mitigate against an anticipated increase in ammonia emissions (over those produced by 300,000 broiler chickens), the poultry houses would be fitted with ammonia scrubbing equipment, which would be capable of providing all normal ventilation requirements with guaranteed outlet concentrations of 2 ppm, or less, of ammonia. The currently permitted ventilation systems would be retained for use in exceptional circumstances only; that is, very hot weather, or failure of the scrubber systems.

There are no areas of Ancient Woodland (AW) within 2 km of the site of the proposed poultry houses and AS Modelling & Data have not identified any Local Wildlife Sites (LWSs) within 2 km of the site. Parts of the Breckland Forest Site of Special Scientific Interest (SSSI), which is also designated as a Special Protection Area (SPA), are within 2 km of the site. There are four other SSSIs within 5 km of Methwold Airfield Poultry Unit: Breckland Farmland SSSI; The Brinks Northwold SSSI, Weeting Heath SSSI and Cranwich Camp SSSI, of these, Weeting Heath SSSI and Cranwich Camp SSSI are also designated as part of the Breckland Special Area of Conservation (SAC). Other parts of the Breckland Forest SPA and the Breckland SAC are within 10 km of the site of the proposed poultry unit and there are also parts of The Norfolk Valley Fens SAC within 10 km.

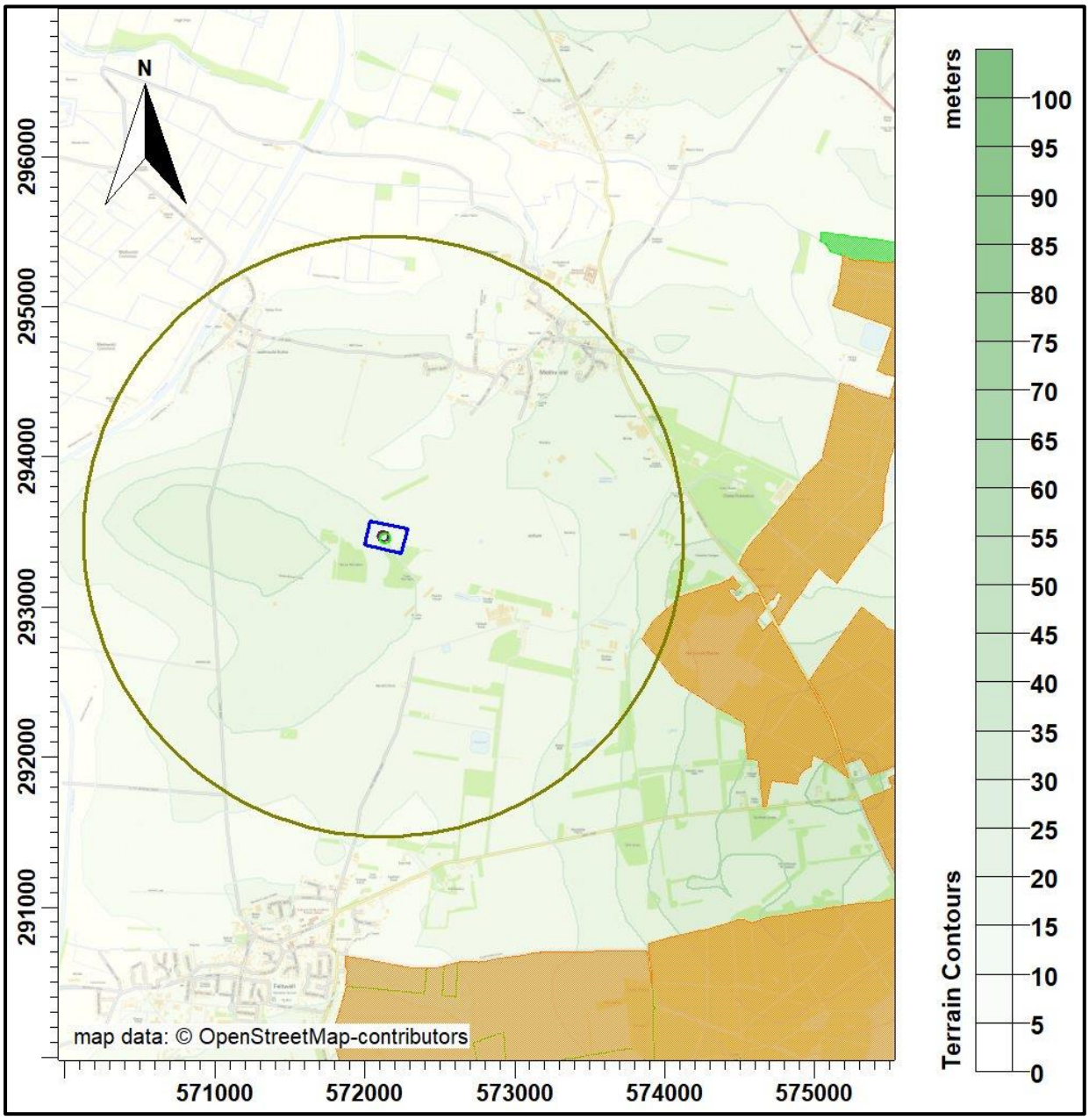
Maps of the surrounding area showing the positions of the poultry unit, the AW, the LWSs, the SSSIs, the SPA and the SAC are provided in Figures 1a and 1b. In these figures; the SSSI is shaded green the SSSIs/SPAs are shaded in orange, the SSSIs/SACs are shaded in purple and the site of the proposed poultry rearing houses is outlined in blue.

Figure 1a. The area surrounding the site, a broad scale view, with concentric circles radii 10 km (purple), 5 km (green) and 2 km (olive)



© Crown copyright and database rights. 2019.

Figure 1b. The area surrounding the site, a closer view focussing on the non-statutory sites, with concentric circle radius 2 km (olive)



© Crown copyright and database rights. 2019.

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 Methwold Airfield and the wildlife sites is 3.27 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 43.82 kg-N/ha/y and to short vegetation is 25.20 kg-N/ha/y. The background acid deposition rate to woodland is 3.11 keq/ha/y and to short vegetation is 1.84 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS, August 2019).

3.3 Critical Levels & Critical Loads

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

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

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

For ammonia concentration in air, the Critical Level for higher plants is 3.0 µg-NH_3/m^3 as an annual mean. For sites where there are sensitive lichens and bryophytes present, or where lichens and bryophytes are an integral part of the ecosystem, the Critical Level is 1.0 µg-NH_3/m^3 as an annual mean.

Critical Loads for nutrient nitrogen are set under the Convention on Long-Range Transboundary Air Pollution. They are based on empirical evidence, mainly observations from experiments and gradient studies. Critical Loads are given as ranges (e.g. 10-20 kg-N/ha/y); these ranges reflect variation in ecosystem response across Europe.

The Critical Levels and Critical Loads at the wildlife sites assumed in this study are provided in Table 1. N.B. Where the Critical Level of 1.0 µg-NH_3/m^3 is assumed, it is usually unnecessary to consider the Critical Load as the Critical Level provides the stricter test. However, it may be necessary to consider nitrogen deposition should a Critical Load of 5.0 kg-N/ha/y be appropriate. Normally, the Critical Load for nitrogen deposition provides a stricter test than the Critical Load for acid deposition.

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

Site	Critical Level (µg-NH_3/m^3)	Critical Load Nitrogen Deposition (kg-N/ha/y)	Critical Load Acid Deposition (keq/ha/y)
Breckland Forest SSSI/SPA	3.0 [2]	10.0 [2]	0.563 [2]
Breckland Farmland SSSI/SPA	n/a [3]	n/a [3]	n/a [3]
The Brinks Northwold SSSI	3.0 [2]	15.0 [2]	4.856 [2]
Didlington Parks Lake SSSI	3.0 [2]	n/a [3]	n/a [3]
Breckland SAC	1.0 [1 & 2]	8.0 [2]	0.688 [2]
Norfolk Valley Fens SAC	1.0 [1 & 2]	10.0 [2]	0.688 [2]

1. A precautionary figure used where no details of the ecology of the site are available, or have not been considered, or the citation for the site contains reference to sensitive lichens and/or bryophytes.
2. Based upon the citation for the site and information from APIS.
3. Designated for arable farmland/waterbodies and/or avian species, which are not assigned a Critical Level and/or Critical Load.

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, for developments which fall outside of Environment Agency permitting, if predicted process contributions exceed 4%[1] of Critical Level or Critical Load at a SSSI, or 1% of Critical Level or Critical Load at a SAC, SPA or Ramsar site, then the local authority should consider the sensitivities of the wildlife sites and whether other farming installations might act in-combination with the farm.

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.

1. Natural England may now be applying a threshold of 1% for all statutory sites, including SSSIs. However, AS Modelling & Data Ltd. have been unable to confirm this.

3.5 IAQM Position Statement on the use of the 1% criterion

A Position Statement issued by the Institute of Air Quality Management (IAQM) in January 2016 further clarifies the use of the 1% criterion for the determination of an '*insignificant*' effect of air quality impacts on sensitive habitats. The Position Statement states: "*the use of a criterion of 1% of an environmental standard or assessment level in the context of habitats should be used only to screen out impacts that will have an insignificant effect. It should not be used as a threshold above which damage is implied.*" Furthermore, if the impacts are plainly above 1% then this should be regarded as potentially significant; where impacts are just slightly greater than 1% then a degree of professional judgement should be applied with regards to the theoretical risk.

3.6 Quantification of ammonia emissions

Ammonia emission rates from poultry houses 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.

3.6.1 Unabated emissions

The Environment Agency provided an Intensive farming guidance note which lists standard ammonia emission factors for a variety of livestock, including broiler chickens. The emission factor for egg laying chickens on a flat deck/deep litter system is 0.21 kg-NH_3/bird place/y; this figure is used to calculate the unabated emissions from the proposed poultry houses.

3.6.1 Abated emissions

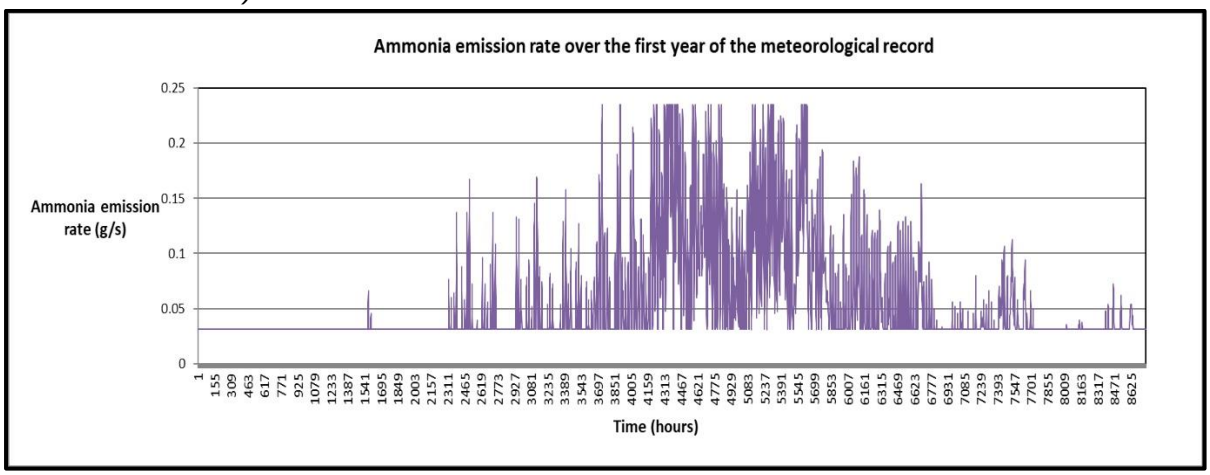
For the calculation of the emission rates from the scrubbers, the outlet ammonia concentration is assumed to be a constant 2 ppm (1,408.8 µg/m^3). This figure is based upon the guaranteed maximum outlet concentration from the manufacturers of the ammonia scrubbing equipment.

The ventilation rates used in the calculations are based on industry standard practices. For the calculations, the minimum ventilation rate is set at 1.0 m^3-air/bird/h and the maximum ventilation rate is 7.5 m^3-air/bird/h. If the external temperature is 13 Celsius, or lower, minimum ventilation only is assumed for the calculation. If the external temperature is 23 Celsius, or more, then the maximum ventilation rate is assumed. A transitional ventilation rate is calculated between these extremes.

For the poultry house at Methwold Airfield, each housing 13,333 birds, the minimum ventilation rate is 3.7 m^3/s (13,333 m^3/h) and the maximum ventilation rate is 27.8 m^3/s (100,000 m^3/h).

Based upon these principles, an ammonia emission rate for each hour of the period modelled is calculated by multiplying the outlet concentration by the ventilation rate. As an example, a graph of the calculated emission rates over the first year of the meteorological record is shown in Figure 2. The emissions (over 4 years of the meteorological record) are equivalent to an emission factor of 0.024 kg-NH_3/bird place/y.

Figure 2. Total ammonia emission rate over the first year of the meteorological record (from all scrubbers combined)



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

- Calm periods in traditional records may be over represented because the instrumentation used may not record wind speed 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 because 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 Methwold Airfield is shown in Figure 3b; it should be noted that elsewhere in the modelling domain the modified wind roses may differ more markedly, reflecting the local flow in that part of the domain. The resolution of the wind field in terrain runs is approximately 380 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 3a. The wind rose. Raw GFS derived data for 52.511 N, 0.535 E, 2015-2018

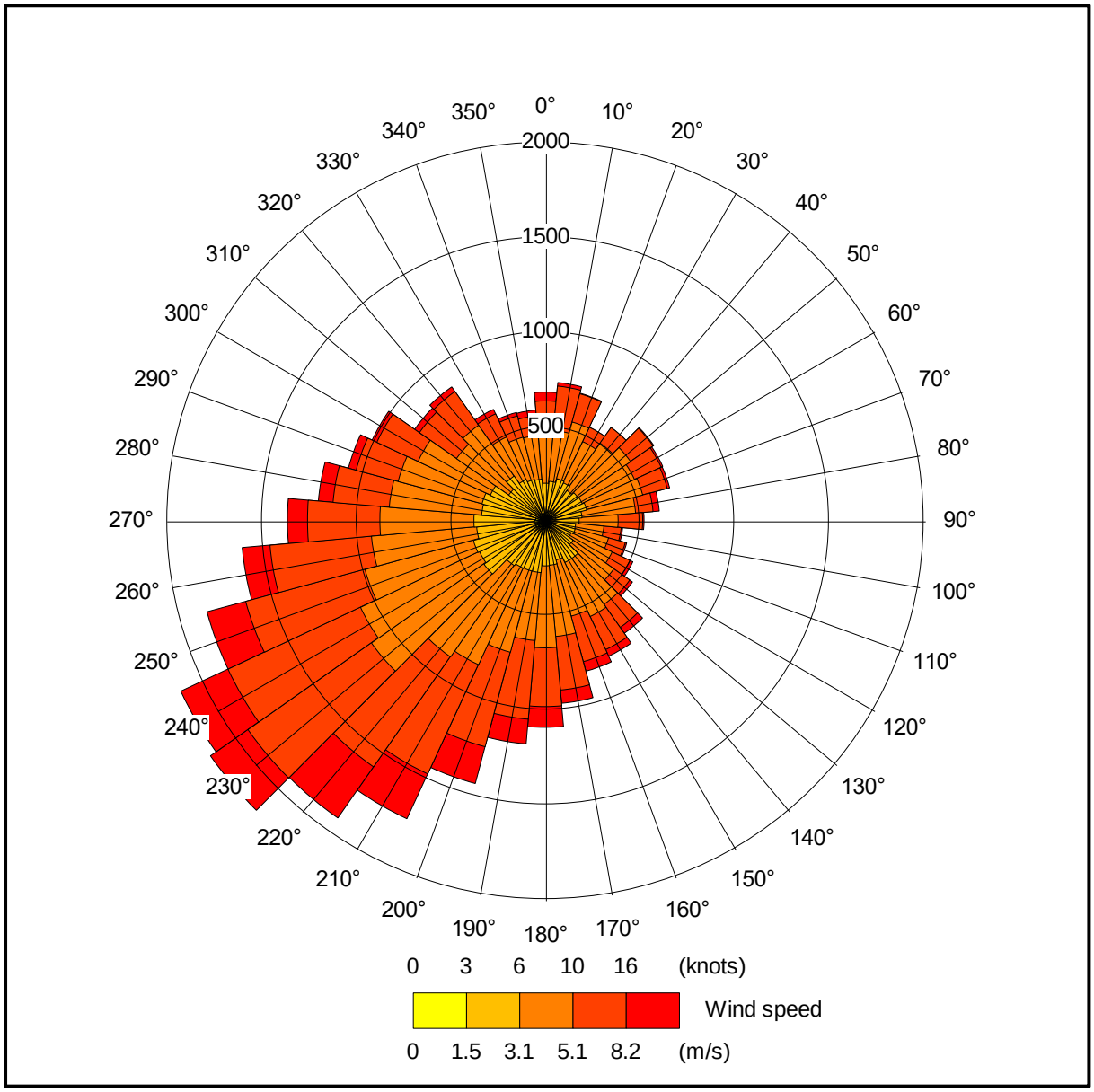
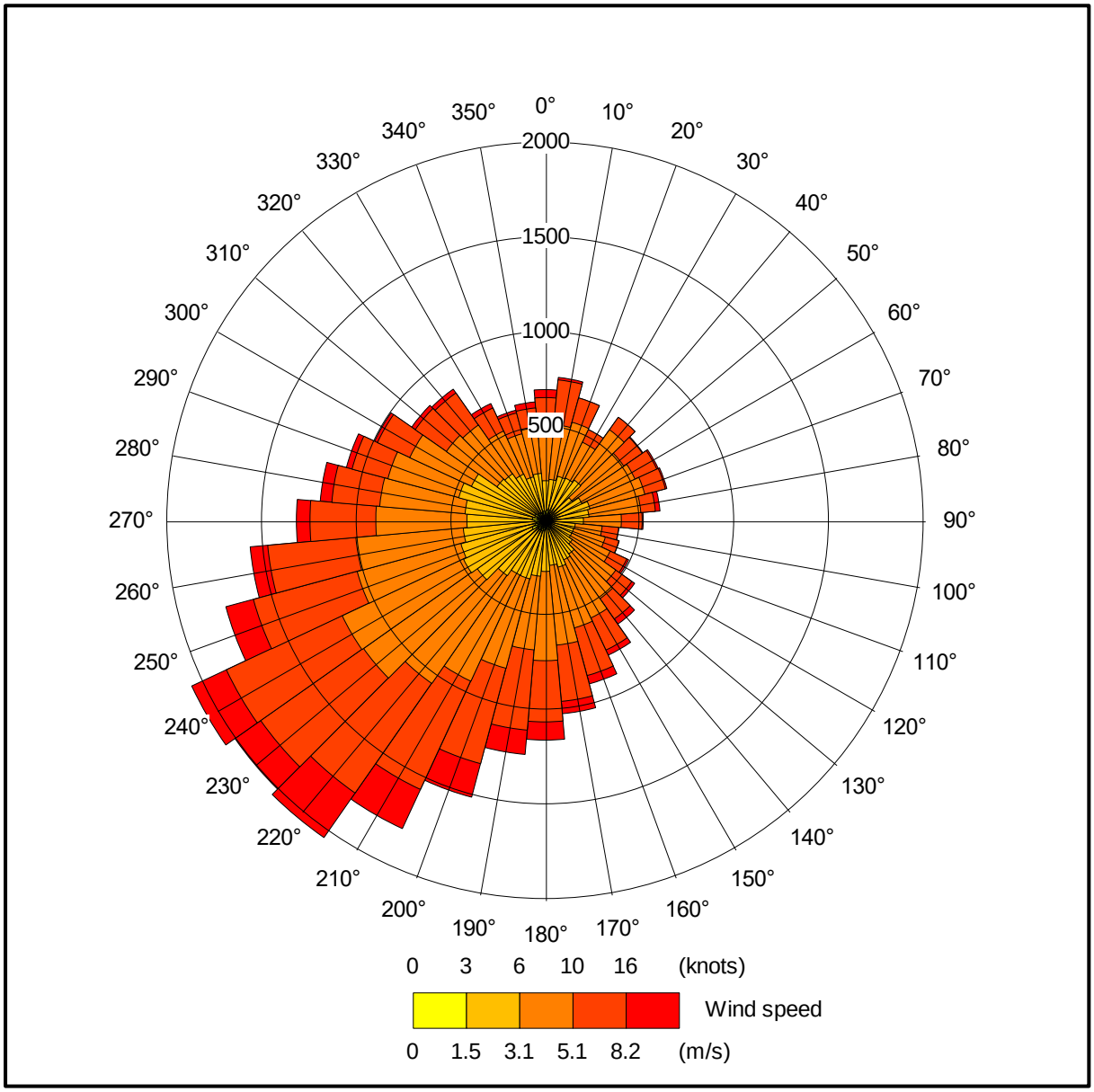


Figure 3b. The wind rose. FLOWSTAR modified GFS derived data for NGR 572100, 293450



4.2 Emission sources

Emissions from the chimneys of the scrubber units are represented by a single point sources per scrubber within ADMS (PR1 to PR6). The uncapped high speed ridge or roof fans that would be used for emergency ventilation of the proposed houses are represented by three point sources per house within ADMS (PR1_STAN 1, 2 & 3 to PR6_STAN 1, 2 & 3). Details of the point source parameters are shown in Table 4 and their positions may be seen in Figure 4, where they are marked by red star symbols.

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)
PR1 to PR6	6.5	0.8	11.0	Variable [1]	Variable [1]
PR1_STAN to PR6_STAN 1, 2 & 3	6.5	0.8	11.0	22.0	0.029576

1. Dependent on ambient temperature.

4.3 Modelled buildings

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

4.4 Discrete receptors

Forty-five discrete receptors have been defined at the SSSIs/SACs/SPAs. These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figures 5a and 5b, where they are marked by enumerated pink rectangles.

4.5 Cartesian grid

To produce the contour plots presented in Section 5 of this report and to define the spatially varying deposition velocity field, 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 Figures 5a and 5b, where it is marked by grey lines.

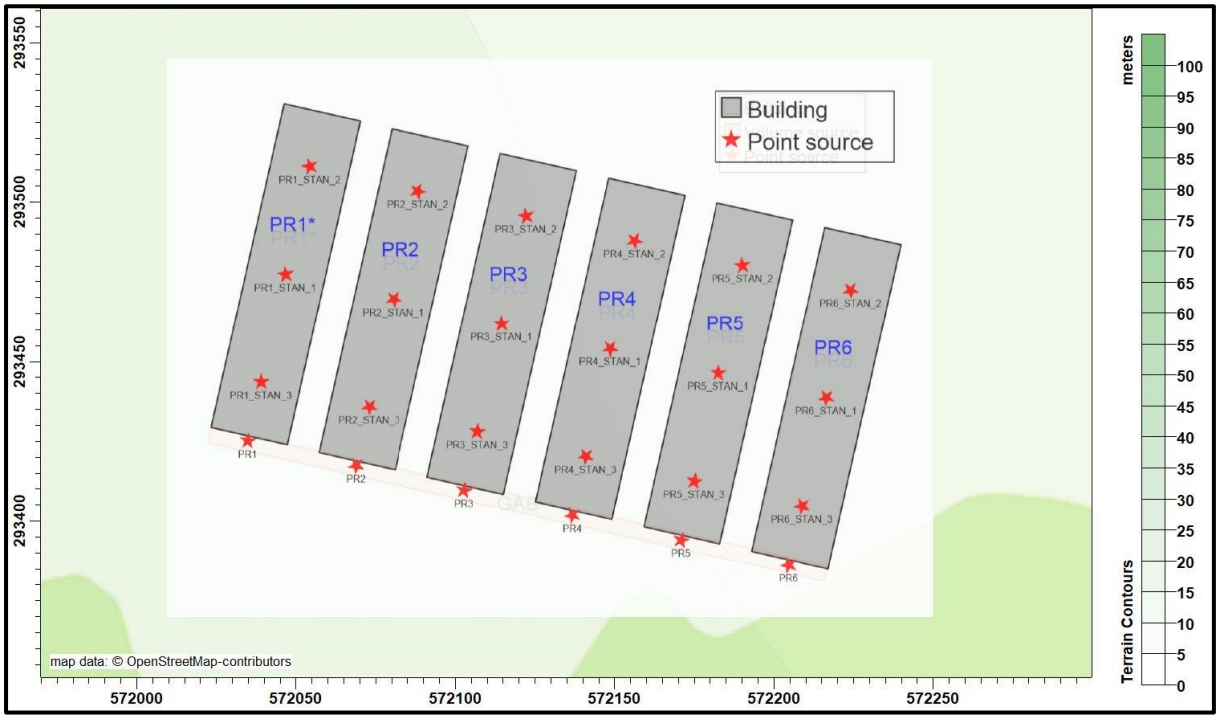
4.6 Terrain data

Terrain has been considered in the modelling. The terrain data are based upon the Ordnance Survey 50 m Digital Elevation Model. A 25.0 km x 25.0 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 380 m.

4.7 Roughness Length

A fixed surface roughness length of 0.3 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.

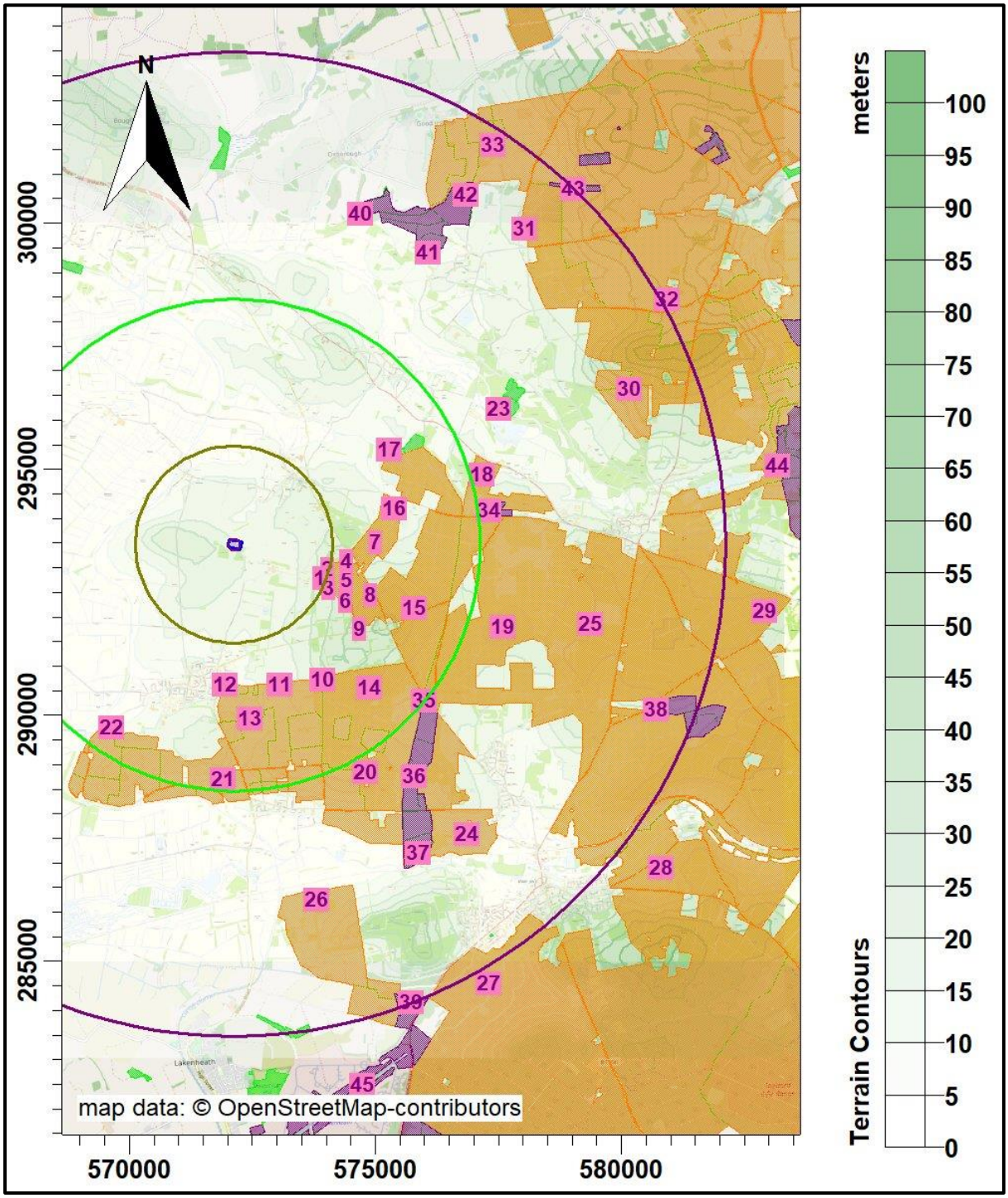
Figure 4. The positions of modelled buildings and sources



© Crown copyright and database rights. 2019.

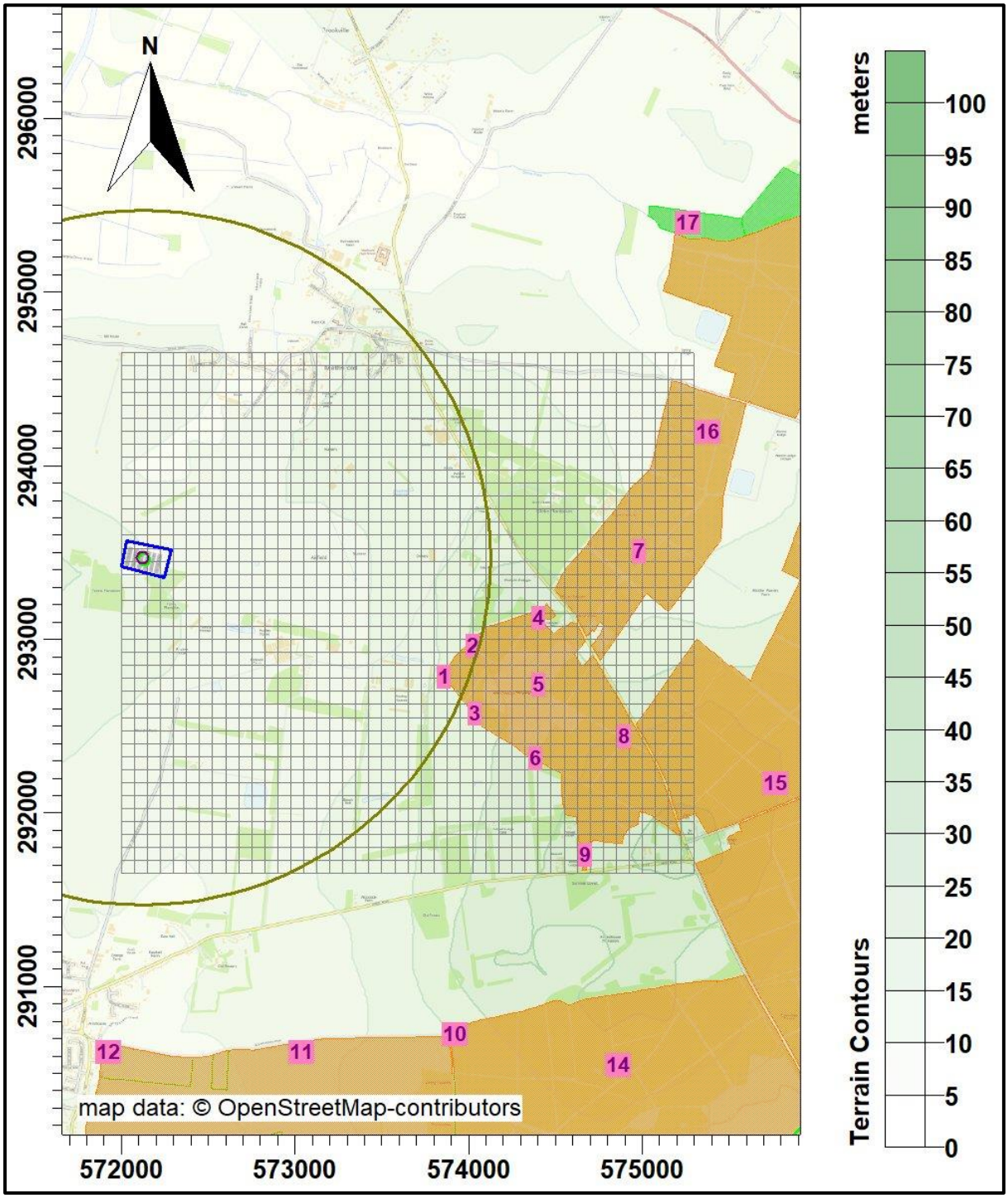
.

Figure 5a. The discrete receptors and regular Cartesian grid, a broad scale view



© Crown copyright and database rights. 2019.

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



© Crown copyright and database rights. 2019.

4.8 Deposition

The method used to model deposition of ammonia and consequent plume depletion is based on a document titled "Guidance on modelling the concentration and deposition of ammonia emitted from intensive farming" from the Environment Agency's Air Quality Modelling and Assessment Unit, 22 November 2010. N.B. AS Modelling & Data Ltd. has restricted deposition over arable farmland and heavily grazed and fertilised pasture; this is to compensate for possible saturation effects due to fertilizer application and to allow for periods when fields are clear of crops (Sutton), the deposition is also restricted over areas with little or no vegetation and the deposition velocity is set to 0.002 m/s where grid points are over the poultry housing and 0.010 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

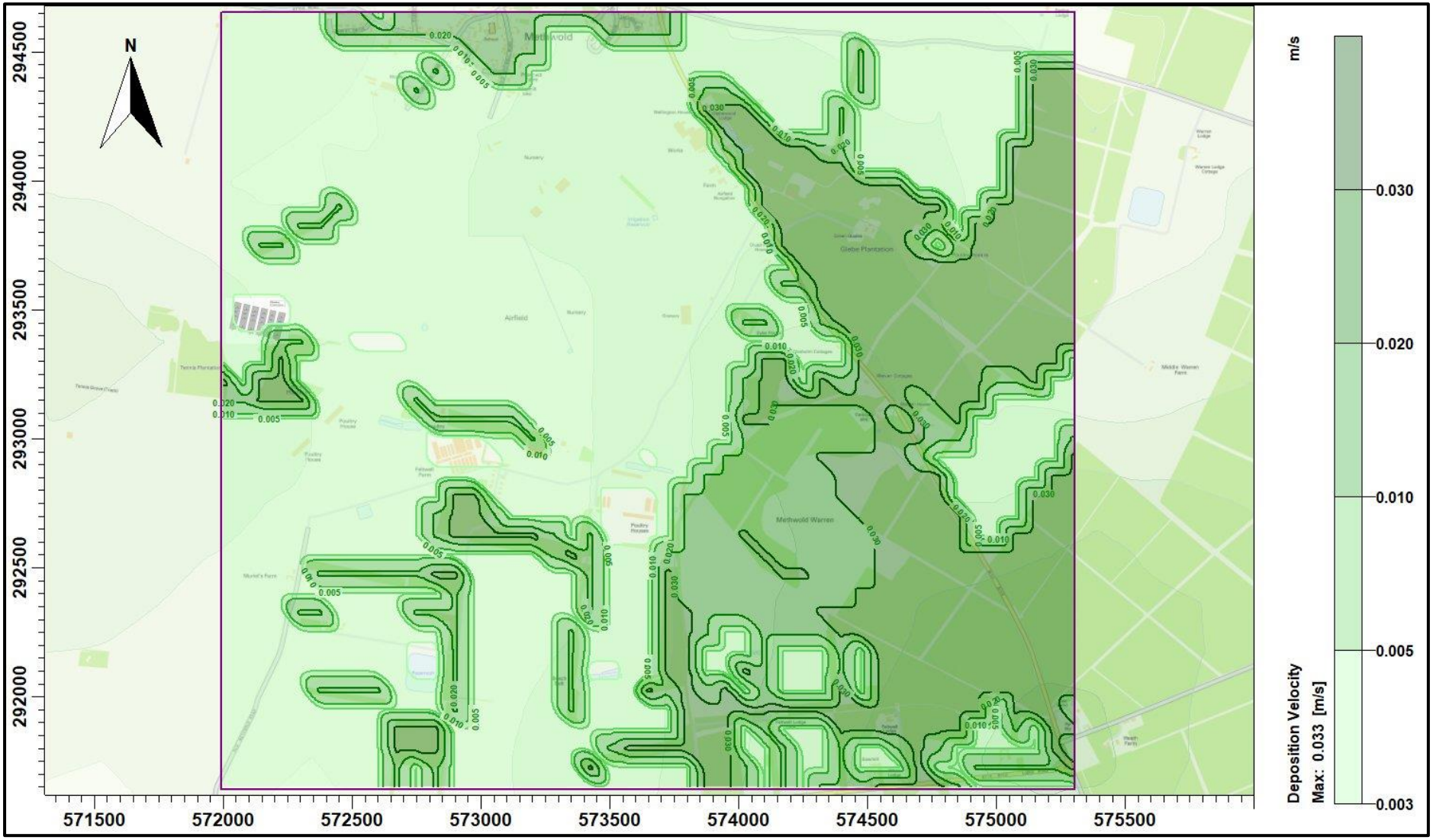
NH_3 concentration (PC + background) (µg/m³)	< 10	10 - 20	20 - 30	30 – 80	> 80
Deposition velocity – woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity – short vegetation (m/s)	0.02 (0.010 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity – arable farmland/rye grass (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, in this case, as part of the preliminary modelling, 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 deposition were modelled explicitly as Environment Agency guidance, particularly where there is some distance between the source and a receptor.

Figure 6. The spatially varying deposition field



© Crown copyright and database rights. 2019.

5. Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

ADMS was run a total of sixteen times, once for each year of the meteorological record 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.

Four scenarios were run:

- Scenario 1 - All emissions unabated from the standard ridge mounted fans/chimneys.
- Scenario 2 - All emissions abated to 2 ppm from the scrubber stacks.
- Scenario 3 - Unabated emissions from the standard ridge mounted fans/chimneys of one of the houses and abated emissions from the scrubber stacks of five of the houses.
- Scenario 4 - Unabated emissions from the standard ridge mounted fans/chimneys of two of the houses and abated emissions from the scrubber stacks of four of the houses.

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

Details of the predicted annual mean ammonia concentrations at each receptor are provided in Table 4. In the Table, predicted ammonia concentrations (or concentrations 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 (20% for a SAC/SPA and 50% for a SSSI) are coloured red. Predicted ammonia concentrations (or concentrations equivalent to nitrogen deposition rates) that are in the range between the Environment Agency's upper threshold and lower threshold of the relevant Critical Level or Critical Load (4% and 20% for a SAC/SPA and 20% and 50% for a SSSI) are coloured blue. Additionally, predicted ammonia concentrations and nitrogen deposition rates that exceed the Natural England advisory criterion, (4% of the relevant Critical Level or Critical Load for a SSSI and 1% of Critical Level or Critical Load for a SAC/SPA) are highlighted with bold text.

Table 4. Predicted maximum annual mean ammonia concentration at the discrete receptors

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)															
				All Standard Ventilation				Scrubbers on 4 houses				Scrubbers on 5 houses				All Scrubbers			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s
1	573858	292785	Breckland Forest SPA	0.146	0.146	0.143	0.117	0.057	0.057	0.056	0.045	0.035	0.035	0.035	0.028	0.014	0.014	0.014	0.011
2	574022	292960	Breckland Forest SPA	0.140	0.140	0.134	0.111	0.054	0.054	0.052	0.043	0.033	0.033	0.032	0.026	0.013	0.013	0.012	0.010
3	574033	292573	Breckland Forest SPA	0.116	0.116	0.114	0.091	0.046	0.045	0.045	0.035	0.028	0.028	0.028	0.022	0.011	0.011	0.011	0.008
4	574404	293119	Breckland Forest SPA	0.111	0.111	0.105	0.086	0.043	0.043	0.041	0.033	0.026	0.026	0.025	0.020	0.010	0.010	0.009	0.008
5	574404	292737	Breckland Forest SPA	0.103	0.102	0.098	0.079	0.040	0.040	0.038	0.031	0.025	0.025	0.024	0.019	0.010	0.010	0.009	0.007
6	574382	292313	Breckland Forest SPA	0.086	0.086	0.083	0.065	0.034	0.034	0.033	0.025	0.021	0.021	0.020	0.016	0.008	0.008	0.008	0.006
7	574981	293506	Breckland Forest SPA	0.087	0.087	0.082	0.065	0.034	0.034	0.032	0.025	0.021	0.021	0.020	0.016	0.008	0.008	0.007	0.006
8	574891	292440	Breckland Forest SPA	0.074	0.074	0.070	0.054	0.029	0.029	0.028	0.021	0.018	0.018	0.017	0.013	0.007	0.007	0.007	0.005
9	574669	291757	Breckland Forest SPA	0.059	0.059	0.058	0.043	0.023	0.023	0.023	0.017	0.015	0.015	0.015	0.010	0.006	0.006	0.006	0.004
10	573913	290723	Breckland Forest SPA	0.040	0.040	0.041	0.029	0.016	0.016	0.017	0.011	0.010	0.010	0.010	0.007	0.004	0.004	0.004	0.003
11	573031	290620	Breckland Farmland SPA	0.048	0.048	0.047	0.031	0.019	0.019	0.019	0.012	0.013	0.013	0.013	0.008	0.006	0.006	0.006	0.004
12	571918	290620	Breckland Farmland SPA	0.066	0.065	0.069	0.046	0.026	0.026	0.027	0.018	0.016	0.016	0.017	0.012	0.007	0.007	0.007	0.005
13	572439	289925	Breckland Farmland SPA	0.046	0.046	0.048	0.031	0.018	0.018	0.019	0.012	0.011	0.011	0.012	0.008	0.005	0.005	0.005	0.003
14	574859	290545	Breckland Forest SPA	0.036	0.036	0.037	0.024	0.015	0.015	0.015	0.010	0.009	0.009	0.009	0.006	0.004	0.004	0.004	0.002
15	575766	292166	Breckland Forest SPA	0.049	0.049	0.046	0.034	0.020	0.020	0.018	0.014	0.012	0.012	0.011	0.008	0.005	0.005	0.005	0.003
16	575372	294193	Breckland Forest SPA	0.075	0.075	0.072	0.057	0.029	0.029	0.028	0.022	0.018	0.018	0.017	0.014	0.007	0.007	0.007	0.005
17	575259	295397	The Brinks Northwold SSSI	0.075	0.075	0.077	0.054	0.031	0.031	0.031	0.021	0.020	0.020	0.020	0.014	0.009	0.009	0.009	0.007
18	577143	294879	Breckland Forest SPA	0.039	0.039	0.038	0.028	0.015	0.015	0.015	0.011	0.010	0.010	0.009	0.007	0.004	0.004	0.004	0.003
19	577560	291785	Breckland Forest SPA	0.028	0.028	0.026	0.019	0.011	0.011	0.010	0.007	0.007	0.007	0.007	0.005	0.003	0.003	0.003	0.002
20	574788	288828	Breckland Forest SPA	0.020	0.020	0.020	0.013	0.008	0.008	0.008	0.005	0.005	0.005	0.005	0.003	0.002	0.002	0.002	0.001
21	571890	288685	Breckland Farmland SPA	0.034	0.034	0.035	0.021	0.013	0.013	0.014	0.008	0.008	0.008	0.008	0.005	0.003	0.003	0.003	0.002
22	569619	289740	Breckland Farmland SPA	0.029	0.030	0.030	0.020	0.012	0.012	0.012	0.008	0.007	0.007	0.007	0.005	0.003	0.003	0.003	0.002

Table 4. (continued)

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)															
				Standard Ventilation				Scrubbers on 4 houses				Scrubbers on 5 houses				All Sceubbers			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s
23	577489	296223	Didlington Parks Lake SSSI	0.038	0.038	0.038	0.024	0.015	0.016	0.016	0.010	0.010	0.010	0.010	0.006	0.004	0.004	0.004	0.003
24	576845	287576	Breckland Forest SPA	**0.014**	**0.014**	**0.015**	0.009	0.006	0.006	0.006	0.003	0.004	0.004	0.004	0.002	0.001	0.002	0.002	0.001
25	579349	291850	Breckland Forest SPA	**0.020**	**0.020**	**0.018**	**0.013**	0.008	0.008	0.007	0.005	0.005	0.005	0.004	0.003	0.002	0.002	0.002	0.001
26	573786	286243	Breckland Farmland SPA	0.016	0.016	0.017	0.009	0.006	0.007	0.007	0.004	0.004	0.004	0.004	0.002	0.002	0.002	0.002	0.001
27	577287	284553	Breckland Forest SPA	0.008	0.008	0.009	0.005	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.000
28	580788	286887	Breckland Forest SPA	**0.011**	**0.011**	**0.011**	0.006	0.004	0.004	0.005	0.002	0.003	0.003	0.003	0.001	0.001	0.001	0.001	0.001
29	582881	292118	Breckland Forest SPA	**0.012**	**0.012**	**0.011**	0.007	0.005	0.005	0.004	0.003	0.003	0.003	0.003	0.002	0.001	0.001	0.001	0.001
30	580145	296626	Breckland Forest SPA	**0.022**	**0.022**	**0.021**	**0.013**	0.009	0.009	0.008	0.005	0.006	0.006	0.005	0.003	0.002	0.002	0.002	0.001
31	578012	299885	Breckland Forest SPA	**0.017**	**0.017**	**0.018**	**0.012**	0.007	0.007	0.007	0.005	0.004	0.005	0.005	0.003	0.002	0.002	0.002	0.001
32	580909	298436	Breckland Forest SPA	**0.019**	**0.019**	**0.018**	0.010	0.008	0.008	0.007	0.004	0.005	0.005	0.005	0.003	0.002	0.002	0.002	0.001
33	577368	301575	Breckland Forest SPA	**0.013**	**0.013**	**0.013**	0.009	0.005	0.005	0.005	0.004	0.003	0.004	0.003	0.002	0.002	0.002	0.002	0.001
34	577291	294145	Breckland SAC (Cranwich Camp)	**0.038**	**0.038**	**0.036**	**0.026**	**0.015**	**0.015**	**0.014**	**0.010**	0.009	0.009	0.009	0.006	0.003	0.004	0.003	0.002
35	575977	290289	Breckland SAC (Weeting Heath)	**0.029**	**0.029**	**0.030**	**0.018**	**0.012**	**0.012**	**0.012**	0.007	0.007	0.007	0.007	0.004	0.003	0.003	0.003	0.002
36	575775	288757	Breckland SAC (Weeting Heath)	**0.019**	**0.019**	**0.020**	**0.012**	0.008	0.008	0.008	0.005	0.005	0.005	0.005	0.003	0.002	0.002	0.002	0.001
37	575859	287191	Breckland SAC (Weeting Heath)	**0.013**	**0.013**	**0.014**	0.008	0.005	0.005	0.005	0.003	0.003	0.003	0.003	0.002	0.001	0.002	0.002	0.001
38	580689	290118	Breckland SAC	**0.014**	**0.014**	**0.013**	0.008	0.005	0.006	0.005	0.003	0.003	0.003	0.003	0.002	0.001	0.001	0.001	0.001
39	575701	284168	Breckland SAC	0.010	0.010	0.010	0.005	0.004	0.004	0.004	0.002	0.003	0.003	0.003	0.001	0.001	0.001	0.001	0.001
40	574679	300183	Norfolk Valley Fens SAC	**0.018**	**0.018**	**0.018**	**0.011**	0.007	0.007	0.007	0.005	0.005	0.005	0.005	0.003	0.002	0.002	0.002	0.001
41	576062	299402	Norfolk Valley Fens SAC	**0.020**	**0.020**	**0.021**	**0.015**	0.008	0.008	0.008	0.006	0.005	0.005	0.005	0.004	0.003	0.003	0.003	0.002
42	576813	300574	Norfolk Valley Fens SAC	**0.016**	**0.016**	**0.016**	**0.011**	0.006	0.006	0.006	0.004	0.004	0.004	0.004	0.003	0.002	0.002	0.002	0.001
43	579006	300694	Breckland SAC	**0.014**	**0.014**	**0.014**	0.010	0.006	0.006	0.006	0.004	0.004	0.004	0.004	0.002	0.002	0.002	0.002	0.001
44	583152	295075	Breckland SAC	**0.013**	**0.013**	**0.013**	0.008	0.005	0.005	0.005	0.003	0.003	0.003	0.003	0.002	0.001	0.001	0.001	0.001
45	574709	282486	Breckland SAC	0.009	0.009	0.010	0.005	0.004	0.004	0.004	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001

5.2 Detailed deposition modelling

The detailed deposition modelling was carried out over a domain covering the poultry units and closer parts of the Breckland Forest SSSI/SPA, where the preliminary modelling indicated that annual mean ammonia concentrations, or concentrations equivalent to nitrogen or acid deposition rates, would potentially exceed the Natural England advisory criterion, (4% of the relevant Critical Level or Critical Load for a SSSI and 1% of Critical Level or Critical Load for a SAC/SPA).

Spatially varying deposition cannot be modelled in conjunction with the calms module of ADMS; however, in this case, the preliminary modelling suggests that the effect of calms is insignificant. Therefore, the deposition runs were made without calms and with terrain. The model was run four times, once for each year of the meteorological record, results for the following three scenarios are presented (results from Scenario 1 are available upon request).

- Scenario 2 - All emissions abated to 2 ppm from the scrubber stacks.
- Scenario 3 - Unabated emissions from the standard ridge mounted fans/chimneys of one of the houses and abated emissions from the scrubber stacks of five of the houses.
- Scenario 4 - Unabated emissions from the standard ridge mounted fans/chimneys of two of the houses and abated emissions from the scrubber stacks of four of the houses.

The results at the discrete receptors are shown in Tables 5a (Scenario2), 5b (Scenario3) and 5c (Scenario 4). In the Tables, predicted ammonia concentrations and nitrogen deposition rates that are in excess of the Environment Agency's upper threshold (20% of Critical Level/Load for a SPA) are coloured red. Concentrations in the range between the Environment Agency's upper threshold and lower threshold (4% to 20% for a SPA) are coloured blue. Additionally, predicted ammonia concentrations and nitrogen deposition rates that exceed the Natural England advisory criterion, (1% of Critical Level or Critical Load for a SPA) are highlighted with bold text.

Contour plots of the predicted maximum annual ammonia concentration, acid deposition rate and acid deposition rate are shown in Figures 7a, 7b and 7c (Scenario 2) and 8a, 8b and 8c (Scenario 3). Note that Scenario 3 would represent the each of scrubbers having a 17% down-time, or emergency ventilation being used for 17% of the time, which is considered to be very unlikely to occur; therefore Scenarios 1 and 4 must be considered extremely unlikely to ever occur. Please also note that, results from Scenario 1 and 4 are available upon request and the modelling was conducted in such manner, that estimates of impact could be made for any percentage of scrubber down-time and/or emergency ventilation use.

Table 5a. Annual ammonia concentration and nitrogen and acid deposition rate – Scenario 2

Receptor number	X(m)	Y(m)	Name	Site Parameters				Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate		Maximum annual acid deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load N (kg/ha)	Critical Load H+ (keq/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load	Process Contribution (keq/ha)	%age of Critical Load
1	573858	292785	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.009	0.3	0.07	0.7	0.0049	0.9
2	574022	292960	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.008	0.3	0.06	0.6	0.0044	0.8
3	574033	292573	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.007	0.2	0.05	0.5	0.0037	0.7
4	574404	293119	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.006	0.2	0.05	0.5	0.0032	0.6
5	574404	292737	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.006	0.2	0.04	0.4	0.0031	0.6
6	574382	292313	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.004	0.1	0.03	0.3	0.0025	0.4
7	574981	293506	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.005	0.2	0.04	0.4	0.0026	0.5
8	574891	292440	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.004	0.1	0.03	0.3	0.0021	0.4
9	574669	291757	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.003	0.1	0.02	0.2	0.0015	0.3

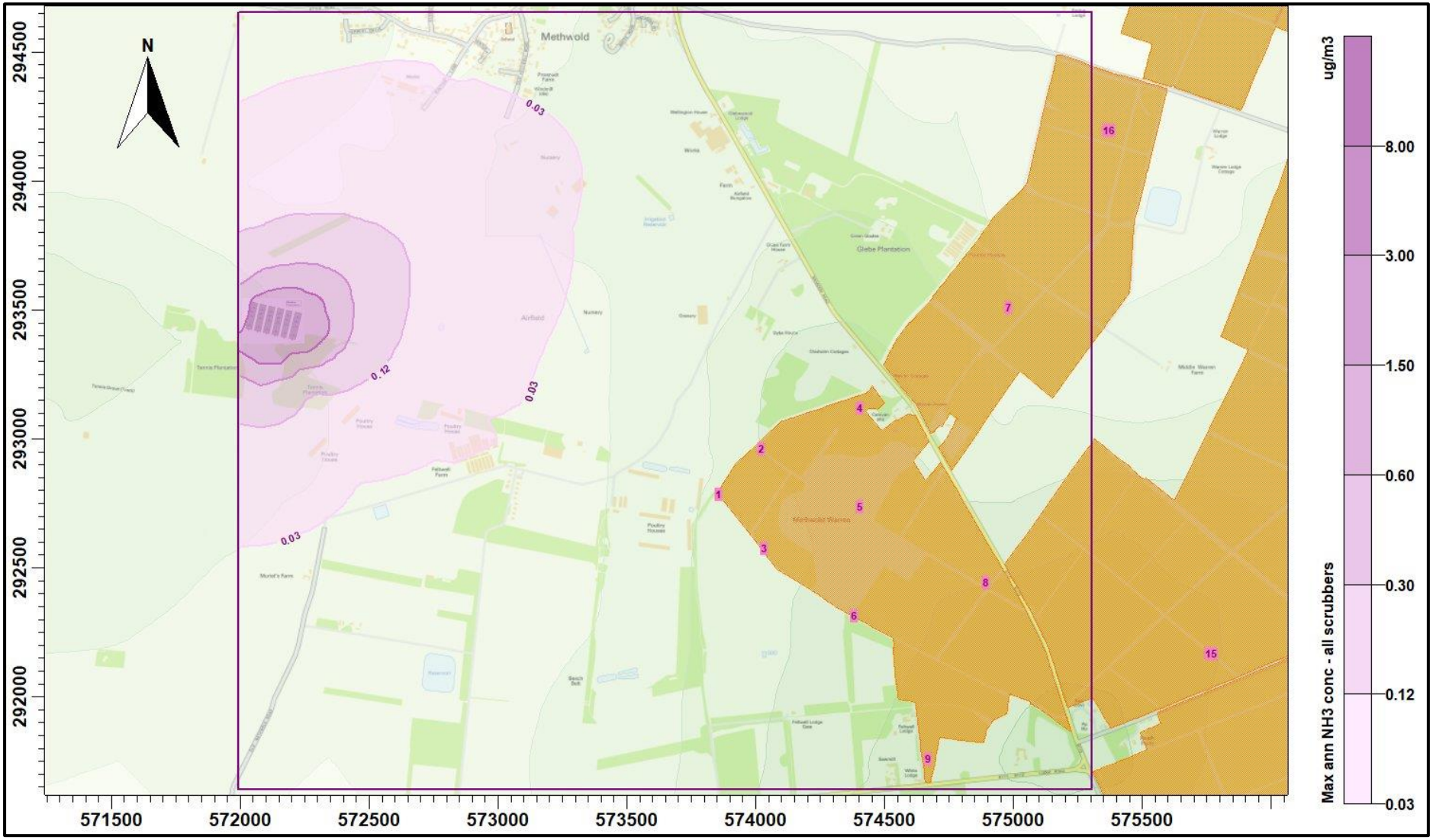
Table 5b. Annual ammonia concentration and nitrogen and acid deposition rate – Scenario 3

Receptor number	X(m)	Y(m)	Name	Site Parameters				Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate		Maximum annual acid deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load N (kg/ha)	Critical Load H+ (keq/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load	Process Contribution (keq/ha)	%age of Critical Load
1	573858	292785	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.022	0.7	0.17	**1.7**	0.0122	**2.2**
2	574022	292960	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.020	0.7	0.16	**1.6**	0.0111	**2.0**
3	574033	292573	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.017	0.6	0.13	**1.3**	0.0094	**1.7**
4	574404	293119	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.015	0.5	0.11	**1.1**	0.0082	**1.4**
5	574404	292737	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.014	0.5	0.11	**1.1**	0.0079	**1.4**
6	574382	292313	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.011	0.4	0.09	0.9	0.0063	**1.1**
7	574981	293506	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.012	0.4	0.09	0.9	0.0064	**1.1**
8	574891	292440	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.009	0.3	0.07	0.7	0.0051	0.9
9	574669	291757	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.007	0.2	0.06	0.6	0.0040	0.7

Table 5c. Annual ammonia concentration and nitrogen and acid deposition rate – Scenario 4

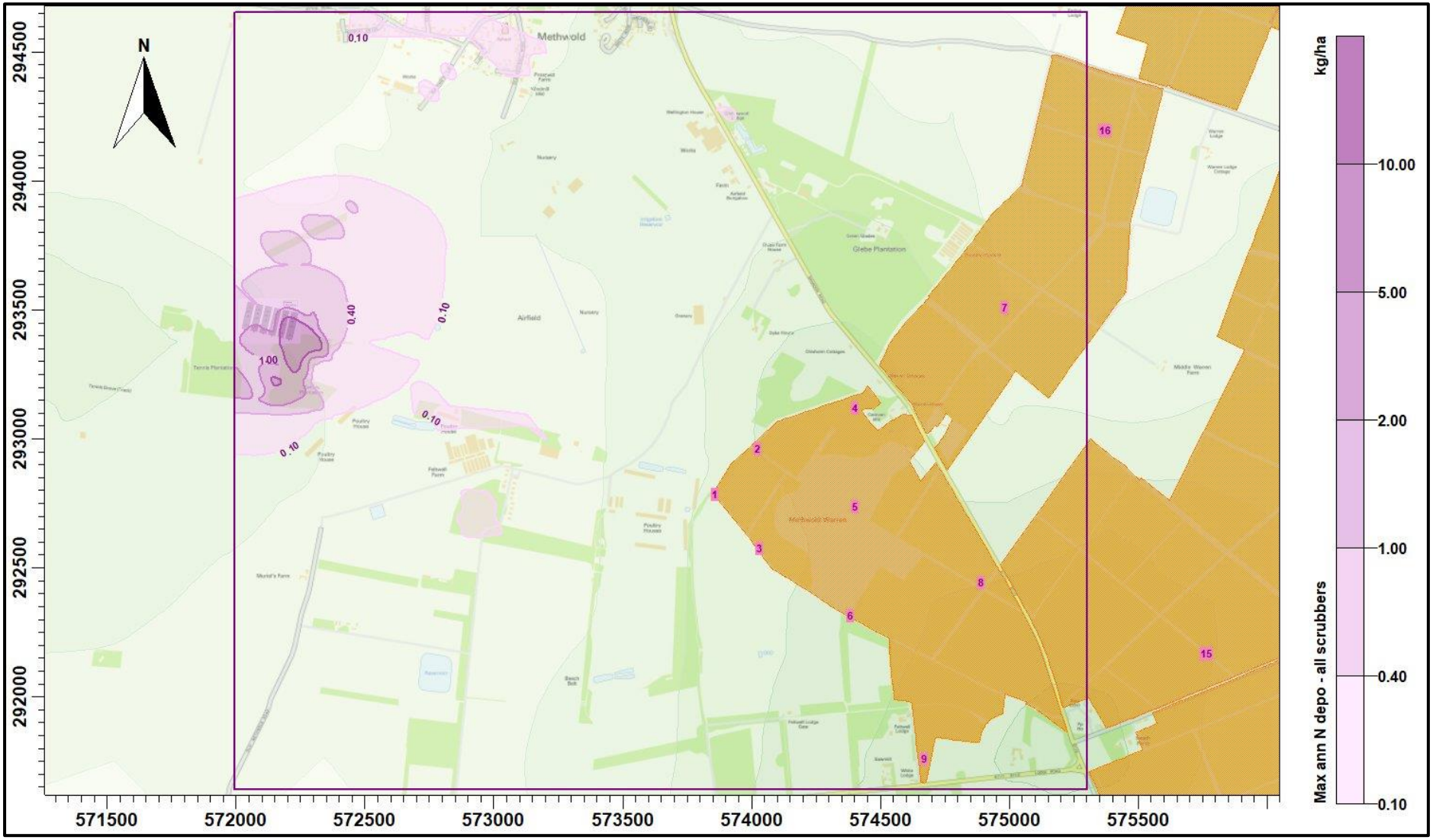
Receptor number	X(m)	Y(m)	Name	Site Parameters				Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate		Maximum annual acid deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load N (kg/ha)	Critical Load H+ (keq/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load	Process Contribution (keq/ha)	%age of Critical Load
1	573858	292785	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.035	**1.2**	0.28	**2.8**	0.0196	**3.5**
2	574022	292960	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.032	**1.1**	0.25	**2.5**	0.0180	**3.2**
3	574033	292573	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.027	0.9	0.21	**2.1**	0.0152	**2.7**
4	574404	293119	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.024	0.8	0.18	**1.8**	0.0132	**2.3**
5	574404	292737	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.023	0.8	0.18	**1.8**	0.0127	**2.3**
6	574382	292313	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.018	0.6	0.14	**1.4**	0.0102	**1.8**
7	574981	293506	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.019	0.6	0.14	**1.4**	0.0104	**1.8**
8	574891	292440	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.015	0.5	0.12	**1.2**	0.0083	**1.5**
9	574669	291757	Breckland Forest SPA	0.030	3.0	10.0	0.563	0.012	0.4	0.09	0.9	0.0065	**1.2**

Figure 7a. Maximum annual mean ammonia concentration - Scenario 2



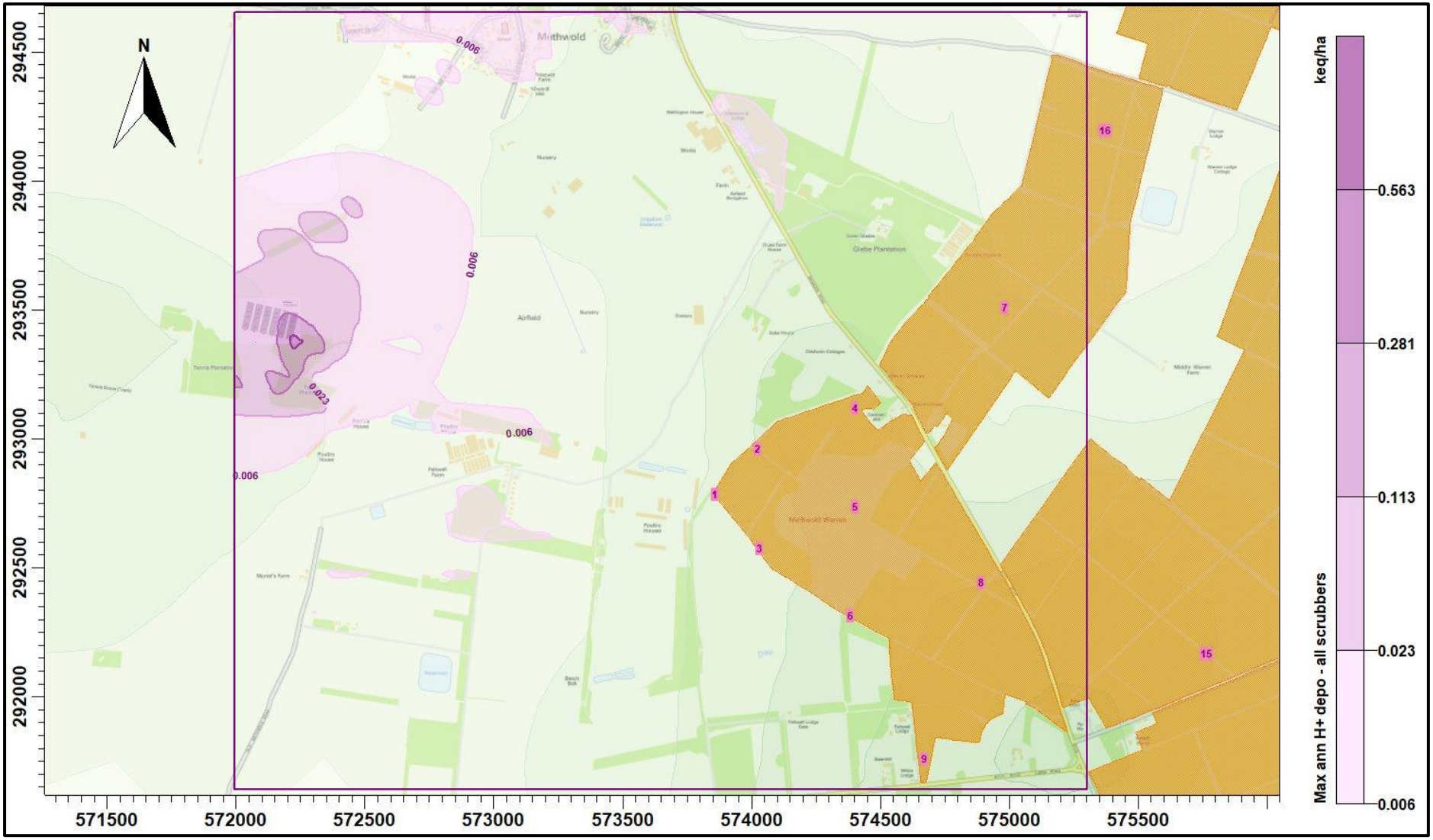
© Crown copyright and database rights. 2019.

Figure 7b. Maximum annual nitrogen deposition rate - Scenario 2



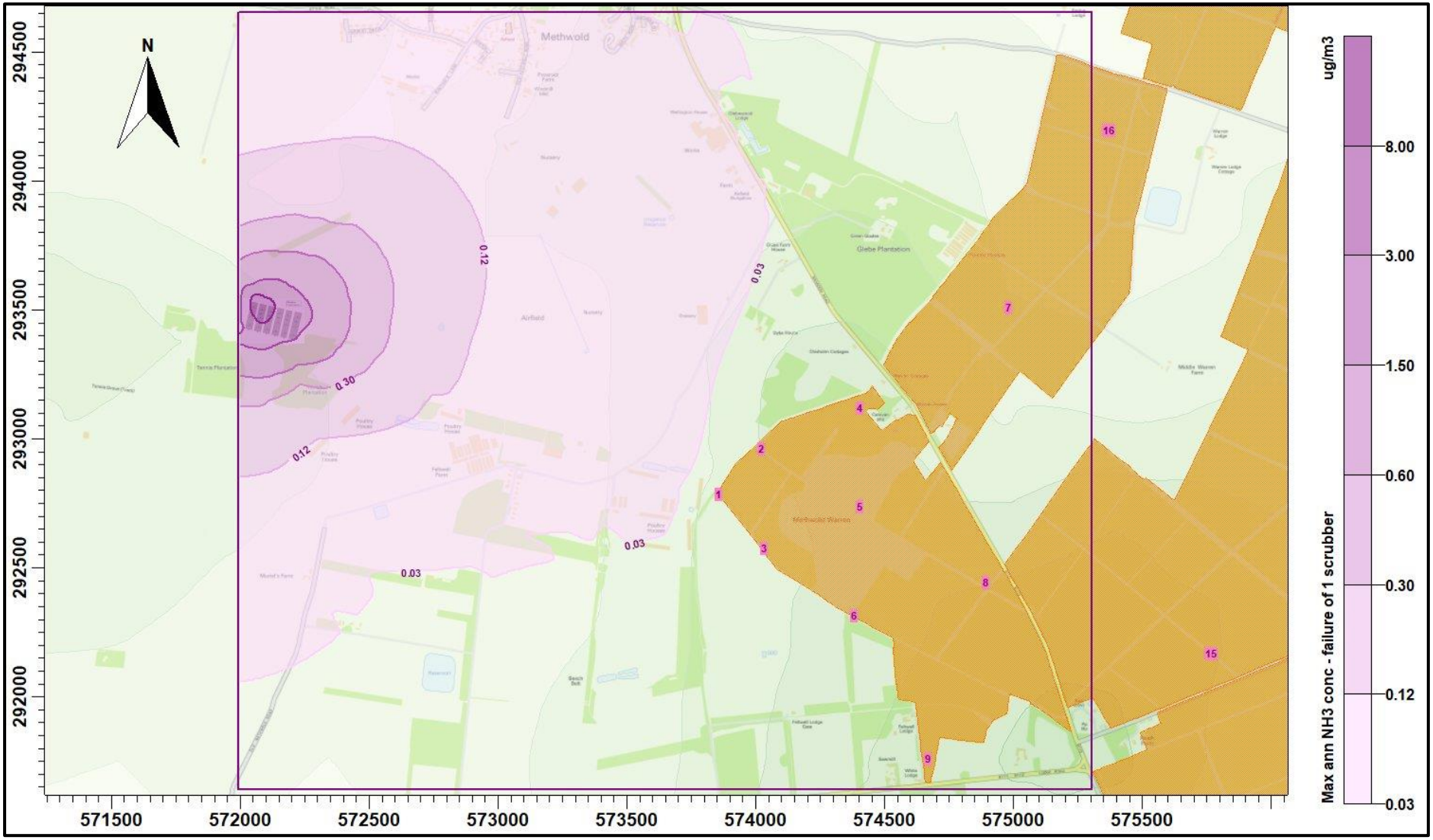
© Crown copyright and database rights. 2019.

Figure 7c. Maximum annual acid deposition rate - Scenario 2



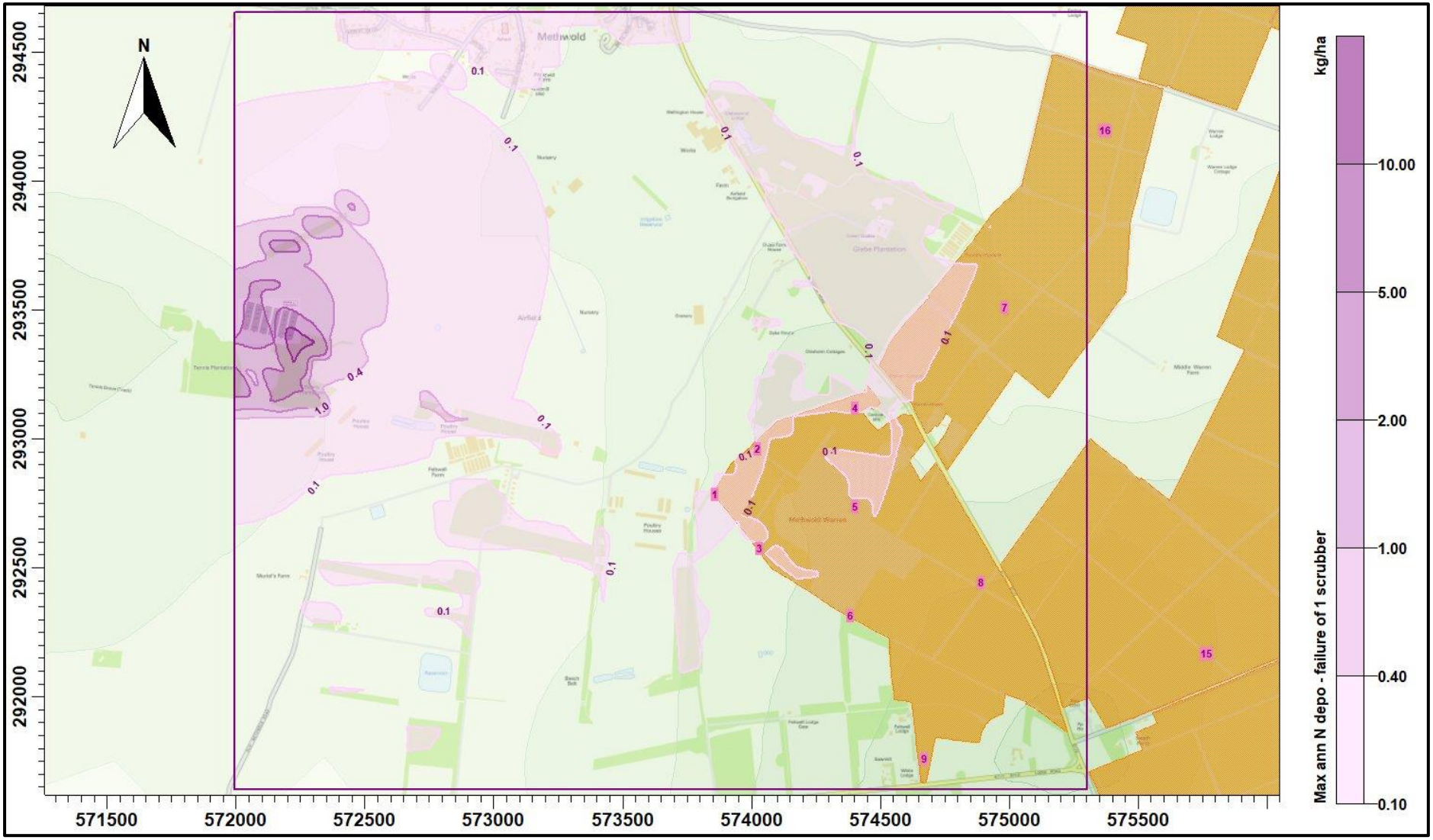
© Crown copyright and database rights. 2019.

Figure 8a. Maximum annual mean ammonia concentration - Scenario 3



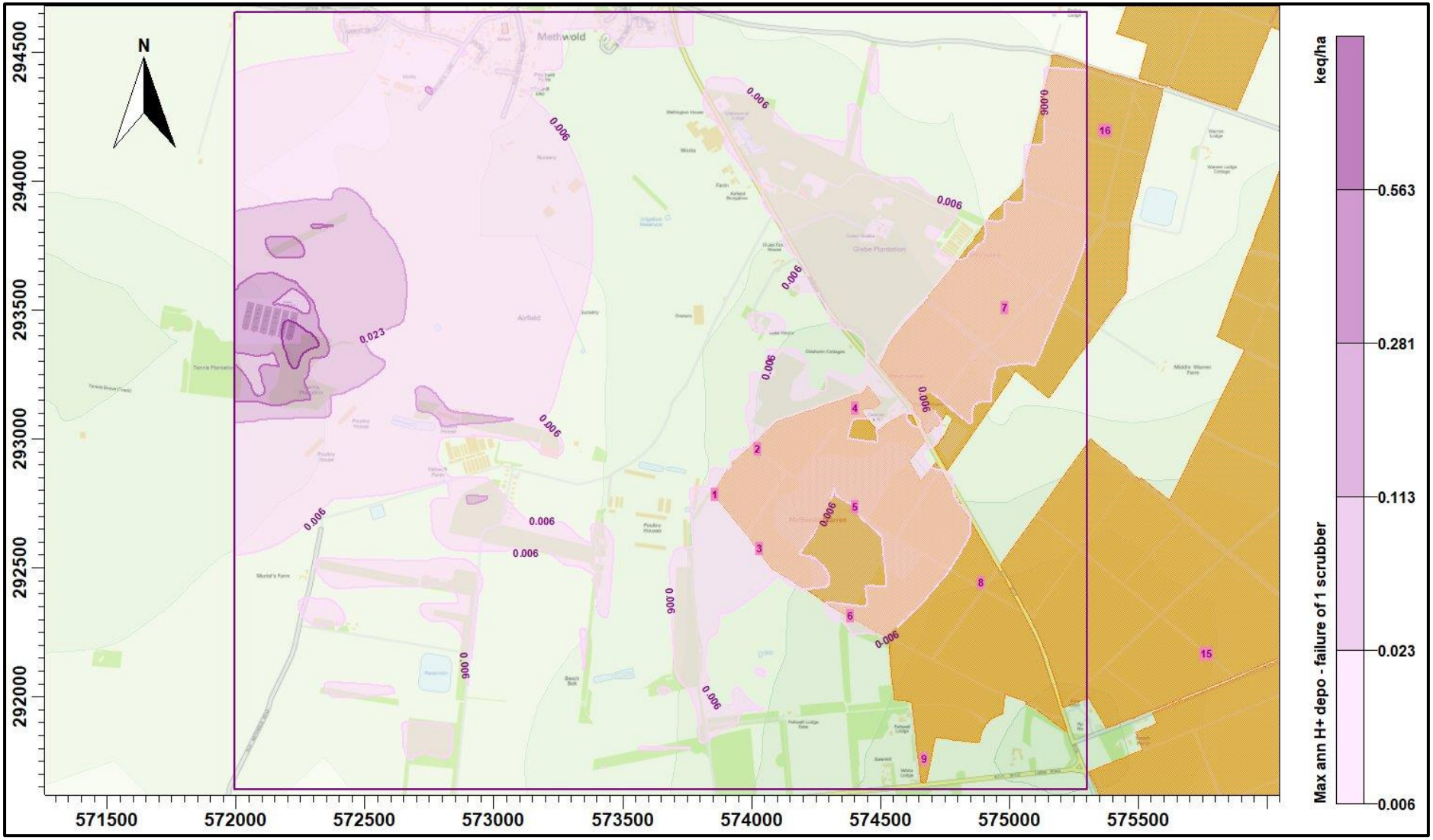
© Crown copyright and database rights. 2019.

Figure 8b. Maximum annual nitrogen deposition rate - Scenario 3



© Crown copyright and database rights. 2019.

Figure 8c. Maximum annual acid deposition rate - Scenario 3



© Crown copyright and database rights. 2019.

6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Annyalla Chicks Limited and I.P.T. Technology Limited, to use computer modelling to assess the impact of ammonia emissions from the proposed egg laying chicken houses at Methwold Airfield Poultry Unit, off Brandon Road, near Methwold in Norfolk. IP26 4DU.

Ammonia emission rates from the proposed poultry houses have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors and calculations based upon guaranteed outlet ammonia concentrations from the ammonia scrubbing systems that would be fitted to the poultry houses and known ventilation rates of egg laying chicken houses. The ammonia emission rates so obtained have then been used as inputs to an atmospheric dispersion and deposition model which calculates ammonia exposure levels and nitrogen deposition rates in the surrounding area.

Pessimistic Results (Scenario 3)

The modelling predicts that:

- At all SSSIs, SPAs and SACs considered, the process contribution to the annual ammonia concentration and the nitrogen and acid deposition rates would be below the Environment Agency's lower threshold percentage of Critical Level or Critical Load (20% for a SSSI and 4% for a SPA/SAC).

- At closer parts of the Breckland Forest SSSI/SPA, the process contribution to the nitrogen and acid deposition rates would be slightly in excess of the Natural England advisory criterion, (1% of the relevant Critical Level or Critical Load for a SPA).

Best Case Results (Scenario 2)

The modelling predicts that:

- At all SSSIs, SPAs and SACs considered, the process contribution to the annual ammonia concentration and the nitrogen and acid deposition rates would be below the Environment Agency's lower threshold percentage of Critical Level or Critical Load (20% for a SSSI and 4% for a SPA/SAC).

- At all SSSIs, SPAs and SACs considered, the process contribution to the annual ammonia concentration and the nitrogen and acid deposition rates would be below the Natural England advisory criterion, (4% of the relevant Critical Level or Critical Load for a SSSI and 1% for a SPA/SAC).

7. References

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

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

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

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

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

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

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

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