A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing and Proposed Broiler Chicken Rearing Houses at Boiling Wells Farm, Grantham Road, South Rauceby near Sleaford

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Mr. Oliver Grundy of JHG Planning Consultancy Ltd., on behalf of Mr. David Bellamy of Greylees Ltd. to use computer modelling to assess the impact of ammonia emissions from the existing and proposed broiler chicken rearing houses at Boiling Wells Farm, Grantham Road, South Rauceby, Sleaford. NG34 8QX.

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

This report is arranged in the following manner:

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

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

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

- Section 5 contains the results of the modelling.

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

2. Background Details

The site of the broiler rearing unit at Boiling Wells Farm is in an isolated rural area. The surrounding land is used primarily for arable farming although there are some wooded areas nearby. The site is at an altitude of between 25 m and 30 m, with the land falling towards level drained fenland to the south-east and rising towards low hills to the north-west.

There are currently six broiler chicken rearing houses at Boiling Wells Farm. These houses are used to rear up to 198,900 broiler chickens and are primarily ventilated by uncapped high speed ridge mounted fans, each with a short chimney, with gable end fans which provide supplementary ventilation in hot weather conditions. The chickens are reared from day old chicks to up to around 38 days old and there are approximately 7.5 flocks per annum.

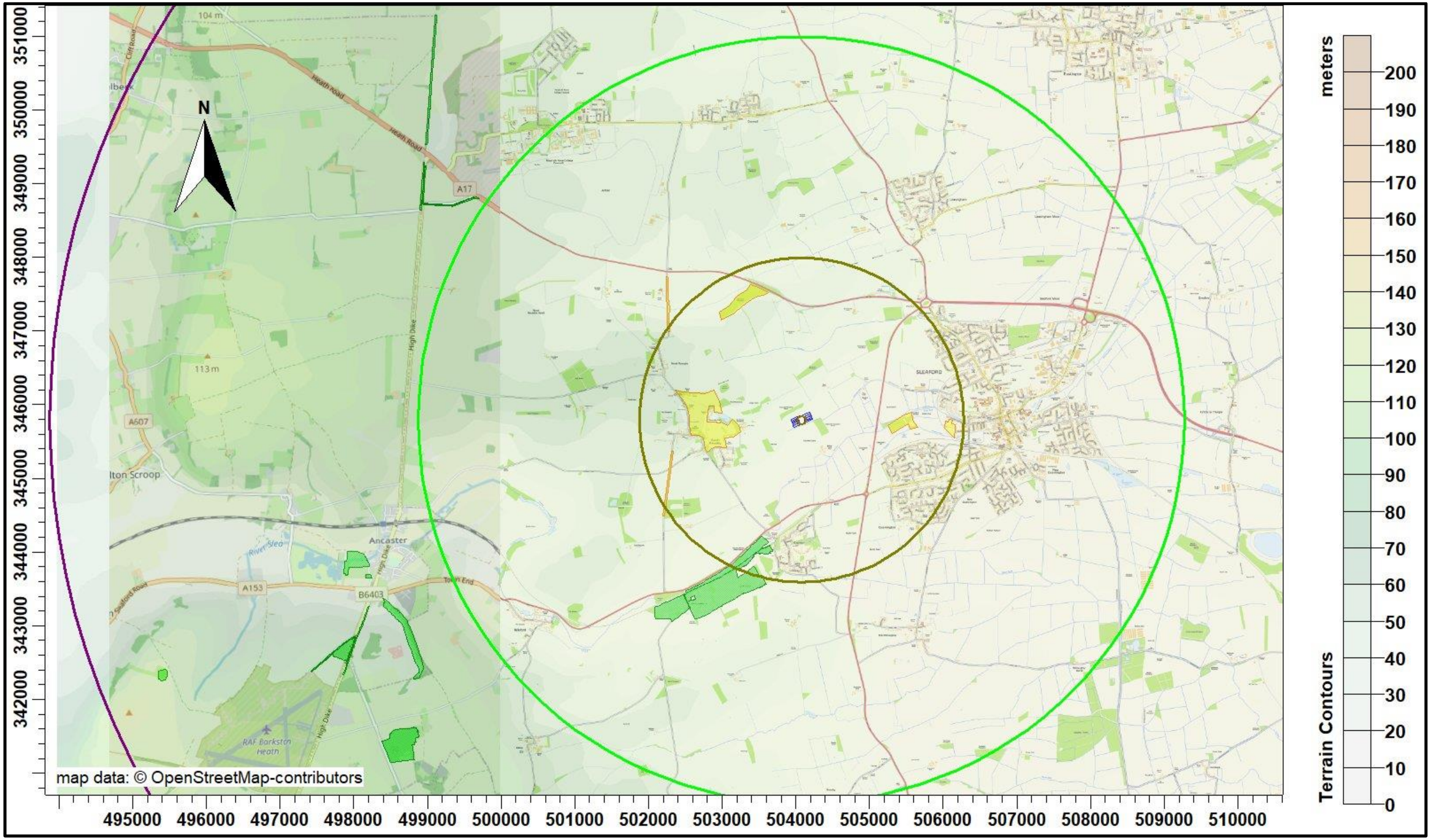
It is proposed that two new broiler rearing houses be constructed to the west of the existing houses. These two houses would provide accommodation for up to 66,300 additional broiler chickens and would be primarily ventilated by uncapped high speed ridge mounted fans, each with a short chimney, with gable end fans which would provide supplementary ventilation in hot weather conditions. The chickens would be reared from day old chicks to up to around 38 days old and there would be approximately 7.5 flocks per annum.

Although it is difficult to obtain information on Local Wildlife Sites in North Kesteven, there are four areas previously identified and potentially designated as Local Wildlife Sites (LWSs) within 2 km of Boiling Wells Farm. There are no areas designated as Ancient Woodland (AW) within 2km. There are seven areas designated as a Sites of Special Scientific Interest (SSSIs) within 10 km of the site. There are no internationally designated wildlife sites within 10 km of the farm. Some further details of the SSSIs is provided below:

- **Wilsford & Rauceby Warrens SSSI** - Approximately 1.5 km to the south-west - The most extensive remaining areas of limestone grass heath in South Lincolnshire. There is an abundance of *Caledonia* species of lichen and local dominance of the mosses *Polytrichum juniperinum* and *Dicranium scoparium*.
- **High Dyke SSSI** - Approximately 5.2 km to the north-west - Comprises the wide verges of Ermine Street, along with some further roadside verges, consisting of permanent species-rich calcareous grassland, managed by mowing rather than grazing.
- **Moor Closes SSSI** - Approximately 6.0 km to the west-south-west - Of national importance as an outstanding example of a traditionally managed calcareous loam pasture.
- **Ancaster Valley SSSI** - Approximately 5.8 km to the west-south-west - The best example of a species-rich limestone grassland in the area with scarce plants on the edge of their range. Communities on the slopes of this narrow glacial overflow valley range from those restricted to permanent unimproved grassland. through scrub, to pedunculate oak-ash-beech woodland.
- **Copper Hill SSSI** - Approximately 6.2 km to the west-south-west - The main biological interest of the site lies in the wide verges of Ermine Street and the branch road to Belton, which have a rich and varied limestone flora.
- **Wilsford Heath Quarry SSSI** - Approximately 6.5 km to the south-west - A disused limestone quarry with semi-natural deciduous woodland and species rich grassland.
- **Honington Camp SSSI** - Approximately 9.1 km to the west-south-west - The earth banks and central portion of this iron age fort support a rich limestone flora, with species which are scarce and decreasing in the county. Where there is shelter from the wind, especially along the south facing banks, the area is a sanctuary for butterflies.

A map of the surrounding area showing the positions of the poultry house at Boiling Wells Farm, the LWSs and the SSSI is provided in Figure 1. In the figure, the LWSs are shaded in yellow, the SSSIs are shaded in green and the positions of the existing and proposed poultry houses are outlined in blue.

Figure 1. The area surrounding Boiling Wells Farm – concentric circle radius 2 km (olive)



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 source of the background figures is the Air Pollution Information System (APIS, April 2023, source attribution data 2017 - 2019). It should be noted that the APIS background levels used are an average over a 5 km grid square (they are also modelled values, they are not measured in any way and no particular farms are included explicitly in the sources attribution data). Ammonia levels vary markedly over relatively short distances and the APIS website itself notes that, the background values cannot be considered representative on any particular location within the 5 km grid square.

Although previous gross errors have been recently corrected (January 2023), the most recent 1 km resolution data from APIS is not used as there is no proper documentation of the processes used to derive the data and AS Modelling & Data Ltd. continues to have considerable doubts about the veracity of these data, particularly as there is no source data that could be used to derive 1 km resolution data (the source attribution data is stated to be at 0.1 degree resolution, approximately 10 km). It should be noted that ammonia levels vary markedly over relatively short distances and large sources that should be apparent at 1 km resolution (if the 1 km data were valid) are not apparent. Additionally, there are marked differences to the older 5 km resolution data that are thus far unexplained and do not appear to have any rational explanation. In this case whilst the older 5 km does show a maximum over Boiling Wells Far, the new 1km data does not.

The background ammonia concentration (annual mean) in the area around Boiling Wells Farm is 3.1 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 40.5 kg-N/ha/y and to short vegetation is 23.2 kg-N/ha/y. Acid deposition rates are no longer provided in APIS.

3.3 Critical Levels and Critical Loads

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

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

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

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

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

The Critical Levels and Critical Loads at the wildlife sites assumed in this study are provided in Table 1. N.B. Where the Critical Level of 1.0 $\mu g\text{-}NH_3/m^3$ 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 ($\mu g\text{-}NH_3/m^3$)	Critical Load - Nitrogen Deposition (kg-N/ha/y)	Critical Load - Acid Deposition (keq/ha/y)
Unnamed LWS	1.0 [1]	10.0	-
Wilsford & Rauceby Warrens SSSI	1.0 [1 & 3]	15.0 [2]	-
Ancaster Valley SSSI	1.0 [1 & 3]	10.0 [2]	-
High Dyke SSSI, Moor Closes SSSI, Wilsford Heath Quarry SSSI and Honington Camp SSSI	3.0 [3]	15.0 [2]	-

1. A precautionary figure used where no details of the ecology of the site are available, or the citation of the site indicates species/habitats sensitive to ammonia are present.
2. The lower bound of the range of Critical Loads for the site.
3. Based upon the citation for the site.

3.4 Guidance on the Significance of Ammonia Emissions

3.4.1 Environment Agency Criteria

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

If the predicted process contributions to Critical Level or Critical Load are in the range between the lower and upper thresholds; 4% to 20% for SACs, SPAs and Ramsar sites; 20% to 50% for SSSIs and 100% to 100% for other non-statutory wildlife sites, whether or not the impact is deemed acceptable is at the discretion of the Environment Agency. In making their decision, the Environment Agency will consider whether other farming installations might act in-combination with the farm and the sensitivities of the wildlife sites. In the case of LWSs and AWs, the Environment Agency do not usually consider other farms that may act in-combination and therefore a PC of up to 100% of Critical Level or Critical Load is usually deemed acceptable for permitting purposes and therefore the upper and lower thresholds are the same (100%).

3.4.2 Natural England advisory criterion

Natural England are a statutory consultee at planning and usually advise that, if predicted process contributions exceed 1% (in some circumstances <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.

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

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

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

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

- For lichens and bryophytes - 0.08%, 0.20%, 0.34% and 0.75% of the Critical Level for high, medium, low and very low development density areas, respectively.

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

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

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

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

3.6 Quantification of Ammonia Emissions

3.5.1 General information

Ammonia emission rates from poultry houses depend on many factors and are likely to be highly variable. However, the benchmarks for assessing impacts of ammonia and nitrogen deposition are framed in terms of an annual mean ammonia concentration and annual nitrogen deposition rates. To obtain relatively robust figures for these statistics it is not normally 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.

However, the ventilation system at Boiling Wells farm is not conducive to modelling simple continuous steady emission rate for the following reasons.

- Emission rates are likely to be very variable.
- Low emission rates associated with early stages of the crop have much less impact, because of their smaller magnitude and because they are almost always emitted from the high speed ridge fans with superior initial dispersion characteristics.
- High emission rates associated with later stages of the crop have much more impact, because of their larger magnitude and because a proportion of them are emitted from the gable end fans with inferior initial dispersion characteristics.
- The proportions of emission emitted from high speed ridge fans and gable end fans are dependent on crop stage and weather condition.

The Environment Agency provides an Intensive Farming guidance note which lists standard ammonia emission factors for a variety of livestock, including poultry. For broiler chickens, the Environment Agency figure is 0.034 kg-NH_3/bird place/year. The emission model is “tuned” to produce very similar emissions to a continuous steady emission rate and in this case, the average emission rate expressed as an annual figure is calculated to be 0.034128 kg-NH_3/bird place/year. Details of the poultry numbers and types and emission factors used and calculated ammonia emission rates are provided in Table 2.

Table 2. Details of poultry numbers and ammonia emission rates

Source	Animal numbers	Type or weight	Emission factor (kg-NH_3/place/y)	Emission rate (g-NH_3/s)
Poultry houses	265,200	Broiler Chickens	0.034128	0.286801 [1]

1. Average of 4 years and three separate crop cycles. This figure is not used in the modelling and is only provided to show the equivalence with the standard emission factor.

3.5.2 Details of the emission model

To calculate the hourly ammonia emission rates, it is necessary to know the internal odour concentration and ventilation rate of the poultry house. For the calculation, the internal concentration is assumed to be a function of the age of the crop. The internal concentrations used in the calculations increase exponentially from 1,000 µg-NH_3/m^3 at day 1 of the crop, to 4,500 µg-NH_3/m^3 at day 16 of the crop, and a maximum of approximately 5,900 ou_E/m^3 at day 23 of the crop. These figures are obtained from measurements available to AS Modelling & Data Ltd. adjusted on a case by case basis to approximate equivalence with the standard emission factor.

The ventilation rates used in the calculations are based on industry practices and standard bird growth factors. Minimum ventilation rates are as those of an operational poultry house and maximum ventilation rates are based on Defra guidelines. Target internal temperature is 33 Celsius at the beginning of the crop and is decreased to 22 Celsius by day 34 of the crop. If the external temperature is 7 Celsius, or more, lower than the target temperature, minimum ventilation only is assumed for the calculation. Above this, ventilation rates are increased in proportion to the difference between ambient temperature and target internal temperature. A maximum transitional ventilation rate (35% of the maximum possible ventilation rate) is reached when the ambient temperature is equal to the target temperature. A high ventilation rate (70% maximum possible ventilation rate) is reached when the temperature is 4 degrees above target and if external temperature is above 33 Celsius the maximum ventilation rate is assumed. An estimation of the peak emissions during the cleaning out process can also be included. In this case, it is assumed that the houses are cleared sequentially and each house takes 2 hours to clear. If the calculated ventilation rate is below the capacity of the ridge/roof fans (48 m^3/s), then all emissions are assumed to be from the ridge/roof fans. If the calculated ventilation rate is greater the capacity of the ridge/roof fans proportional emissions from both ridge/roof fans and the gable end fans are assumed. It should be noted that the use of the gable end fans is relatively rare and for example, the gable end fans were only used three times in the exceptionally hot summer of 2022. Additionally, as a precautionary measure, the gable end fans are assumed to operate during clearing out of the houses.

In this case, it is assumed for the calculations that the crop length is 38 days and that there is an empty period of 10 days after each crop. To provide robust statistics, three sets of calculations were performed: the first with the first day of the meteorological record coinciding with day 1 of the crop cycle; the second coinciding with day 16 of the crop and the third coinciding with day 32 of the crop. As examples, graphs of the emission rate for a single house for all three of the crop cycles over the first year of the meteorological record, 2019, and as it was an exceptional year in terms of summer temperatures and ventilation rates, 2022, are shown in Figures 2a and 2b.

Figure 2a. Emission rates in 2019 for each of the three crop cycles - single house, 33,150 birds stocked

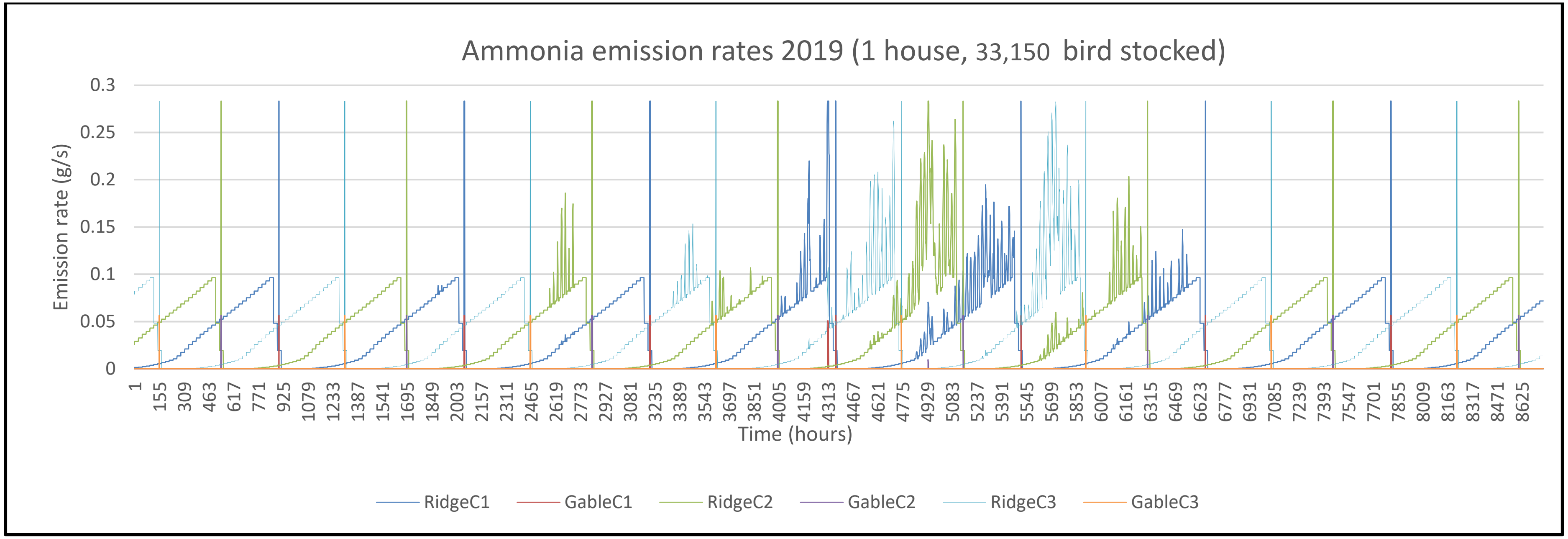
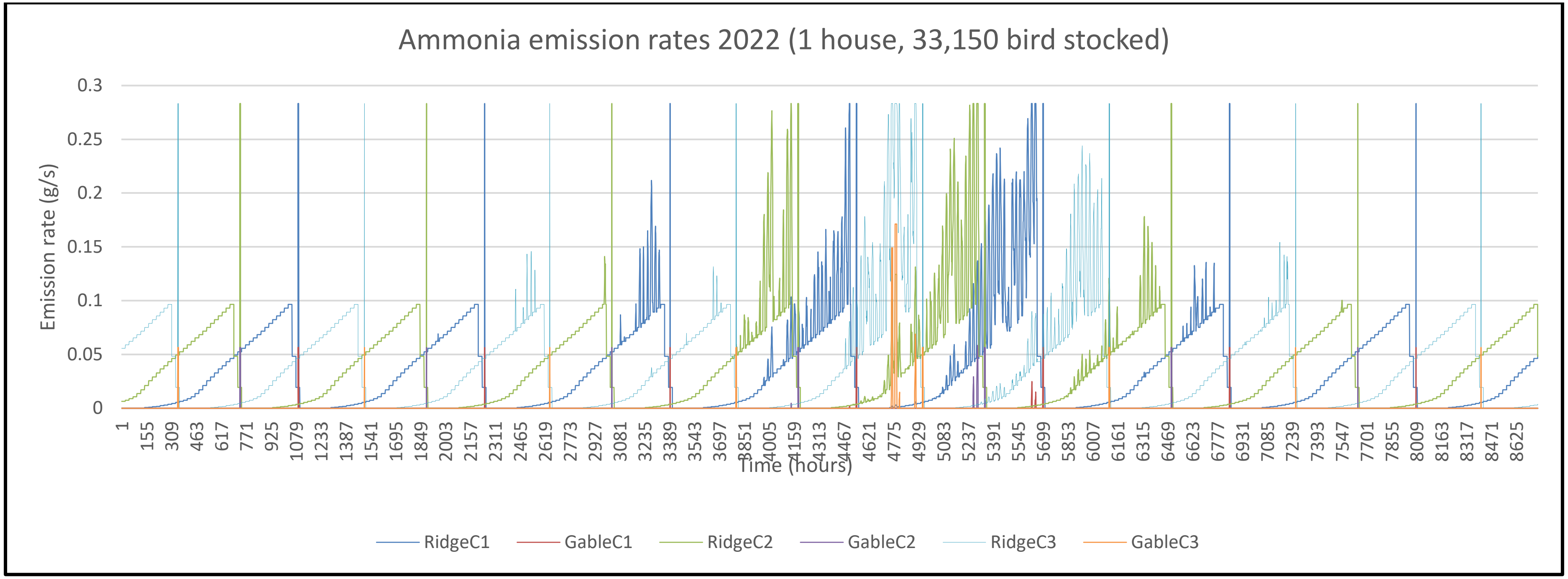


Figure 2b. Emission rate in 2022 for each of the three crop cycles - single house, 33,150 birds stocked



4. The Atmospheric Dispersion Modelling System (ADMS) and model parameters

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

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

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

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

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

4.1 Meteorological data

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

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

Prior to April 2019 the GFS was a spectral model, post April 2019 the physics are discrete. The physics/dynamics model has a resolution or had an equivalent resolution of approximately 7 km over the UK; terrain is understood to be resolved at a resolution of approximately 2 km, with sub-7 km terrain effects parameterised. Site specific data may be extrapolated from nearby archive grid points or a most representative grid point chosen. The GFS resolution adequately captures major topographical features and the broad-scale characteristics of the weather over the UK. Smaller scale topological features may be included in the dispersion modelling by using the flow field module of ADMS (FLOWSTAR[2]). The use of NWP data has advantages over traditional meteorological records because:

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

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

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

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 3a. Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and where terrain data is included in the modelling, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for the site is shown in Figure 3b. The resolution of the wind field in terrain runs is approximately 300 m. Please also note that FLOWSTAR[2] is used to obtain a local flow field, not to explicitly model dispersion in complex terrain as defined in the ADMS User Guide; therefore, the ADMS default value for minimum turbulence length has been amended [3].

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

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

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

Figure 3a. The wind rose. Raw GFS derived data for 53.00 N, 0.45 W, 2019-2022

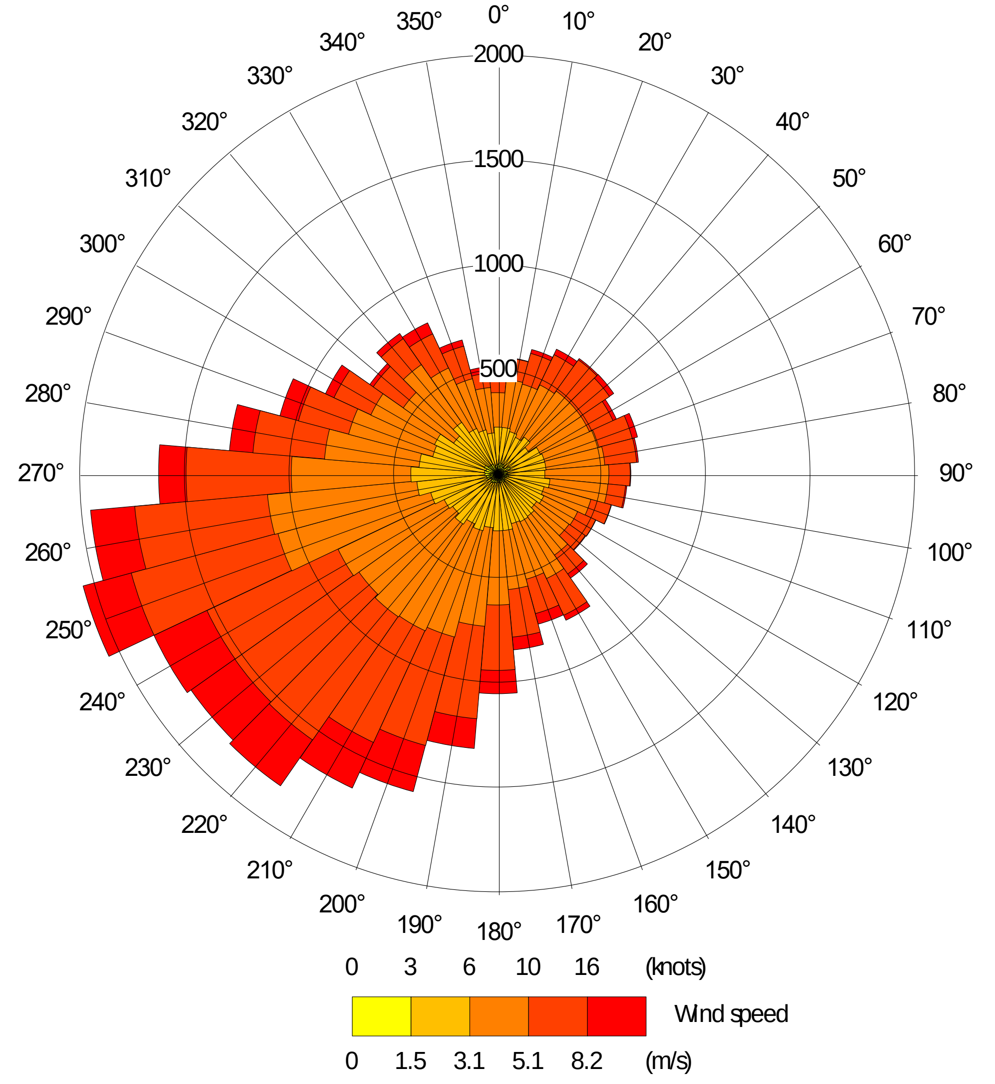
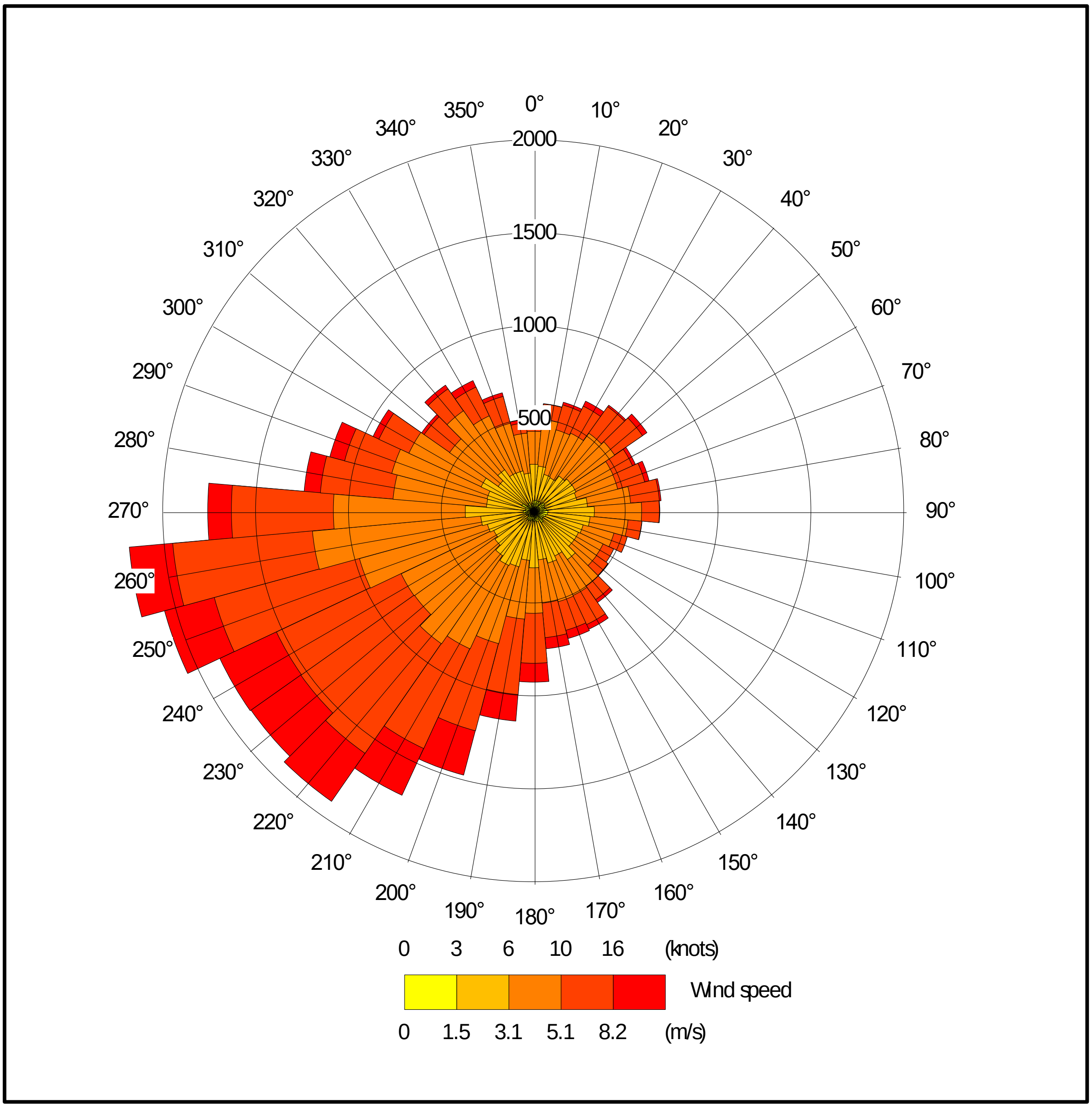


Figure 3b. The wind rose. FLOWSTAR modified GFS derived data for NGR 504100, 345800, 2019-2022



4.2 Emission sources

Emissions from the chimneys of the uncapped high speed ridge fans that are/would be used for the ventilation of the existing and proposed poultry houses are represented by three point sources per house within ADMS (H1 to H8; 1, 2 & 3).

Emissions from the gable end fans that would be used to supplement the primary ventilation have been represented by two volume sources within ADMS (H1toH4_GAB and H5toH8_GAB).

The emissions from the gable end fans are assumed to be zero unless the ventilation requirement within the poultry houses exceeds the capacity of the high speed ridge fans, taken to be 48 m^3/h, which is determined as a function of the age/weight of the flock and ambient temperature. Once this threshold has been reached, the total house emissions are assigned to the high speed ridge fans depending on the proportion that the capacity of these fans represents to the ventilation requirement for the poultry house, with the remainder being assigned to the gable end fans.

Details of the point source parameters are shown in Table 3a and details of the volume source parameters are shown in Table 3b. The positions of the point sources used are shown in Figure 4 (point sources are marked by green circles and the volume sources are marked by red shaded rectangles).

Table 3a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source (g/s)
H1 to H8; 1, 2 & 3	6.0	0.8	12.0	Variable [1]	Variable [1 & 2]

1. Dependent on crop stage and ambient temperature.
2. Reduced, when ambient conditions and age of the flock requires it, to the proportion the high speed fan capacity represents of the total house ventilation requirement.

Table 3b. Volume source parameters

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g/s)
H1toH4_GAB	109.0	10.0	3.0	0.5	Ambient	Variable [3]
H5toH8_GAB	109.0	10.0	3.0	0.5	Ambient	Variable [3]

3. Proportion of emissions determined by ventilation requirement above the roof fan capacity, when ambient conditions and age of the flock requires it.

4.3 Modelled buildings

The structure of the existing and 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 (marked by grey rectangles).

Figure 4. The positions of modelled buildings and sources

4.4 Discrete receptors

Twenty-five discrete receptors have been defined at the LWSs and SSSIs. These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figure 5 (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, two regular Cartesian grids have been defined within ADMS. The individual grid receptors are defined at ground level within ADMS. The positions of the Cartesian grids may be seen in Figure 5 (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 20.0 km by 20.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS for the modelling. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field for the terrain runs is approximately 300 m.

4.7 Roughness Length

In this case, a spatially varying roughness length file has been defined, this is based upon the Defra Living Landscapes land use database. The GFS meteorological data is assumed to have a roughness length of 0.2 m (arithmetic average of the spatially varying roughness over the modelling domain). The sample of the central area of the spatially varying roughness length field is shown in Figure 6.

Figure 5. The discrete receptors and Cartesian grids

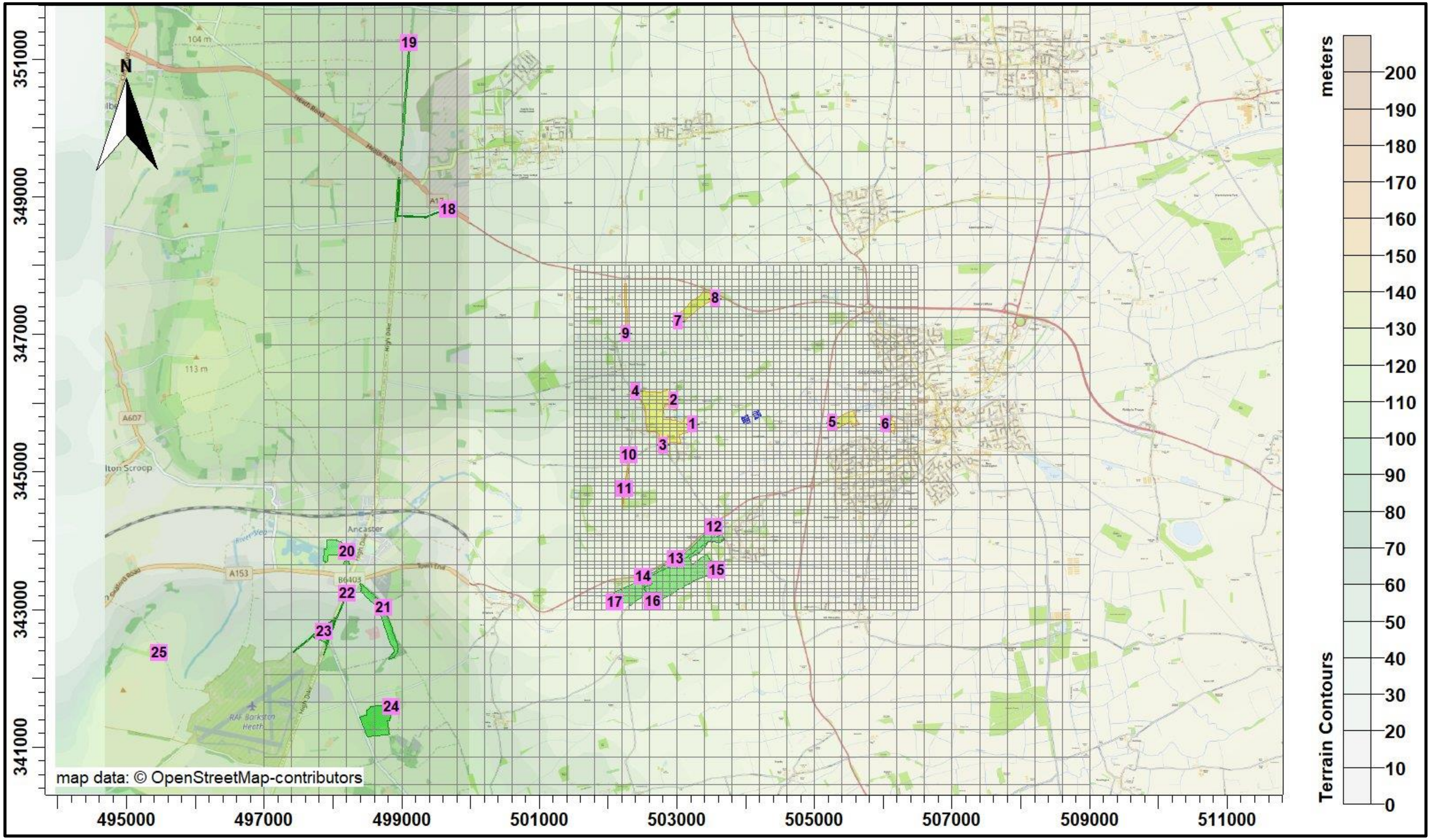
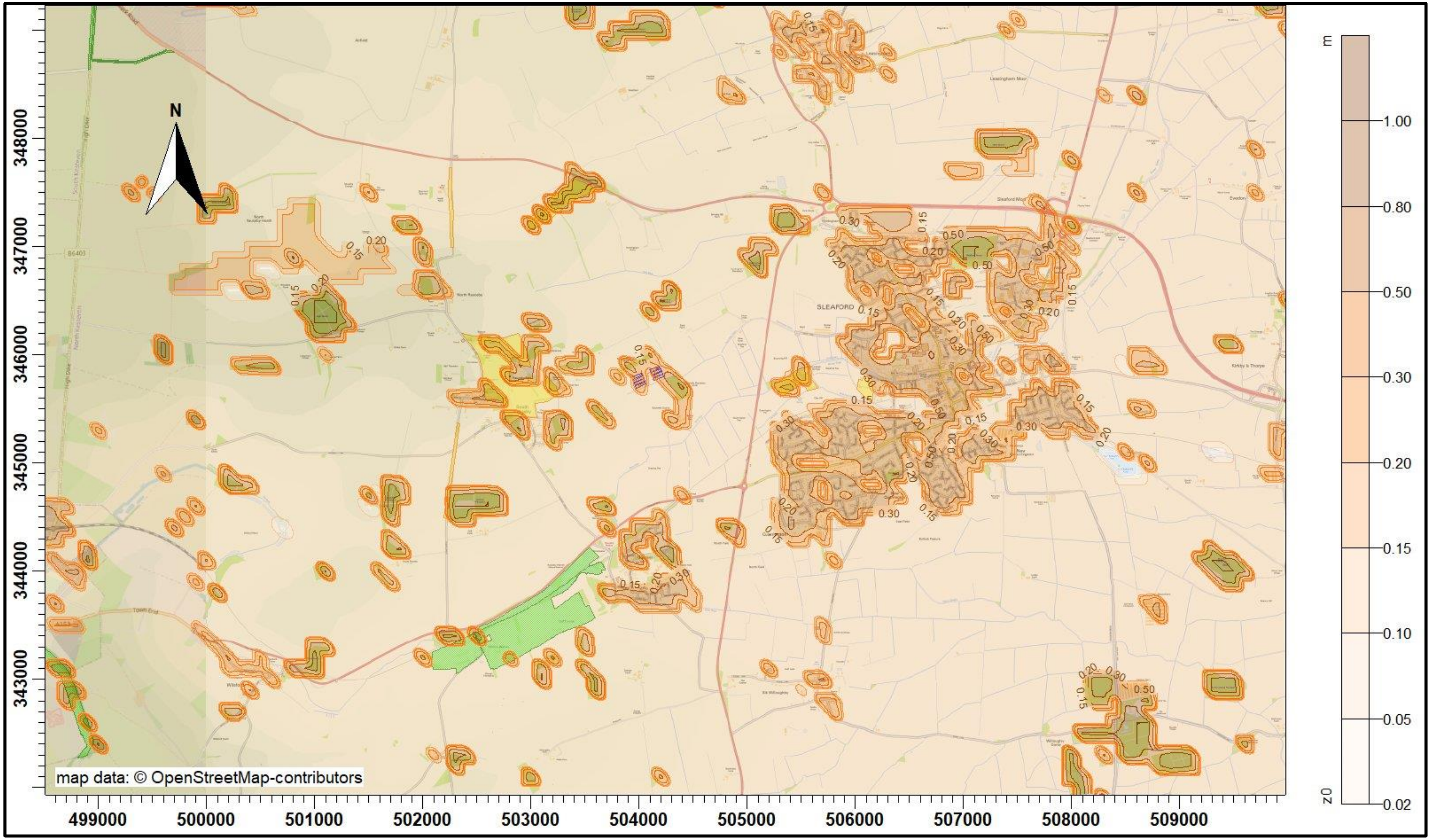


Figure 6. The spatially varying surface roughness field (central area)



4.8 Deposition

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

In summary, the method is as follows:

- A preliminary run of the model without deposition is used to provide an ammonia concentration field.
- The preliminary ammonia concentration field, along with land usage, has been used to define a deposition velocity field. The deposition velocities used are provided in Table 4.

Table 4. Deposition velocities

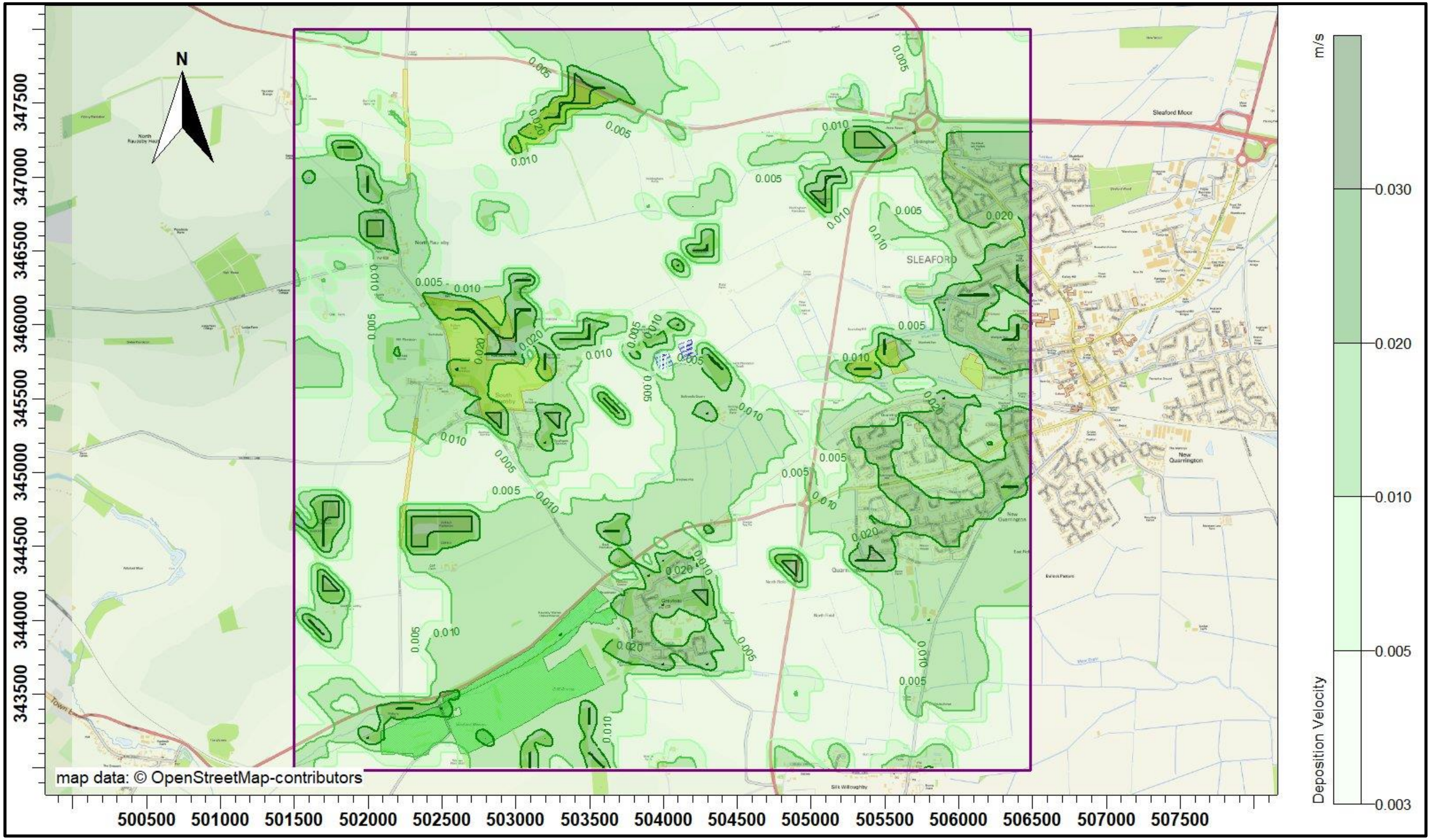
NH_3 concentration (PC + background) (µg/m^3)	< 10	10 - 20	20 - 30	30 - 80	> 80
Deposition velocity - woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity - short vegetation (m/s)	0.02 (0.010 to 0.015 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity - arable farmland/rye 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 fields is provided in Figure 7.

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

Figure 7. The spatially varying deposition field



5. Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

ADMS was effectively run a total of sixteen times, once for each year in 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 a fixed deposition velocity of 0.003 m/s – GFS data.

For each mode, statistics for the maximum annual mean ammonia concentration at each receptor were compiled for the proposed houses only and the whole farm (existing and proposed).

Details of the predicted annual mean ammonia concentrations at each receptor are provided in Table 5. In the Table, predicted ammonia concentrations, including those that would lead to a nitrogen deposition rate, that are in excess of the Environment Agency's upper threshold (50% of a Critical Level or Load for the SSSI and 100% of a Critical Level or Load for an LWS) are coloured red. Concentrations in the range between the Environment Agency's upper threshold and lower threshold (20% to 50% of a Critical Level or Load for the SSSI and 50% to 100% for an LWS) are coloured blue. In addition, predicted ammonia concentrations, including those that would lead to a nitrogen deposition rate, that are in excess of 1% of the Critical Level or Load are highlighted in bold type. For convenience, cells referring to the LWSs are shaded olive and cells referring to the SSSI are shaded green.

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

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)							
				Proposed Only				Existing & Proposed			
				No Calms No Terrain	Calms No Terrain	No Calms Terrain	No Calms Terrain Fixed depv	No Calms No Terrain	Calms No Terrain	No Calms Terrain	No Calms Terrain Fixed depv
1	503230	345690	Unnamed LWS	0.050	0.050	0.047	0.040	0.172	0.170	0.161	0.136
2	502953	346047	Unnamed LWS	0.023	0.023	0.024	0.020	0.082	0.082	0.087	0.071
3	502800	345389	Unnamed LWS	0.022	0.022	0.020	0.017	0.081	0.080	0.075	0.061
4	502402	346172	Unnamed LWS	0.012	0.012	0.013	0.010	0.046	0.046	0.049	0.036
5	505262	345717	Unnamed LWS	0.035	0.035	0.032	0.029	0.158	0.156	0.144	0.129
6	506032	345691	Unnamed LWS	0.018	0.018	0.016	0.013	0.077	0.076	0.067	0.057
7	503019	347184	Unnamed LWS	0.015	0.014	0.017	0.013	0.055	0.054	0.064	0.050
8	503558	347519	Unnamed LWS	0.016	0.015	0.017	0.013	0.061	0.061	0.069	0.054
9	502253	347013	Unnamed LWS	0.009	0.009	0.009	0.007	0.033	0.033	0.035	0.025
10	502302	345244	Unnamed LWS	0.014	0.013	0.013	0.010	0.051	0.051	0.048	0.037
11	502245	344755	Unnamed LWS	0.010	0.010	0.011	0.009	0.039	0.039	0.041	0.032
12	503541	344203	Wilsford & Rauceby Warrens SSSI	**0.012**	**0.011**	**0.012**	**0.010**	**0.045**	**0.045**	**0.048**	**0.041**
13	502984	343735	Wilsford & Rauceby Warrens SSSI	0.007	0.007	0.008	0.007	**0.028**	**0.028**	**0.031**	**0.026**
14	502516	343474	Wilsford & Rauceby Warrens SSSI	0.006	0.005	0.006	0.005	**0.021**	**0.021**	**0.026**	**0.020**
15	503575	343566	Wilsford & Rauceby Warrens SSSI	0.007	0.007	0.007	0.006	**0.029**	**0.029**	**0.029**	**0.023**
16	502647	343117	Wilsford & Rauceby Warrens SSSI	0.005	0.005	0.005	0.004	**0.020**	**0.020**	**0.021**	**0.017**
17	502094	343106	Wilsford & Rauceby Warrens SSSI	0.004	0.004	0.005	0.004	**0.017**	**0.017**	**0.021**	**0.016**
18	499671	348808	High Dyke SSSI	0.003	0.003	0.003	0.002	0.011	0.011	0.011	0.006
19	499114	351239	High Dyke SSSI	0.002	0.002	0.003	0.001	0.009	0.009	0.010	0.005
20	498201	343835	Moor Closes SSSI	0.003	0.003	0.003	0.002	0.011	0.011	0.011	0.007
21	498738	343027	Ancaster Valley SSSI	0.003	0.003	0.003	0.002	**0.011**	**0.011**	**0.012**	0.007
22	498201	343236	Copper Hill SSSI	0.003	0.003	0.003	0.002	0.010	0.010	0.011	0.006
23	497867	342672	Copper Hill SSSI	0.002	0.002	0.002	0.001	0.009	0.009	0.010	0.005
24	498856	341578	Wilsford Heath Quarry SSSI	0.002	0.002	0.002	0.001	0.009	0.009	0.010	0.006
25	495471	342372	Honington Camp SSSI	0.002	0.002	0.002	0.001	0.007	0.007	0.007	0.003

5.2 Detailed modelling

In this case, detailed modelling has been carried out over a high resolution 5 km x 5 km domain covering Boiling Wells Farm and Wilsford & Rauceby Warrens SSSI. The primary purpose is to determine the magnitude of deposition of ammonia and consequent plume depletion close to the sources where it is of the greatest importance. Outside of the 5 km x 5 km domain a fixed deposition velocity of 0.005 m/s is assumed (with appropriate deposition velocities applied post-modelling at the discrete receptors).

The detailed deposition run was made with terrain. Calms cannot be used with terrain or spatially varying deposition; therefore, calms have not been included in the detailed modelling; however, the results of the preliminary modelling indicate that the effects of calms are insignificant in this case.

Note that as part of the sensitivity testing, the model was also run in “regulatory” mode, with constant fixed emissions at the standard Environment Agency emission factor). The results are not presented in this report but are available upon request.

The predicted maximum annual mean ground level ammonia concentrations and nitrogen deposition rates at the discrete receptors included within the detailed modelling are shown in Table 6a (proposed houses only) and Table 6b (existing and proposed houses). In the Tables, predicted ammonia concentrations or nitrogen deposition rates that are in excess of the Environment Agency’s upper threshold (50% of Critical Level or Load for a SSSI) are coloured red. Ammonia concentrations or nitrogen deposition rates in the range between the Environment Agency’s upper threshold and lower threshold (20% to 50% of Critical Level or Load for a SSSI) are coloured blue and ammonia concentrations or nitrogen deposition rates that exceed 1% of the Critical Level or Load are highlighted with bold text.

Contour plots of the predicted ground level maximum annual mean ammonia concentration and maximum annual nitrogen deposition rate are shown in Figures 8a and 8b (proposed houses only) and 9a and 9b (existing and proposed houses).

Table 6a. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates -proposed houses only

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (μg/m³)	Critical Load (kg/ha)	Process Contribution (μg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	503230	345690	Unnamed LWS	0.030	1.0	10.0	0.033	3.3	0.26	2.6
2	502953	346047	Unnamed LWS	0.030	1.0	10.0	0.016	1.6	0.12	1.2
3	502800	345389	Unnamed LWS	0.030	1.0	10.0	0.013	1.3	0.11	1.1
4	502402	346172	Unnamed LWS	0.030	1.0	10.0	0.008	0.8	0.06	0.6
5	505262	345717	Unnamed LWS	0.030	1.0	10.0	0.023	2.3	0.18	1.8
6	506032	345691	Unnamed LWS	0.030	1.0	10.0	0.011	1.1	0.08	0.8
7	503019	347184	Unnamed LWS	0.030	1.0	10.0	0.011	1.1	0.08	0.8
8	503558	347519	Unnamed LWS	0.030	1.0	10.0	0.011	1.1	0.08	0.8
9	502253	347013	Unnamed LWS	0.030	1.0	10.0	0.006	0.6	0.04	0.4
10	502302	345244	Unnamed LWS	0.030	1.0	10.0	0.009	0.9	0.07	0.7
11	502245	344755	Unnamed LWS	0.030	1.0	10.0	0.008	0.8	0.06	0.6
12	503541	344203	Wilsford & Rauceby Warrens SSSI	0.020	1.0	15.0	0.009	0.88	0.05	0.30
13	502984	343735	Wilsford & Rauceby Warrens SSSI	0.020	1.0	15.0	0.005	0.53	0.03	0.18
14	502516	343474	Wilsford & Rauceby Warrens SSSI	0.020	1.0	15.0	0.004	0.39	0.02	0.14
15	503575	343566	Wilsford & Rauceby Warrens SSSI	0.020	1.0	15.0	0.005	0.47	0.02	0.16
16	502647	343117	Wilsford & Rauceby Warrens SSSI	0.020	1.0	15.0	0.004	0.39	0.02	0.14
17	502094	343106	Wilsford & Rauceby Warrens SSSI	0.020	1.0	15.0	0.003	0.34	0.02	0.12
18	499671	348808	High Dyke SSSI	0.020	3.0	15.0	0.001	0.05	0.01	0.05
19	499114	351239	High Dyke SSSI	0.020	3.0	15.0	0.001	0.04	0.01	0.04
20	498201	343835	Moor Closes SSSI	0.030	3.0	15.0	0.001	0.05	0.01	0.08
21	498738	343027	Ancaster Valley SSSI	0.030	1.0	10.0	0.001	0.15	0.01	0.11
22	498201	343236	Copper Hill SSSI	0.020	3.0	15.0	0.001	0.04	0.01	0.05
23	497867	342672	Copper Hill SSSI	0.020	3.0	15.0	0.001	0.04	0.01	0.04
24	498856	341578	Wilsford Heath Quarry SSSI	0.020	3.0	15.0	0.001	0.04	0.01	0.04
25	495471	342372	Honington Camp SSSI	0.020	3.0	15.0	0.001	0.02	0.00	0.02

Table 6b. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates -existing and proposed houses

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (μg/m³)	Critical Load (kg/ha)	Process Contribution (μg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	503230	345690	Unnamed LWS	0.030	1.0	10.0	0.112	11.2	0.87	8.7
2	502953	346047	Unnamed LWS	0.030	1.0	10.0	0.056	5.6	0.44	4.4
3	502800	345389	Unnamed LWS	0.030	1.0	10.0	0.049	4.9	0.38	3.8
4	502402	346172	Unnamed LWS	0.030	1.0	10.0	0.028	2.8	0.22	2.2
5	505262	345717	Unnamed LWS	0.030	1.0	10.0	0.103	10.3	0.80	8.0
6	506032	345691	Unnamed LWS	0.030	1.0	10.0	0.047	4.7	0.36	3.6
7	503019	347184	Unnamed LWS	0.030	1.0	10.0	0.040	4.0	0.31	3.1
8	503558	347519	Unnamed LWS	0.030	1.0	10.0	0.043	4.3	0.34	3.4
9	502253	347013	Unnamed LWS	0.030	1.0	10.0	0.021	2.1	0.16	1.6
10	502302	345244	Unnamed LWS	0.030	1.0	10.0	0.033	3.3	0.26	2.6
11	502245	344755	Unnamed LWS	0.030	1.0	10.0	0.030	3.0	0.23	2.3
12	503541	344203	Wilsford & Rauceby Warrens SSSI	0.020	1.0	15.0	0.035	**3.46**	0.18	**1.20**
13	502984	343735	Wilsford & Rauceby Warrens SSSI	0.020	1.0	15.0	0.021	**2.09**	0.11	0.72
14	502516	343474	Wilsford & Rauceby Warrens SSSI	0.020	1.0	15.0	0.016	**1.57**	0.08	0.54
15	503575	343566	Wilsford & Rauceby Warrens SSSI	0.020	1.0	15.0	0.019	**1.88**	0.10	0.65
16	502647	343117	Wilsford & Rauceby Warrens SSSI	0.020	1.0	15.0	0.015	**1.54**	0.08	0.53
17	502094	343106	Wilsford & Rauceby Warrens SSSI	0.020	1.0	15.0	0.014	**1.37**	0.07	0.47
18	499671	348808	High Dyke SSSI	0.020	3.0	15.0	0.006	0.19	0.03	0.20
19	499114	351239	High Dyke SSSI	0.020	3.0	15.0	0.005	0.16	0.02	0.16
20	498201	343835	Moor Closes SSSI	0.030	3.0	15.0	0.006	0.19	0.05	0.30
21	498738	343027	Ancaster Valley SSSI	0.030	1.0	10.0	0.006	0.57	0.04	0.45
22	498201	343236	Copper Hill SSSI	0.020	3.0	15.0	0.005	0.17	0.03	0.18
23	497867	342672	Copper Hill SSSI	0.020	3.0	15.0	0.004	0.15	0.02	0.15
24	498856	341578	Wilsford Heath Quarry SSSI	0.020	3.0	15.0	0.005	0.16	0.03	0.17
25	495471	342372	Honington Camp SSSI	0.020	3.0	15.0	0.003	0.09	0.01	0.09

Figure 8a. Maximum annual ammonia concentration - proposed houses only

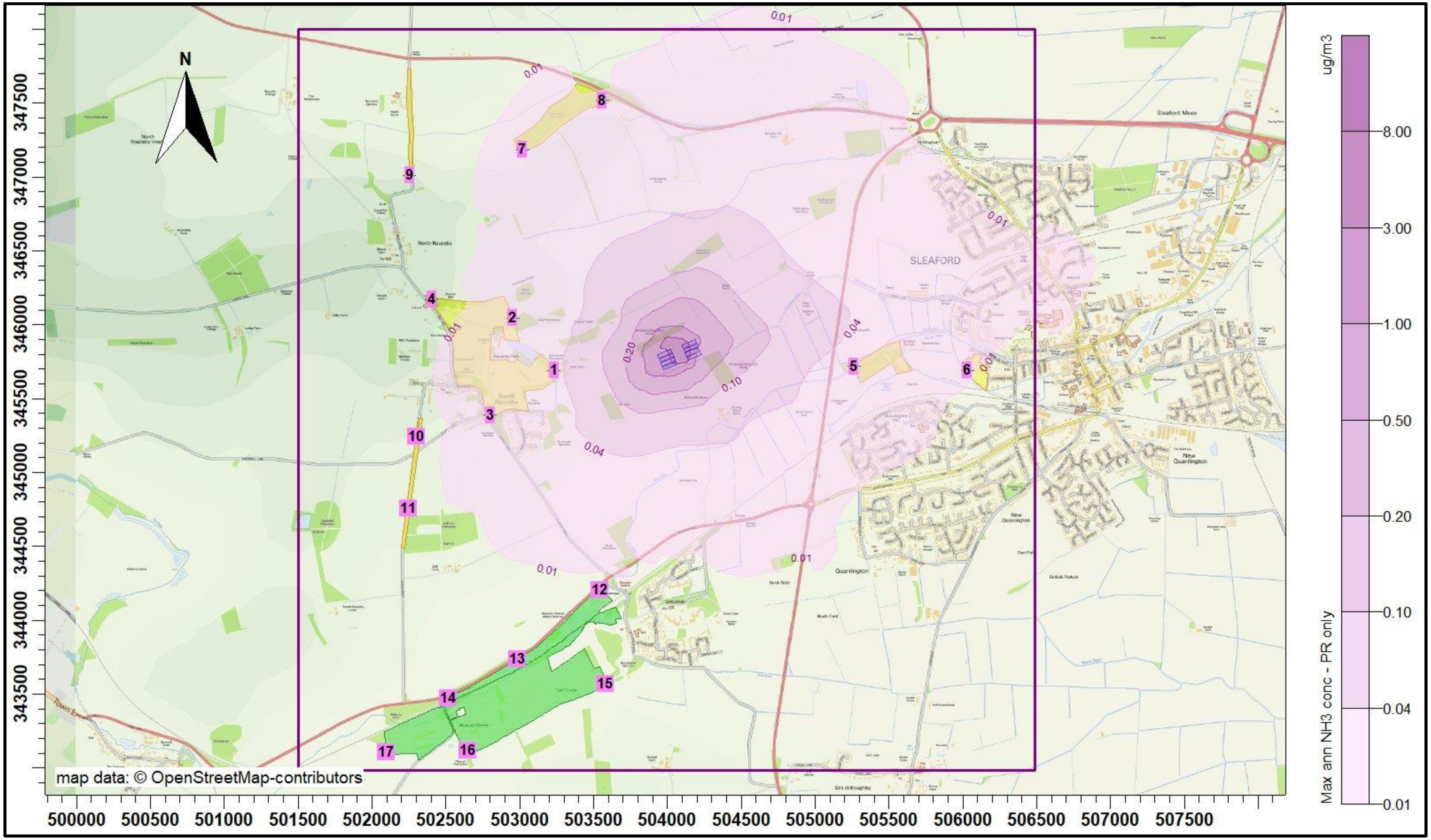


Figure 8b. Maximum annual nitrogen deposition rates - proposed houses only

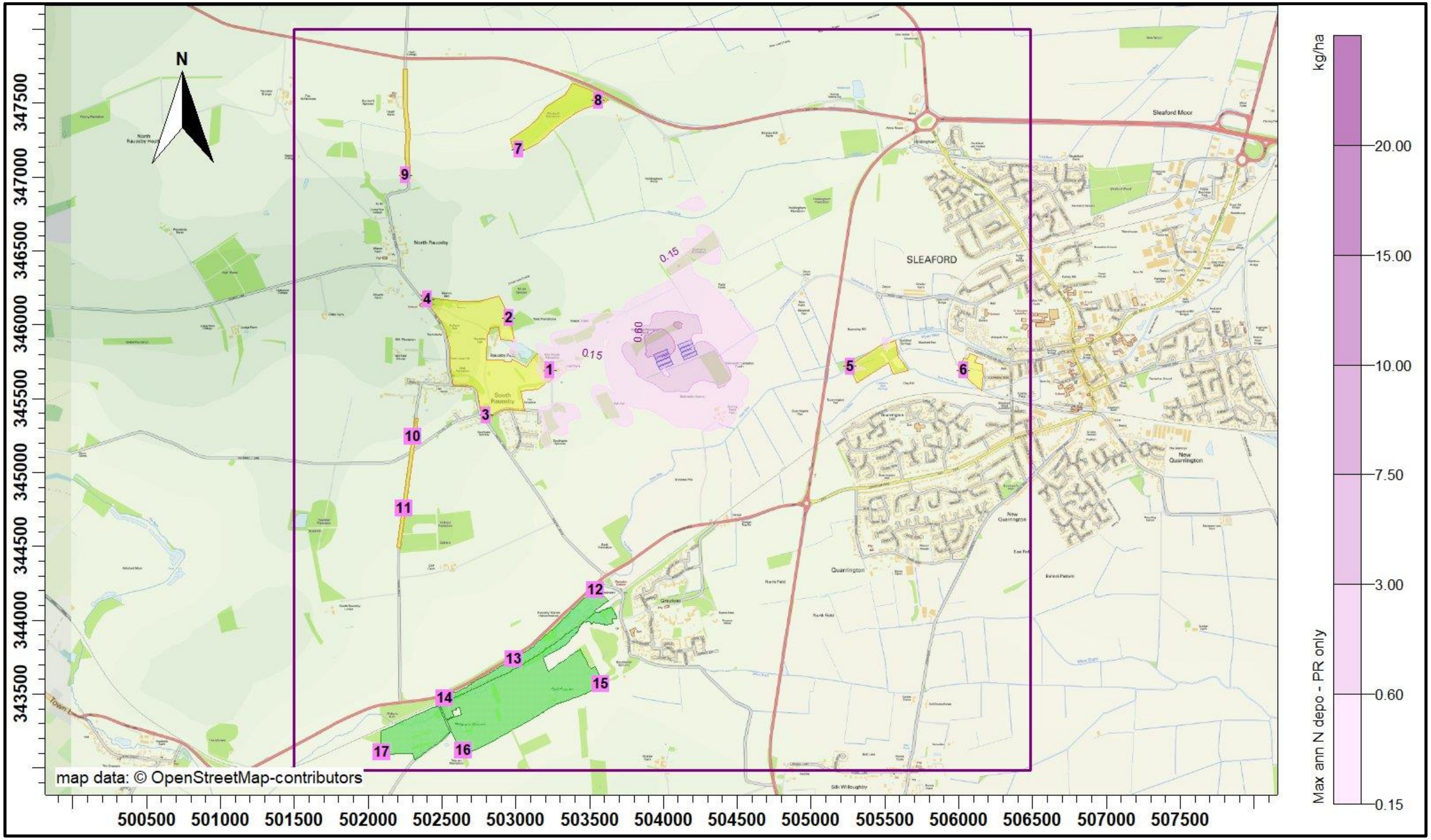


Figure 9a. Maximum annual ammonia concentration - existing and proposed houses

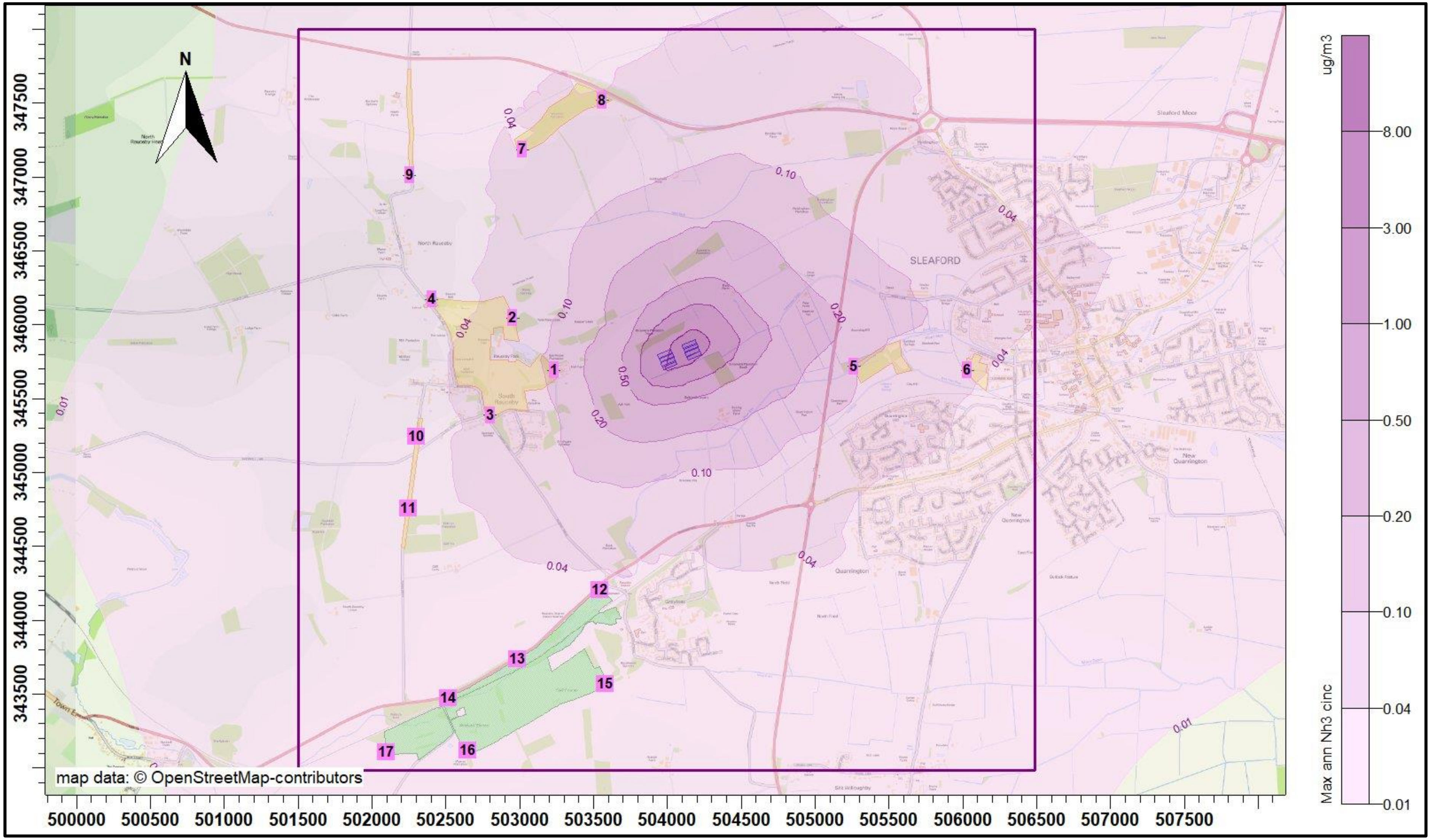
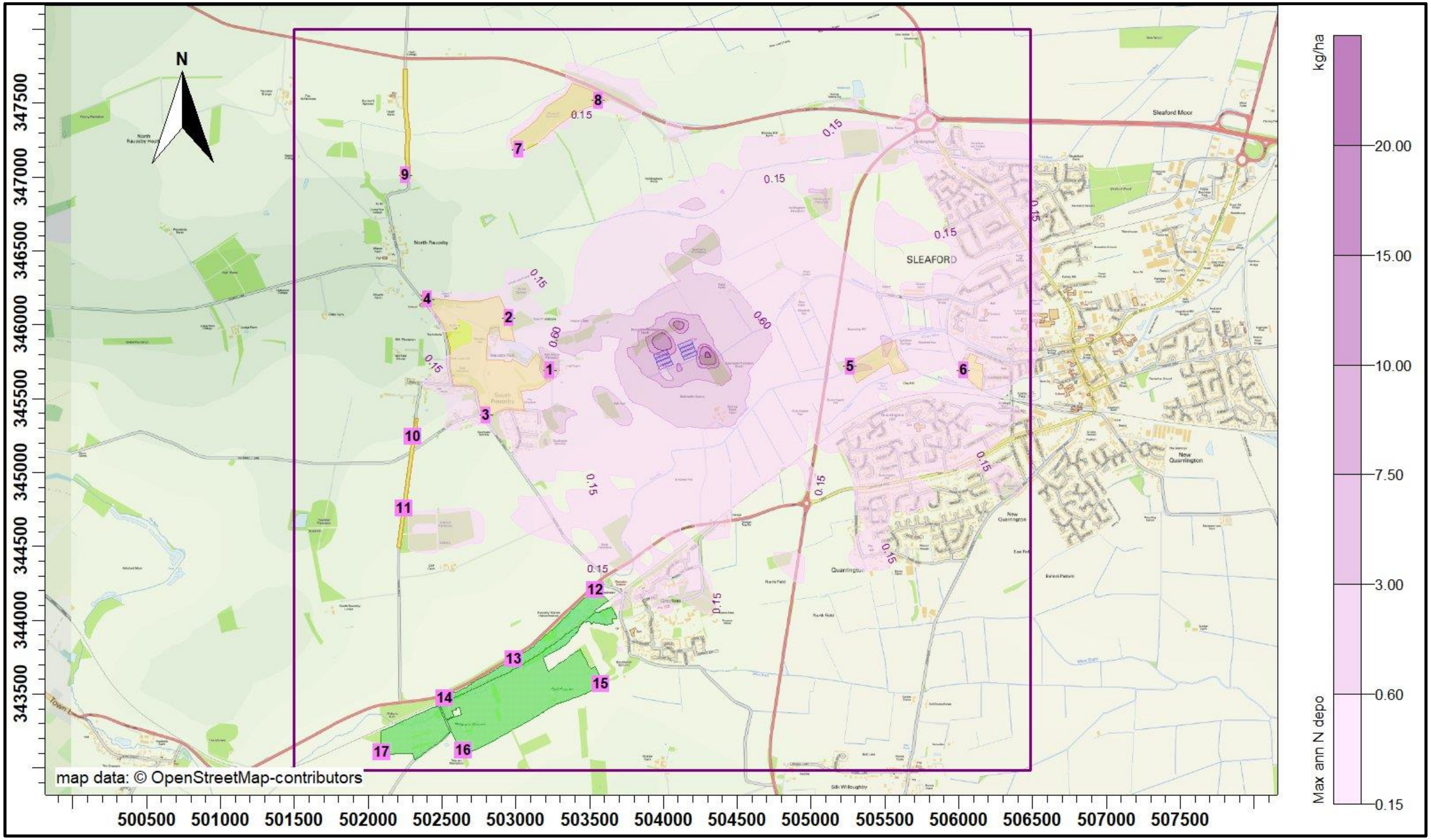


Figure 9b. Maximum annual nitrogen deposition rates - existing and proposed houses



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Mr. Oliver Grundy of JHG Planning Consultancy Ltd., on behalf of Mr. David Bellamy of Greylees Ltd. to use computer modelling to assess the impact of ammonia emissions from the existing and proposed broiler chicken rearing houses at Boiling Wells Farm, Grantham Road, South Rauceby, Sleaford. NG34 8QX.

Ammonia emission rates from the existing and proposed poultry rearing 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.

Existing and Proposed houses

The modelling predicts that:

- At all the wildlife sites considered, the process contribution to ammonia concentration and nitrogen deposition rate would be below the Environment Agency lower threshold percentage of Critical Level or Critical Load for the site (20% for a SSSI and 100% for a non-statutory site).

- At Wilsford & Rauceby Warrens SSSI, the process contribution to ammonia concentration would exceed 1% of the Critical Level of 1 $\mu g\text{-}NH_3/m^3$ and over a small part of the SSSI, 1% of the Critical Load of 10 kg-N/ha/y.

Proposed houses only

The modelling predicts that:

- At all the wildlife sites, the process contribution to ammonia concentration and nitrogen deposition rate would be below the Environment Agency lower threshold percentage of Critical Level or Critical Load for the site (20% for a SSSI and 100% for a non-statutory site).

- The process contribution to ammonia concentrations and nitrogen deposition rates would be below 1% of the Critical level of 1 $\mu g\text{-}NH_3/m^3$ at all statutory wildlife sites considered.

7. References

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