A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing and Proposed Broiler Chicken Rearing Houses at True Hill Farm Poultry Unit, near Brookville in Norfolk

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Revised 24th June 2026 – Amended bird numbers and corrected gable end fan emission rate

Revised 27th June 2026 – Amended bird numbers to 44,000 broilers per house

Revised 30th June 2026 – Added SAC/SPA names and revised scenario 3

Revised 1st July 2026 – Revised Cle/Clo of Breckland SPA in Tables 7a-7d

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Mr. Angus Bridges of Acorus Rural Property Services Ltd., on behalf of his client, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed broiler chicken rearing houses at True Hill Farm Poultry Unit, Main Road, Brookville, Thetford, Norfolk. IP26 4RB.

Ammonia emission rates have been assessed and quantified based upon the Environment Agency standard ammonia emission factors also upon an emissions model that estimates emissions from the Munters Reventa Lavamatic ammonia scrubbing equipment (using information supplied by the manufacturer) that would be fitted to the proposed poultry houses. The 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

True Hill Poultry Unit is located in a rural area approximately 250 m to the north of Brookville in Norfolk. The surrounding land is used mainly for arable and livestock farming and there are some wooded areas. The site is at an altitude of around 15 m, falling gently towards the Norfolk Fens to the west.

There are eight poultry houses at True Hill Farm Poultry Unit, which provide accommodation for up to 352,000 broiler chickens (44,000 per house). The existing poultry houses are ventilated primarily by air scrubbing units, served by two stacks per house on the eastern gable ends, with wall mounted fans providing supplementary ventilation if required in periods of hot weather. The chickens are reared from day old chicks for a period of around 38 days and houses would be empty for around 10 days at the end of each crop.

It is proposed that two new poultry houses be constructed immediately north of the existing housing. The new houses would provide accommodation for an additional 88,000 broiler chickens. Ventilation would be provided primarily by air scrubbing units, served by two stacks per house on the eastern gable ends, with wall mounted fans providing supplementary ventilation if required in periods of hot weather. The chickens would be reared from day old chicks for a period of around 38 days and houses would be empty for around 10 days at the end of each crop.

At the request of the Environment Agency, four scenarios have been considered in this report:

- Baseline scenario – Eight poultry houses with 352,000 broiler chickens. Ventilated primarily by air scrubbing units, served by two stacks per house on the eastern gable ends, with wall mounted fans providing supplementary ventilation if required in periods of hot weather.
- Proposed scenario – The eight existing poultry houses and two additional houses with a total of 440,000 broiler chickens. All houses are/would be ventilated primarily by air scrubbing units, served by two stacks per house on the eastern gable ends, with wall mounted fans providing supplementary ventilation if required in periods of hot weather.
- Proposed scenario no abatement – The eight existing poultry houses and two additional houses with a total of 440,000 broiler chickens. Ventilated by wall-mounted gable end fans.
- Proposed houses only – with abatement – Two proposed poultry houses with 88,000 broiler chickens. Ventilated primarily by air scrubbing units, served by two stacks per house on the eastern gable ends, with wall mounted fans providing supplementary ventilation if required in periods of hot weather.

There are several areas designated as Local Wildlife Sites (LWSs) within 2 km (the normal screening distance for non-statutory sites) of True Hill Farm Poultry Unit. There are no Ancient Woodlands (AWs) within 2 km. There are six areas designated as Sites of Special Scientific Interest (SSSIs) within 5 km of the site (Natural England and Environment Agency screening distance). There are further SSSIs within 10 km, some of the SSSIs are also designated as Special Areas of Conservation (SACs) and/or Special Protection Areas (SPAs).

Some further details of the statutory wildlife sites are provided below:

- **The Brinks, Northwold SSSI** - Approximately 2.3 km to the south-west - Unimproved grazed herb-rich meadows.
- **Didlington Park Lakes SSSI** - Approximately 3.9 km to the east - Three shallow lakes constructed in the early nineteenth century important for breeding birds.
- **Boughton Fen SSSI** - Approximately 4.5 km to the north-north-west - Shallow fen peats with several interesting plants.
- **Wretton SSSI** - Approximately 4.9 km to the north-west - Geological.
- **Hilgay Heronry SSSI** - Approximately 9.9 km to the north-west - Ornithological.
- **Foulden Common SSSI/SAC** - Approximately 3.3 km to the north-north-east - A wide range of habitats supporting a large number of plant and animal species including national rarities.
- **Gooderstone Warren SSSI/SAC/SPA** - Approximately 7.0 km to the north-east - Species-rich heathland and a shallow grassland valley.
- **Cranwich Camp SSSI/SPA** - Approximately 4.7 km to the south-east - Breckland grassland with high botanical and entomological interest.
- **Field Barn Heaths, Hilborough SSSI/SAC/SPA** - Approximately 9.1 km to the north-east - Species-rich calcareous and mixed grassland situated close to the northern edge of the Breckland region. The soils are typical light sandy tills with flints overlying chalk and the characteristic Breck grassland communities are maintained by rabbit grazing.
- **Weeting Heath SSSI/SAC/SPA** - Approximately 7.0 km to the south-south-east - Open, rabbit-grazed, Breckland grass-heath. Most of the site is covered by calcareous grassland and lichen-dominated heath, and a number of rare plants characteristic of Breckland are present. A small arable weed reserve is included within the site and many of the rare Breckland annuals have been introduced into it. The site is of considerable ornithological importance supporting a high breeding density and variety of heathland birds.
- **Breckland Forest SSSI/SPA** - Approximately 2.3 km to the south-east (closest point) - The clear fell areas and young plantations within Breckland Forest SSSI provide suitable breeding habitat for woodlark *Lullula arborea* and nightjar *Caprimulgus europaeus*, which occur in internationally important numbers. The forest also supports an important assemblage of Nationally Rare and nationally scarce vascular plant species, a number of which are largely restricted to East Anglia and occupy habitats characteristic of Breckland. Breckland Forest SSSI also supports an exceptionally rich invertebrate fauna with Red Data Book and nationally scarce species across most taxonomic groups that have been studied. A mammal species associated with the conifer plantations is the red squirrel *Sciurus vulgaris*.
- **Breckland Farmland SSSI/SPA** - Approximately 4.2 km to the north-east (closest point) - Notable for its internationally important population of stone curlew *Burhinus oedicnemus*. The predominant land use within the SSSI is arable.
- **Stanford Training Area SSSI/SAC/SPA** - Approximately 9.8 km to the east-south-east - A very extensive area of Breckland grassland and heath. Habitats of particular nature conservation importance include the calcareous grass-heath, the heather heath, and the areas which support an intimate mosaic of acid and calcareous communities. The fluctuating meres, fed by groundwater, are internationally important. The site also includes other areas of standing water, wetlands and many springs and streams. These benefit from the large area of the SSSI because they are largely unaffected by drainage, pollution, eutrophication or water abstraction. Many of them are consequently extremely species-rich. The SSSI also contains a substantial acreage of woodland which increases the overall habitat diversity. This diversity is reflected in the great variety of bird and insect life that the area supports.

Maps of the surrounding area showing the positions of True Hill Farm Poultry Unit (outlined in blue), the LWSs (shaded in yellow), the SSSIs (shaded in green), the SACs (shaded in purple) and the SPAs (shaded in orange) are provided in Figures 1a and 1b. Note that where there are multiple designations, the SACs and SPAs are given prominence.

Figure 1a. The area surrounding True Hill Poultry Unit – concentric circles radii 2.0 km (olive), 5.0 km (green) and 10.0 km (purple)

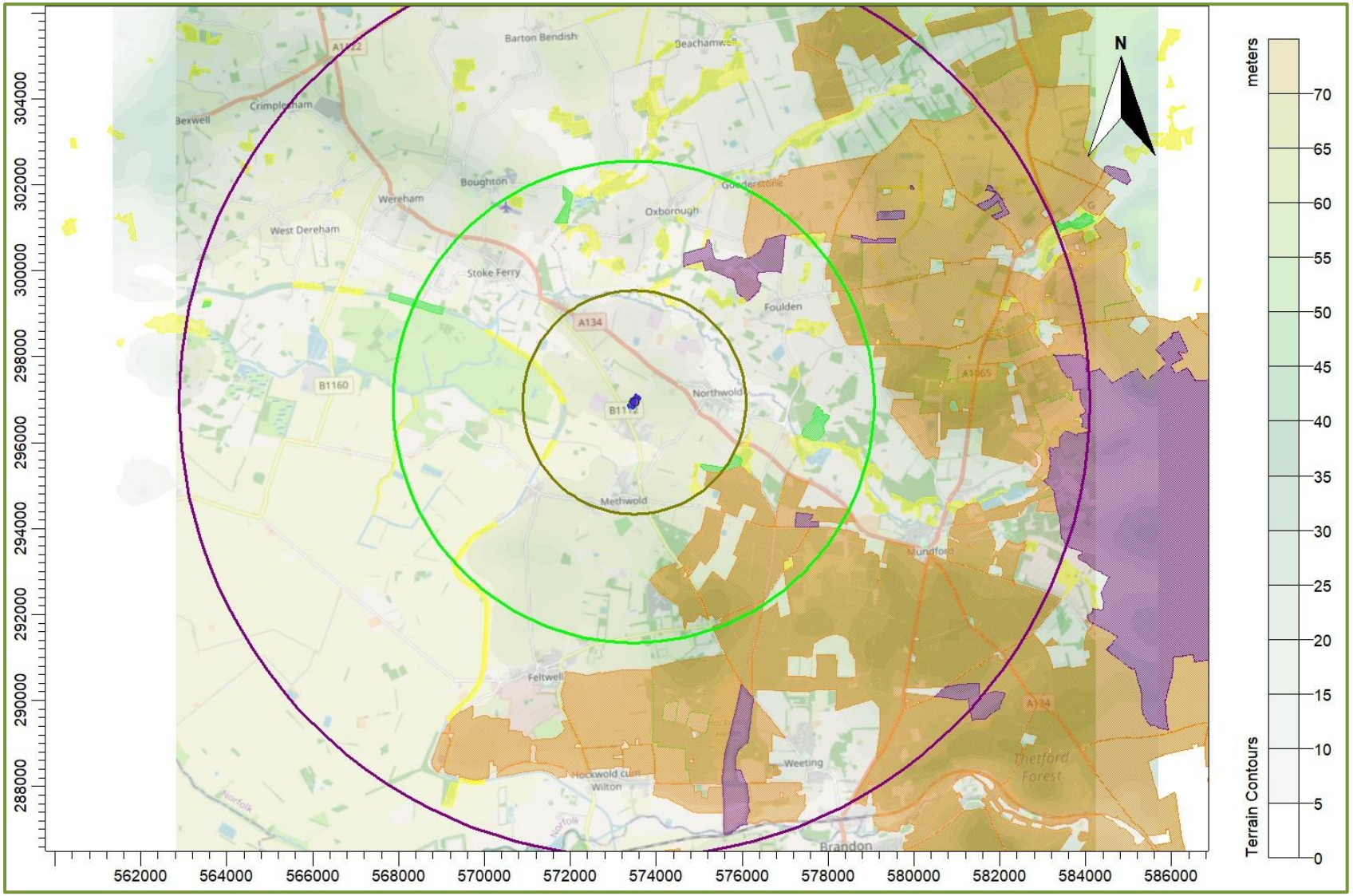
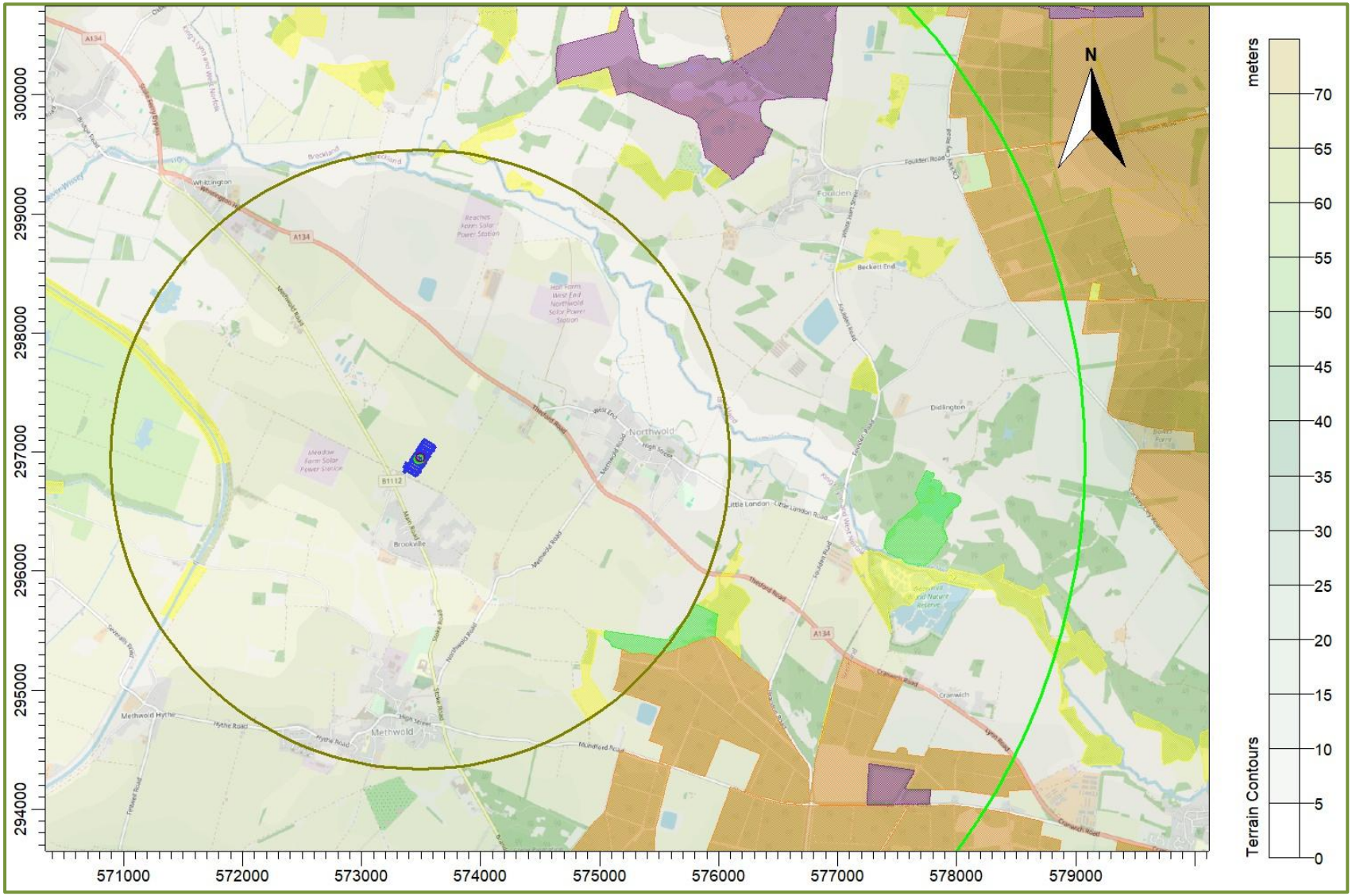


Figure 1b. The area surrounding True Hill Poultry Unit – a closer view



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

3.1 Ammonia concentration and nitrogen and acid deposition

When assessing potential impact on ecological receptors, ammonia concentration is usually expressed in terms of micrograms of ammonia per metre cubed of air (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, May 2026). It should be noted that the 1 km APIS database background levels are extrapolated from 5 km modelled data. Ammonia levels may vary markedly over relatively short distances and the APIS website itself notes that, the background values should be used only to assist the user in obtaining a broad indication of the likely pollutant impact at a specific location and cannot be considered representative of any particular location within the 5 km grid square; extrapolation to a 1 km grid does not alter this.

The APIS figures for background ammonia concentration in the area around True Hill Poultry Unit is 1.99 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 33.01 kg-N/ha/y and to short vegetation is 17.63 kg-N/ha/y. The background acid deposition rate to woodland is 2.4 keq/ha/y and to short vegetation is 1.28 keq/ha/y.

The APIS background figures are subject to correction and revision and appear to change fairly frequently, the latest figures can be obtained at https://www.apis.ac.uk/app.

In most cases, the APIS background figures, which are modelled, extrapolated and statistically manipulated figures, nevertheless, are the only figures available and although it is noted that the background values should be used only to assist in obtaining a broad indication of the likely pollutant impact, it is also noted that across the majority of the UK the lower bounds of the Critical Level and Critical Load are already exceeded.

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). However, AS Modelling & Data Ltd. would note that effects have been shown to occur at loads that are well below existing Critical Loads (as currently defined) and that these effects are likely to adversely impact the most sensitive species first. Furthermore, recent research suggests that responses are far from linear and where background levels are high and sensitive species that may be associated with the habitat have already been negatively impacted, or indeed are now absent, responses to changes in nitrogen load (in terms of biodiversity) are relatively limited compared to where background levels are low. Therefore, what is deemed significant (in terms of a percentage of Critical Load), where background levels are low, is not necessarily significant where background levels are high.

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 used as the assessment criteria at the relevant receptor locations 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, therefore acid deposition has not been considered further.

Please note that the assessment requirement is to use the lower bound of the range of Critical Loads for habitats that are present; however, the APIS database (https://www.apis.ac.uk/app) may contain Critical Levels and Critical Loads for species/habitats that are not present at the site, or not present at the parts of the site under consideration.

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)
LWSs	1.0 [1]	-	-
Didlington Park Lakes SSSI; Breckland Forest SSSI [5]	3.0 [2]	n/a [4]	n/a [4]
Cranwich Camp SSSI/SPA [5]; Gooderstone Warren SSSI/SPA [5]; Foulden Common SSSI/SAC [5]; Weeting Heath SSSI/SAC/SPA [5]; Grime's Graves SSSI/SAC/SPA [5]; Stanford Training Area SSSI/SAC/SPA [5]	1.0 [1 & 2]	5.0 [2 & 3]	-
The Brinks Northwold SSSI;	3.0 [2]	10.0 [2 & 3]	-
Boughton Fen SSSI	3.0 [2]	15.0 [2 & 3]	-
Wretton SSSI; Field Barn Heaths, Hilborough SSSI/SAC/SPA [5]	1.0 [1]	10.0 [1]	-
Hilgay Heronry SSSI; Breckland Farmland SSSI [5]	n/a [2 & 4]	n/a [3 & 4]	n/a [3 & 4]

1. A precautionary figure used where details of the site are entirely unknown, or where although citations do not explicitly mention lichens or bryophytes, they are likely to be present.
2. Based upon the citation for the site (note that in some cases, the APIS database contains Critical Levels/Loads for habitats/species that are not present or not present at the site/parts of the site within the relevant screening distance).
3. The lower bound of the range of Critical Loads for habitats present at the site. (please note that in some cases, the APIS database contains Critical Loads for habitats/species that are not present at the site/parts of the site within the relevant screening distance).
4. No Critical Levels/Loads for designated features/habitats present.
5. Several SSSIs share a designation with Breckland SPA/SAC and Norfolk Valley Fens SAC. Whilst the SPA/SACs have Critical Levels and Loads listed on APIS the sites are vast and varied and not all of those habitats are present at each of the SSSIs considered, therefore, in these cases the SSSIs Critical Level/Load has been retained.

3.4 Guidance on the Significance of Ammonia Emissions

3.4.1 Environment Agency Criteria

The Environment Agency and Department for Environment, Food & Rural Affairs published guidance "Intensive farming risk assessment for your environmental permit" (last updated August 2025) applies to ammonia emitting developments requiring a permit. The Environment Agency ammonia screening thresholds for designated nature conservation sites are given in Table 2.

Table 2. Environment Agency Screening Thresholds

Nature conservation site designation	Distance from site (km)	Lower threshold %	Upper threshold %
Special Protection Areas (SPAs), Special Areas of Conservation (SACs), Ramsar sites	5	1	No upper threshold
Sites of Special Scientific Interest (SSSIs)	5	20	50
Local nature sites (National Nature Reserves, Local Nature Reserves, Local Wildlife Sites, Ancient Woodlands)	2	100	100

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, 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 Process Contribution of up to 100% of Critical Level and/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 guidance for Local Authorities

Natural England, a statutory consultee at planning, published the "Air pollution and development: advice for local authorities" guidance document in October 2025, which is applicable to ammonia assessments of agricultural proposals in England.

For livestock and poultry units (over 500 m^2 floorspace) the screening distance for SSSIs is 5 km and for habitats sites (SPAs, SAC's and Ramsar Sites) is 10 km. It should be noted that Natural England screening distances may differ from the Environment Agency and Department for Environment, Food & Rural Affairs published guidance.

If the predicted process contributions of the proposal to the relevant Critical Level and/or Critical Load are 1% or more, further assessment may be required. If a proposal does not exceed 1% of the Critical Level and/or Critical Load alone, the Local Authority should consider the proposal in-combination. It is a legal requirement to assess process contributions in-combination for habitats sites (SPAs, SACs and Ramsar sites) only. In-combination assessment would not be required where the proposal would result in a reduction in emissions or where process contributions would be below the Joint Nature Conservancy Committee Decision Making Thresholds.

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 NH_3 - 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 - 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.

3.5 Quantification of Ammonia Emissions

Ammonia emission rates from poultry housing depends on many factors and are likely to be highly variable. However, the benchmarks for assessing impacts of ammonia and nitrogen deposition are framed in terms of an annual mean ammonia concentration and annual nitrogen deposition rates. To obtain relatively robust figures for these statistics, it is not necessary to model short term temporal variations and a steady continuous emission rate can be assumed. In fact, modelling short term temporal variations might introduce rather more uncertainty than modelling continuous emissions.

3.5.1 Emissions from the existing and proposed air scrubbers

The ventilation rates used in the calculations for the poultry houses 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 (the maximum ventilation rate is ~10 m^3-air/bird/h). 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.

The capacities of the air scrubbers would be 110,000 m^3/h (30.55 m^3/s) each, if the modelled ventilation rate exceeds the scrubber capacity, additional ventilation would be provided by the ridge mounted fans. The concentration is based upon long term, high temporal resolution monitoring of broiler rearing houses elsewhere and is dependent upon the crop stage. Similarly, to the scrubber emissions, an emission rate from the bypass ventilation system is calculated by multiplying the internal concentration by the ventilation rate. It should be noted that, the internal ammonia concentrations assumed are set so as to give approximately the same overall emission factor as the regulatory standard emission factor; however, bypass ventilation is only likely to be used if the crop is in the latter stages, therefore, real emissions from bypass systems (and AS Modelling & Data Ltd emissions) are somewhat higher than if the regulatory fixed emission rate were to be used.

The annual emission rates are variable, as they depend on ambient temperature and for example how often bypass ventilation is used. However, the average emission rate over the four year meteorological record is equivalent to an emission factor of 0.005938 kg-NH_3/bird place/y, which is approximately 24.7% of the standard emission factor of 0.024 kg-NH_3/bird place/y, i.e. assuming an outlet concentration of 1.0 ppm (704.4 µg/m^3) from the DLG test certificate and data provided by the manufacturer, the use of scrubbers would reduce housing emissions by approximately 75.3% from regulatory emission figures. This estimated reduction in ammonia emissions is consistent with the DLG test certificate for the air scrubbers, which states that in testing 73.8% of ammonia was removed in summer and 83% in winter.

The modelling of the houses assumes that the scrubbers are 100% operational.

For the calculation of the emission rates from the bypass ventilation, the internal concentration of the houses is assumed to be approximately 8.5 ppm at the end of the crop cycle; this figure is used because, assuming standard ventilation rates, it approximates the regulatory ammonia emission factor. Similarly to the scrubber emissions, an emission rate from the bypass ventilation system is calculated by multiplying the internal concentration by the ventilation rate. It should be noted that the use of the bypass system would only be required in what would currently be considered extremely hot weather conditions for northernmost parts of England.

As an example, the ammonia emission rates from the AS Modelling & Data Ltd. emissions model for one of the houses for 2022 (the warmest year) is shown graphically in Figure 2.

3.5.2 Emissions from the gable end fans with no abatement

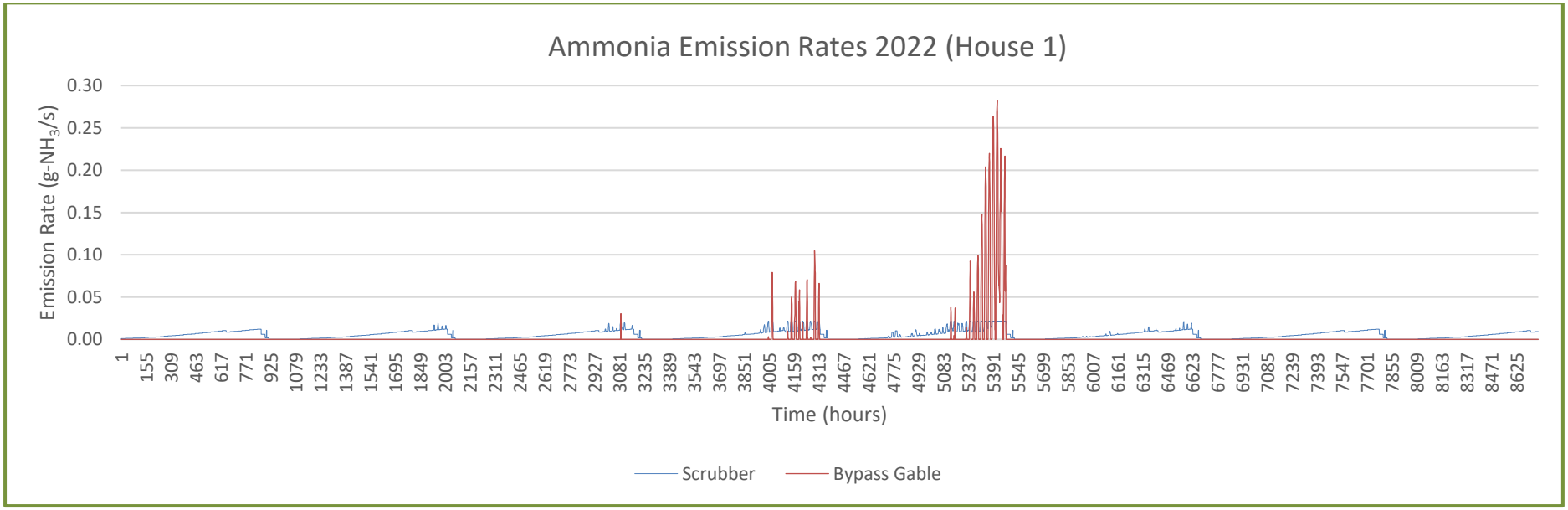
The emission factor used for the broiler rearing chickens (with no abatement) at True Hill has been obtained from: https://www.gov.uk/guidance/ammonia-emission-factors-for-pig-and-poultry-screening-modelling-and-reporting.

Details of the poultry numbers and types, emission factors and calculated ammonia emission rates to be used in the modelling are provided in Table 3.

Table 3. Details of modelled bird numbers, emission factors used and calculated ammonia emission rates

Scenario	Animal numbers (broilers)	Ventilation Type	Emission factor (kg-NH_3/place/y)	Emission rate (g-NH_3/s)
Baseline Scenario	352,000	Air scrubbing units with bypass wall-mounted gable end fans	0.024	0.267701
Proposed Scenario	440,000	Air scrubbing units with bypass wall-mounted gable end fans	0.024	0.334626
Proposed Scenario – no abatement	440,000	Wall-mounted gable end fans	0.024	0.334626
Proposed Houses Only – with abatement	88,000	Air scrubbing units with bypass wall-mounted gable end fans	0.006	0.016731

Figure 2. Ammonia emission rates over 2022 (House 1, 44,000 birds stocked)



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

The Atmospheric Dispersion Modelling System (ADMS) ADMS 6 is a new generation Gaussian plume air dispersion model, which means that the atmospheric boundary layer properties are characterised by two parameters; the boundary layer depth, and the Monin-Obukhov length rather than in terms of the single parameter Pasquill-Gifford class.

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

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

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

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

4.1 Meteorological data

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

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

The GFS is a discrete model. The physics/dynamics model has a resolution or had a resolution of approximately 7 km over the central 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 overrepresented, 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 2a. Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and where terrain data is included in the modelling, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for the site is shown in Figure 2b. Please 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 2a. The wind rose. Raw GFS derived data for 52.543N, 0.559 E, 2022-2025

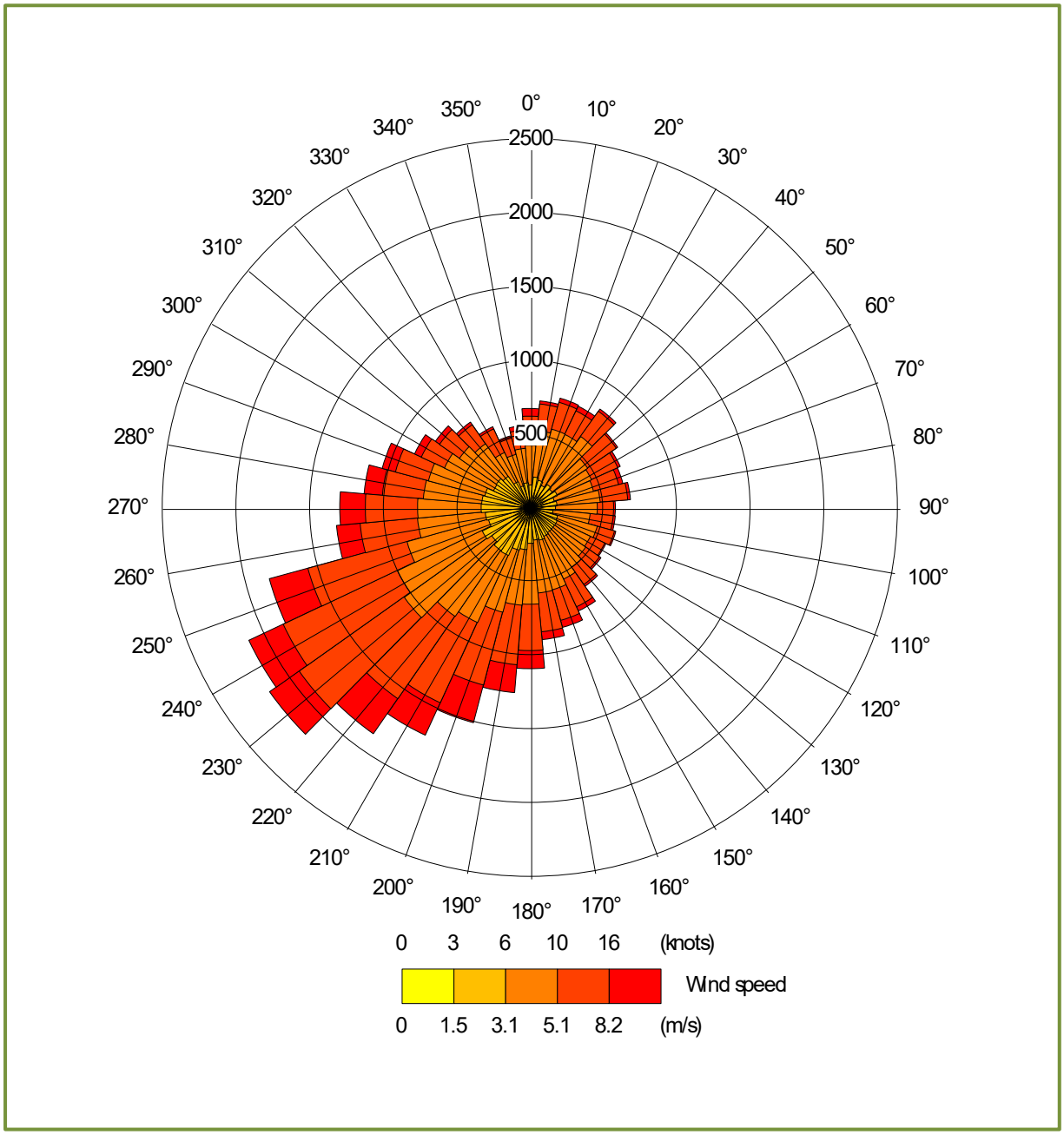
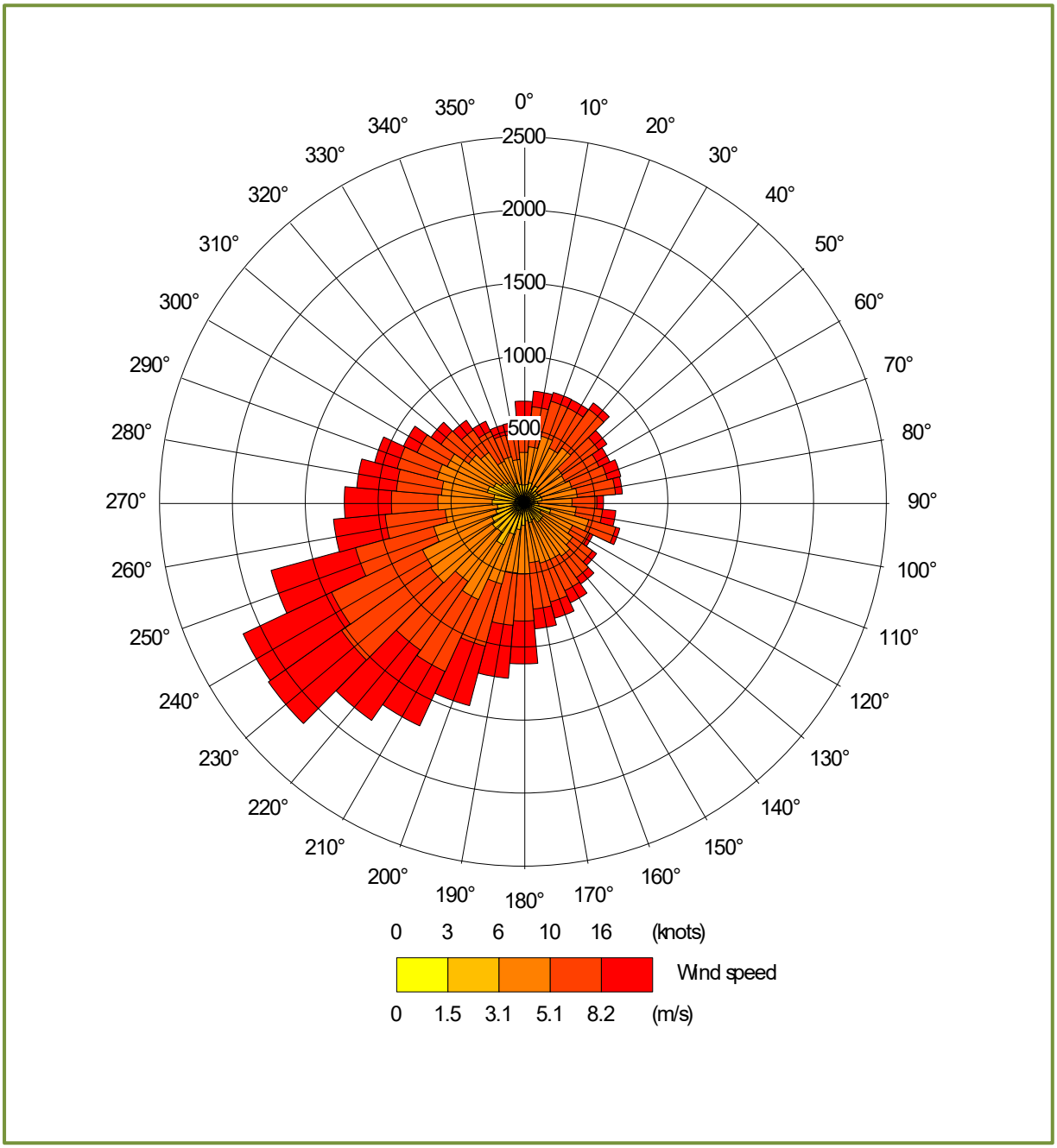


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 573500,297000, 2022-2025



4.2 Emission sources

Emissions from the air scrubbers that provide/would provide the primary ventilation for the houses are represented by two point sources per house within ADMS (SCR1a & SCR1b to SCR8a & SCR8b and PRSCR1a & PRSCR1b and PRSCR2a and PRSCR2b).

Emissions from the gable end fans that would be used for supplementary ventilation of the houses (and the only ventilation of houses in the 'no abatement' scenario) are characterised by volume sources within ADMS (EX_GAB and PR_GAB).

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

Table 4a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Baseline emission rate per source (g-NH_3/s) [3]
SCR1A & B to SCR8A & B	4.2	1.27	3.5	Variable [1]	Variable [1 & 2]
PRSCR1A & B to PRSCR2A & B	4.2	1.27	3.5	Variable [1]	Variable [1 & 2]

1. Dependent on crop stage and ambient temperature.
2. See section 3.5.2
3. The model was initially run with an emission rate per source calculated based on 45,000 broiler chickens per house. The results have been scaled post-modelling to reflect 44,000 broiler chickens per house.

Table 4b. Volume source parameters

Source ID (Scenario)	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Baseline emission rate (g-NH_3/s) [3]
GAB_EX	234.0	10.0	4.0	1.0	Ambient	Variable [1 & 2]
GAB_PR (with abatement)	55.3	10.0	4.0	1.0	Ambient	Variable [1 & 2]
GAB_EX (no abatement)	234.0	10.0	4.0	1.0	Ambient	0.273785
GAB_PR (no abatement)	55.3	10.0	4.0	1.0	Ambient	0.066925

4.3 Modelled buildings

The structures of the poultry houses and other nearby buildings may affect the plumes from the point sources. Therefore, the buildings are modelled within ADMS. The positions of the modelled buildings may be seen in Figure 3 (marked by grey rectangles).

4.4 Discrete receptors

Forty-two discrete receptors have been defined at the nearby wildlife sites. These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figures 4a and 4b (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 4a and 4b (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 23.0 km by 23.0 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 350 m.

4.7 Roughness Length

In this case, a spatially varying roughness length file has been defined, this is based upon the UK Centre for Ecology and Hydrology 25 m land use database, with permission. The GFS meteorological data is assumed to have a roughness length of 0.264 m (arithmetic average of the spatially varying roughness over the modelling domain). A sample area of the spatially varying roughness length field is shown in Figure 5.

Figure 3. The positions of the modelled buildings and sources

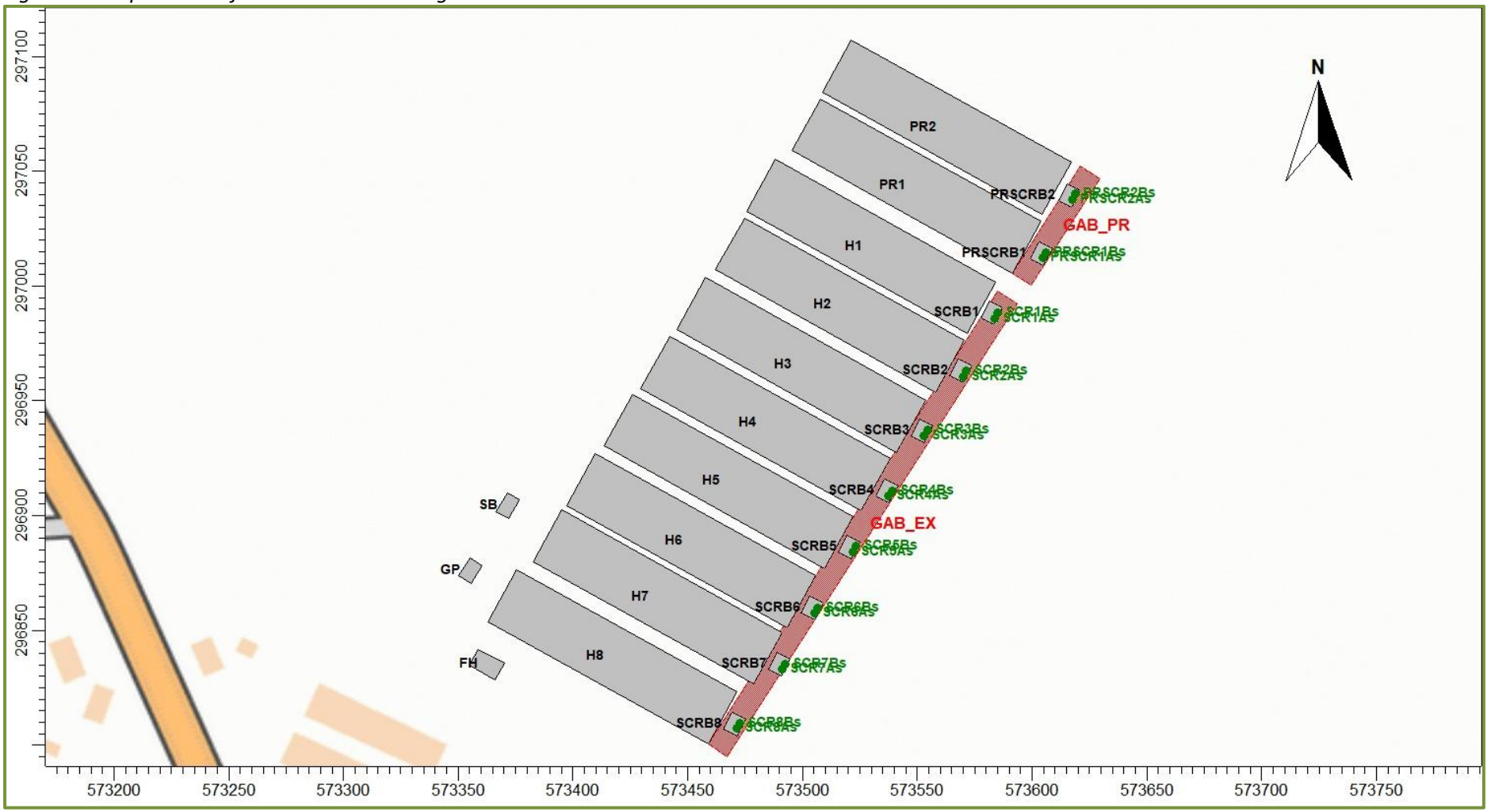


Figure 4a. The discrete receptors and regular Cartesian grids – broadscale view

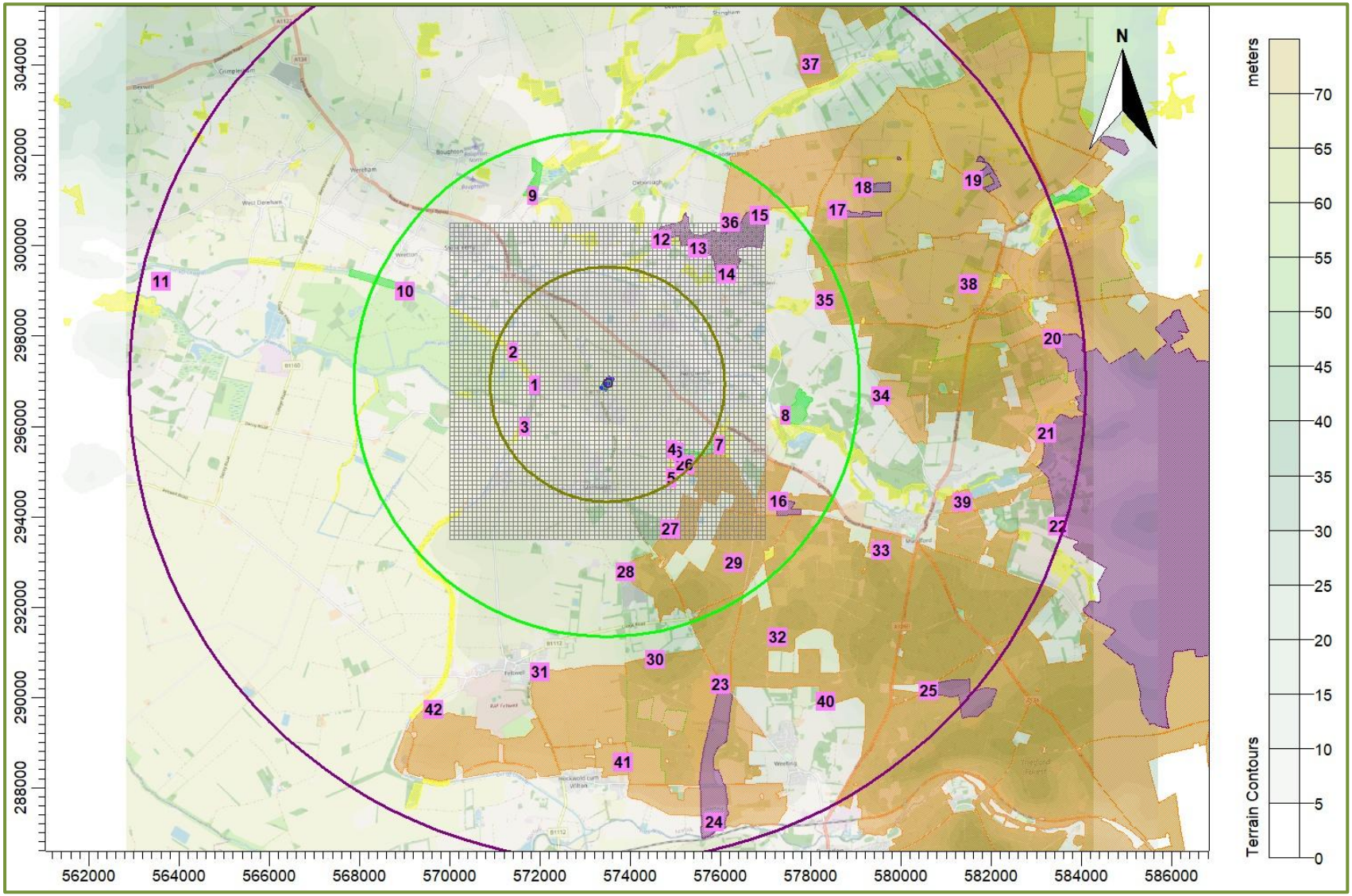


Figure 4b. The discrete receptors and regular Cartesian grid – a closer view

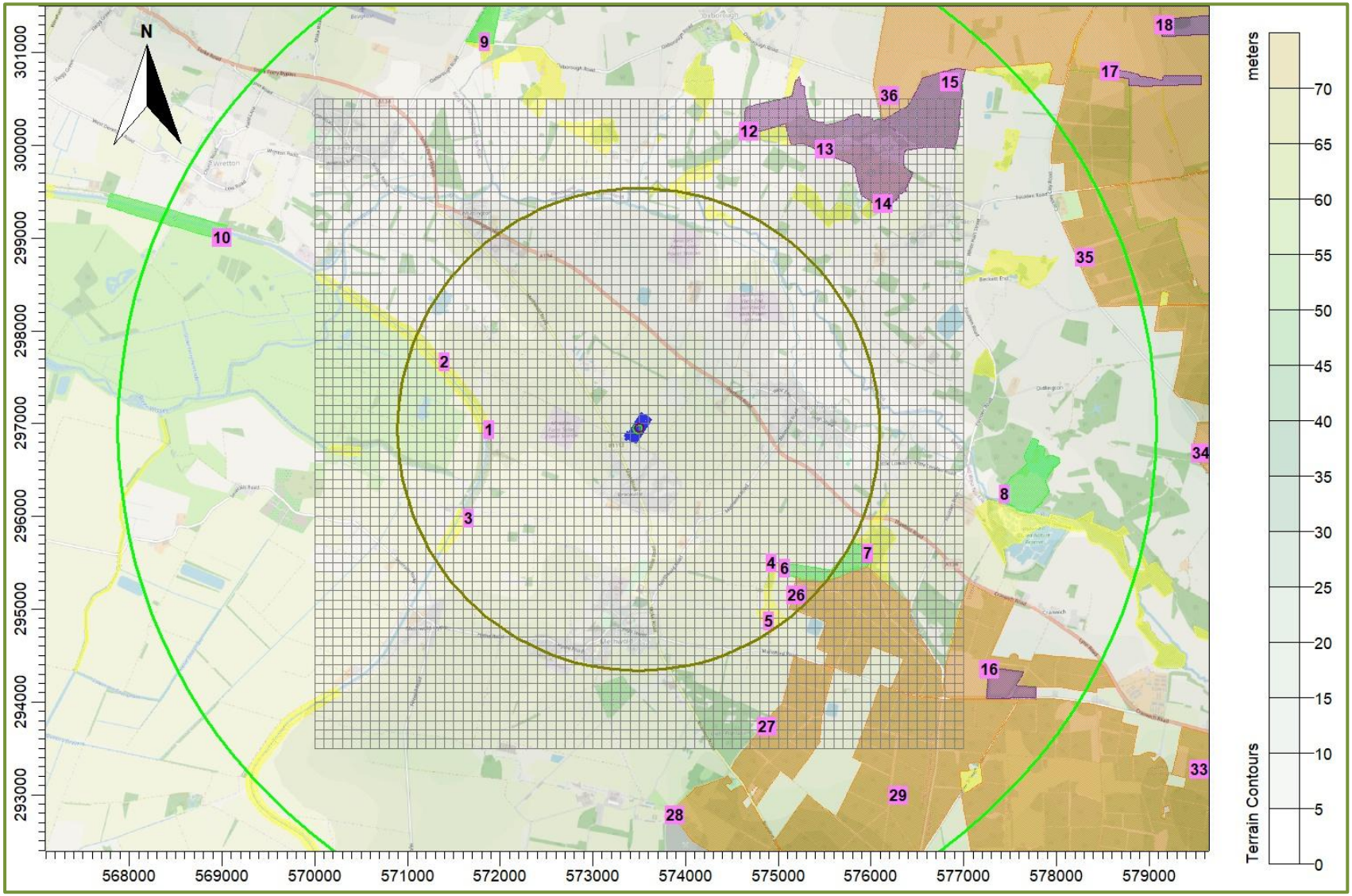
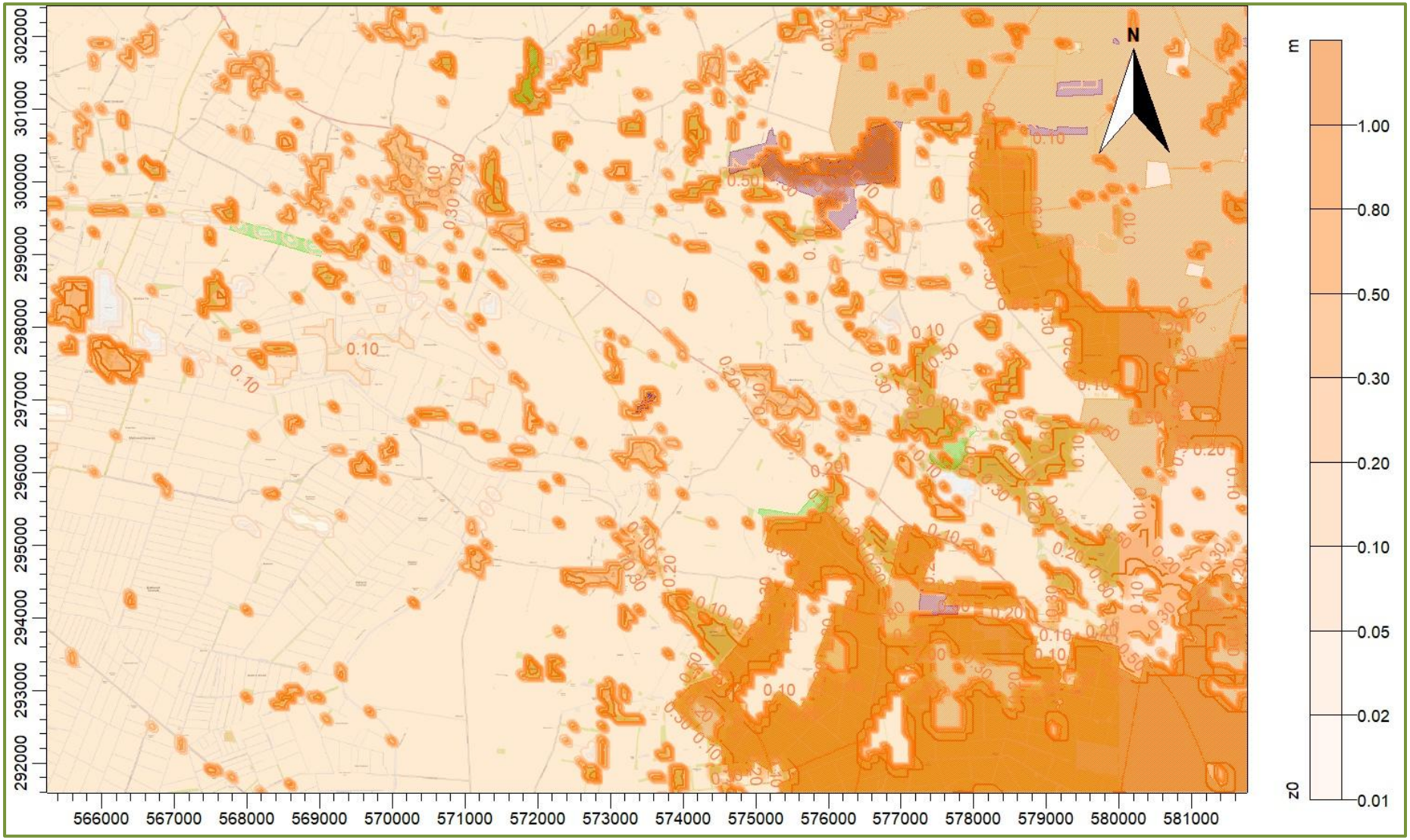


Figure 5. The spatially varying surface roughness field (central area)



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 5.

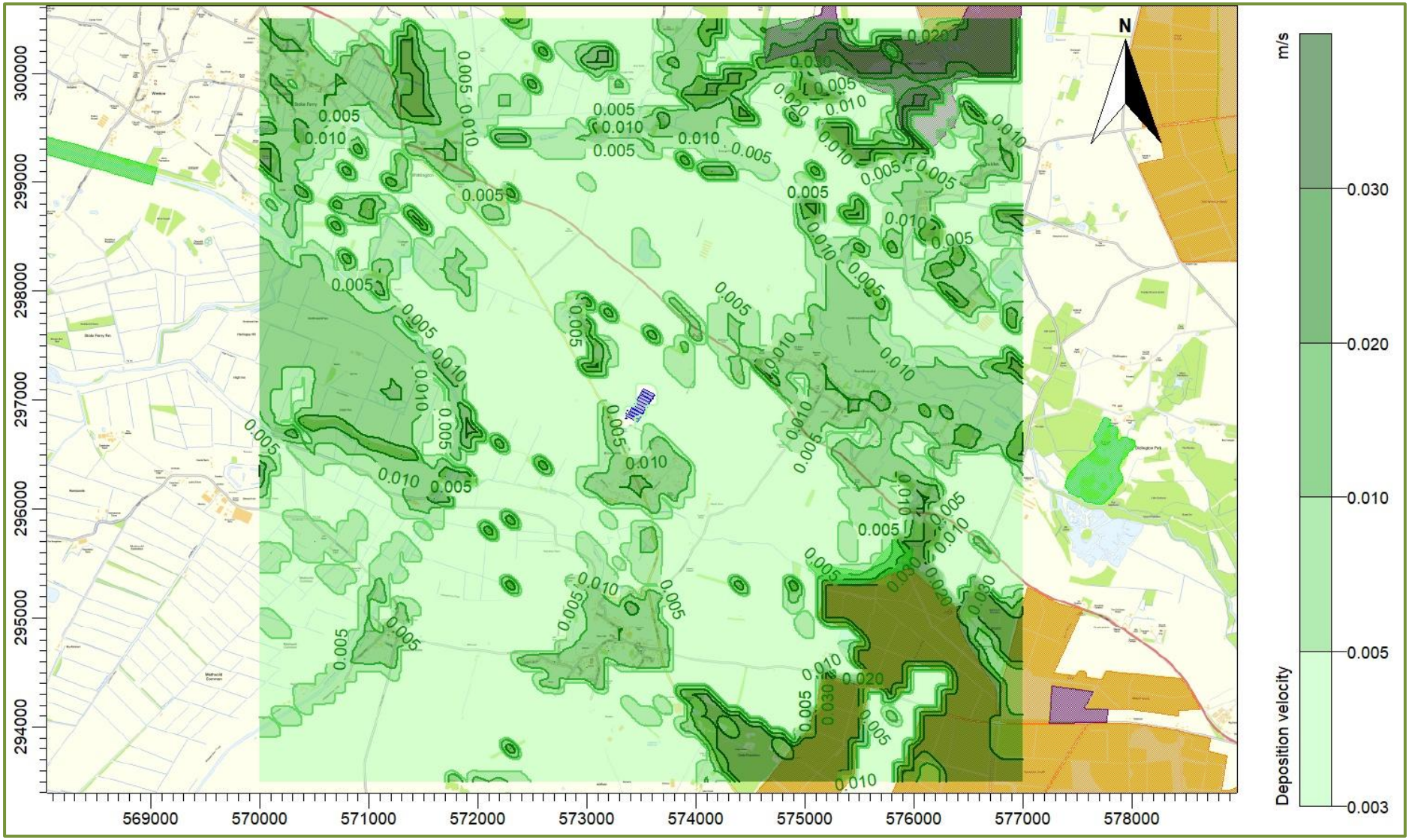
Table 5. Deposition velocities

NH_3 concentration (PC + background) ($\mu g/m^3$)	< 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 6.

Figure 6. The spatially varying deposition field



5. Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

ADMS was run a total of four times, once for each year of the meteorological record in the following modes:

- In basic mode without calms, or terrain – GFS data.
- With calms and without terrain – GFS data.

For each mode, statistics for the maximum annual mean ammonia concentration at each receptor were compiled. Details of the predicted annual mean ammonia concentrations at each receptor are provided in Table 6. The primary purpose of the preliminary modelling is to assess the effect of calms on the results.

Table 6. 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)			
				Existing		Proposed	
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms No Terrain	GFS Calms No Terrain
1	571877	296939	LWS	0.016	0.023	0.020	0.028
2	571394	297673	LWS	0.011	0.015	0.013	0.018
3	571654	295991	LWS	0.010	0.015	0.012	0.018
4	574923	295508	LWS	0.008	0.013	0.010	0.016
5	574895	294877	LWS	0.005	0.008	0.006	0.010
6	575063	295453	The Brinks Northwold SSSI	0.007	0.012	0.009	0.014
7	575964	295611	The Brinks Northwold SSSI	0.007	0.008	0.008	0.010
8	577432	296251	Didlington Park Lakes SSSI	0.004	0.005	0.005	0.006
9	571831	301121	Boughton Fen SSSI	0.002	0.004	0.003	0.005
10	568989	299010	Wretton SSSI	0.004	0.005	0.005	0.006
11	563581	299219	Hilgay Heronry SSSI	0.001	0.001	0.001	0.002
12	574672	300158	Foulden Common SSSI/Norfolk Valley Fens SAC	0.005	0.007	0.007	0.009
13	575493	299967	Foulden Common SSSI/Norfolk Valley Fens SAC	0.006	0.007	0.008	0.009
14	576123	299376	Foulden Common SSSI/Norfolk Valley Fens SAC	0.009	0.011	0.011	0.014
15	576848	300692	Foulden Common SSSI/Norfolk Valley Fens SAC	0.005	0.006	0.006	0.007
16	577268	294356	Cranwich Camp SSSI/Breckland SPA	0.003	0.004	0.004	0.005
17	578565	300807	Gooderstone Warren SSSI/Breckland SAC/SPA	0.004	0.005	0.005	0.006
18	579157	301308	Gooderstone Warren SSSI/Breckland SAC/SPA	0.004	0.004	0.005	0.005
19	581586	301460	Field Barn Heaths, Hilborough SSSI/Breckland SAC/SPA	0.002	0.002	0.003	0.003
20	583346	297969	Stanford Training Area SSSI/Breckland SAC/SPA	0.001	0.001	0.002	0.002
21	583210	295859	Stanford Training Area SSSI/Breckland SAC/SPA	0.001	0.001	0.002	0.002
22	583468	293810	Stanford Training Area SSSI/Breckland SAC/SPA	0.001	0.001	0.002	0.002
23	575989	290305	Weeting Heath SSSI/Breckland SAC/SPA	0.001	0.001	0.001	0.002
24	575836	287244	Weeting Heath SSSI/Breckland SAC/SPA	0.001	0.001	0.001	0.001
25	580602	290163	Grime's Graves SSSI/Breckland SAC/SPA	0.001	0.001	0.001	0.001
26	575184	295163	Breckland Forest SSSI/Breckland SPA	0.006	0.009	0.007	0.011
27	574867	293744	Breckland Forest SSSI/Breckland SPA	0.002	0.004	0.003	0.005
28	573877	292792	Breckland Forest SSSI/Breckland SPA	0.003	0.003	0.003	0.004
29	576286	292997	Breckland Forest SSSI/Breckland SPA	0.002	0.003	0.002	0.004
30	574531	290850	Breckland Forest SSSI/Breckland SPA	0.001	0.002	0.002	0.002
31	571991	290570	Breckland Farmland SSSI/Breckland SPA	0.002	0.002	0.002	0.002
32	577257	291354	Breckland Forest SSSI/Breckland SPA	0.001	0.002	0.001	0.002
33	579535	293278	Breckland Forest SSSI/Breckland SPA	0.002	0.002	0.002	0.002
34	579554	296695	Breckland Farmland SSSI/Breckland SPA	0.002	0.003	0.003	0.003
35	578303	298804	Breckland Forest SSSI/Breckland SPA	0.003	0.004	0.004	0.005
36	576193	300541	Breckland Farmland SSSI/Breckland SPA	0.005	0.006	0.006	0.007
37	577987	304033	Breckland Forest SSSI/Breckland SPA	0.002	0.002	0.002	0.003
38	581474	299159	Breckland Farmland SSSI/Breckland SPA	0.002	0.002	0.002	0.002
39	581348	294328	Breckland Forest SSSI/Breckland SPA	0.002	0.002	0.002	0.002
40	578324	289917	Breckland Forest SSSI/Breckland SPA	0.001	0.001	0.001	0.002
41	573828	288572	Breckland Farmland SSSI/Breckland SPA	0.001	0.001	0.001	0.001
42	569627	289749	Breckland Farmland SSSI/Breckland SPA	0.001	0.002	0.001	0.002

5.2 Detailed modelling

In this case, detailed modelling has been carried out over a high resolution 7.0 km x 7.0 km domain surrounding True Hill Poultry Unit. 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, but also to provide results should any further LWSs be identified. Outside of the domain a fixed deposition velocity of 0.005 m/s is assumed (with appropriate deposition velocities applied post-modelling at the discrete receptors).

The predicted maximum annual mean ground level ammonia concentrations and annual nitrogen deposition rates at the discrete receptors are shown in Tables 7a (Baseline Scenario), 7b (Proposed Scenario), 7c (Proposed Scenario – no abatement) and 7d (Proposed Houses Only – with abatement). In these tables, all predicted ammonia concentrations or nitrogen deposition rates are below the Environment Agency's lower threshold (100% for non-statutory sites, 20% for a SSSI and 1% for an internationally designated site). Predicted ammonia concentrations or nitrogen deposition rates are also below 1% of the relevant Critical Level or Load at all SSSIs.

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. The results of the preliminary modelling indicate that the effects of calms may be significant, therefore a correction is applied to the results in the tables at receptors within approximately 2 km.

Table 7a. Predicted maximum annual mean ammonia concentrations and annual nitrogen deposition rates – Baseline Scenario

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	571877	296939	LWS	0.030	1.0	10.0	0.026	2.61	0.203	2.03
2	571394	297673	LWS	0.030	1.0	10.0	0.014	1.42	0.111	1.11
3	571654	295991	LWS	0.030	1.0	10.0	0.016	1.60	0.125	1.25
4	574923	295508	LWS	0.030	1.0	10.0	0.010	1.01	0.079	0.79
5	574895	294877	LWS	0.030	1.0	10.0	0.005	0.54	0.042	0.42
6	575063	295453	The Brinks Northwold SSSI	0.020	3.0	10.0	0.009	0.29	0.046	0.46
7	575964	295611	The Brinks Northwold SSSI	0.020	3.0	10.0	0.006	0.19	0.030	0.30
8	577432	296251	Didlington Park Lakes SSSI	-	3.0	-	0.003	0.10	-	-
9	571831	301121	Boughton Fen SSSI	0.020	3.0	15.0	0.002	0.08	0.013	0.09
10	568989	299010	Wretton SSSI	0.030	1.0	10.0	0.003	0.32	0.025	0.25
11	563581	299219	Hilgay Heronry SSSI	-	-	-	0.001	-	-	-
12	574672	300158	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.005	0.48	0.025	0.50
13	575493	299967	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.005	0.48	0.025	0.50
14	576123	299376	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.006	0.63	0.033	0.66
15	576848	300692	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.003	0.34	0.018	0.35
16	577268	294356	Cranwich Camp SSSI/Breckland SPA	0.020	1.0	5.0	0.001	0.14	0.008	0.15
17	578565	300807	Gooderstone Warren SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.002	0.21	0.011	0.22
18	579157	301308	Gooderstone Warren SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.002	0.17	0.009	0.18
19	581586	301460	Field Barn Heaths, Hilborough SSSI/Breckland SAC/SPA	0.020	1.0	10.0	0.001	0.09	0.005	0.05
20	583346	297969	Stanford Training Area SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.001	0.06	0.003	0.06
21	583210	295859	Stanford Training Area SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.001	0.06	0.003	0.06
22	583468	293810	Stanford Training Area SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.001	0.05	0.003	0.06
23	575989	290305	Weeting Heath SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.000	0.05	0.002	0.05
24	575836	287244	Weeting Heath SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.000	0.03	0.002	0.03
25	580602	290163	Grime's Graves SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.000	0.03	0.002	0.04
26	575184	295163	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.004	0.38	0.030	0.60
27	574867	293744	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.001	0.14	0.011	0.22
28	573877	292792	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.002	0.19	0.015	0.29
29	576286	292997	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.001	0.10	0.008	0.16
30	574531	290850	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.001	0.08	0.006	0.12
31	571991	290570	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.001	0.11	0.006	0.11
32	577257	291354	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.001	0.06	0.004	0.09
33	579535	293278	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.001	0.07	0.006	0.11
34	579554	296695	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.001	0.13	0.007	0.14
35	578303	298804	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.002	0.25	0.019	0.38
36	576193	300541	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.004	0.39	0.020	0.41
37	577987	304033	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.001	0.12	0.009	0.18
38	581474	299159	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.001	0.09	0.005	0.09
39	581348	294328	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.001	0.08	0.006	0.13
40	578324	289917	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.000	0.04	0.003	0.06
41	573828	288572	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.001	0.06	0.003	0.06
42	569627	289749	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.001	0.07	0.004	0.07

Table 7b. Predicted maximum annual mean ammonia concentrations and annual nitrogen deposition rates – Proposed Scenario

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	571877	296939	LWS	0.030	1.0	10.0	0.033	3.27	0.254	2.54
2	571394	297673	LWS	0.030	1.0	10.0	0.018	1.75	0.137	1.37
3	571654	295991	LWS	0.030	1.0	10.0	0.020	1.97	0.154	1.54
4	574923	295508	LWS	0.030	1.0	10.0	0.012	1.24	0.097	0.97
5	574895	294877	LWS	0.030	1.0	10.0	0.007	0.67	0.052	0.52
6	575063	295453	The Brinks Northwold SSSI	0.020	3.0	10.0	0.011	0.36	0.057	0.57
7	575964	295611	The Brinks Northwold SSSI	0.020	3.0	10.0	0.007	0.24	0.037	0.37
8	577432	296251	Didlington Park Lakes SSSI	-	3.0	-	0.004	0.12	-	-
9	571831	301121	Boughton Fen SSSI	0.020	3.0	15.0	0.003	0.10	0.016	0.11
10	568989	299010	Wretton SSSI	0.030	1.0	10.0	0.004	0.39	0.030	0.30
11	563581	299219	Hilgay Heronry SSSI	-	-	-	0.001	-	-	-
12	574672	300158	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.006	0.61	0.032	0.63
13	575493	299967	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.006	0.61	0.032	0.63
14	576123	299376	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.008	0.80	0.042	0.83
15	576848	300692	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.004	0.43	0.022	0.45
16	577268	294356	Cranwich Camp SSSI/Breckland SPA	0.020	1.0	5.0	0.002	0.18	0.009	0.19
17	578565	300807	Gooderstone Warren SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.003	0.26	0.013	0.27
18	579157	301308	Gooderstone Warren SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.002	0.21	0.011	0.22
19	581586	301460	Field Barn Heaths, Hilborough SSSI/Breckland SAC/SPA	0.020	1.0	10.0	0.001	0.11	0.006	0.06
20	583346	297969	Stanford Training Area SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.001	0.07	0.004	0.07
21	583210	295859	Stanford Training Area SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.001	0.07	0.004	0.07
22	583468	293810	Stanford Training Area SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.001	0.07	0.003	0.07
23	575989	290305	Weeting Heath SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.001	0.06	0.003	0.06
24	575836	287244	Weeting Heath SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.000	0.04	0.002	0.04
25	580602	290163	Grime's Graves SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.000	0.04	0.002	0.04
26	575184	295163	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.005	0.47	0.037	0.73
27	574867	293744	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.002	0.18	0.014	0.27
28	573877	292792	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.002	0.24	0.018	0.37
29	576286	292997	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.001	0.13	0.010	0.19
30	574531	290850	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.001	0.10	0.008	0.15
31	571991	290570	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.001	0.14	0.007	0.14
32	577257	291354	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.001	0.07	0.005	0.11
33	579535	293278	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.001	0.09	0.007	0.14
34	579554	296695	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.002	0.17	0.009	0.17
35	578303	298804	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.003	0.31	0.024	0.48
36	576193	300541	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.005	0.49	0.026	0.51
37	577987	304033	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.001	0.15	0.012	0.23
38	581474	299159	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.001	0.11	0.006	0.12
39	581348	294328	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.001	0.10	0.008	0.16
40	578324	289917	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.000	0.05	0.004	0.07
41	573828	288572	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.001	0.07	0.004	0.08
42	569627	289749	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.001	0.09	0.005	0.09

Table 7c. Predicted maximum annual mean ammonia concentrations and annual nitrogen deposition rates – Proposed Scenario - No abatement

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	571877	296939	LWS	0.030	1.0	10.0	0.1288	12.876	1.0032	10.032
2	571394	297673	LWS	0.030	1.0	10.0	0.0764	7.638	0.5951	5.951
3	571654	295991	LWS	0.030	1.0	10.0	0.0892	8.915	0.6946	6.946
4	574923	295508	LWS	0.030	1.0	10.0	0.1053	10.534	0.8207	8.207
5	574895	294877	LWS	0.030	1.0	10.0	0.0519	5.193	0.4046	4.046
6	575063	295453	The Brinks Northwold SSSI	0.020	3.0	10.0	0.0929	**3.096**	0.4824	**4.824**
7	575964	295611	The Brinks Northwold SSSI	0.020	3.0	10.0	0.0537	**1.790**	0.2789	**2.789**
8	577432	296251	Didlington Park Lakes SSSI	-	3.0	-	0.0239	0.797	-	-
9	571831	301121	Boughton Fen SSSI	0.020	3.0	15.0	0.0173	0.577	0.0899	0.599
10	568989	299010	Wretton SSSI	0.030	1.0	10.0	0.0108	**1.077**	0.0839	0.839
11	563581	299219	Hilgay Heronry SSSI	-	-	-	0.0031	-	-	-
12	574672	300158	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.0358	**3.583**	0.1861	**3.722**
13	575493	299967	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.0334	**3.339**	0.1734	**3.468**
14	576123	299376	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.0441	**4.406**	0.2288	**4.577**
15	576848	300692	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.0225	**2.248**	0.1168	**2.335**
16	577268	294356	Cranwich Camp SSSI/Breckland SPA	0.020	1.0	5.0	0.0120	**1.198**	0.0622	**1.245**
17	578565	300807	Gooderstone Warren SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0150	**1.498**	0.0778	**1.556**
18	579157	301308	Gooderstone Warren SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0116	**1.165**	0.0605	**1.210**
19	581586	301460	Field Barn Heaths, Hilborough SSSI/Breckland SAC/SPA	0.020	1.0	10.0	0.0058	0.579	0.0301	0.301
20	583346	297969	Stanford Training Area SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0037	0.366	0.0190	0.381
21	583210	295859	Stanford Training Area SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0041	0.411	0.0214	0.427
22	583468	293810	Stanford Training Area SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0038	0.379	0.0197	0.393
23	575989	290305	Weeting Heath SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0031	0.315	0.0163	0.327
24	575836	287244	Weeting Heath SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0017	0.174	0.0090	0.181
25	580602	290163	Grime's Graves SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0025	0.253	0.0131	0.262
26	575184	295163	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0423	**4.231**	0.3296	**6.592**
27	574867	293744	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0116	**1.157**	0.0901	**1.802**
28	573877	292792	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0104	**1.042**	0.0812	**1.624**
29	576286	292997	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0081	0.810	0.0631	**1.263**
30	574531	290850	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0042	0.422	0.0329	0.658
31	571991	290570	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.0061	0.606	0.0315	0.630
32	577257	291354	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0042	0.424	0.0330	0.661
33	579535	293278	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0059	0.591	0.0460	0.920
34	579554	296695	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.0107	**1.067**	0.0554	**1.109**
35	578303	298804	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0170	**1.703**	0.1327	**2.654**
36	576193	300541	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.0237	**2.370**	0.1231	**2.462**
37	577987	304033	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0071	0.709	0.0552	**1.105**
38	581474	299159	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.0055	0.553	0.0287	0.574
39	581348	294328	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0059	0.589	0.0459	0.918
40	578324	289917	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0028	0.282	0.0220	0.439
41	573828	288572	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.0029	0.288	0.0150	0.299
42	569627	289749	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.0041	0.412	0.0214	0.428

Table 7d. Predicted maximum annual mean ammonia concentrations and annual nitrogen deposition rates – Proposed Houses Only - With abatement

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	571877	296939	LWS	0.030	1.0	10.0	0.0064	0.64	0.050	0.50
2	571394	297673	LWS	0.030	1.0	10.0	0.0032	0.32	0.025	0.25
3	571654	295991	LWS	0.030	1.0	10.0	0.0036	0.36	0.028	0.28
4	574923	295508	LWS	0.030	1.0	10.0	0.0023	0.23	0.018	0.18
5	574895	294877	LWS	0.030	1.0	10.0	0.0013	0.13	0.010	0.10
6	575063	295453	The Brinks Northwold SSSI	0.020	3.0	10.0	0.0020	0.07	0.011	0.11
7	575964	295611	The Brinks Northwold SSSI	0.020	3.0	10.0	0.0013	0.04	0.007	0.07
8	577432	296251	Didlington Park Lakes SSSI	-	3.0	-	0.0008	0.03	-	-
9	571831	301121	Boughton Fen SSSI	0.020	3.0	15.0	0.0007	0.02	0.003	0.02
10	568989	299010	Wretton SSSI	0.030	1.0	10.0	0.0007	0.07	0.006	0.06
11	563581	299219	Hilgay Heronry SSSI	-	-	-	0.0002	-	-	-
12	574672	300158	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.0013	0.13	0.007	0.13
13	575493	299967	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.0013	0.13	0.007	0.13
14	576123	299376	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.0017	0.17	0.009	0.17
15	576848	300692	Foulden Common SSSI/Norfolk Valley Fens SAC	0.020	1.0	5.0	0.0009	0.09	0.005	0.09
16	577268	294356	Cranwich Camp SSSI/Breckland SPA	0.020	1.0	5.0	0.0004	0.04	0.002	0.04
17	578565	300807	Gooderstone Warren SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0005	0.05	0.003	0.06
18	579157	301308	Gooderstone Warren SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0004	0.04	0.002	0.04
19	581586	301460	Field Barn Heaths, Hilborough SSSI/Breckland SAC/SPA	0.020	1.0	10.0	0.0002	0.02	0.001	0.01
20	583346	297969	Stanford Training Area SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0001	0.01	0.001	0.01
21	583210	295859	Stanford Training Area SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0001	0.01	0.001	0.01
22	583468	293810	Stanford Training Area SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0001	0.01	0.001	0.01
23	575989	290305	Weeting Heath SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0001	0.01	0.001	0.01
24	575836	287244	Weeting Heath SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0001	0.01	0.000	0.01
25	580602	290163	Grime's Graves SSSI/Breckland SAC/SPA	0.020	1.0	5.0	0.0001	0.01	0.000	0.01
26	575184	295163	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0009	0.09	0.007	0.14
27	574867	293744	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0004	0.04	0.003	0.05
28	573877	292792	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0005	0.05	0.004	0.07
29	576286	292997	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0002	0.02	0.002	0.04
30	574531	290850	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0002	0.02	0.002	0.03
31	571991	290570	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.0003	0.03	0.001	0.03
32	577257	291354	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0001	0.01	0.001	0.02
33	579535	293278	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0002	0.02	0.001	0.03
34	579554	296695	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.0003	0.03	0.002	0.03
35	578303	298804	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0006	0.06	0.005	0.10
36	576193	300541	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.0010	0.10	0.005	0.11
37	577987	304033	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0003	0.03	0.002	0.05
38	581474	299159	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.0002	0.02	0.001	0.02
39	581348	294328	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0002	0.02	0.002	0.03
40	578324	289917	Breckland Forest SSSI/Breckland SPA	0.030	1.0	5.0	0.0001	0.01	0.001	0.01
41	573828	288572	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.0002	0.02	0.001	0.02
42	569627	289749	Breckland Farmland SSSI/Breckland SPA	0.020	1.0	5.0	0.0002	0.02	0.001	0.02

6. Summary and Conclusions

Ammonia emission rates have been assessed and quantified based upon the Environment Agency standard ammonia emission factors and information supplied by the manufacturers of the Munters Reventa Lavamatic ammonia scrubbing equipment that are/would be fitted to the poultry houses. The 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.

At the request of the Environment Agency, four scenarios have been considered in this report:

- Baseline scenario – Eight poultry houses with 352,000 broiler chickens. Ventilated primarily by air scrubbing units, served by two stacks per house on the eastern gable ends, with wall mounted fans providing supplementary ventilation if required in periods of hot weather.
- Proposed scenario – The eight existing poultry houses and two additional houses with a total of 440,000 broiler chickens. All houses are/would be ventilated primarily by air scrubbing units, served by two stacks per house on the eastern gable ends, with wall mounted fans providing supplementary ventilation if required in periods of hot weather.
- Proposed scenario no abatement – The eight existing poultry houses and two additional houses with a total of 440,000 broiler chickens. Ventilated by wall-mounted gable end fans.
- Proposed houses only – with abatement – Two proposed poultry houses with 88,000 broiler chickens. Ventilated primarily by air scrubbing units, served by two stacks per house on the eastern gable ends, with wall mounted fans providing supplementary ventilation if required in periods of hot weather.

Baseline Scenario

The modelling predicts that the process contributions to the maximum annual mean ammonia concentrations and annual nitrogen deposition rates:

- Are currently below the Environment Agency lower thresholds (100% for a LWS, 20% for a SSSI and 1% for a SAC/SPA) of the relevant Critical Level and Critical Load at all wildlife sites considered.
- Are below 1% of the relevant Critical Level and Critical Load at all SSSIs considered.

Proposed Scenario

The modelling predicts that, should the proposal proceed, the process contributions to the maximum annual mean ammonia concentrations and annual nitrogen deposition rates:

- Would be below the Environment Agency lower thresholds (100% for a LWS, 20% for a SSSI and 1% for a SAC/SPA) of the relevant Critical Level and Critical Load at all wildlife sites considered.
- Would be below 1% of the relevant Critical Level and Critical Load at all SSSIs considered.

Proposed Scenario - no abatement

The modelling predicts that, the process contributions to the maximum annual mean ammonia concentrations and annual nitrogen deposition rates from the proposed scenario with no abatement:

- Would be exceed the Environment Agency lower thresholds of the relevant Critical Level and Critical Load at parts of the Norfolk Valley Fens SAC and Breckland SPA/SAC.
- Would be below the Environment Agency lower thresholds of the relevant Critical Level and Critical Load at all other wildlife sites considered.
- Would exceed 1% of the relevant Critical Level and Critical Load at The Brinks Northwold SSSI.

Proposed Houses Only - with abatement

The modelling predicts that, the process contributions to the maximum annual mean ammonia concentrations and annual nitrogen deposition rates from the proposed houses only with the planned ventilation:

- Would be well below the Environment Agency lower thresholds of the relevant Critical Level and Critical Load at all wildlife sites considered.
- Would be below 1% of the relevant Critical Level and Critical Load at all of the SSSIs considered.

7. References

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