A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing Duck Rearing Houses and the Proposed Broiler Chicken Rearing Houses at Friars Farm, near Morningthorpe in Norfolk

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Mr. Karl Collett of Green Inc Solutions Ltd., on behalf of Mr. David Sargent and Mr. Christopher Sargent, to use computer modelling to assess the impact of ammonia emissions from the existing duck rearing houses and the proposed broiler chicken rearing houses at Friars Farm, Morningthorpe, Long Stratton, Norfolk. NR15 2QL.

Ammonia emission rates from the existing duck rearing houses and the proposed broiler chicken rearing houses have been assessed and quantified based upon the Environment Agency standard ammonia emission factors. 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 site 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

Friars Farm is in a rural area, approximately 700 m to the west of the village of Fritton in Norfolk. The site is at an elevation of around 49 m with the land rising towards slightly higher ground to the south-west and falling towards the River Tas valley to the north-east. The surrounding land is used predominantly for arable farming, however there are some wooded areas and areas of semi-natural grasslands.

There are five existing poultry houses at Friars Farm, which are used to rear up to 49,000 ducks. These houses are currently naturally ventilated, although the larger of the houses (House 5) does have gable end fans for use in warm weather conditions.

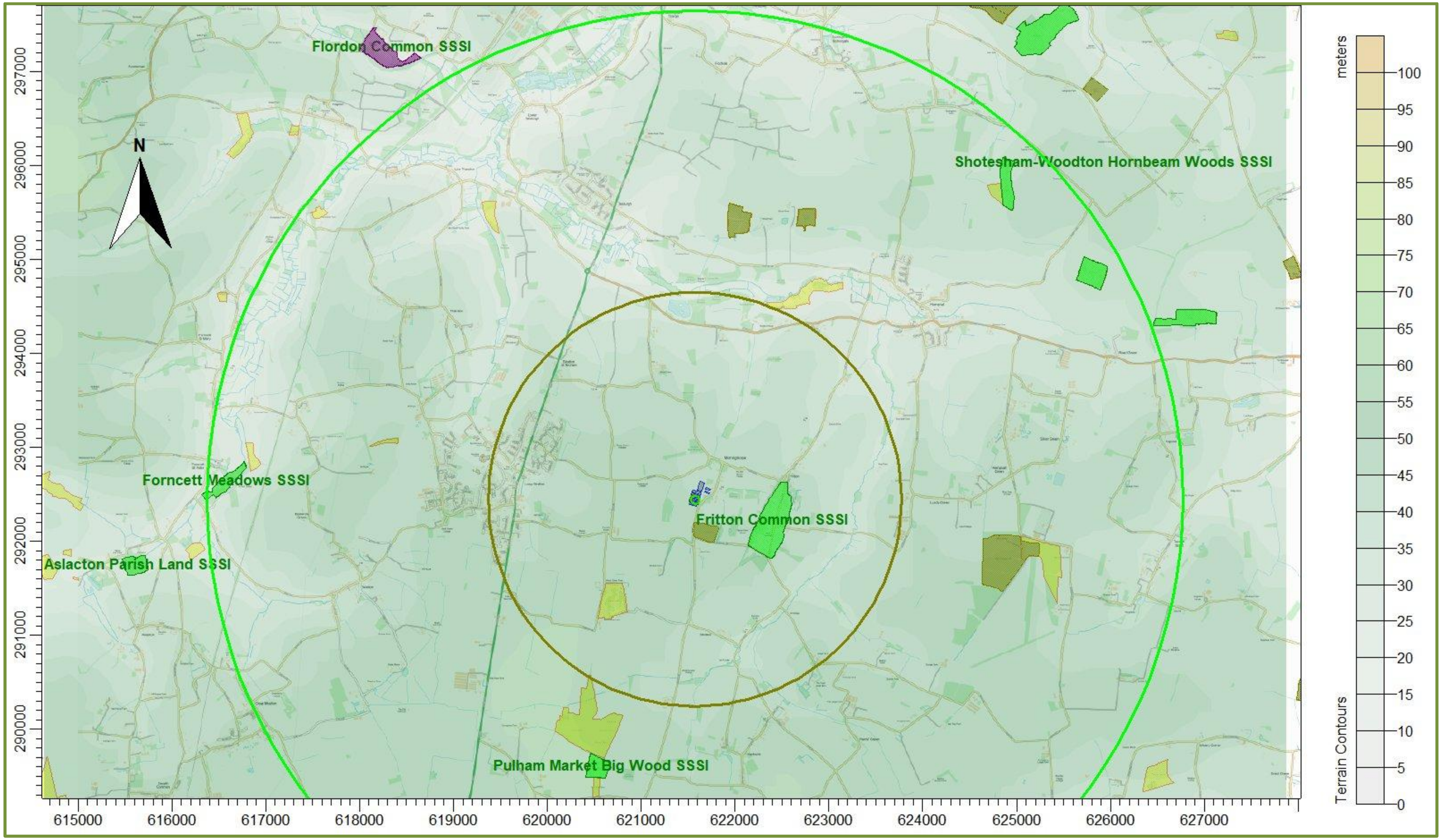
It is proposed that the poultry houses at Friars Farm be renovated and used to provide accommodation for up to 181,725 broiler chickens. The renovated poultry houses would be ventilated by high-speed ridge fans, each with a short chimney and the gable end fans on the larger of the houses would be retained for use in hot weather conditions. The birds would be raised from day old chicks to around 38 days old and there would be around 7.5 flocks per year.

AS Modelling & Data Ltd. have identified three areas designated as County Wildlife Sites (CWSs) within 2 km of the site (the normal screening distance for non-statutory wildlife sites). There is also one area of Ancient Woodland (AW) within 2 km of the site. There are four Sites of Special Scientific Interest (SSSIs) within 5 km of the site (Natural England and Environment Agency screening distance) and one SSSI that is also designated as a Special Area of Conservation (SAC) within 10 km of the site (Natural England screening distance). Some further details of the SSSIs and the SAC are provided below:

- **Fritton Common SSSI** - Approximately 660 m to the east - One of only a few large grassy commons remaining in south Norfolk still under traditional management by light cattle grazing. The site forms an excellent example of the locally uncommon damp acidic grassland habitat developed over loess soils. Several natural ponds are present and these support well developed marginal and aquatic vegetation. Isolated ancient oak and ash trees carry a wide range of epiphytic lichens including some locally scarce species.
- **Shotesham-Woodton Hornbeam Woods SSSI** - Approximately 4.4 km to the north-east - Ancient coppice-with-standards woodlands that were probably once part of a continuous cover of primary hornbeam forest. The flora is exceptionally rich and there are several locally scarce and uncommon plants present.
- **Pulham Market Big Wood SSSI** - Approximately 2.8 km to the south - An ancient woodland site probably of primary origin and appears to be the sole remaining fragment of a once much larger area of woodland. The ground flora is fairly diverse and contains a few uncommon species.
- **Forncett Meadows SSSI** - Approximately 4.7 km to the west - One of only three examples of unimproved meadow now remaining in the valley of the River Tas. An interesting mosaic of grassland types has developed in response to natural variation in soil type and wetness and to a long period of stable non-intensive grazing management.
- **Flordon Common SSSI/SAC** - Approximately 5.4 km to the north-west - Situated in the valley of the River Tas on shallow fenland peats. Springs emerge on the valley-side bearing base-rich waters from the underlying chalk and in these areas species-rich calcareous fen has developed. Conditions are locally acidic and this has encouraged the recent growth of a few tussocks of Bog Moss *Sphagnum* sp. On higher ground unimproved pasture is present which includes a number of species characteristic of chalk grassland.

A map of the surrounding area showing the positions of the proposed poultry houses (outlined in blue) and the CWSs (shaded in yellow); the AW (shaded in olive); the SSSIs (shaded in green) and the SAC (shaded in purple) is provided in Figure 1.

Figure 1. The area surrounding Friars Farm



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

3.1 Ammonia concentration and nitrogen and acid deposition

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

3.2 Background ammonia levels and nitrogen and acid deposition

The source of the background figures is the Air Pollution Information System (APIS, April 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 (2021) in the area around the site is 1.91 $\mu g\text{-}NH_3/m^3$. The background nitrogen deposition rate to woodland is 31.16 kg-N/ha/y and to short vegetation is 16.39 kg-N/ha/y. The background acid deposition rate to woodland is 2.12 keq/ha/y and to short vegetation is 1.07 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 & 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 $\mu g\text{-}NH_3/m^3$ 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 used as the assessment criteria at the relevant receptor locations 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. 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 ($\mu g\text{-}NH_3/m^3$)	Critical Load - Nitrogen Deposition (kg-N/ha/y)	Critical Load - Acid Deposition (keq/ha/y)
AW and CWSs	1.0 [1]	-	-
Fritton Common SSSI	1.0 [1 & 2]	6.0 - 10.0 [3]	-
Shotesham-Woodton Hornbeam Woods SSSI and Pulham Market Big Wood SSSI	1.0 [1 & 2]	15.0 [3]	-
Forncett Meadows SSSI	3.0 [2]	10.0 [3]	-
Flordon Common SSSI/SAC	1.0 [1 & 2]	10.0 [3]	-

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. Please 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.
3. The lower bound of the range of Critical Loads for habitats present at the site (Review and revision of empirical critical loads of nitrogen for Europe 2022). Please note that the APIS database may contain Critical Loads for habitats/species that are not present at the site.

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.

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

The emission factors used in this report have been obtained from: https://www.gov.uk/guidance/ammonia-emission-factors-for-pig-and-poultry-screening-modelling-and-reporting#ammonia-emission-factors-for-poultry.

Details of the poultry numbers and type, emission factors used and calculated ammonia emission rates are provided in Table 3.

Table 3. Details of poultry numbers and ammonia emission rates

Housing	Bird numbers	Emission Factor ($kg\text{-}NH_3$/place/y)	Emission rate ($g\text{-}NH_3$/s)
Existing Duck Rearing Houses	49,000	0.151	0.234460
Proposed Broiler Chicken Rearing Houses	181,715	0.024	0.138197

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 several 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 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 records may be overrepresented because the instrumentation used may not record wind speed below approximately 0.5 m/s and start up wind speeds may be greater than 1.0 m/s. In NWP data, the wind speed is continuous down to 0.0 m/s, allowing the calms module of ADMS to function correctly.

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

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

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 2a. Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and because terrain data is included in the modelling, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for 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].

As discussed above, the use of NWP data (suitably processed and quality controlled), removes the usual uncertainties and gross errors associated with using "representative" data from a remote meteorological station.

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 52.485 N, 1.264 E, 2022-2025

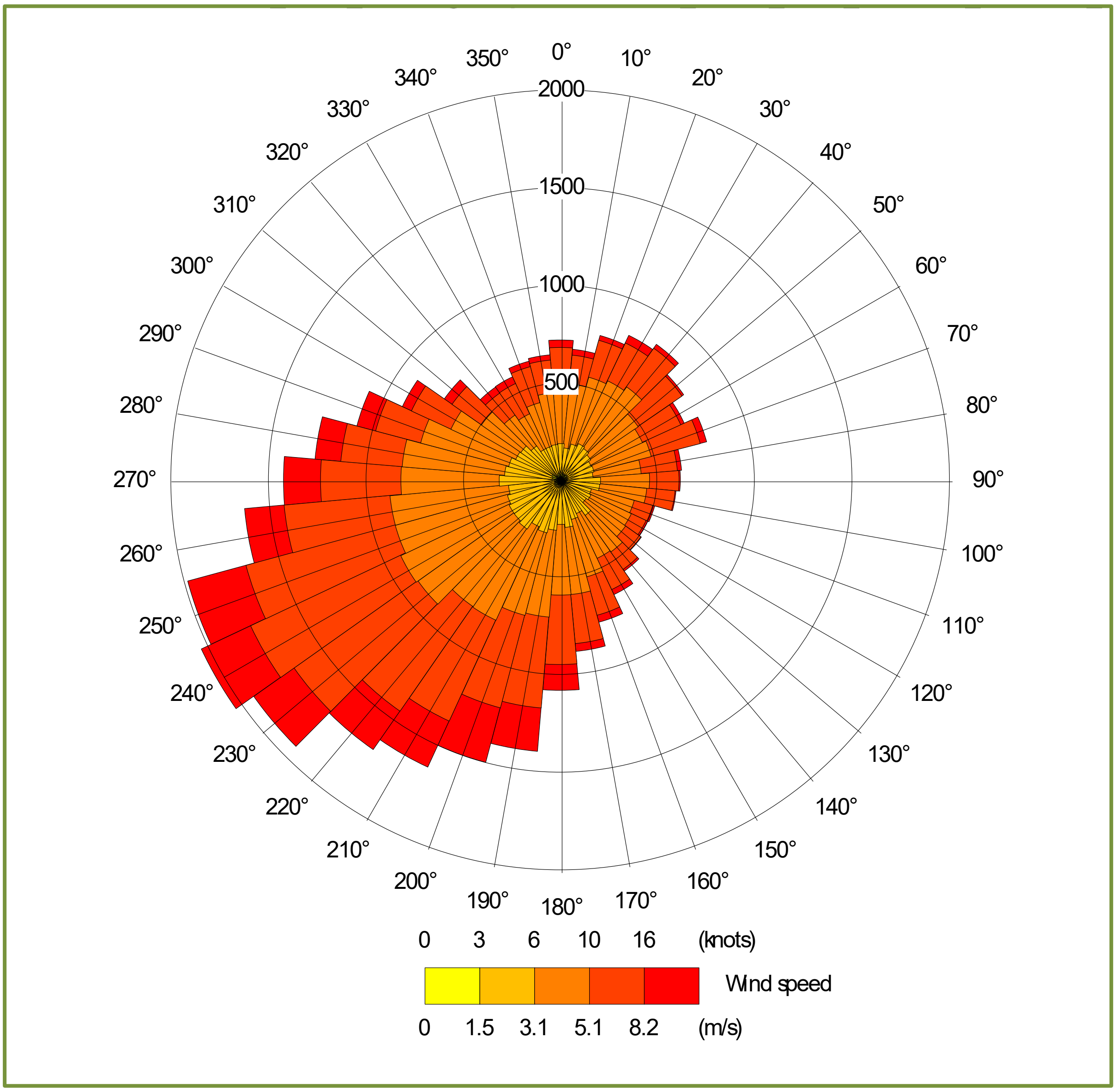
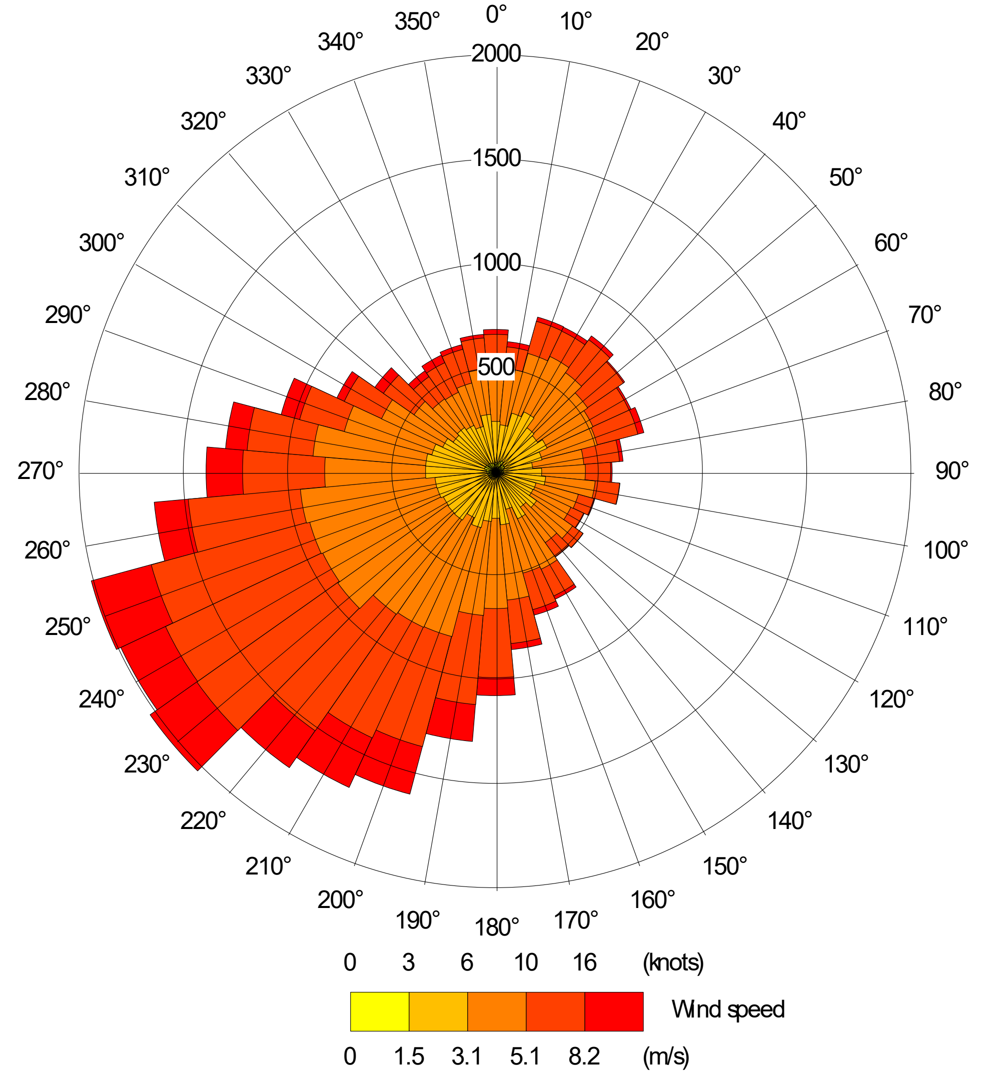


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 621600, 292500, 2022-2025



4.2 Emission sources

Emissions from the chimneys of the uncapped high-speed ridge fans that would be used for the primary ventilation of the poultry houses in the proposed scenario are characterised by three point sources per house within ADMS (H1 to H5; 1, 2 & 3).

Emissions from the existing naturally ventilated houses and the gable end fans that would be used for supplementary ventilation of house five in the proposed scenario are characterised by volume sources within ADMS (EX and H5_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 ridge fans. As a precautionary measure, it is assumed this occurs whenever the ambient temperature exceeds 23 Celsius and the proportion of emissions is 50:50 between ridge fans and gable end fans.

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

Table 4a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Baseline Emission rate per source ($g\text{-}NH_3/s$)
H1; 1, 2 & 3	5.9	0.8	10.0	Variable [1]	0.008330 [2]
H2; 1, 2 & 3	5.9	0.8	10.0	Variable [1]	0.008228 [2]
H3; 1, 2 & 3	5.9	0.8	10.0	Variable [1]	0.008231 [2]
H4; 1, 2 & 3	6.8	0.8	10.0	Variable [1]	0.009838 [2]
H5; 1, 2 & 3	7.1	0.8	10.0	Variable [1]	0.011439 [1 & 2]

Table 4b. Volume source parameters

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Baseline Emission rate ($g\text{-}NH_3/s$)
H5_GAB	10.0	22.9	3.0	1.0	Ambient	0.034316 [1 & 3]
EX	100.0	133.0	3.0	1.0	Ambient	0.234460

1. Dependent on crop stage and ambient temperature.
2. Reduced by 50% when ambient temperature exceeds 23 Celsius.
3. 50% of total only emitted when ambient temperature exceeds 23 Celsius.

4.3 Modelled buildings

The structure of the poultry houses and other nearby buildings may affect the plumes from the point sources. Therefore, the buildings are modelled within ADMS. 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

Nine-teen 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, two regular Cartesian grids have been defined within ADMS. The individual grid receptors are defined at ground level within ADMS. The position of the Cartesian grids 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 13.0 km by 13.0 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 200 m.

4.7 Roughness Length

In this case, a spatially varying roughness length file has been defined, this is based upon the Defra land use database. The GFS meteorological data is assumed to have a roughness length of 0.127 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 5.

Figure 3. The positions of modelled buildings and sources

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

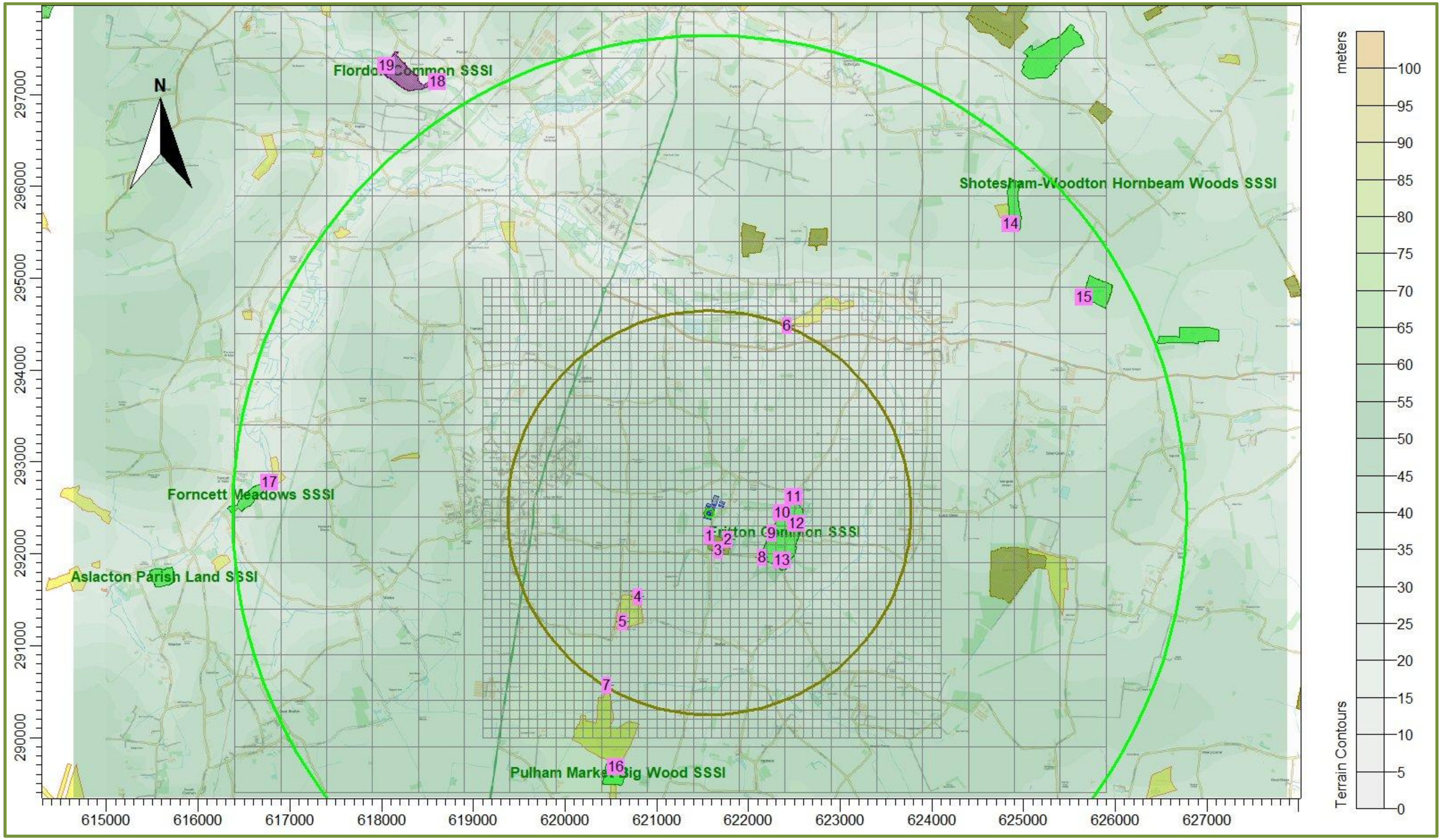


Figure 4b. The discrete receptors and regular Cartesian grids – a closer view

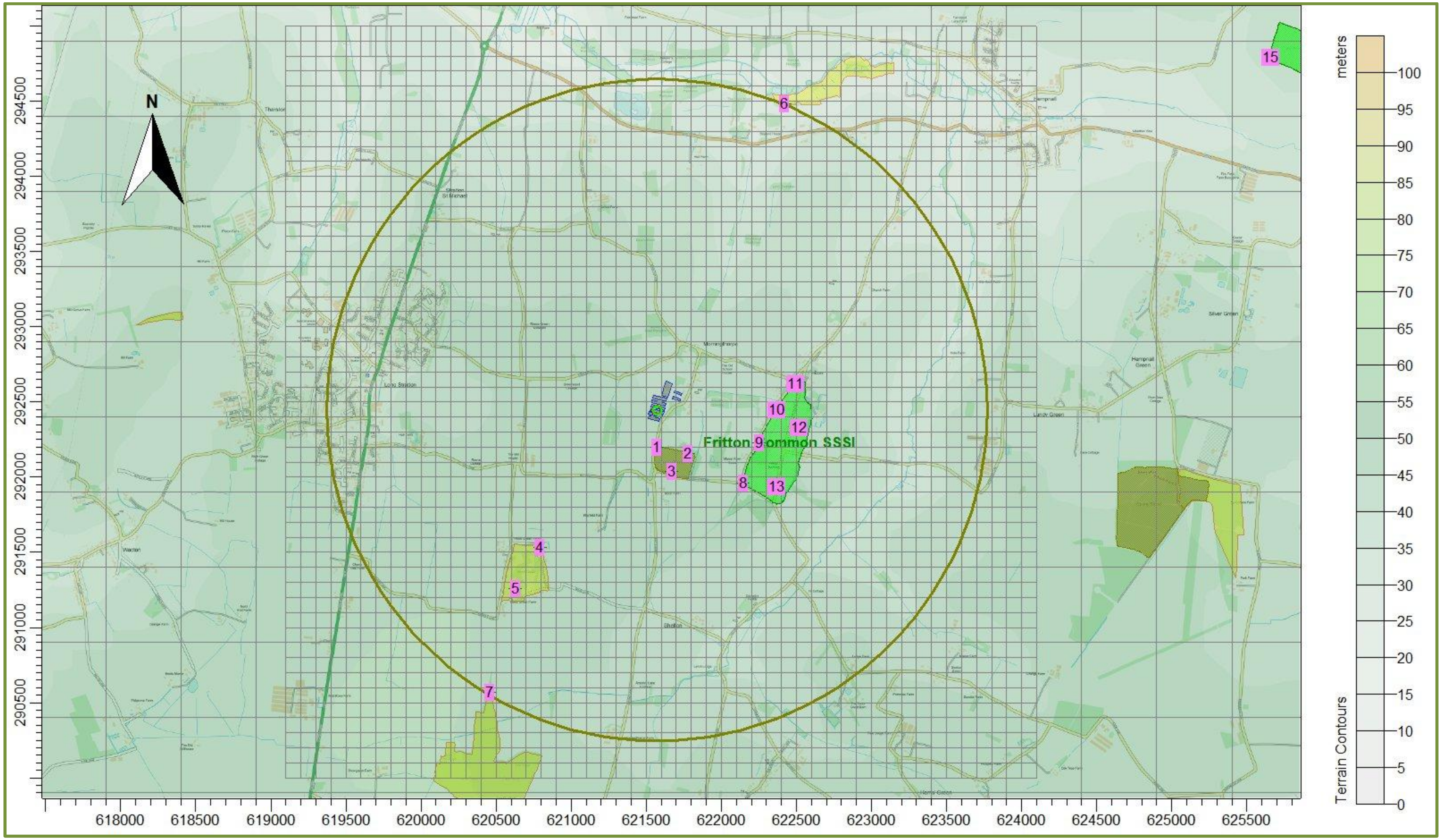
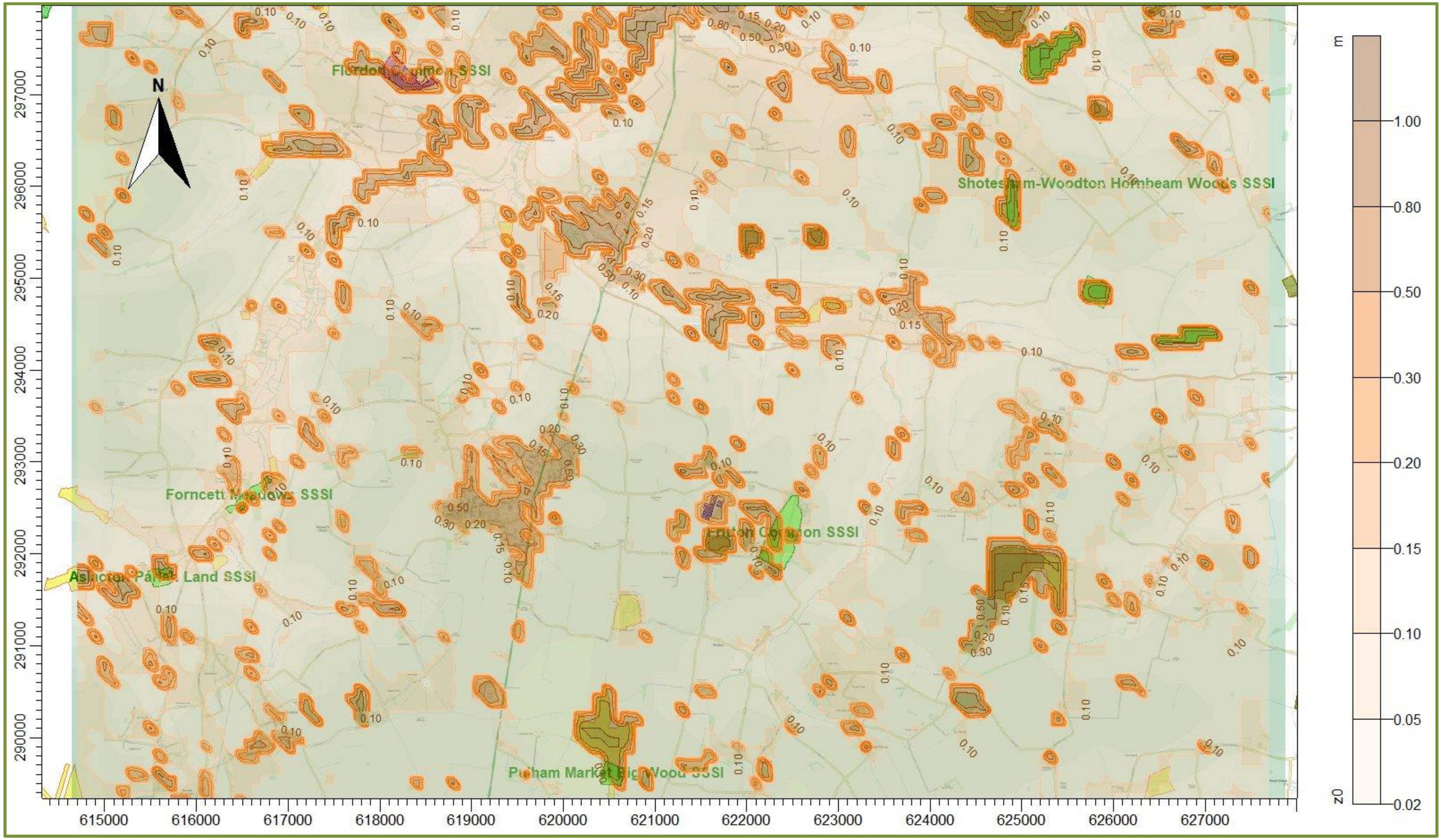


Figure 5. The spatially varying surface roughness field (central area)



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.

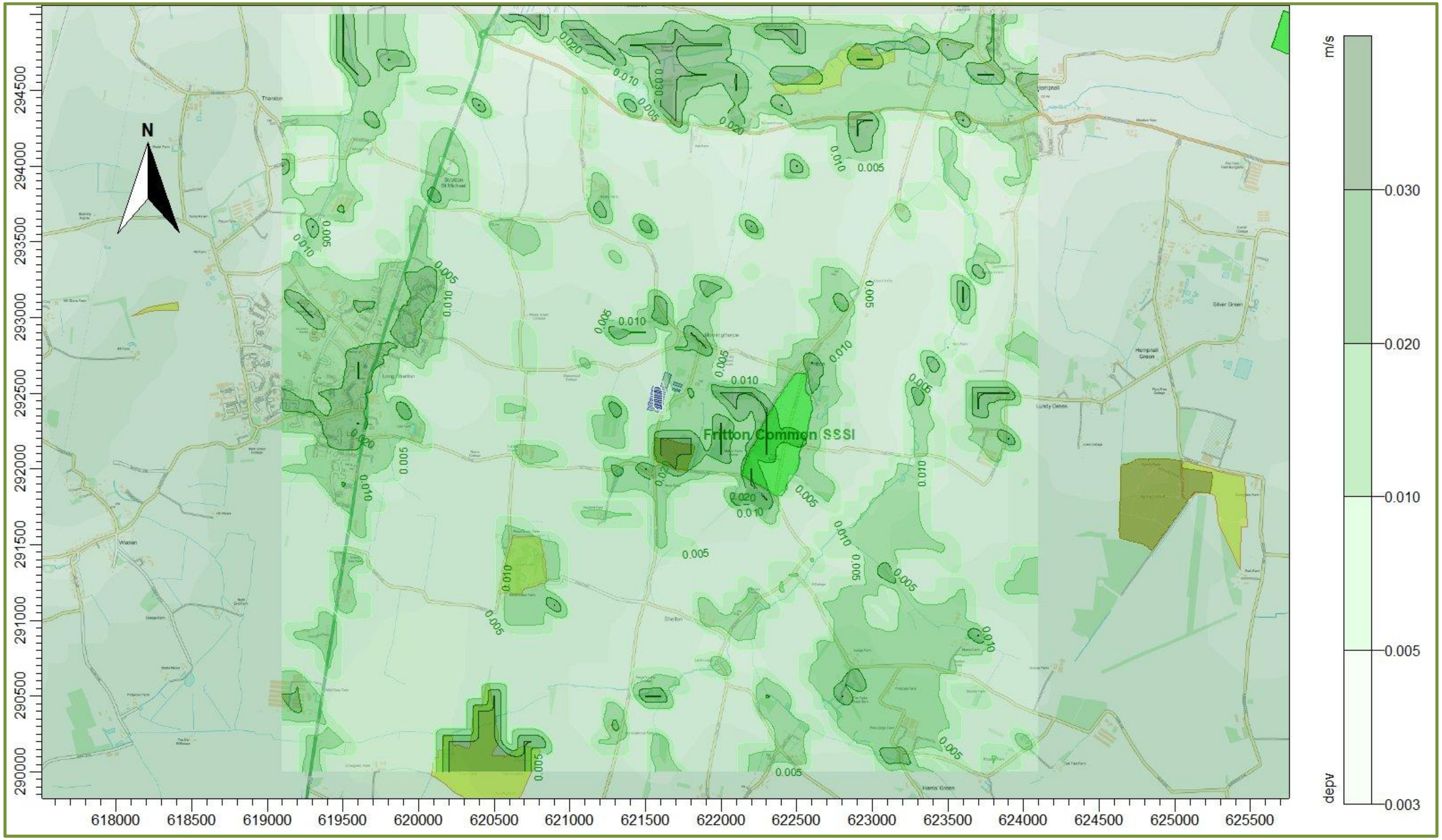
Table 5. Deposition velocities

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

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

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

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 eight times: once for each year of the meteorological record and 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)	Name/Designation	Maximum annual mean ammonia concentration (µg/m³)			
				Existing Ducks		Proposed Broiler Chickens	
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms No Terrain	GFS Calms No Terrain
1	621571	292198	AW	3.455	3.889	0.538	0.537
2	621778	292159	AW	1.714	1.953	0.264	0.263
3	621669	292038	AW	1.514	1.707	0.239	0.239
4	620790	291533	LWS	0.303	0.343	0.063	0.062
5	620627	291262	LWS	0.213	0.240	0.044	0.044
6	622422	294482	LWS	0.113	0.130	0.036	0.036
7	620454	290569	LWS	0.125	0.141	0.029	0.029
8	622144	291959	Fritton Common SSSI	0.695	0.780	0.112	0.112
9	622251	292228	Fritton Common SSSI	0.902	1.003	0.163	0.162
10	622367	292446	Fritton Common SSSI	0.724	0.807	0.172	0.171
11	622492	292624	Fritton Common SSSI	0.558	0.618	0.151	0.150
12	622519	292330	Fritton Common SSSI	0.501	0.568	0.118	0.118
13	622368	291936	Fritton Common SSSI	0.557	0.619	0.093	0.093
14	624857	295590	Shotesham-Woodton Hornbeam Woods SSSI	0.041	0.044	0.014	0.014
15	625661	294792	Shotesham-Woodton Hornbeam Woods SSSI	0.039	0.042	0.014	0.014
16	620559	289686	Pulham Market Big Wood SSSI	0.073	0.084	0.018	0.018
17	616774	292780	Forncett Meadows SSSI	0.035	0.039	0.011	0.011
18	618606	297144	Flordon Common SSSI/SAC	0.018	0.022	0.006	0.006
19	618055	297320	Flordon Common SSSI/SAC	0.017	0.020	0.006	0.006

5.2 Detailed modelling

In this case, detailed modelling has been carried out over a high resolution 5.0 km x 5.0 km domain surrounding the site of the poultry houses. 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 non-statutory wildlife sites be identified within 2 km. Outside of this 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 maximum annual nitrogen deposition rates at the discrete receptors are shown in Tables 7a and 7b. In the Tables, predicted ammonia concentrations or nitrogen deposition rates that are in excess of the Environment Agency upper threshold (20% for a SSSI and 100% for a AW/CWS) of the Critical Level/Load are highlighted in red text. Process contributions in the range of the Environment Agency lower and upper thresholds (1% and 'no upper threshold' for a SAC, 20% and 50% for a SSSI and 100% and 100% for an AW/CWS) of the Critical Level/Load are highlighted in blue text. Additionally, exceedances of 1% of the Critical Level and/or Load at a SSSI are highlighted in bold text.

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. In this case, the results of the preliminary modelling indicate that the effects of calms are significant in the existing scenario only. Therefore, in Table 7a, a calms correction has been applied to the detailed modelling results at receptors within approximately 2 km.

It has been noted previously that at least the lower bound Critical Levels and Loads are almost certainly already exceeded and that available background levels are suitable only to provide a broad indication of likely pollutant impact at a specific location. Therefore, in this case, PECs are not presented.

Contour plots of the predicted ground level maximum annual mean ammonia concentration and maximum annual nitrogen deposition rates for the proposed scenario are shown in Figures 7a and 7b. Contour plots for other scenarios/partial scenarios can be made available upon request.

Table 7a. Predicted maximum annual mean ammonia concentrations and maximum annual nitrogen deposition – Existing Duck Rearing

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level ($\mu g/m^3$)	Critical Load (kg/ha)	Process Contribution ($\mu g/m^3$)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	621571	292198	AW	0.03	1.0	10.0	1.993	**199.26**	15.524	**155.24**
2	621778	292159	AW	0.03	1.0	10.0	0.773	77.34	6.026	60.26
3	621669	292038	AW	0.03	1.0	10.0	0.566	56.60	4.409	44.09
4	620790	291533	LWS	0.03	1.0	10.0	0.115	11.54	0.899	8.99
5	620627	291262	LWS	0.03	1.0	10.0	0.075	7.47	0.582	5.82
6	622422	294482	LWS	0.03	1.0	10.0	0.052	5.25	0.409	4.09
7	620454	290569	LWS	0.03	1.0	10.0	0.042	4.25	0.331	3.31
8	622144	291959	Fritton Common SSSI	0.03	1.0	10.0	0.198	**19.79**	1.542	**15.42**
9	622251	292228	Fritton Common SSSI	0.03	1.0	10.0	0.303	**30.30**	2.361	**23.61**
10	622367	292446	Fritton Common SSSI	0.02	1.0	6.0	0.325	**32.46**	1.686	**28.10**
11	622492	292624	Fritton Common SSSI	0.02	1.0	6.0	0.289	**28.94**	1.503	**25.05**
12	622519	292330	Fritton Common SSSI	0.02	1.0	6.0	0.190	**18.96**	0.985	**16.42**
13	622368	291936	Fritton Common SSSI	0.02	1.0	6.0	0.137	**13.74**	0.713	**11.89**
14	624857	295590	Shotesham-Woodton Hornbeam Woods SSSI	0.02	1.0	15.0	0.015	**1.45**	0.075	0.50
15	625661	294792	Shotesham-Woodton Hornbeam Woods SSSI	0.02	1.0	15.0	0.016	**1.60**	0.083	0.55
16	620559	289686	Pulham Market Big Wood SSSI	0.02	1.0	15.0	0.021	**2.07**	0.108	0.72
17	616774	292780	Forncett Meadows SSSI	0.02	3.0	10.0	0.007	0.23	0.036	0.36
18	618606	297144	Flordon Common SSSI/SAC	0.02	1.0	10.0	0.007	0.71	0.037	0.37
19	618055	297320	Flordon Common SSSI/SAC	0.02	1.0	10.0	0.006	0.60	0.031	0.31

Table 7b. Predicted maximum annual mean ammonia concentrations and maximum annual nitrogen deposition - Proposed Broiler Chicken Rearing

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level ($\mu g/m^3$)	Critical Load (kg/ha)	Process Contribution ($\mu g/m^3$)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	621571	292198	AW	0.03	1.0	10.0	0.408	40.80	3.179	31.79
2	621778	292159	AW	0.03	1.0	10.0	0.193	19.35	1.507	15.07
3	621669	292038	AW	0.03	1.0	10.0	0.168	16.82	1.310	13.10
4	620790	291533	LWS	0.03	1.0	10.0	0.039	3.94	0.307	3.07
5	620627	291262	LWS	0.03	1.0	10.0	0.028	2.80	0.218	2.18
6	622422	294482	LWS	0.03	1.0	10.0	0.023	2.30	0.179	1.79
7	620454	290569	LWS	0.03	1.0	10.0	0.019	1.93	0.150	1.50
8	622144	291959	Fritton Common SSSI	0.03	1.0	10.0	0.071	**7.10**	0.553	**5.53**
9	622251	292228	Fritton Common SSSI	0.03	1.0	10.0	0.100	**10.00**	0.779	**7.79**
10	622367	292446	Fritton Common SSSI	0.02	1.0	6.0	0.118	**11.82**	0.614	**10.23**
11	622492	292624	Fritton Common SSSI	0.02	1.0	6.0	0.109	**10.89**	0.566	**9.43**
12	622519	292330	Fritton Common SSSI	0.02	1.0	6.0	0.076	**7.63**	0.396	**6.61**
13	622368	291936	Fritton Common SSSI	0.02	1.0	6.0	0.057	**5.68**	0.295	**4.92**
14	624857	295590	Shotesham-Woodton Hornbeam Woods SSSI	0.02	1.0	15.0	0.009	0.89	0.046	0.31
15	625661	294792	Shotesham-Woodton Hornbeam Woods SSSI	0.02	1.0	15.0	0.010	0.97	0.051	0.34
16	620559	289686	Pulham Market Big Wood SSSI	0.02	1.0	15.0	0.012	**1.20**	0.062	0.42
17	616774	292780	Forncett Meadows SSSI	0.02	3.0	10.0	0.005	0.16	0.025	0.25
18	618606	297144	Flordon Common SSSI/SAC	0.02	1.0	10.0	0.004	0.38	0.020	0.20
19	618055	297320	Flordon Common SSSI/SAC	0.02	1.0	10.0	0.003	0.33	0.017	0.17

Figure 7a. Maximum annual mean ammonia concentration – Proposed Broiler Chicken Rearing

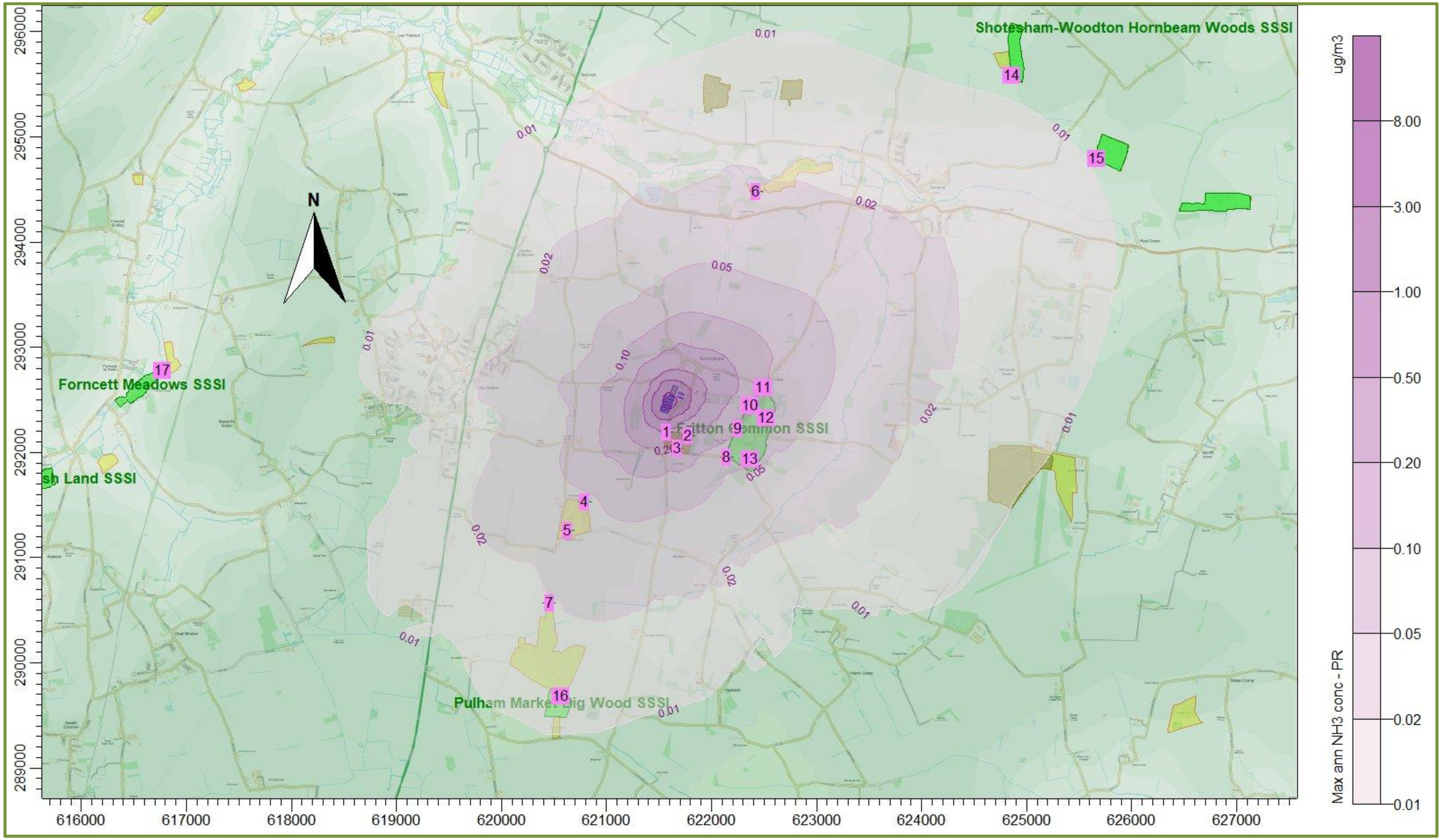
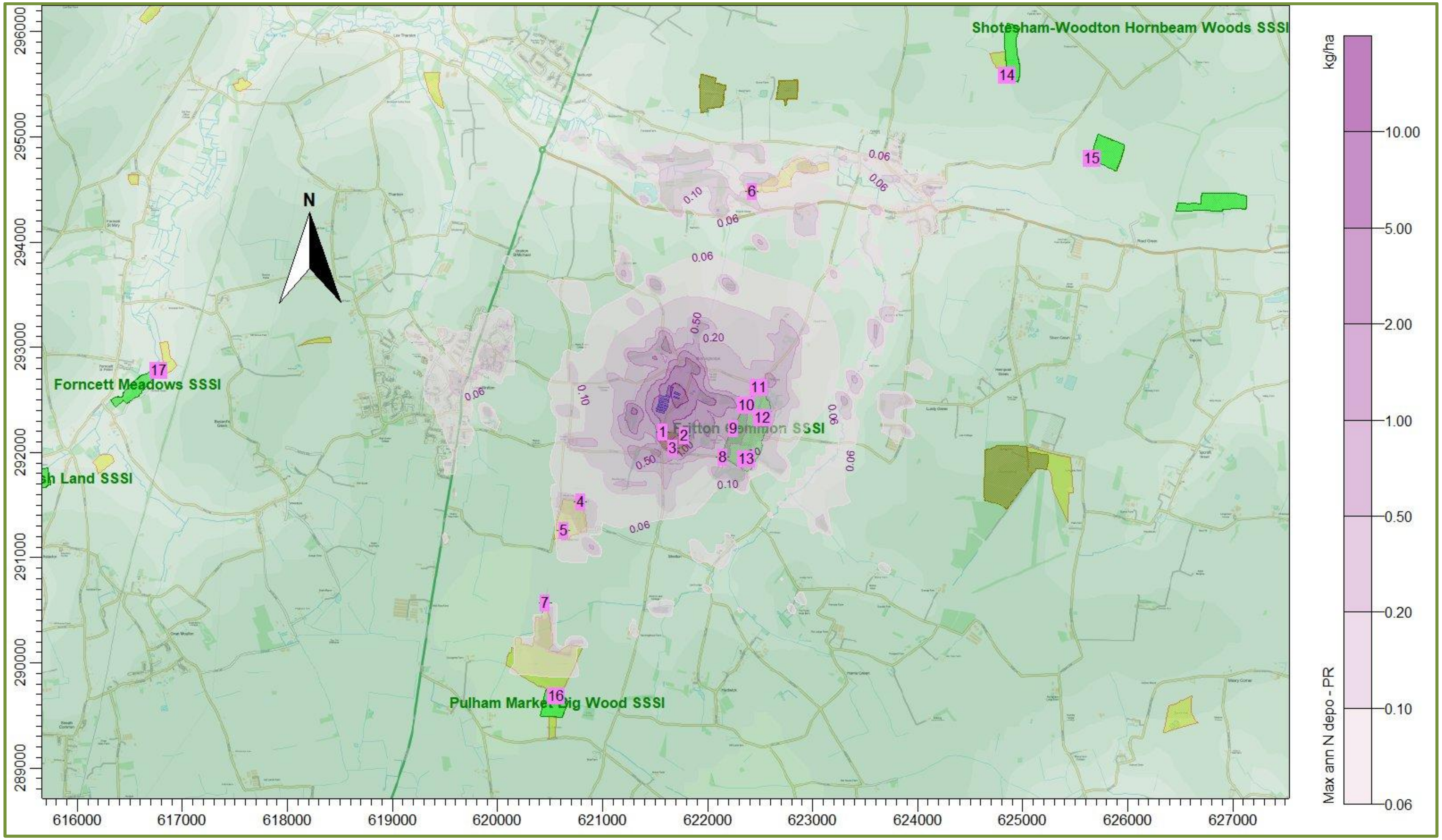


Figure 7b. Maximum annual nitrogen deposition rates – Proposed Broiler Chicken Rearing



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Mr. Karl Collett of Green Inc Solutions Ltd., on behalf of Mr. David Sargent and Mr. Christopher Sargent, to use computer modelling to assess the impact of ammonia emissions from the existing duck rearing houses and the proposed broiler chicken rearing houses at Friars Farm, Morningthorpe, Long Stratton, Norfolk. NR15 2QL.

Ammonia emission rates from the existing duck rearing houses and the proposed broiler chicken rearing houses have been assessed and quantified based upon the Environment Agency standard ammonia emission factors. 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.

Existing Duck Rearing

The modelling predicts that:

- Process contributions to ammonia concentrations and nitrogen deposition rates currently exceed the Environment Agency lower/upper threshold of 100% of the Critical Level/Load at closer parts of the nearby AW.
- There are exceedances of the Environment Agency lower threshold of 20% of the Critical Level/Load at closer parts of Fritton Common SSSI.
- At all other wildlife sites considered, process contributions are below the Environment Agency lower thresholds. However, there are exceedances of 1% of the Critical Level/Load at Shotesham-Woodton Hornbeam Woods SSSI and Pulham Market Big Wood SSSI.

Proposed Broiler Chicken Rearing

The modelling predicts that, should the redevelopment of Friars Farm proceed:

- Process contributions to ammonia concentrations and nitrogen deposition rates would be below the Environment Agency lower/upper threshold of 100% of the Critical Level/Load at all of the AW and CWSs considered.
- Process contributions at Fritton Common SSSI would be reduced from the existing scenario to below the Environment Agency lower threshold of 20% of the Critical Level/Load.
- At all other wildlife sites considered process contributions would remain below the Environment Agency thresholds.
- Process contributions would be reduced at all receptors considered, significantly so in the case of the closer wildlife sites.

7. References

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