A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing Turkey Rearing Houses and Proposed Broiler Chicken Rearing Houses at Badcocks Farm Poultry Unit, Saling Road, near Stebbing in Essex

AS Modelling & Data Ltd.

www.asmodata.co.uk

Prepared by Steve Smith

stevesmith@asmodata.co.uk
07523 993370
17th June 2025

Reviewed by Sally Young

sally@asmodata.co.uk
07483 345124
18th June 2025

1. Introduction

AS Modelling & Data Ltd. has been instructed by Mr. Karl Collett of Green Inc Solutions Ltd., on behalf of GST Ltd., to use computer modelling to assess the impact of ammonia emissions from the existing turkey rearing houses and proposed broiler chicken rearing houses at Badcocks Farm Poultry Unit, Saling Road, Stebbing, Dunmow, Essex. CM6 3XF.

Ammonia emission rates from the existing and proposed poultry units have been assessed and quantified based upon Environment Agency bespoke and standard ammonia emission factors. The ammonia emission rates have then been used as inputs to an atmospheric dispersion and deposition model which calculates ammonia exposure levels and nitrogen 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

Badcocks Farm Poultry Unit is in a rural area approximately 1.8 km to the east of the village of Stebbing in Essex. The surrounding land is used primarily for arable farming, although there are some wooded areas. The site is at an altitude of around 86 m, rising towards slightly higher ground to the north and falling towards the south.

There are currently two poultry houses at Badcocks Farm Poultry Unit, which are used to rear up to 29,852 turkeys. The houses are ventilated using uncapped high speed ridge mounted fans, each with a short chimney, with gable end fans to provide supplementary ventilation during periods of hot weather.

Under the proposal, one of the existing poultry houses would be replaced by a new poultry house and an additional poultry house would be constructed to the north of the existing houses. The three houses would provide accommodation for up to 105,600 broiler chickens, which would be reared from day old chicks to around 38 days old. Ventilation would be provided by uncapped high speed ridge mounted fans, each with a short chimney, there would also be gable end fans to provide supplementary ventilation during periods of hot weather. There would be approximately 7.5 flocks per annum.

AS Modelling & Data Ltd. have identified several areas designated as Local Wildlife Sites (LWSs) (source: Local Authority policies/constraints mapping) and/or Ancient Woodlands (AWs) within 2 km of the site. There are four areas designated as Sites of Special Scientific Interest (SSSIs) within 10 km of the site. There are no internationally designated wildlife sites within 10 km of the site. Some further details of the SSSIs are provided below:

- **Bovingdon Hall Woods SSSI** - Approximately 8.0 km to the east-north-east - Eight adjacent woods, predominantly ancient coppice-with-standards woodland. This site is the largest extant example of small-leaved lime *Tilia cordata* woodland in Essex, supporting both the acid pedunculate oak-lime woodland type and the only known example in Essex of the sessile oak-lime type. The presence of plateau alder woodland is also of conservation interest since this habitat is uncommon in Essex. Maid's Wood contains a small heronry and the woodland complex as a whole supports a rich and diverse fauna.

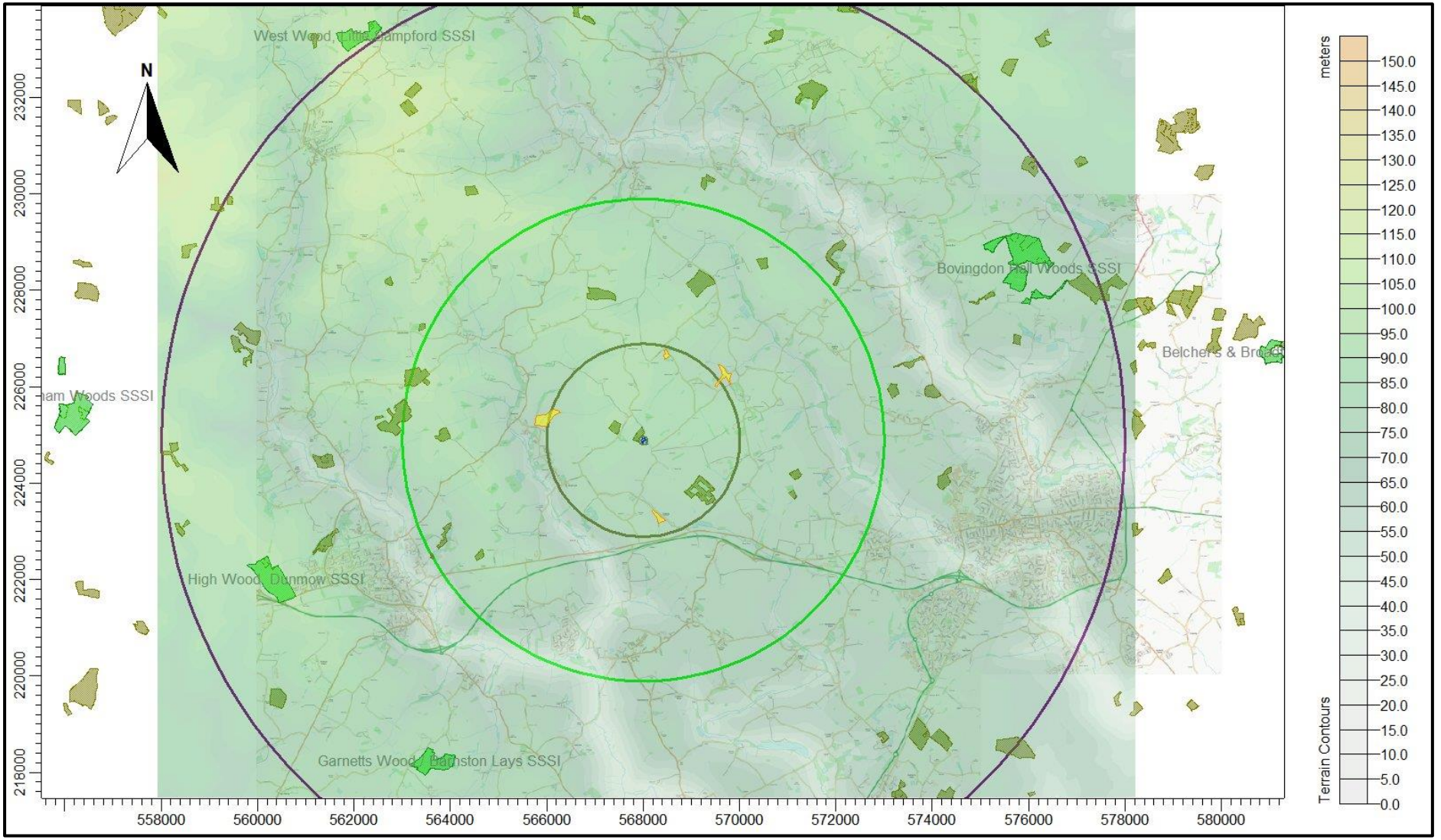
- **West Wood, Little Sampford SSSI** - Approximately 9.9 km to the north-west - An ancient wood formerly dominated by elm which has since died, the wood is now mostly ash as a result of a natural regeneration. The ill-drained clay areas give rise to wet conditions that favour a rich and varied flora, including Oxlip. The wood has wide rides which support a varied flora including damp-loving species such as Meadow-sweet *Filipendula ulmaria*, Corn and Water Mints *Mentha arvensis* and *M. aquatica*. Two ponds, and a small area of secondary scrub on the eastern corner of the wood, are included within the boundary of the site.

- **High Wood, Dunmow SSSI** - Approximately 7.6 km to the west-south-west - A wet Ash-Maple and Pedunculate Oak-Hornbeam wood. The site includes both ancient woodland, formerly managed as coppice-with-standards, and a smaller area of secondary woodland which arose in the eighteenth century (New Wood). The wood also contains isolated stands of Plateau Alder (dominated by *Alnus glutinosa*), a woodland type which is scarce in Essex. The ground flora is varied, most areas being dominated by Dog's Mercury *Mercurialis perennis* with locally abundant *Bramble Rubus* sp. and Primrose *Primula vulgaris*. Pendulous Sedge *Carex pendula*, Meadowsweet *Filipendula ulmaria* and Tufted Hair-grass *Deschampsia cespitosa* are locally dominant in the wetter areas.

- **Garnetts Wood / Barnston Lays SSSI** - Approximately 7.6 km to the south-south-west - Small-leaved Lime T*ilia cordata* is the dominant tree in the larger Garnetts Wood. It is locally mixed with Hornbeam *Carpinus betulus*, with Oak *Quercus robur* or Birch *Betula* sp. Ash *Fraxius excelsior* is found throughout the wood and Maple *Acer campestre* at the northern end. The smaller Barnston Lays is made up of a mixture of Ash and Maple with Oak and Hornbeam. The ground flora of the woods is mainly Bramble *Rubus fruticosus agg*. or Dog's Mercury *Mercurialis perennis*. The flora includes Wood Sorrel *Oxalis acetosella* and Bluebell *Hyacinthoides non-scripta*. There are two ponds and Water Purslane *Peplis portula*, a species found infrequently in the county, is recorded on the site.

A map of the surrounding area showing the poultry houses at Badcocks Farm Poultry Unit (outlined in blue), the AWs/LWSs (shaded in olive), the LWSs (shaded in yellow) and the SSSIs (shaded in green) is provided in Figure 1.

Figure 1. The area surrounding Badcocks Farm Poultry Unit - concentric circles radii 2 km (olive), 5 km (green) and 10 km (purple)



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

3.1 Ammonia concentration and nitrogen and acid deposition

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

3.2 Background ammonia levels and nitrogen and acid deposition

The source of the background figures is the Air Pollution Information System (APIS, June 2025). 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 Badcocks Farm Poultry Unit is 1.3 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 26.0 kg-N/ha/y and to short vegetation is 13.5 kg-N/ha/y. The background acid deposition rate to woodland is 1.77 keq/ha/y and to short vegetation is 0.83 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.

3.3 Critical Levels and Critical Loads

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

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

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

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

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

The Critical Levels and Critical Loads at the wildlife sites assumed in this study are provided in Table 1. Where the Critical Level of 1.0 µg-NH_3/m^3 is assumed, it is usually unnecessary to consider the Critical Load as the Critical Level provides the stricter test. Normally, the Critical Load for nitrogen deposition provides a stricter test than the Critical Load for acid deposition and this has therefore 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)
AWs/LWSs	1.0 [1]	-	-
Hoplands Wood SSSI	1.0 [1 & 3]	15.0 [2 & 3]	-
Bovingdon Hall Woods SSSI; West Wood, Little Sampford SSSI; High Wood, Dunmow SSSI and Garnetts Wood / Barnston Lays SSSI	1.0 [1 & 3]	10.0 [2 & 3]	-
Mouslin Wood AW/LWS	3.0 [4]	10.0 [4]	-

1. A precautionary figure used where no details of the ecology of the site are available, or the citation for the sites indicates that sensitive lichens and/or bryophytes are present.
2. Based upon APIS (https://www.apis.ac.uk/search-habitat-impacts) and the citation for the site. . Note that the APIS database may contain entries habitats/species that are not present at the site or part of the site under consideration.
3. The lower bound of the range of Critical Load for habitats/species present at the site (https://www.apis.ac.uk/search-habitat-impacts) and Review and revision of empirical critical loads of nitrogen for Europe, 2022. Note that the APIS database may contain entries habitats/species that are not present at the site or part of the site under consideration.
4. Environment Agency pre-application screening report (30th May 2025)

3.4 Guidance on the Significance of Ammonia Emissions

3.4.1 Environment Agency Criteria

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

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

3.4.2 Natural England advisory criterion

Natural England are a statutory consultee at planning and usually advise that, if predicted process contributions exceed 1% (in some circumstances <1%) of Critical Level or Critical Load at a SSSI, SAC, SPA or Ramsar site, then the local authority should consider whether other farming installations[1] might act in-combination or cumulatively with the farm and the sensitivities of the wildlife sites.

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

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

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

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

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

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

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

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

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

Whilst this guidance is useful for decision makers, it has not been used further in this report.

3.5 Quantification of Ammonia Emissions

Ammonia emission rates from poultry houses depend on many factors and are likely to be highly variable. However, the benchmarks for assessing impacts of ammonia and nitrogen deposition are framed in terms of an annual mean ammonia concentration and annual nitrogen deposition rates. 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 factor used for the turkey rearing housing at Badcocks Farm Poultry Unit is understood to be a bespoke emission factor provided to AS Modelling & Data Ltd. by the applicant.

The emission factor used for the broiler chicken rearing housing at Badcocks Farm Poultry Unit has 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 types and emission factors used and calculated ammonia emission rates are provided in Table 2.

Table 2. Details of poultry numbers and ammonia emission rates

Source	Animal numbers	Type or weight	Emission factor ($kg\text{-}NH_3/place/y$)	Emission rate ($g\text{-}NH_3/s$)
Turkey Rearing Houses	29,852	Turkey Rearing	0.510	0.482436
Broiler Chicken Rearing Houses	105,600	Broiler Chicken Rearing	0.024	0.080310

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. Although, as might be expected, there is little modification in this case, elsewhere in the modelling domain, the modified wind roses may differ more markedly. 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. GFS derived data for 51.897 N, 0.442 E, 2021-2024

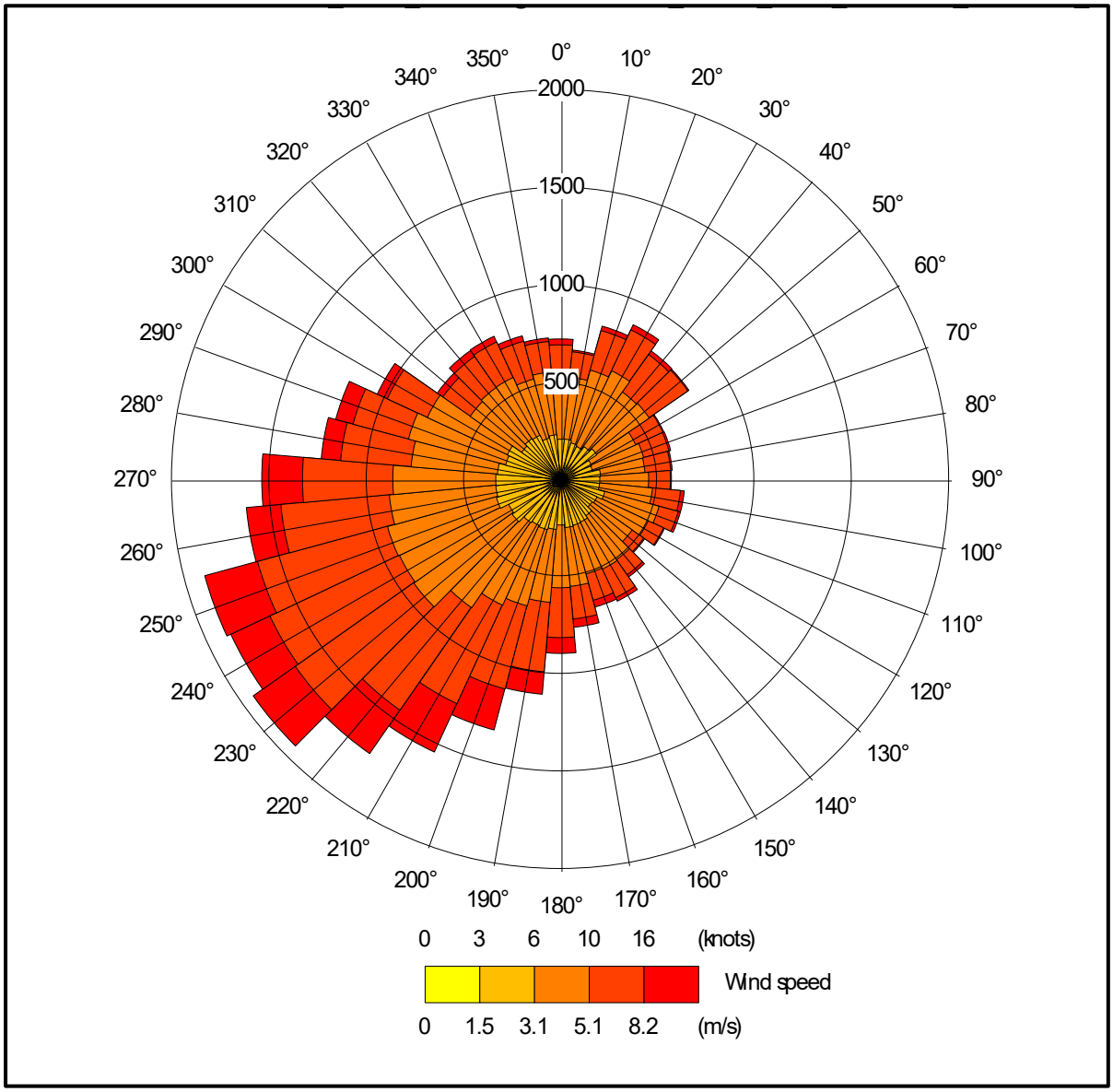
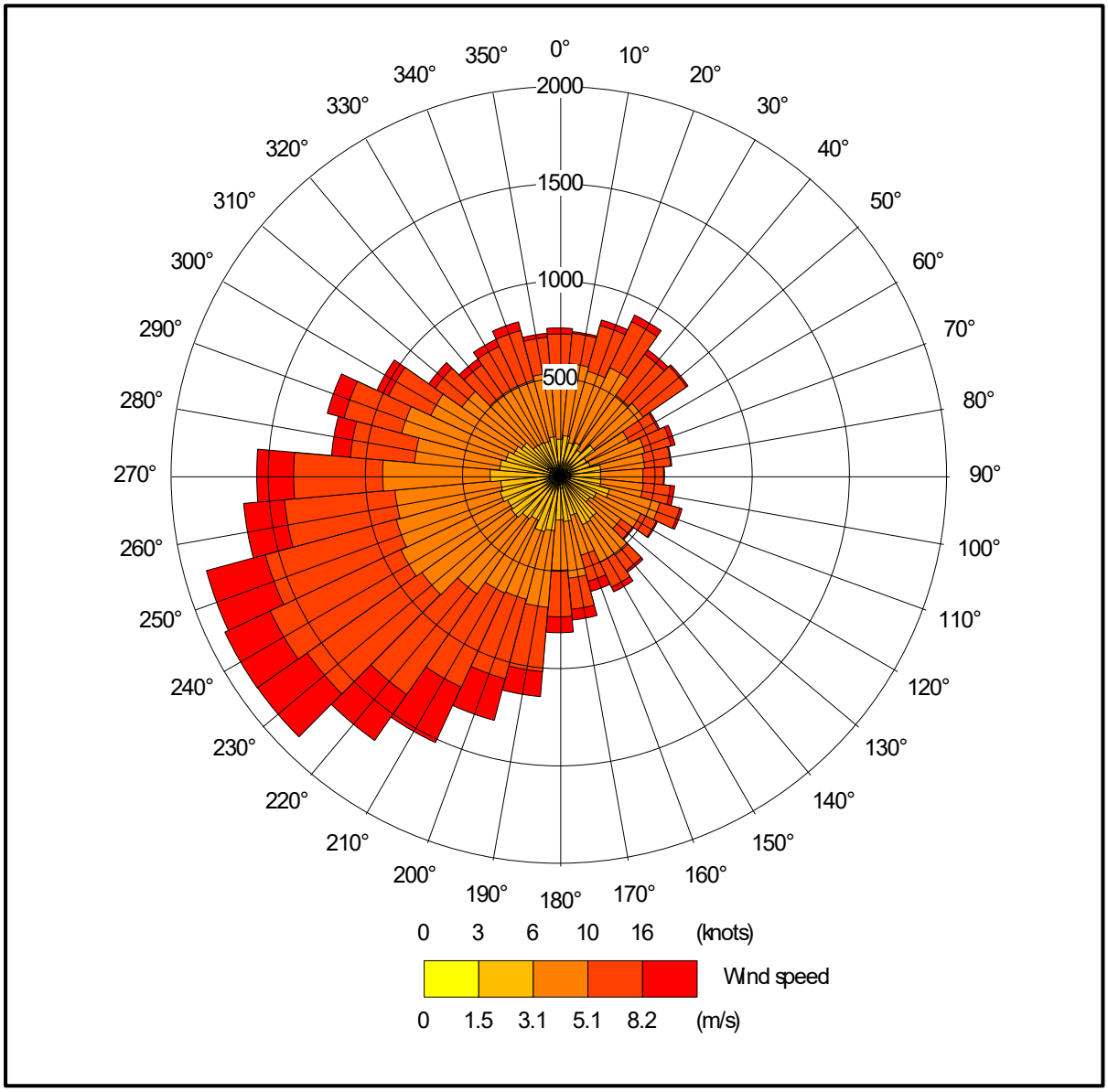


Figure 2b. The wind rose. FLOWSTAR derived data for NGR 568000,224900, 2021-2024



4.2 Emission sources

Emissions from the chimneys of the uncapped high speed ridge fans that are/would be used for the primary ventilation of the existing and proposed poultry houses are represented by three point sources per house within ADMS (H1EX 1, 2 & 3, H2EX 1, 2 & 3, H1PR 1, 2 & 3, H2PR 1, 2 & 3 and H3PR 1, 2 & 3).

Emissions from the gable end fans that are/would be used to supplement the primary ventilation have been represented by volume sources within ADMS (H1EX_GAB, H2EX_GAB, H1PR_GAB, H2PR_GAB and H3PR_GAB).

The emissions from the gable end fans are assumed to be zero unless the ambient temperature equals or exceeds 22 Celsius. Once this threshold has been reached, 50% of the total house emissions are assigned to the high speed ridge fans and 50% are assigned to the gable end fans.

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

Table 3a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source (g-NH_3/s)
H1EX 1, 2 & 3	6.05	0.8	11.0	Variable [1]	0.105054 [1 & 2]
H2EX 1, 2 & 3	4.75	0.8	7.0	Variable [1]	0.055757 [1 & 2]
H1PR 1, 2 & 3	6.05	0.8	11.0	Variable [1]	0.011680 [1 & 2]
H2PR 1, 2 & 3	5.76	0.8	11.0	Variable [1]	0.007771 [1 & 2]
H3PR 1, 2 & 3	8.26	0.8	11.0	Variable [1]	0.007319 [1 & 2]

Table 3b. Volume source parameters

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
H1EX_GAB	25.0	10.0	3.0	0.0	Ambient	0.315163 [1 & 3]
H2EX_GAB	12.0	10.0	3.0	0.0	Ambient	0.167272 [1 & 3]
H1PR_GAB	25.0	10.0	3.0	0.0	Ambient	0.035041 [1 & 3]
H2PR_GAB	17.3	10.0	3.0	0.0	Ambient	0.023314 [1 & 3]
H3PR_GAB	29.9	10.0	3.0	0.0	Ambient	0.021956 [1 & 3]

1. Dependent on ambient temperature.
2. Reduced by 50% when ambient temperature equals or exceeds 22 Celsius.
3. 50% of emissions emitted only when ambient temperature equals or exceeds 22 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. The positions of the modelled buildings may be seen in Figures 3a and 3b (marked by blue rectangles).

4.4 Discrete receptors

Twenty 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). At Mouslin Wood AW/LWS receptors have also been defined at canopy level (10 m).

4.5 Cartesian grid

To produce the contour plots presented in Section 5 of this report and to define the spatially varying deposition velocity field, two regular Cartesian grids have been defined within ADMS. The individual grid receptors are defined at ground level within ADMS. The positions of the Cartesian grids may be seen in 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 20.0 km by 20.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS for the modelling. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field for the terrain runs is approximately 300 m.

4.7 Roughness Length

In this case, a spatially varying roughness length file has been defined, this is based upon the Defra Living Landscapes database. The GFS meteorological data is assumed to have a roughness length of 0.160 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 3a. The positions of modelled buildings and sources – Existing Turkey Rearing

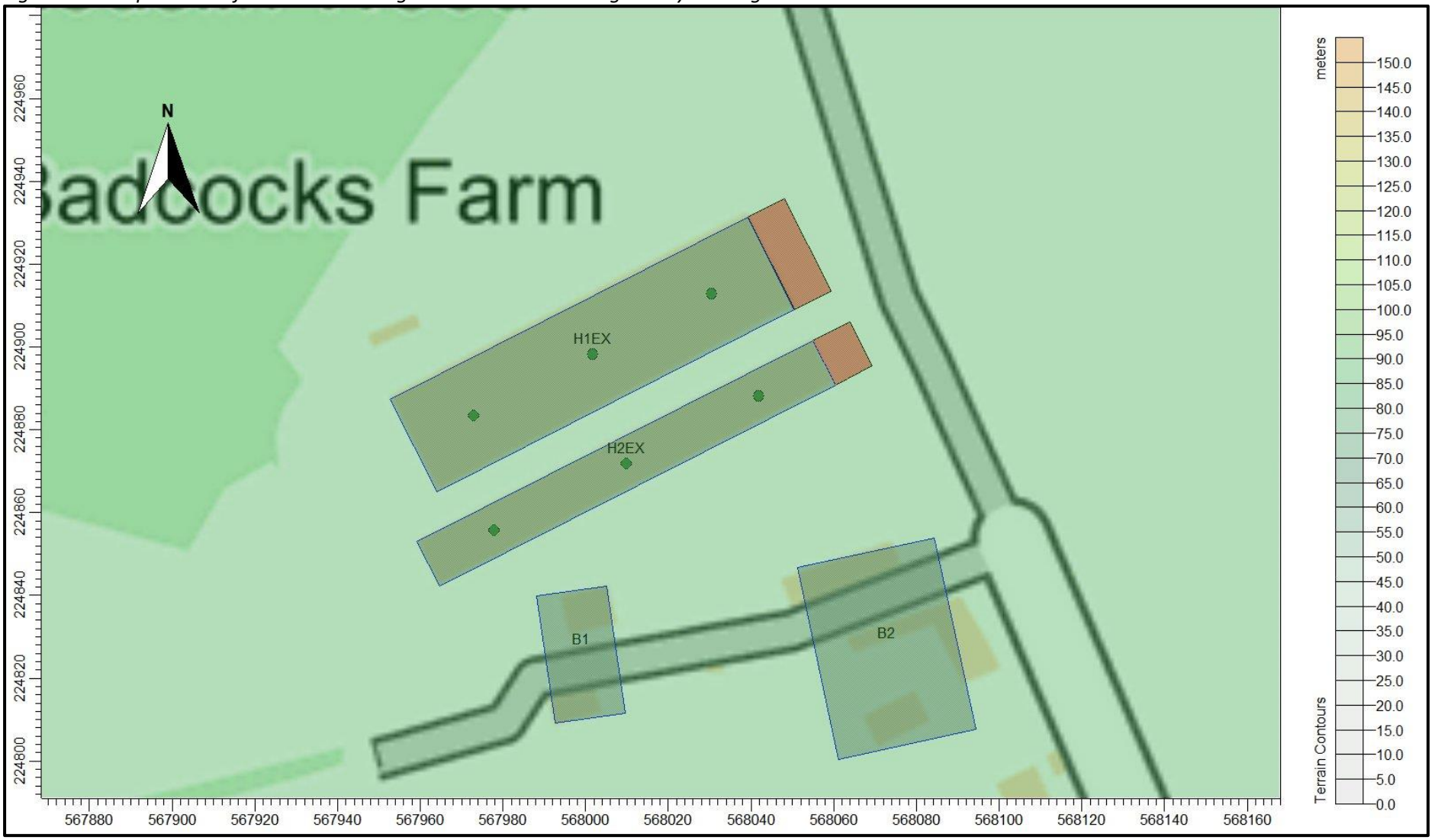


Figure 3b. The positions of modelled buildings and sources – Proposed Broiler Chicken Rearing

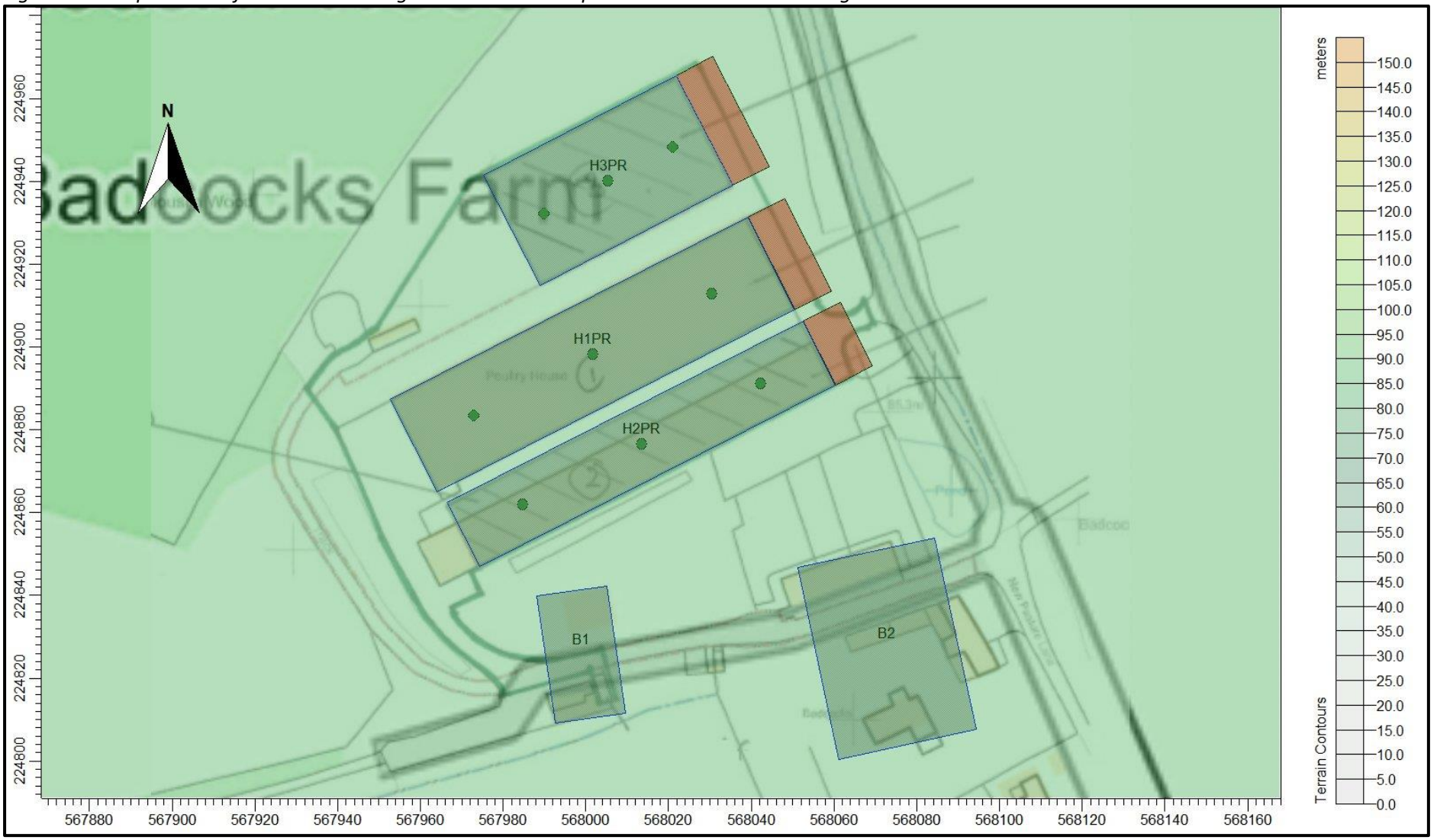


Figure 4a. The discrete receptors and regular Cartesian grids – a broadscale view

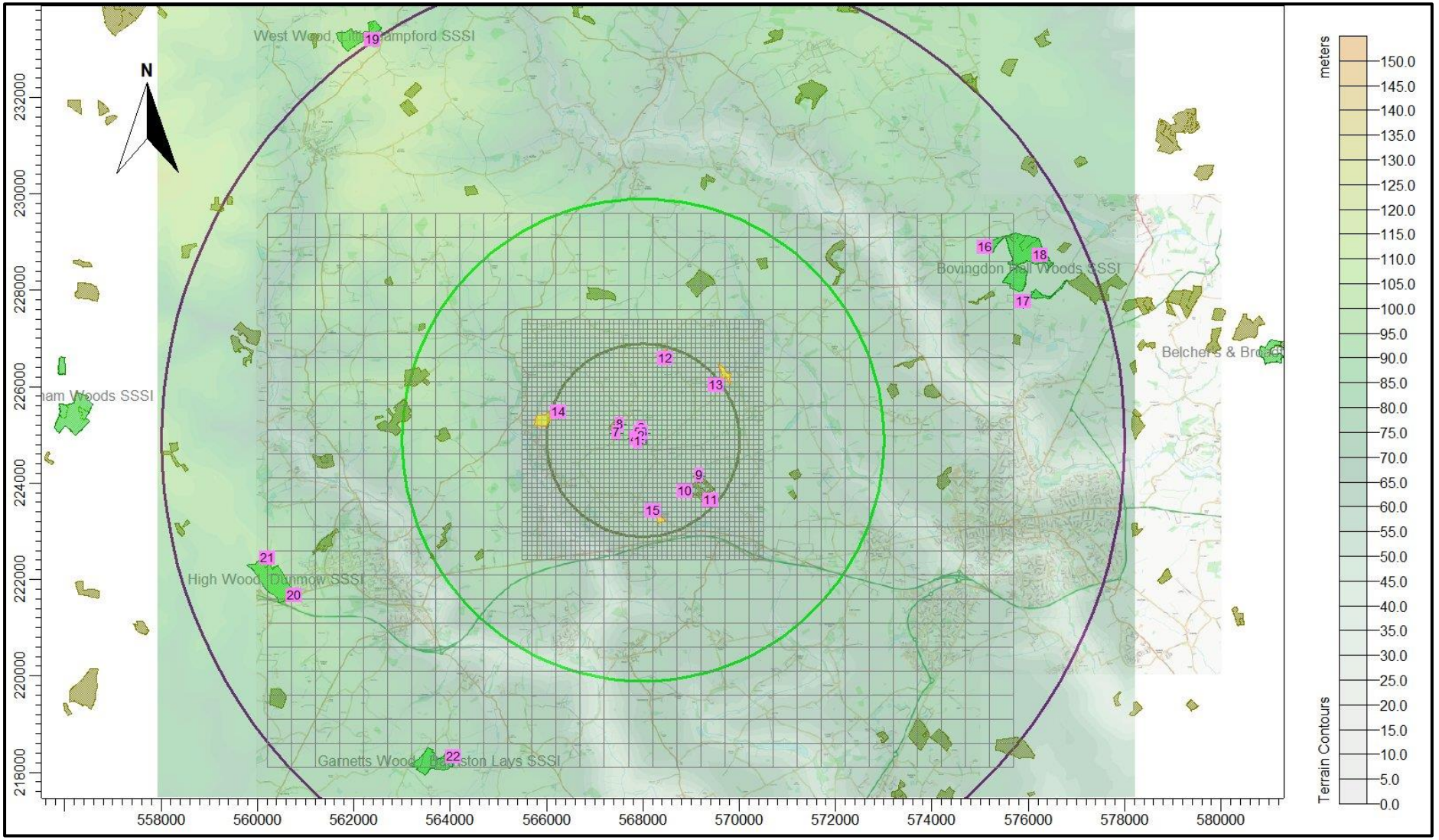


Figure 4b. The discrete receptors and regular Cartesian grids – a closer view

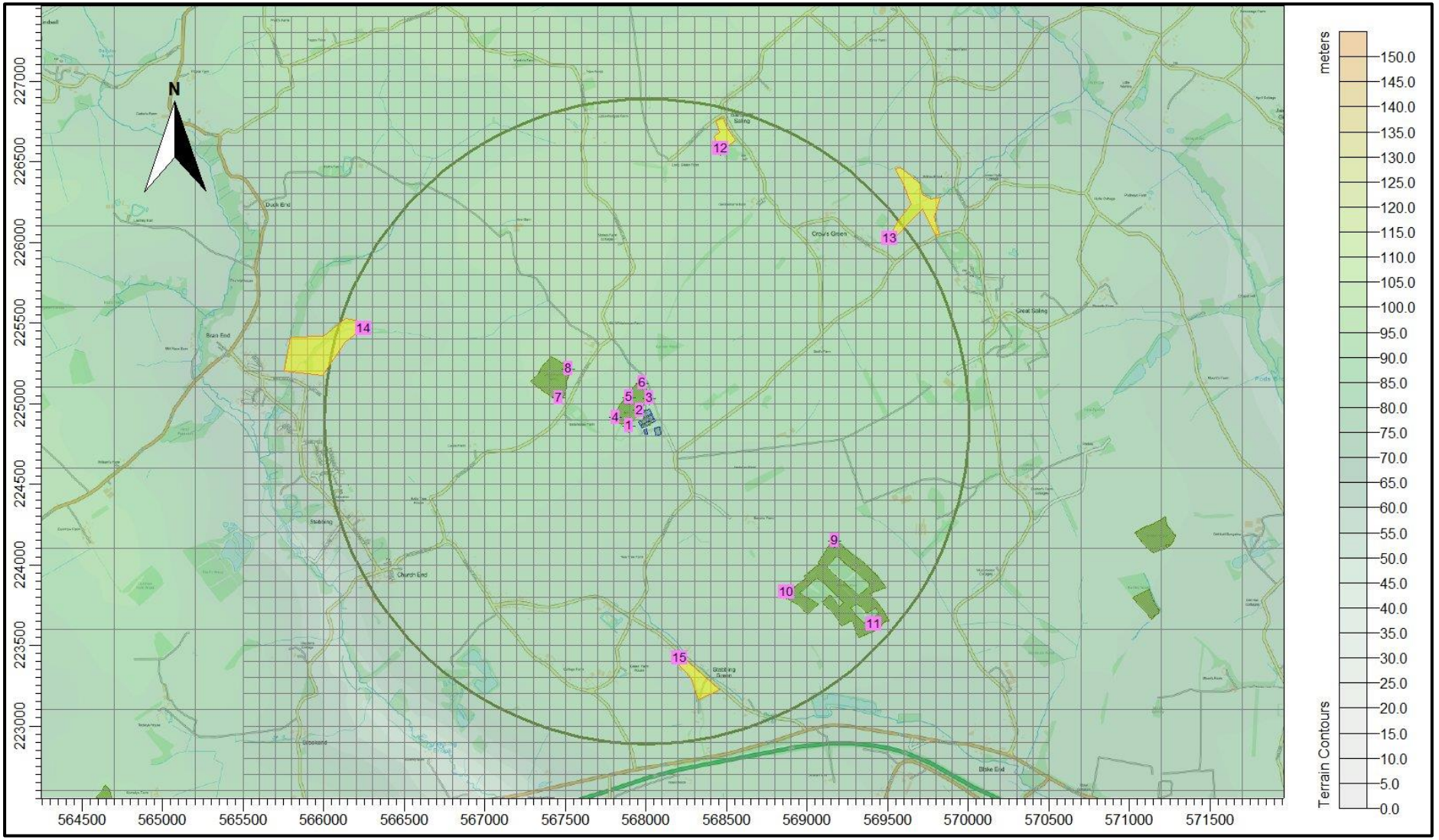
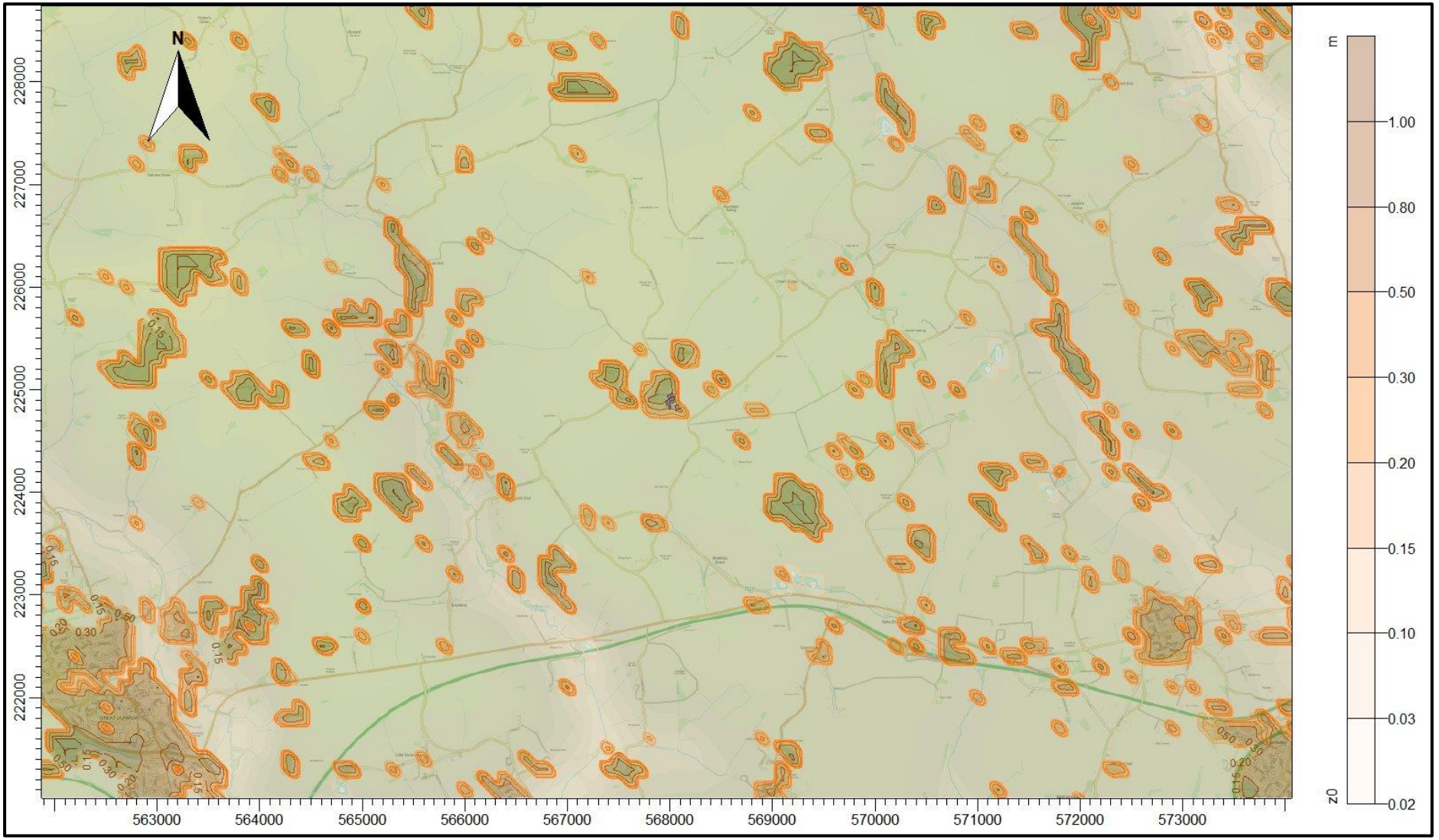


Figure 5. The spatially varying surface roughness field (central area)



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 4.

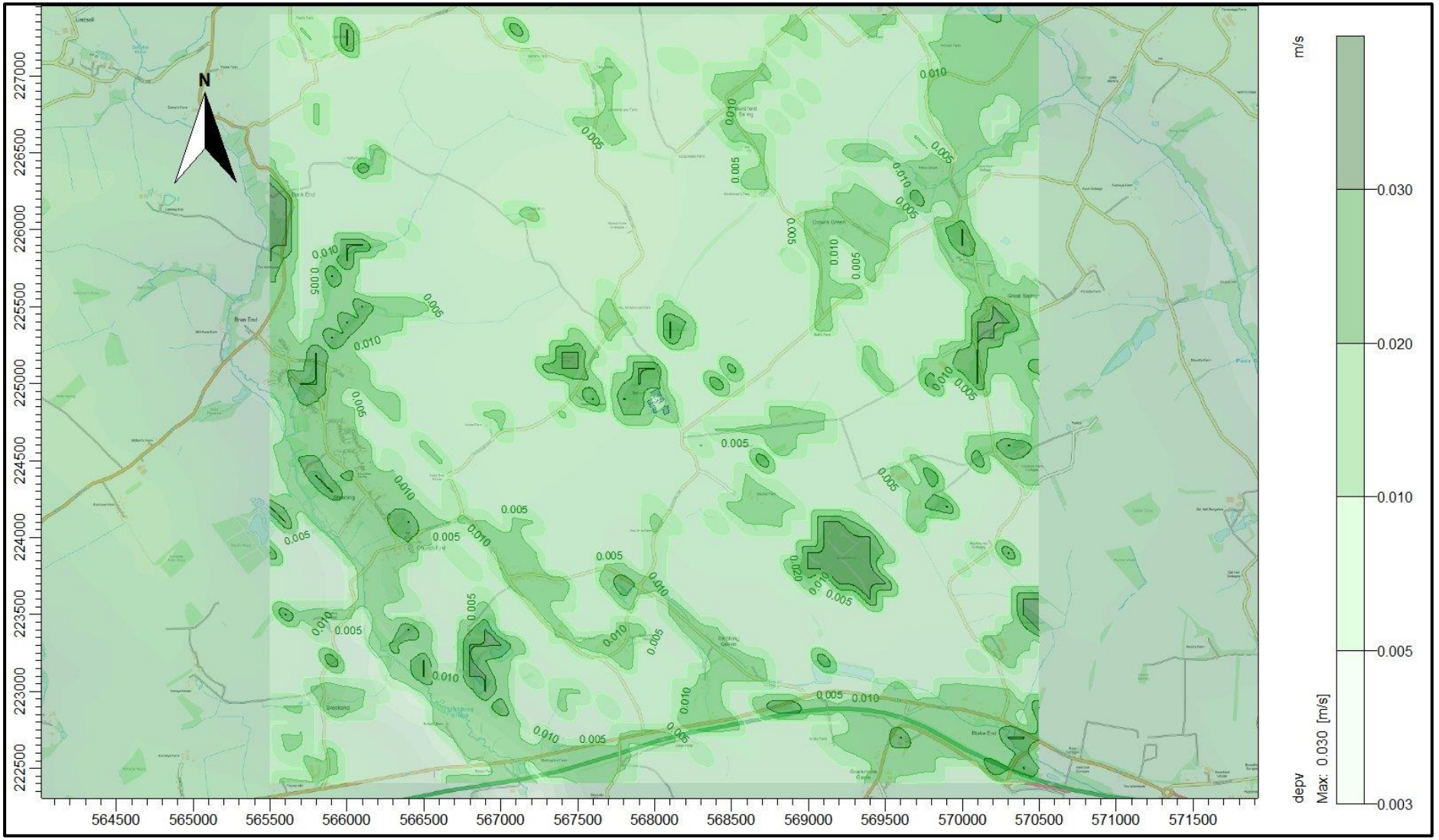
Table 4. Deposition velocities

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 effectively run a total of sixteen times, once for each year of the meteorological record, for both the existing turkey rearing and proposed broiler chicken rearing, 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 5. The primary purpose of the preliminary modelling is to assess the effect of calms on the results.

Table 5. 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)		Maximum annual mean ammonia concentration - (µg/m³)	
				Existing Turkeys		Proposed Broilers	
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms No Terrain	GFS Calms No Terrain
1	567896	224861	Mouslin Wood AW/LWS	4.712	4.691	0.663	0.660
2	567959	224958	Mouslin Wood AW/LWS	7.202	7.153	0.985	0.978
3	568019	225032	Mouslin Wood AW/LWS	5.738	5.700	1.060	1.053
4	567812	224913	Mouslin Wood AW/LWS	1.915	1.927	0.290	0.292
5	567896	225038	Mouslin Wood AW/LWS	2.620	2.602	0.443	0.440
6	567974	225126	Mouslin Wood AW/LWS	2.180	2.167	0.363	0.361
1(C)	567896	224861	Mouslin woood AW/LWS (Canopy)	5.503	5.477	0.749	0.746
2(C)	567959	224958	Mouslin woood AW/LWS (Canopy)	8.858	8.796	1.661	1.649
3(C)	568019	225032	Mouslin woood AW/LWS (Canopy)	5.816	5.777	1.062	1.055
4(C)	567812	224913	Mouslin woood AW/LWS (Canopy)	2.292	2.280	0.332	0.331
5(C)	567896	225038	Mouslin woood AW/LWS (Canopy)	2.879	2.858	0.472	0.469
6(C)	567974	225126	Mouslin woood AW/LWS (Canopy)	2.431	2.415	0.396	0.393
7	567457	225034	AW/LWS	0.432	0.434	0.067	0.068
8	567516	225215	AW/LWS	0.452	0.449	0.072	0.071
9	569167	224148	AW/LWS	0.169	0.168	0.026	0.026
10	568873	223829	AW/LWS	0.163	0.162	0.025	0.025
11	569411	223630	AW/LWS	0.102	0.101	0.016	0.016
12	568461	226580	LWS	0.142	0.141	0.022	0.022
13	569515	226025	LWS	0.159	0.159	0.025	0.025
14	566249	225466	LWS	0.084	0.084	0.013	0.013
15	568211	223421	LWS	0.127	0.127	0.020	0.020
16	575093	228889	Bovingdon Hall Woods SSSI	0.020	0.020	0.003	0.003
17	575895	227749	Bovingdon Hall Woods SSSI	0.020	0.019	0.003	0.003
18	576254	228725	Bovingdon Hall Woods SSSI	0.017	0.017	0.003	0.003
19	562385	233190	West Wood, Little Sampford SSSI	0.010	0.010	0.002	0.002
20	560755	221662	High Wood, Dunmow SSSI	0.015	0.015	0.002	0.002
21	560198	222437	High Wood, Dunmow SSSI	0.016	0.016	0.002	0.002
22	564074	218322	Garnetts Wood / Barnston Lays SSSI	0.014	0.014	0.002	0.002

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 Badcocks Farm 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. Outside of the 5.0 km x 5.0 km domain, a fixed deposition velocity of 0.005 m/s is assumed (with appropriate deposition velocities applied post-modelling at the discrete receptors).

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

The predicted maximum annual mean ground level ammonia concentrations and nitrogen deposition rates at the discrete receptors are shown in Tables 6a (Existing Turkeys) and 6b (Proposed Broiler Chickens).

In the tables, ammonia concentrations or nitrogen deposition rates that are in excess of the Environment Agency's upper threshold (100% of Critical level/Load for non-statutory sites, 50% for a SSSI) are highlighted in red bold text. There are no process contributions in the range between the Environment Agency's upper threshold and lower threshold (100% and 100% of Critical level/Load for non-statutory sites, 20% and 50% for a SSSI). Exceedances of 1% of the relevant Critical Level or Load at any of the statutory wildlife sites are highlighted with bold text.

Contour plots of the predicted ground level maximum annual mean ammonia concentration and maximum annual nitrogen deposition rates are shown in Figures 7a and 7b (Existing Turkeys) and 8a and 8b (Proposed Broiler Chickens).

Table 6a. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates - Existing Turkeys

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual mean ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m^3)	Critical Load (kg/ha)	Process Contribution (µg/m^3)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	567896	224861	Mouslin Wood AW/LWS	0.03	3.0	10.0	3.945	**131.49**	30.73	**307.32**
2	567959	224958	Mouslin Wood AW/LWS	0.03	3.0	10.0	5.994	**199.80**	46.70	**466.98**
3	568019	225032	Mouslin Wood AW/LWS	0.03	3.0	10.0	4.717	**157.25**	36.75	**367.54**
4	567812	224913	Mouslin Wood AW/LWS	0.03	3.0	10.0	1.550	51.65	12.07	**120.72**
5	567896	225038	Mouslin Wood AW/LWS	0.03	3.0	10.0	2.145	71.49	16.71	**167.10**
6	567974	225126	Mouslin Wood AW/LWS	0.03	3.0	10.0	1.687	56.24	13.15	**131.45**
1C	567896	224861	Mouslin Wood AW/LWS (Canopy)	0.03	3.0	10.0	5.289	**176.29**	41.20	-
2C	567959	224958	Mouslin Wood AW/LWS (Canopy)	0.03	3.0	10.0	8.544	**284.81**	66.57	-
3C	568019	225032	Mouslin Wood AW/LWS (Canopy)	0.03	3.0	10.0	5.508	**183.59**	42.91	-
4C	567812	224913	Mouslin Wood AW/LWS (Canopy)	0.03	3.0	10.0	2.096	69.86	16.33	-
5C	567896	225038	Mouslin Wood AW/LWS (Canopy)	0.03	3.0	10.0	2.717	90.56	21.17	-
6C	567974	225126	Mouslin Wood AW/LWS (Canopy)	0.03	3.0	10.0	2.131	71.04	16.60	-
7	567457	225034	AW/LWS	0.03	1.0	10.0	0.346	34.63	2.70	26.98
8	567516	225215	AW/LWS	0.03	1.0	10.0	0.340	34.04	2.65	26.52
9	569167	224148	AW/LWS	0.03	1.0	10.0	0.116	11.56	0.90	9.01
10	568873	223829	AW/LWS	0.03	1.0	10.0	0.105	10.46	0.82	8.15
11	569411	223630	AW/LWS	0.03	1.0	10.0	0.061	6.11	0.48	4.76
12	568461	226580	LWS	0.03	1.0	10.0	0.111	11.13	0.87	8.67
13	569515	226025	LWS	0.03	1.0	10.0	0.126	12.63	0.98	9.84
14	566249	225466	LWS	0.03	1.0	10.0	0.059	5.93	0.46	4.62
15	568211	223421	LWS	0.03	1.0	10.0	0.097	9.71	0.76	7.57
16	575093	228889	Bovingdon Hall Woods SSSI	0.03	1.0	15.0	0.012	**1.20**	0.09	0.62
17	575895	227749	Bovingdon Hall Woods SSSI	0.03	1.0	15.0	0.012	**1.18**	0.09	0.61
18	576254	228725	Bovingdon Hall Woods SSSI	0.03	1.0	15.0	0.010	**1.01**	0.08	0.53
19	562385	233190	West Wood, Little Sampford SSSI	0.03	1.0	15.0	0.004	0.44	0.03	0.23
20	560755	221662	High Wood, Dunmow SSSI	0.03	1.0	15.0	0.006	0.63	0.05	0.33
21	560198	222437	High Wood, Dunmow SSSI	0.03	1.0	15.0	0.006	0.65	0.05	0.34
22	564074	218322	Garnetts Wood / Barnston Lays SSSI	0.03	1.0	15.0	0.008	0.84	0.07	0.44

Table 6b. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates - Proposed Broiler Chickens

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual mean ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m^3)	Critical Load (kg/ha)	Process Contribution (µg/m^3)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	567896	224861	Mouslin Wood AW/LWS	0.03	3.0	10.0	0.556	18.53	4.33	43.30
2	567959	224958	Mouslin Wood AW/LWS	0.03	3.0	10.0	0.795	26.51	6.20	61.97
3	568019	225032	Mouslin Wood AW/LWS	0.03	3.0	10.0	0.873	29.09	6.80	68.00
4	567812	224913	Mouslin Wood AW/LWS	0.03	3.0	10.0	0.233	7.75	1.81	18.12
5	567896	225038	Mouslin Wood AW/LWS	0.03	3.0	10.0	0.362	12.05	2.82	28.18
6	567974	225126	Mouslin Wood AW/LWS	0.03	3.0	10.0	0.283	9.45	2.21	22.08
1C	567896	224861	Mouslin Wood AW/LWS (Canopy)	0.03	3.0	10.0	0.715	23.82	5.57	-
2C	567959	224958	Mouslin Wood AW/LWS (Canopy)	0.03	3.0	10.0	1.572	52.40	12.25	-
3C	568019	225032	Mouslin Wood AW/LWS (Canopy)	0.03	3.0	10.0	0.998	33.27	7.78	-
4C	567812	224913	Mouslin Wood AW/LWS (Canopy)	0.03	3.0	10.0	0.295	9.84	2.30	-
5C	567896	225038	Mouslin Wood AW/LWS (Canopy)	0.03	3.0	10.0	0.444	14.79	3.46	-
6C	567974	225126	Mouslin Wood AW/LWS (Canopy)	0.03	3.0	10.0	0.349	11.62	2.72	-
7	567457	225034	AW/LWS	0.03	1.0	10.0	0.053	5.34	0.42	4.16
8	567516	225215	AW/LWS	0.03	1.0	10.0	0.055	5.45	0.42	4.25
9	569167	224148	AW/LWS	0.03	1.0	10.0	0.018	1.78	0.14	1.39
10	568873	223829	AW/LWS	0.03	1.0	10.0	0.016	1.62	0.13	1.26
11	569411	223630	AW/LWS	0.03	1.0	10.0	0.009	0.95	0.07	0.74
12	568461	226580	LWS	0.03	1.0	10.0	0.018	1.78	0.14	1.39
13	569515	226025	LWS	0.03	1.0	10.0	0.020	2.02	0.16	1.58
14	566249	225466	LWS	0.03	1.0	10.0	0.009	0.93	0.07	0.72
15	568211	223421	LWS	0.03	1.0	10.0	0.015	1.51	0.12	1.18
16	575093	228889	Bovingdon Hall Woods SSSI	0.03	1.0	15.0	0.002	0.20	0.02	0.10
17	575895	227749	Bovingdon Hall Woods SSSI	0.03	1.0	15.0	0.002	0.19	0.01	0.10
18	576254	228725	Bovingdon Hall Woods SSSI	0.03	1.0	15.0	0.002	0.17	0.01	0.09
19	562385	233190	West Wood, Little Sampford SSSI	0.03	1.0	15.0	0.001	0.07	0.01	0.04
20	560755	221662	High Wood, Dunmow SSSI	0.03	1.0	15.0	0.001	0.10	0.01	0.05
21	560198	222437	High Wood, Dunmow SSSI	0.03	1.0	15.0	0.001	0.10	0.01	0.05
22	564074	218322	Garnetts Wood / Barnston Lays SSSI	0.03	1.0	15.0	0.001	0.13	0.01	0.07

Figure 7a. Maximum annual mean ammonia concentration - Existing Turkeys

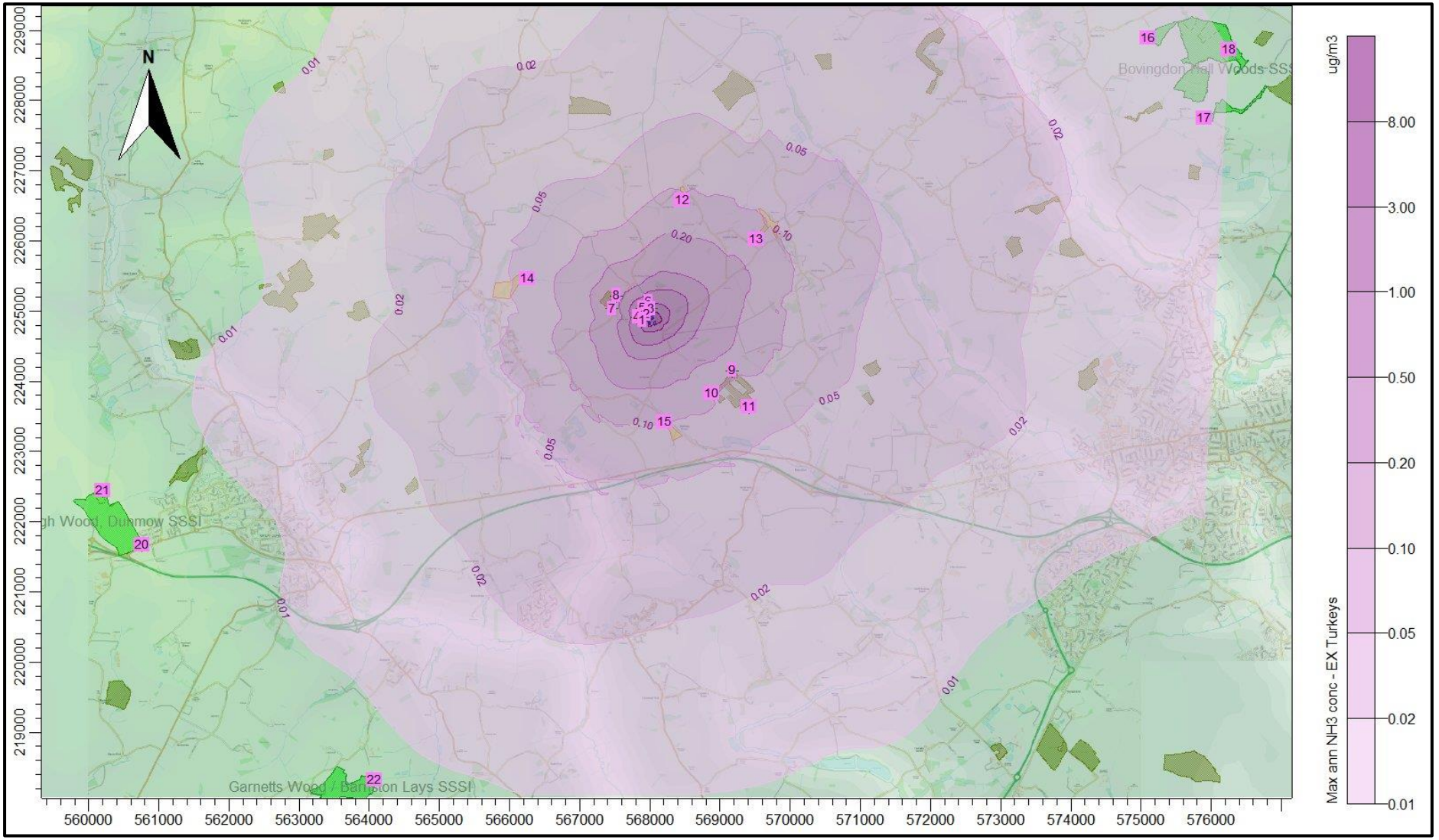


Figure 7b. Maximum annual nitrogen deposition rates - Existing Turkeys

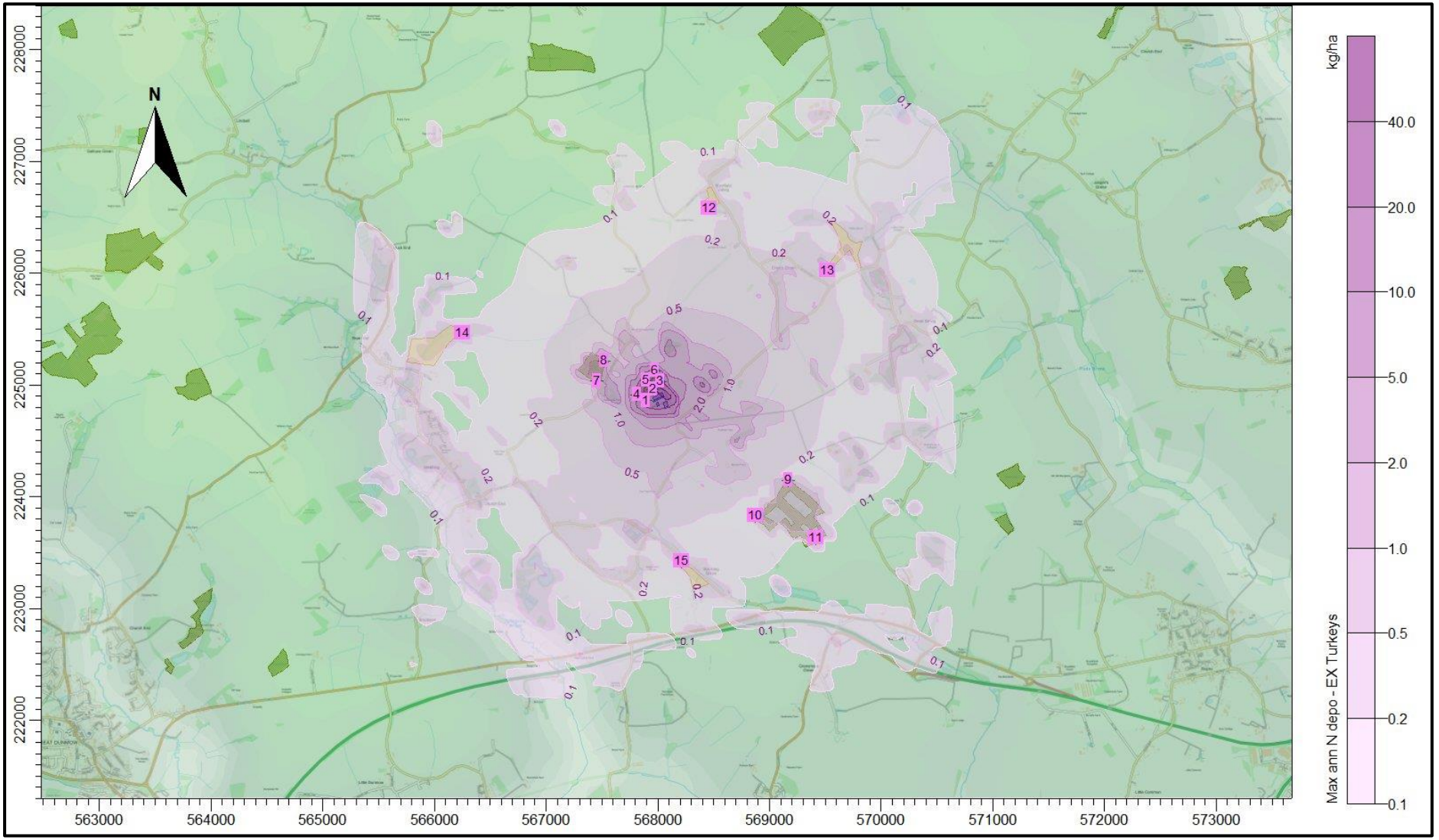


Figure 8a. Maximum annual mean ammonia concentration - Proposed Broiler Chickens

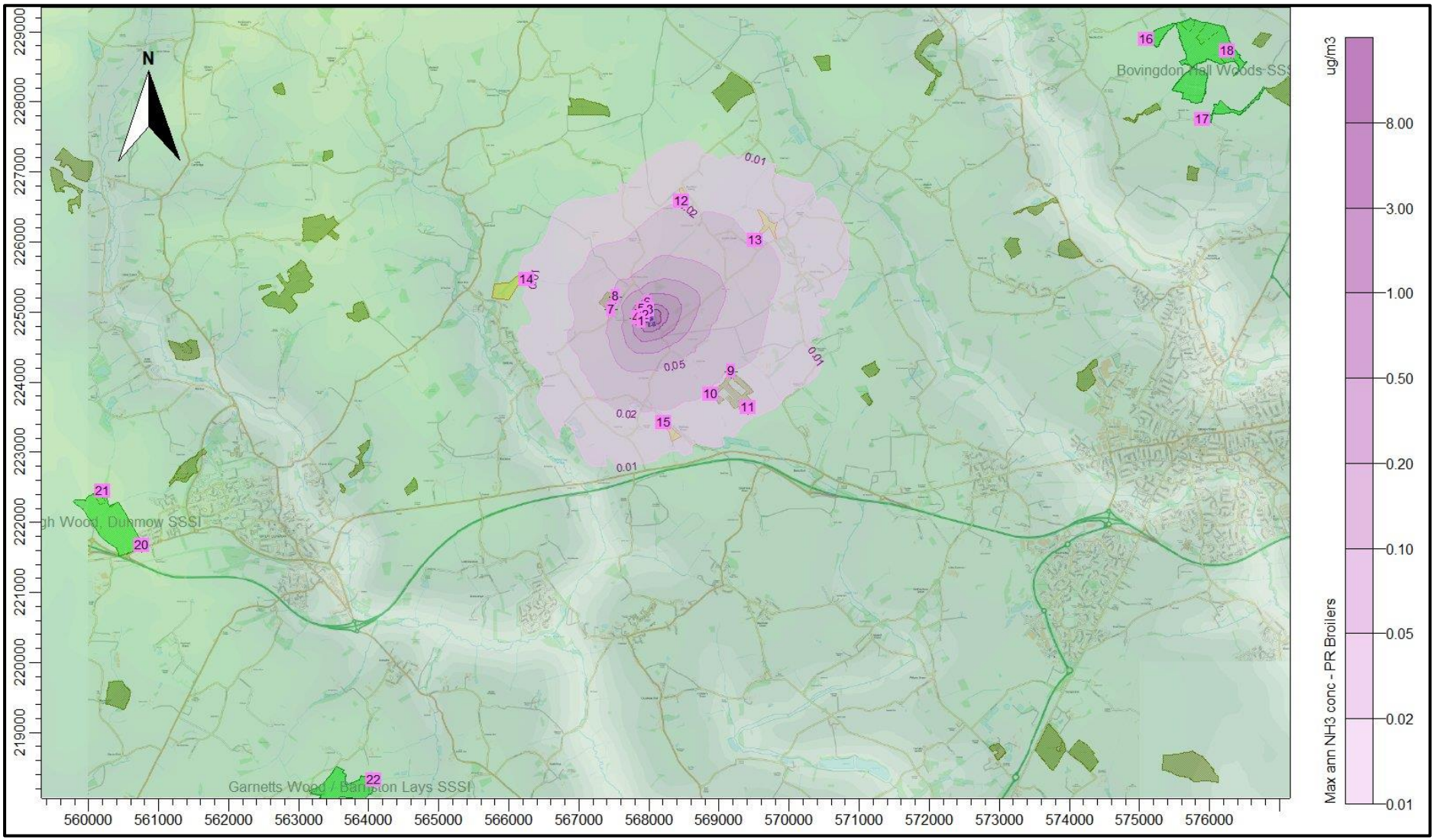
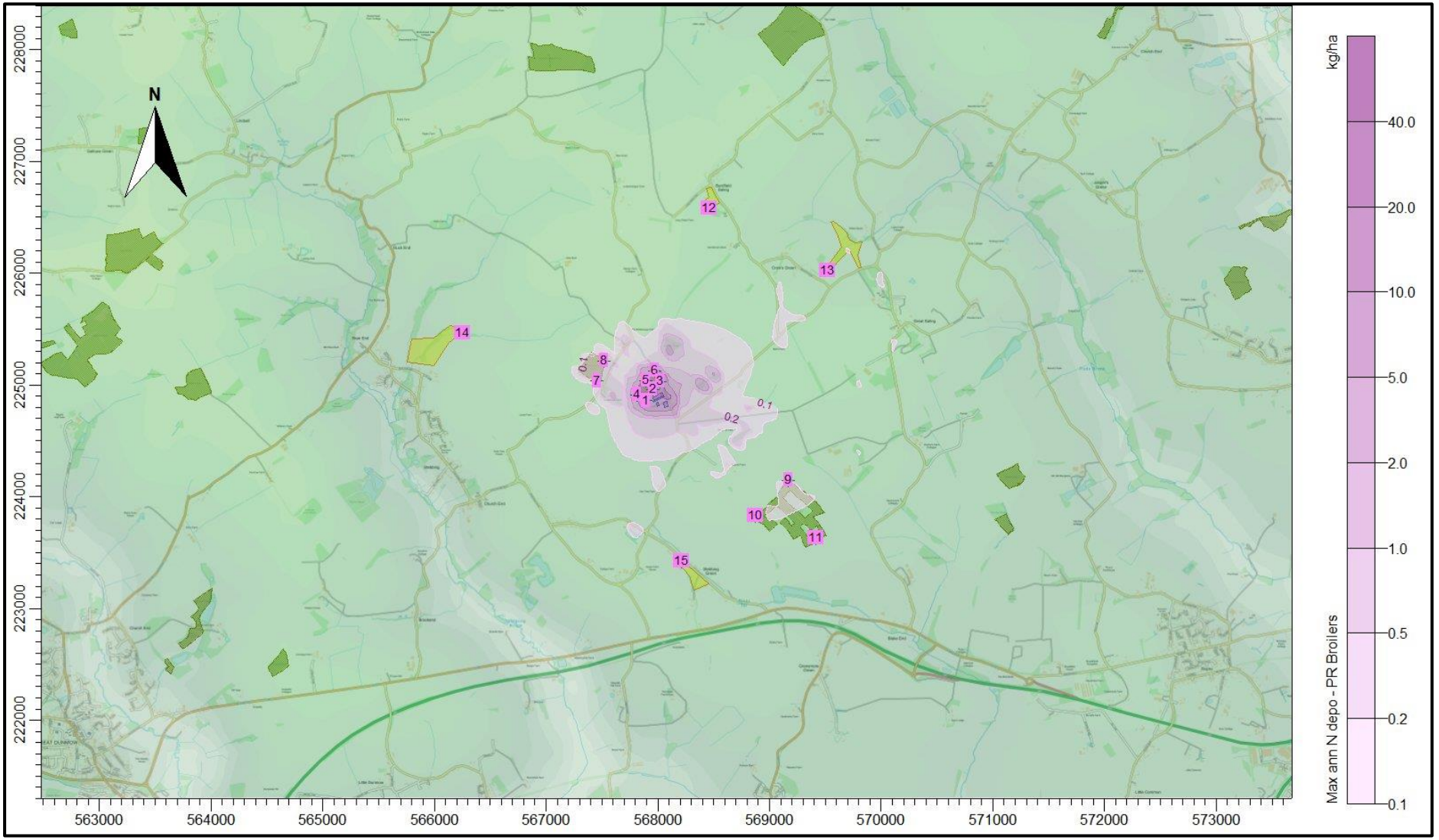


Figure 8b. Maximum annual nitrogen deposition rates - Proposed Broiler Chickens



6. Summary and Conclusions

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

Existing Turkey Rearing

The modelling predicts that:

- At Mouslin Wood AW/LWS, the process contributions to ammonia concentration and nitrogen deposition rate currently exceed the Environment Agency's upper and lower threshold percentage of the relevant Critical Level and/or Critical Load (100%).

- At all other wildlife sites considered, the process contributions to ammonia concentrations and nitrogen deposition rates are below the Environment Agency's lower threshold percentage of the relevant Critical Level and Critical Load (100% for AWs/LWSs and 20% for SSSIs).

- The process contribution to ammonia concentrations exceeds 1% of the relevant Critical Level at Bovingdon Hall Woods SSSI.

Proposed Broiler Chicken Rearing

The modelling predicts that:

- At all the wildlife sites considered, the process contribution to ammonia concentrations and nitrogen deposition rates would be reduced from current levels and would be well below the Environment Agency lower threshold percentages of the relevant Critical Level or Critical Load (100% for AWs/LWSs and 20% for SSSIs).

- The process contribution to ammonia concentrations and nitrogen deposition rates would be reduced significantly and would be well below 1% of the relevant Critical Level/Load at all statutory wildlife sites considered.

7. References

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