A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Proposed Free Range Egg Laying Chicken Houses at Saunders House Farm, Barningham, near to Barnard Castle in County Durham

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Mr. Edward Bennett of AWSM Farming Ltd., on behalf of Saunders House Farm Ltd., to use computer modelling to assess the impact of ammonia emissions from the existing and proposed free range egg laying chicken houses at Saunders House Farm, Barningham, near to Barnard Castle, County Durham. DE11 7EB.

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

This report is arranged in the following manner:

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

2. Background Details

The site of the poultry houses at Saunders House Farm is in a rural area, approximately 1.0 km to the north of the small village of Barningham and approximately 5.5 km to the south-east of the town of Barnard Castle, in County Durham. The land around the farm is used largely for arable cultivation or fodder production, but there are also some wooded areas nearby. The poultry houses are at an elevation of around 185 m and the land rises to the Yorkshire Dales to the south and west. The River Greta, a tributary of the River Tees, flows to the north of the farm.

There are three poultry houses at Saunders House Farm which are used to accommodate up to 39,500 free range egg laying chickens. Two of these poultry houses are ventilated naturally with deep litter and manure collects within these houses prior to being cleared at the end of the production period. The third poultry house is ventilated by ridge mounted fans, each with a short chimney and there is a belt system to allow for the frequent removal of manure from this house, which is taken off site. There are pop holes along the sides of each of the poultry houses which provide access to outdoor ranging areas.

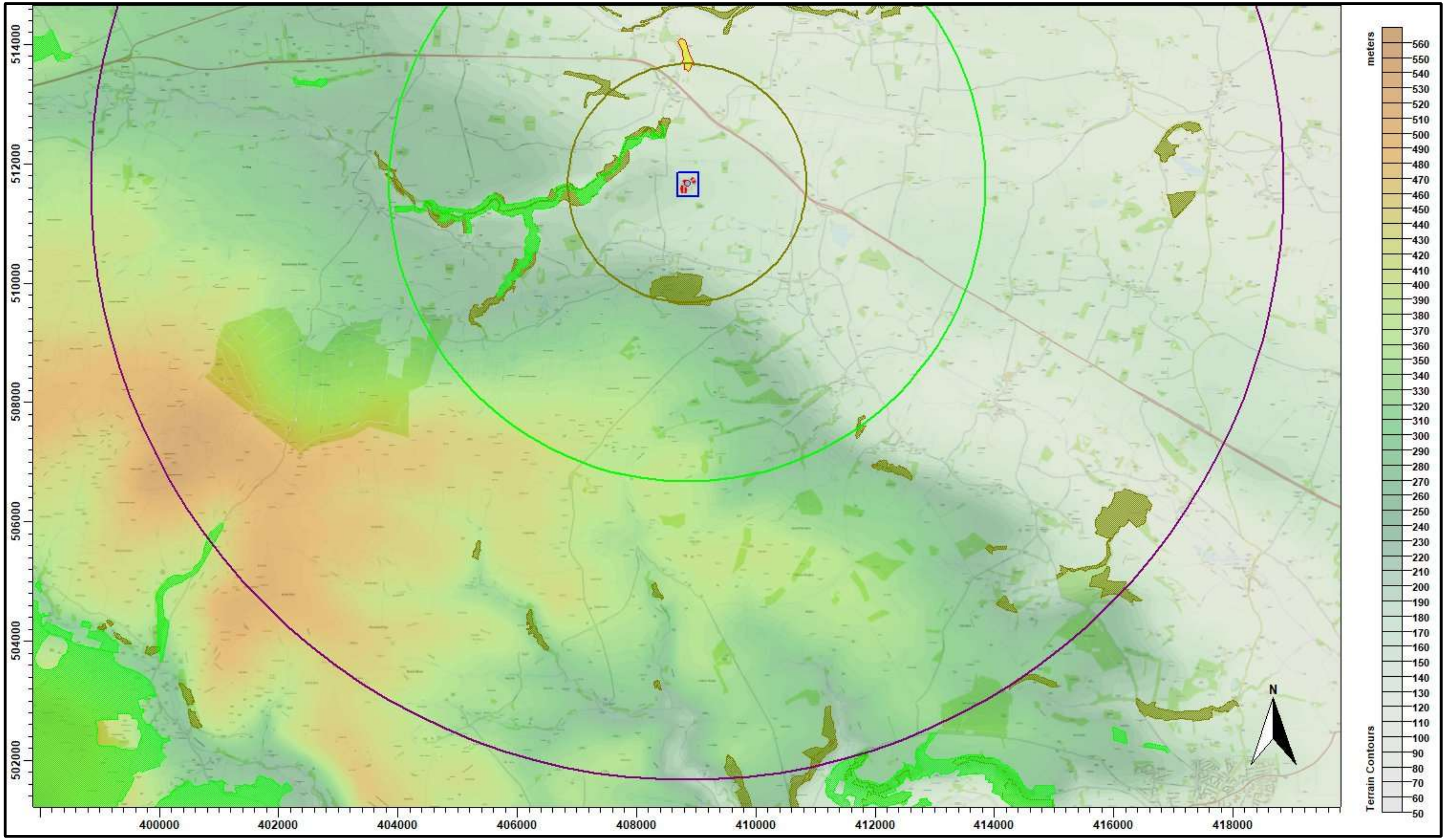
Under the proposals, one of the poultry houses would be extended and the ventilation systems of all three houses would be upgraded with the retro-fitting of high speed ridge fans, each with a short chimney. Manure belt/multi-tier aviary systems would be installed into the two poultry houses that currently have deep litter systems, which would allow the manure to be removed from the houses frequently and taken off site. Pop holes along the sides of each of the poultry houses would provide access to outdoor ranging areas. Should the proposals proceed, the capacity of the poultry unit would increase to a maximum of 77,000 free range egg laying chickens.

There is one area that has been designated as a Local Wildlife Site (LWS) and three areas designated as Ancient Woodlands (AWs) within 2 km (the normal screening distance for non-statutory sites) of the farm. There is one Site of Special Scientific Interest (SSSI) within 5 km (the normal screening distance for SSSIs) of the farm, namely Bignall Banks SSSI. There are a further three SSSIs, but no internationally designated sites, within 10 km (the normal screening distance for international designated sites) of the site. Some details of the SSSIs that are located within the screening distances and are sensitive to ammonia emissions are provided below:

- **Bignall Banks SSSI** - Approximately 0.8 km to the north-north-west of the farm (closest). A large, species rich area of woodland on the steep slopes above the River Greta system. Variation in soil has led to diversity of woodland and where there have been tree felling, immature woodland increases the diversity. The woodlands support varied bryophyte and lichen flora, including several lichens that are sensitive to air pollution and are rare. Noted also for bird communities.
- **Kilmond Scar SSSI** - Approximately 6.2 km to the west-north-west of the farm. A prominent south facing scarp which has been quarried in places but now supports a number of habitats adapted to variations in the soils; scree, rock-ledge, crevice, grassland, scrub and immature woodlands.
- **Lower Swaledale Woods and Grasslands SSSI** - Approximately 9.7 km to the south-south-east of the farm. A complex of woodlands, scrub, grasslands, limestone scar and scree. The SSSI supports the largest area of Ancient Semi-Natural Woodland in the district. Differences in slope, aspect and soil has led to the development of six major types of woodland. Unimproved neutral grassland and limestone grassland, vegetation developed on scars and scrub add to the diversity of the site. There are also breeding and hunting birds and other fauna.

A map of the surrounding area showing the location of the poultry houses at Saunders House Farm and the wildlife sites is provided in Figure 1. In this figure, the LWS is shaded in yellow with a red outline, the AWs are shaded in olive, the SSSIs are shaded in green and the site of the poultry houses at Saunders Farm is outlined in blue.

Figure 1. The area surrounding Saunders House Farm, with concentric circles radii 2.0 km (olive), 5.0 km (green) and 10.0 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 ($\mu g\text{-}NH_3/m^3$) 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, December 2023). 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 Saunders House Farm is 1.55 $\mu g\text{-}NH_3/m^3$. The background nitrogen deposition rate to woodland is 27.85 kg-N/ha/y and to short vegetation is 17.67 kg-N/ha/y. The background acid deposition rate to woodland is 2.03 keq/ha/y and to short vegetation is 1.29 keq/ha/y.

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

3.3 Critical Levels & Critical Loads

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

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

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

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

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

The Critical Levels and Critical Loads at the wildlife sites assumed in this study are provided in Table 1. 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.

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

Site	Critical Level ($\mu g\text{-}NH_3/m^3$)	Critical Load - Nitrogen Deposition (kg-N/ha/y)	Critical Load - Acid Deposition (keq/ha/y)
Unnamed LWS/AWs	1.0 [1]	10.0	-
Bignall Banks SSSI, Kilmond Scar SSSI, Lower Swaledale Woods And Grasslands SSSI	1.0 [1]	10.0 [2 & 3]	-
Shaw Beck Gill SSSI	n/a [4]	n/a [4]	n/a [4]

1. A precautionary figure, used where details of the site are unavailable, or citations/APIS indicate that sensitive lichens and bryophytes may be present.
2. Based upon the citation for the site.
3. The lower bound of the range of Critical Loads.
4. Designated for geomorphological features.

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 criteria

Natural England are a statutory consultee at planning and usually advise that, if predicted process contributions exceed 1% (or lower in some circumstances) 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 are derived from an average for a 5 km by 5 km grid.

3.4.3 Environment Agency and Natural England May 2022 Air Quality Risk Assessment Interim Guidance

Although it seems important to include a reference to this document, it appears to be primarily a discussion document about internal Environment Agency screening models and the SCAIL model and AS Modelling & Data Ltd. have been unable to draw any conclusions from the document as to what thresholds may or may not apply, nor in what circumstances the threshold may or may not apply.

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

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

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

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

3.5 Quantification of ammonia emissions

Ammonia emission rates from poultry houses and ranging areas depend on many factors and are likely to be rather 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 Ammonia emissions from the proposed poultry house

For egg laying chickens, in an aviary system, where manure is removed frequently using a belt system, the Environment Agency standard emission factor is 0.08 kg-NH_3/bird place/y. For free range egg laying chickens, where the birds' droppings collect within the house during the production period, an emission factor of 0.21 kg-NH_3/bird place/y has been assumed.

Previously, it has been customary to reduce housing emissions by a factor based upon the proportion of droppings estimated to occur during ranging. This practice is not followed in this case for two reasons: firstly, ammonia emissions are most probably more dependent on surface area than they are on the absolute amount of excreta and secondly, the emission factors used are probably already at the lower end of the range of likely emission rates from the types of housing under consideration in this case.

3.5.2 Ammonia emissions from ranging areas

As the birds have access to outdoor ranging areas, some of the birds' droppings, which is the source of the ammonia, would be deposited on these ranging areas. The Environment Agency provide an emission factor or 0.225 kg-NH_3/bird place/y (we assume this figure is based upon National Ammonia Emission Inventory figures for total N excreted, proportion of ammoniacal N and proportion of ammoniacal N released as ammonia and is for theoretical birds ranging 100% of the time). The Environment Agency also provide of estimate of 20% of birds ranging and 80% in the housing (we assume that this is an average figure when ranging is available and would note that this figure is at the high end of the range of observed range usage figures). Assuming average daily range availability of 8 hours per day[A] the ammonia emission factor for the ranging is calculated to be 0.015 kg-NH_3/bird place/y.

A. Ranging availability may be longer in the summer and shorter in winter. The unavailability of ranging due to inclement weather or disease control for example is not considered.

A series of other peer reviewed scientific papers have also been considered. The findings from these papers are summarised below. It should be noted that the Aarnink provides direct measurements of ammonia emissions from ranging areas and is in accord with the calculated figure:

1. **Larsen, H., Cronin, G.M., Gebhardt-Henrich, S., Smith, C.L. Hemsworth, P.H. and Rault, J-L. (2017) - Individual ranging behaviour patterns in commercial free-range layers as observed through RFID tracking. Animals, 7 (21).**

   This paper is from Australian studies and given the very different climate regimes in the UK and Australia, there can be no expectation that bird behaviour would be similar. This aside:
   The Simple Summary appears to indicate high range usage (68.6% in Flock A, and 82.2% in Flock B). However, it should be noted that these percentages are the percentages of hens that used the ranging at some point in time, they are not overall range usage figures, which is the number we need to determine.

At page 6 it is stated "Flock A spent a mean of 46 +/- 1.1 h ranging between a total duration of 34 s and 83 h outside over the 13 days, and hens in Flock B spent a mean of 30 +/- 0.7 h ranging between a total duration of 50 min and 57 h outside over the 10 days."

So for Flock A the average range usage is - 68.6% x 46h/(24h x 13d) = **10.1%**.
And for Flock B the average range usage is - 82.2% x 30h/(24h x 10d) = **10.3%**.

It should also be noted that these figures do not account for days where ranging for any reason may not be available (disease control, inclement weather etc.).

2. **Campbell, D.L.M., Hinch, G.N., Dyall, T.R., Warin, L., Little, B.A. and Lee, C (2016) - Outdoor stocking density in free-range laying hens: radio-frequency identification of impacts on range use. Animal: 1 - 10.**

This paper is from New Zealand studies and given the potentially very different climate regimes in the UK and Australia, there can be no expectation that bird behaviour would be similar. This aside:
The abstract states the following "On average, 38% to 48% of hens were seen on the range simultaneously and used all available areas of all ranges". However, these are the figures for when ranging is available.
On page 4, the range availability is given as from 0900 h (pop hole opening) to 1630 h (pop hole closing).

Therefore, range usage is between 38% x 6.5h / 24 h = **10.3 %** and 48% x 6.5h / 24 h = **13.0 %**.

It should also be noted that these figures do not account for days where ranging for any reason may not be available (disease control, inclement weather etc.).

3. **Pettersson, I.C., Freire, R. and Nicol, C.J. (2016) - Factors affecting ranging behaviour in commercial free-range hens. World Poultry Science Journal, 72.**

This is a review of other papers.

It is not stated explicitly whether the figures from all papers are for range usage when ranging is available; however, since it appears to be common practice to express ranging use this way, we have assumed this is the case for all figures reported, except where it is stated otherwise.
It should be noted that the figures with the exception of one (Whay figures) from this report are all from smaller flocks. Figures from small flocks are included, but it should be fully acknowledged that ranging usage in smaller flocks may be higher than for large flocks.
Farmers estimates are excluded and measured figures only are used below:
Range availability is not stated (this may be available in source papers), but assumed to be 8 hours per day, this is likely to be a high figure.

The highest reported ranging usage figure is 57% (count from very small flock), which assuming 8h per day ranging gives an overall figure of **19%**.

The lowest reported ranging usage is 11% (lowest figure from 1000-16000 bird flocks) and the lowest, which assuming 8h per day ranging gives an overall figure of **3.7%**.

The highest lowest reported ranging usage from 1000-16000 bird flocks is >25%, which assuming 8h per day ranging gives an overall figure of **>8.33%**.

It should also be noted that these figures do not account for days where ranging for any reason may not be available (disease control, inclement weather etc.).

4. **L. Hegelund , J.T. Sørensen , J.B. Kjær & I.S. Kristensen b. Use of the range area in organic egg production systems: effect of climatic factors, flock size, age and artificial cover.**

This is a Danish study, but climate and housing/ranging systems are similar to the UK. This is an older study (late 90s) and the flocks were small (513 to 6000 individuals/flock). However, this is still a useful paper.

The paper stated that average range usage was 9% (11% for flocks with artificial cover on ranges).

These figures are range usage when ranging is available. Range availability is not stated, but if it is assumed to be 8 hours per day then the range usage is: 9% x 8h/24h = **3%** and for birds with cover on ranges 11% x 8h/24h = **3.67%**.

5. **Leonard Ikenna Chielo *, Tom Pike and Jonathan Cooper Ranging Behaviour of Commercial Free-Range Laying Hens.**

This is a UK study with large flocks and typical housing/ranging systems, so should carry some weight.
The paper stated that average range usage was 12.5%.

These figures are range usage when ranging is available. Range availability is stated as 7-9h. If it is assumed to be an average 8 hours per day then the range usage is: 12.5 % x 8h/24h = **4.17%**.

It should also be noted that these figures do not account for days where ranging for any reason may not be available (disease control, inclement weather etc.).

6. **Pettersson paper 2. I. C. Pettersson, C. A. Weeks, K. I. Norman, T. G. Knowles & C. J. Nicol. Internal roosting location is associated with differential use of the outdoor range by free-range Laying.**

This is a UK study with typical 16,000 bird flocks and typical housing/ranging systems, so should carry some weight. The paper states that on average, across all flocks and observations 7.34% of the whole flock (both marked and unmarked birds) were seen out on the range at a time.

Range availability is not stated, but if it is assumed to be an average 8 hours per day then the range usage is: 7.34 % x 8h/24h = **2.45%**.

It should also be noted that these figures do not account for days where ranging for any reason may not be available (disease control, inclement weather etc.).

7. **A.J.A. Aarnink*, J.M.G. Hoi and A.G.C. Beurskens. Ammonia emission and nutrient load in outdoor runs of laying hens.**

This paper provides direct measurement of ammonia emissions from ranging areas. The key figure presented is the average ammonia emission rate, this is 2.0 mg-NH_3/hen/h. This equates to an emission factor of **0.017 kg-NH_3/hen/y**.

Details of the poultry numbers and types, emission factors used and calculated ammonia emission rates used in the modelling are provided in Table 2. Note that results obtained using these figures are scaled to actual bird numbers and usage to provide the final results.

Table 2. Details of poultry numbers, manure storage and baseline ammonia emission rates modelled

Source	Number of Birds	Housing Emission Factor (kg-NH_3/bird/y)	Baseline Housing Emission Rate (g-NH_3/s)	Ranging Emission Factor (kg-NH_3/bird/y)	Baseline Ranging Emission Rate (g-NH_3/s)
Existing free range housing	8,265	0.08 (Aviary)	0.020953	0.225 [1]	0.058931 [2]
Existing free range housing	31,235	0.21 (Deep pit)	0.207851	0.225 [1]	0.22697 [2]
Proposed free range housing	77,000	0.08 (Aviary)	0.195199 [3]	0.225 [1]	0.548996 [2 & 3]

1. Assumed to be for 100% ranging.
2. Results obtained using these figures are scaled by a factor of 0.0666 (actual overall range usage) to provide the final results.
3. Modelling performed on the basis of 74,000 egg-laying chickens for the proposed poultry unit. These figures (and the results) have been adjusted by a factor of 1.04 to correct for 77,000 egg-laying chickens, as proposed.

4. The Atmospheric Dispersion Modelling System (ADMS) and Model Parameters

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

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

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

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

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

4.1 Meteorological data

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

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

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

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

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

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

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 2a. Wind speeds and wind directions are modified during the modelling by the treatment of roughness lengths (see Section 4.7) and because terrain data is included in the modelling. The terrain and roughness length modified wind rose for Saunders House Farm, is shown in Figure 2b; although there is little modification in this case, elsewhere in the modelling domain the modified wind roses may differ more markedly, reflecting the local flow in that part of the domain. The resolution of FLOWSTAR is 64 by 64 grid points and the effective resolution of the wind field is approximately 340 m. 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 54.500 N, 1.865 W, 2019-2022

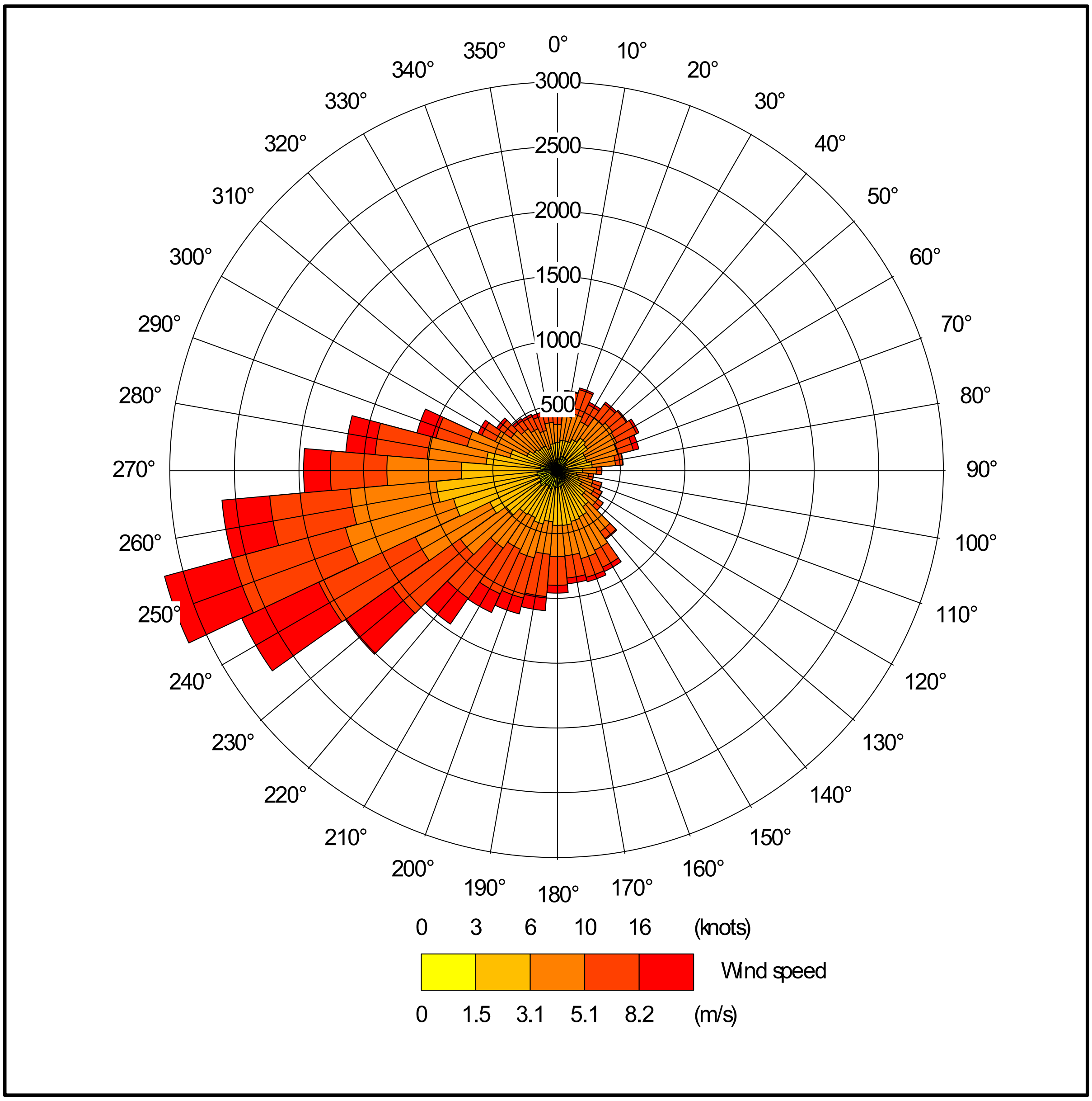
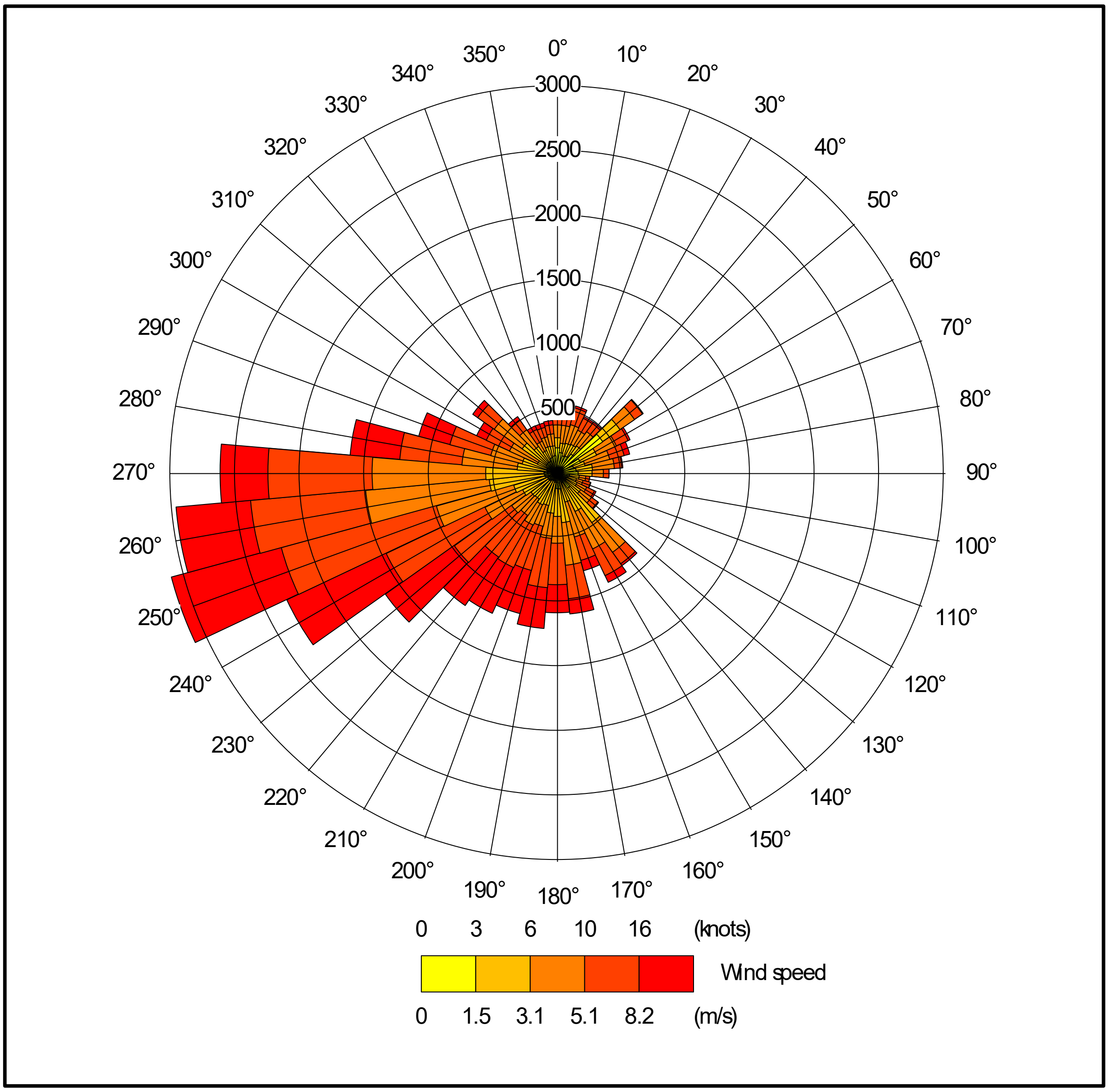


Figure 2b. The wind rose. FLOWSTAR data for NGR 408865, 511680, 2019-2022



4.2 Emission sources

Emissions from the existing naturally ventilated poultry houses have been represented by volume sources within ADMS (EX_SH2v and EX_SH3v). Details of the volume source parameters are shown in Table 3a. The positions of the volume sources used are shown in Figure 3a, for the existing poultry houses (marked by red rectangles).

Table 3a. Volume source parameters

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
EX_SH2v	72.0	30.0	2.0	1.0	Ambient	0.119827
EX_SH3v	85.0	19.0	2.0	1.0	Ambient	0.088024

Emissions from the existing poultry house that is ventilated by ridge fans and from the chimneys of the high speed ridge fans that would be used to ventilate the proposed poultry houses have been represented by point sources within ADMS (EX_SH1, PR_SH1, PR_SH2, PR_SH3_N and PR_SH3_S; 1, 2 and 3). Details of the point source parameters are shown in Table 3b. The positions of the point sources are shown in Figure 3a, for the existing poultry houses and in Figure 3b for the proposed poultry houses (marked by red stars).

Table 3b. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity m/s)	Emission temperature (˚C)	Emission rate per source (g-NH_3/s)
EX_SH1; 1, 2 & 3	5.5	0.7	7.0	21.0	0.006984
PR_SH1; 1, 2 & 3	5.5	0.8	11.0	21.0	0.011830 [1]
PR_SH2; 1, 2 & 3	5.5	0.8	11.0	21.0	0.023660 [1]
PR_SH3_N; 1, 2 & 3	5.5	0.8	11.0	21.0	0.013520 [1]
PR_SH3_S; 1, 2 & 3	5.5	0.8	11.0	21.0	0.013520 [1]

1. Calculated based on 74,000 egg-laying chickens for the proposed poultry unit. Predicted ammonia concentrations and nitrogen deposition rates have been adjusted by a factor of 1.04 to correct for the proposed 77,000 egg-laying chickens.

The existing and proposed poultry houses have, or would have, ranging areas; a further source of ammonia. Emissions from the ranging areas are represented by area sources within ADMS (EX_SH1_RAN, EX_SH2_RAN_N, EX_SH2_RAN_S, EX_SH3_RAN_E, EX_SH3_RAN_W, PR_SH3_EXT_RANE, PR_SH3_EXT_RANW, PR_SH1_RAN, PR_SH2_RAN_N, PR_SH3_RAN_S). Note, the area sources cover the parts of the ranges that are most likely to be used frequently and not the whole of the ranging areas. Details of the area source parameters are shown in Table 3c (scaling factors applied). The positions of the area sources are shown in Figure 3a, for the existing poultry houses and in Figure 3b, for the proposed poultry houses (marked by red polygons).

Table 3c. Area source parameters

Source ID	Area (m²)	Base height (m)	Emission temperature (°C)	Emission rate ($g\text{-}NH_3/s$)
EX_SH1_RAN	1,756	0.0	Ambient	0.003929
EX_SH2_RAN_N	2,269	0.0	Ambient	0.004280
EX_SH2_RAN_S	2,384	0.0	Ambient	0.004280
EX_SH3_RAN_E	1,451	0.0	Ambient	0.003144
EX_SH3_RAN_W	3,025	0.0	Ambient	0.003144
PR_SH3_EXT_RANE	2,888	0.0	Ambient	0.007605 [1]
PR_SH3_EXT_RANW	4,665	0.0	Ambient	0.007605 [1]
PR_SH1_RAN	1,756	0.0	Ambient	0.006655 [1]
PR_SH2_RAN_N	2,269	0.0	Ambient	0. 006655 [1]
PR_SH2_RAN_S	2,384	0.0	Ambient	0. 006655 [1]

1. Calculated based on 74,000 egg-laying chickens for the proposed poultry unit. Predicted ammonia concentrations and nitrogen deposition rates have been adjusted by a factor of 1.04 to correct for the proposed 77,000 egg-laying chickens.

4.3 Modelled buildings

The structure of the existing and proposed poultry houses and other farm buildings may affect the plumes from the point sources. Therefore, these buildings are modelled within ADMS. The positions of the modelled buildings may be seen in Figure 3a, for the existing poultry houses and in Figure 3b, for the proposed poultry houses.

Figure 3a. The positions of modelled sources - existing

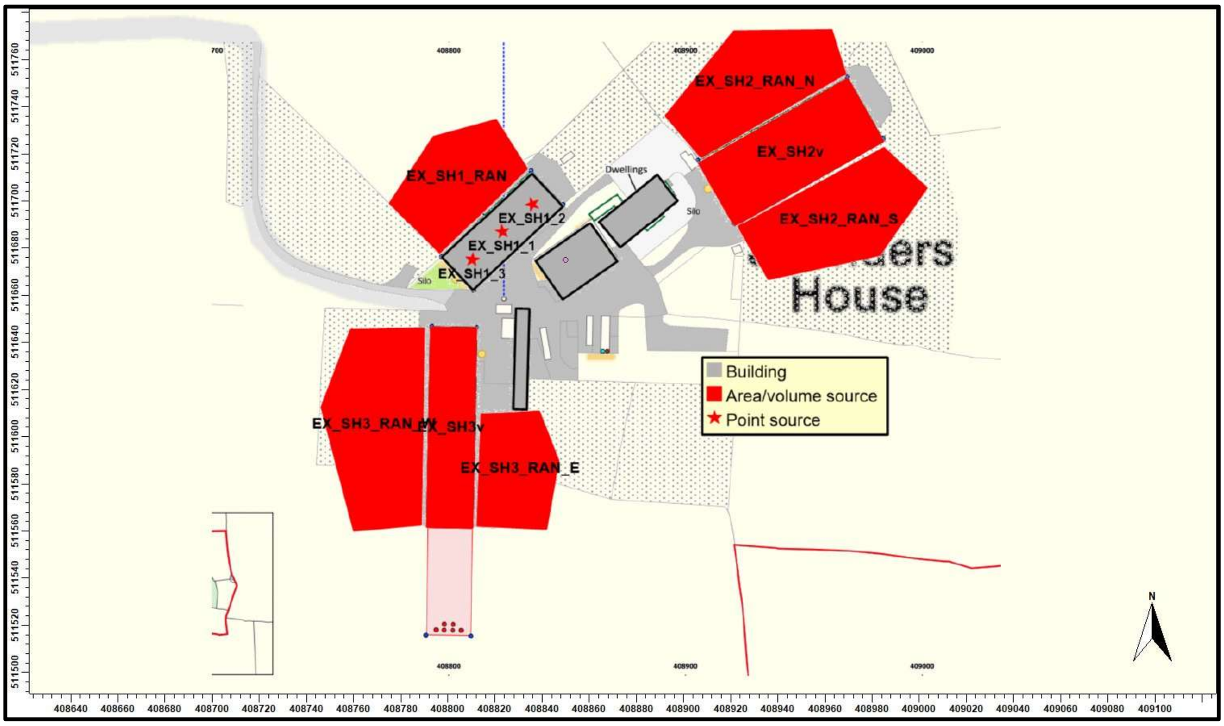
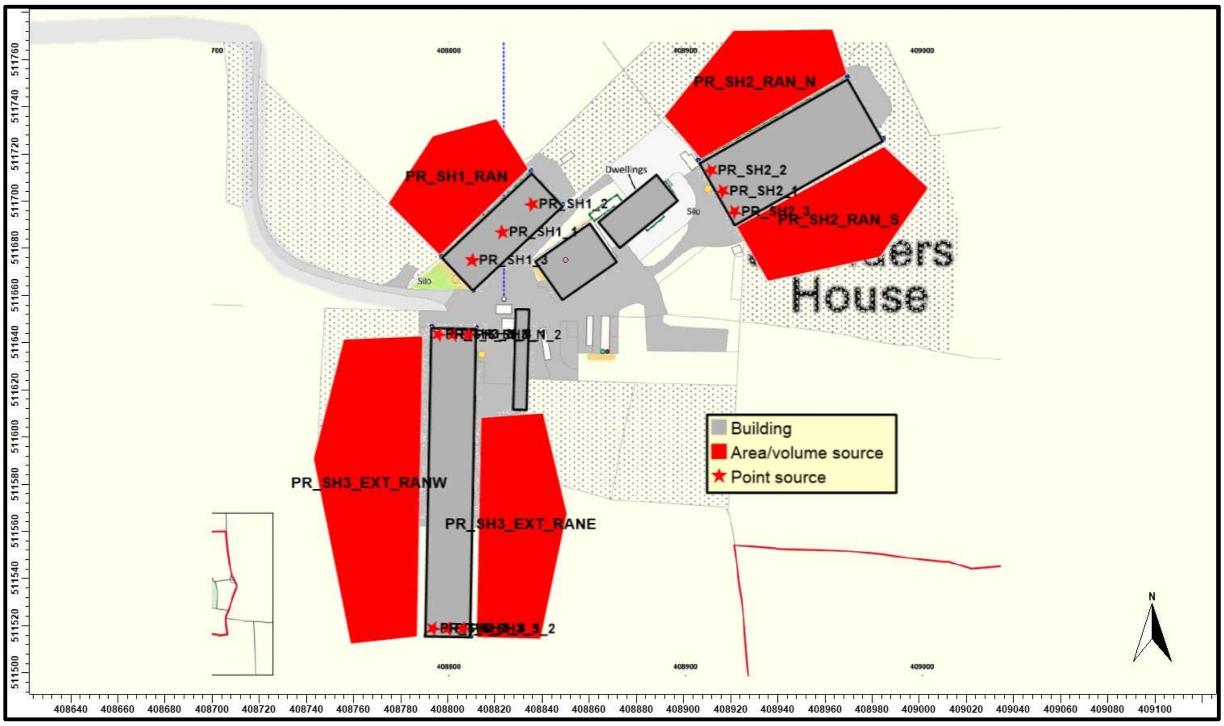


Figure 3b. The positions of modelled sources - proposed



4.4 Discrete receptors

Thirty-six 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 Figure 4a and Figure 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 regular Cartesian grid is shown in Figures 4a and Figure 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 22.0 km by 22.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS; therefore, the effective resolution of the wind field is approximately 340 m.

4.7 Surface Roughness Length

In this case, a spatially varying roughness length file has been defined, this is based upon the Defra Living Landscapes land use database. The GFS meteorological data is assumed to have a roughness length of 0.180 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 (central area of the modelling domain).

Figure 4a. The discrete receptors and regular Cartesian grid

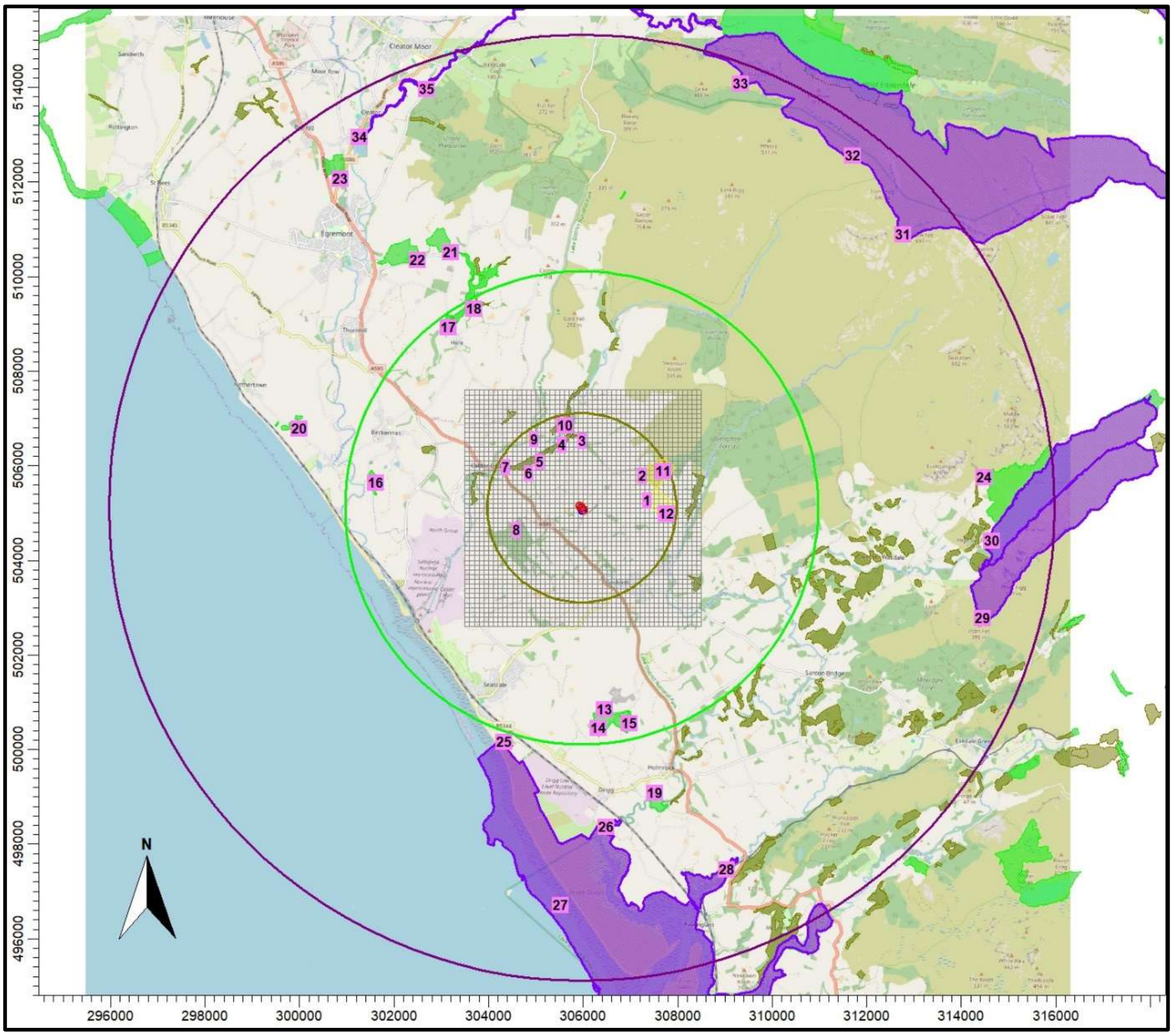


Figure 4b. The discrete receptors and regular Cartesian grid

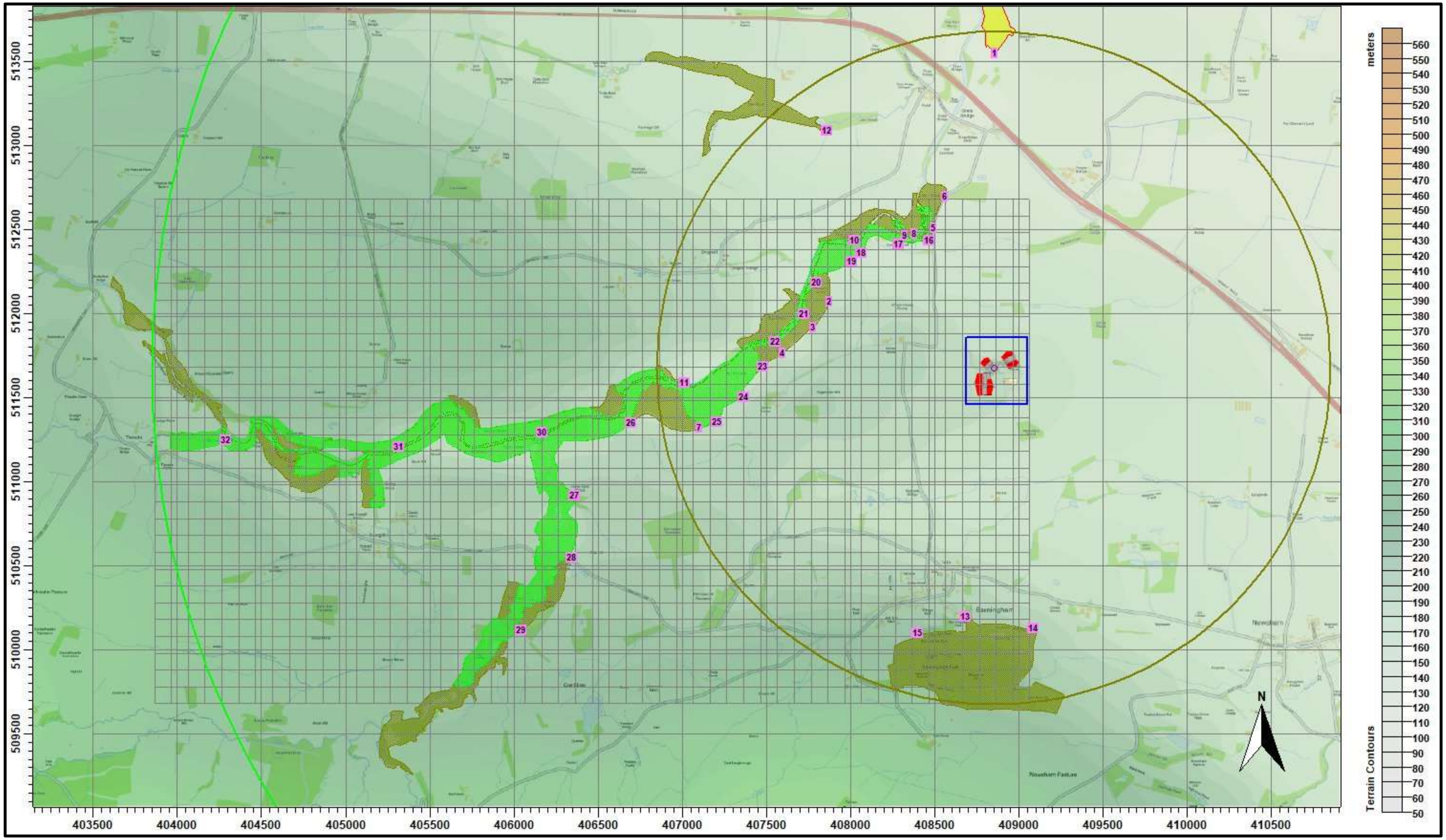
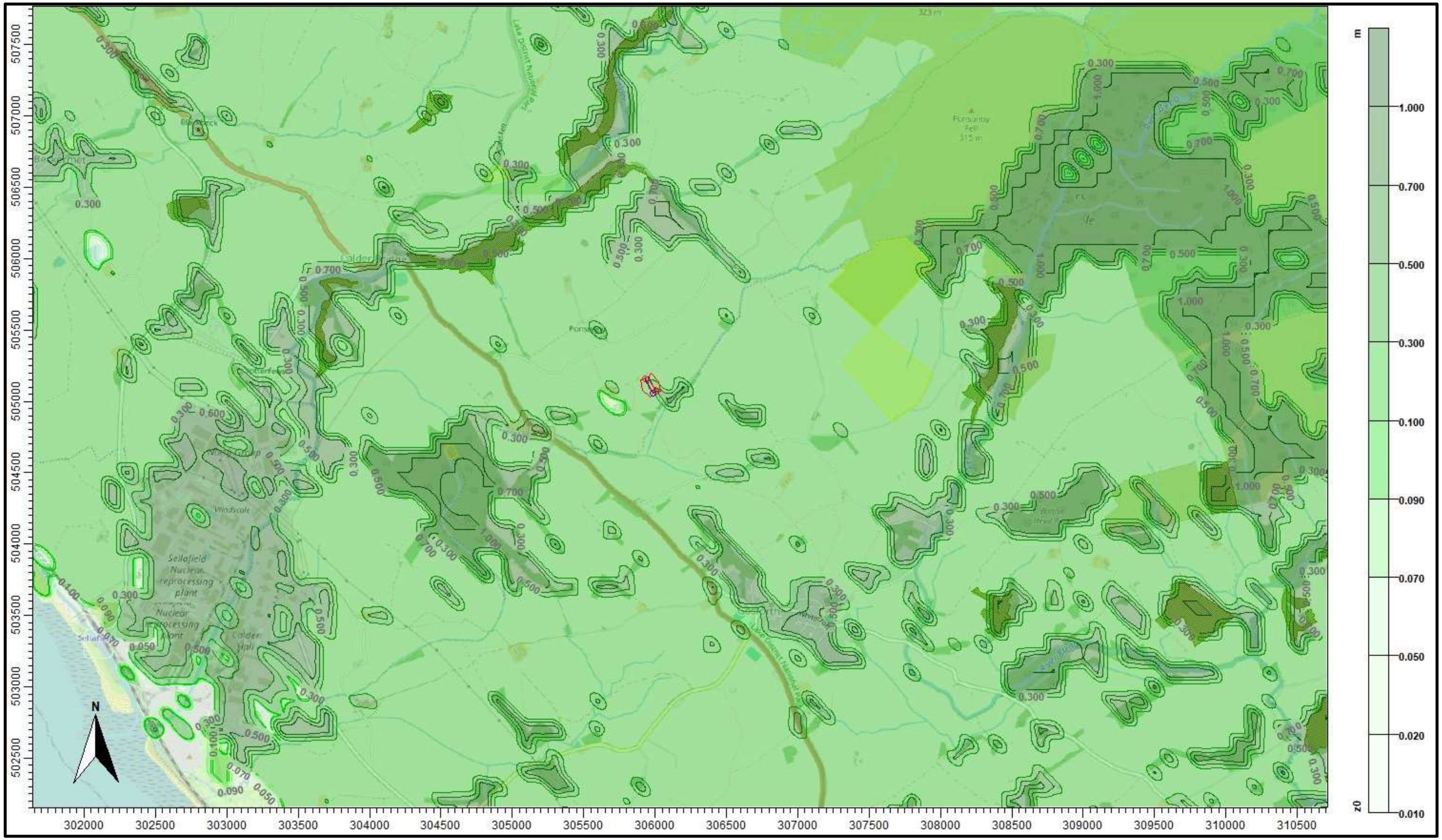


Figure 5. The spatially varying surface roughness field - central area



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 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. Land use data used to derive deposition velocity is based upon the Defra Living Landscapes land use database.

In summary, the method is as follows:

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

Table 4. Deposition velocities

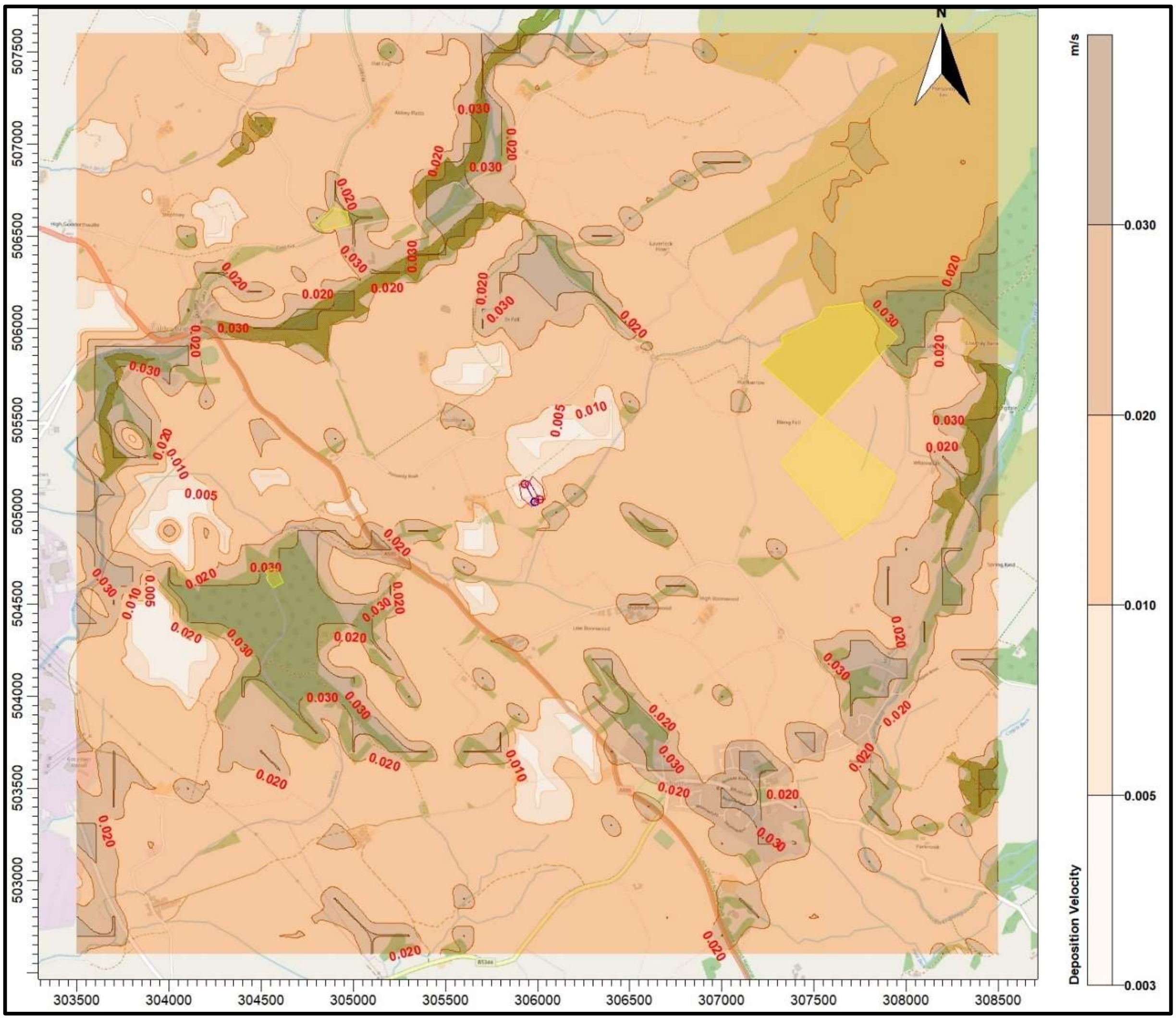
NH_3 concentration (PC + background) (µg/m^3)	< 10	10 - 20	20 - 30	30 - 80	> 80
Deposition velocity - woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity - short vegetation (m/s)	0.02 (0.010 0.015 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity - arable farmland/rye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

Please note that, in this case, as part of the preliminary modelling, the model has also been run with a fixed deposition at 0.003 m/s and similarly to not modelling deposition at all, the predicted ammonia concentrations (and nitrogen and acid deposition rates) are always higher than if deposition were modelled explicitly as Environment Agency guidance, particularly where there is some distance between the source and a receptor.

Figure 6. The spatially varying deposition field



5. Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

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

- In basic mode without calms, or terrain - GFS data.
- With calms and without terrain - GFS data.
- Without calms and with terrain - GFS data.
- Without calms with terrain and fixed deposition at 0.003 m/s - GFS data.

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. In the Table, predicted ammonia concentrations (or concentrations equivalent to deposition rates) that are in excess of the Environment Agency's upper percentage threshold of the relevant Critical Level or Critical Load (50% for a SSSI or 100% for a non-statutory site) are coloured red. Predicted ammonia concentrations (or concentrations equivalent to deposition rates) that are in the range between the Environment Agency's upper threshold and lower percentage threshold of the relevant Critical Level or Critical Load (50% and 20% for a SSSI or 100% and 100% for a non-statutory site) are coloured blue. Additionally, process contributions that exceed 1% of the Critical Level or Critical Load at a statutory site are highlighted with bold text.

Note, the modelling of the proposed poultry houses has been undertaken on the basis they would be accommodated by 74,000 egg-laying chickens. Predicted process contributions from the proposed poultry houses to ammonia concentrations and nitrogen deposition rates have been adjusted by a factor of 1.04 to correct for the proposed stocking of 77,000 egg-laying chickens. For convenience, cells referring to the LWS are shaded in yellow, cells referring to the AWs are shaded in olive and cells referring to the SSSIs are shaded green.

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

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 Terrain	GFS Calms correction Terrain Fixed depo 0.003 m/s	GFS No calms No terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No calms Terrain Fixed depo 0.003 m/s
1	408855	513545	Unnamed LWS	0.276	0.353	0.178	0.128	0.096	0.095	0.068	0.042
2	407873	512067	Unnamed AW	0.375	0.571	0.255	0.176	0.109	0.108	0.087	0.053
3	407775	511914	Unnamed AW	0.344	0.525	0.282	0.176	0.099	0.098	0.092	0.050
4	407596	511765	Unnamed AW	0.289	0.434	0.248	0.149	0.082	0.081	0.086	0.044
5	408489	512505	Unnamed AW	0.717	0.915	0.418	0.391	0.229	0.225	0.190	0.143
6	408561	512696	Unnamed AW	0.603	0.777	0.323	0.305	0.194	0.192	0.157	0.119
7	407103	511321	Unnamed AW	0.163	0.247	0.142	0.089	0.050	0.049	0.061	0.034
8	408381	512472	Unnamed AW	0.642	0.812	0.375	0.349	0.207	0.204	0.173	0.130
9	408321	512460	Unnamed AW	0.585	0.751	0.350	0.320	0.190	0.188	0.162	0.121
10	408023	512436	Unnamed AW	0.343	0.518	0.199	0.176	0.106	0.106	0.106	0.077
11	407011	511586	Unnamed AW	0.155	0.234	0.154	0.084	0.047	0.046	0.054	0.026
12	407858	513088	Unnamed AW	0.217	0.274	0.115	0.103	0.077	0.077	0.066	0.049
13	408683	510194	Unnamed AW	0.297	0.411	0.444	0.232	0.086	0.084	0.131	0.049
14	409083	510129	Unnamed AW	0.228	0.337	0.318	0.171	0.071	0.070	0.078	0.031
15	408400	510102	Unnamed AW	0.278	0.373	0.412	0.204	0.081	0.079	0.166	0.064
16	408468	512435	Bignall Banks SSSI	**0.769**	**0.974**	**0.475**	**0.436**	**0.244**	**0.241**	**0.207**	**0.154**
17	408284	512412	Bignall Banks SSSI	**0.561**	**0.749**	**0.353**	**0.315**	**0.183**	**0.181**	**0.163**	**0.120**
18	408063	512357	Bignall Banks SSSI	**0.389**	**0.588**	**0.230**	**0.197**	**0.117**	**0.117**	**0.114**	**0.084**
19	408004	512306	Bignall Banks SSSI	**0.381**	**0.576**	**0.214**	**0.176**	**0.111**	**0.111**	**0.100**	**0.072**
20	407799	512182	Bignall Banks SSSI	**0.321**	**0.488**	**0.168**	**0.133**	**0.093**	**0.093**	**0.066**	**0.046**
21	407721	511994	Bignall Banks SSSI	**0.308**	**0.472**	**0.217**	**0.142**	**0.090**	**0.090**	**0.075**	**0.045**
22	407554	511830	Bignall Banks SSSI	**0.268**	**0.404**	**0.219**	**0.132**	**0.077**	**0.076**	**0.077**	**0.040**
23	407476	511684	Bignall Banks SSSI	**0.253**	**0.379**	**0.223**	**0.131**	**0.073**	**0.071**	**0.078**	**0.039**

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 Terrain	GFS Calms correction Terrain Fixed depo 0.003 m/s	GFS No calms No terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No calms Terrain Fixed depo 0.003 m/s
24	407362	511505	Bignall Banks SSSI	**0.218**	**0.330**	**0.195**	**0.117**	**0.063**	**0.062**	**0.073**	**0.037**
25	407208	511355	Bignall Banks SSSI	**0.182**	**0.275**	**0.154**	**0.098**	**0.054**	**0.053**	**0.065**	**0.036**
26	406694	511349	Bignall Banks SSSI	**0.116**	**0.176**	**0.124**	**0.046**	**0.036**	**0.036**	**0.051**	**0.025**
27	406362	510917	Bignall Banks SSSI	**0.091**	**0.136**	**0.096**	**0.038**	**0.031**	**0.031**	**0.054**	**0.027**
28	406343	510547	Bignall Banks SSSI	**0.090**	**0.131**	**0.083**	**0.035**	**0.034**	**0.034**	**0.056**	**0.028**
29	406039	510115	Bignall Banks SSSI	**0.072**	**0.103**	**0.061**	**0.024**	**0.030**	**0.030**	**0.046**	**0.021**
30	406167	511292	Bignall Banks SSSI	**0.081**	**0.123**	**0.103**	**0.034**	**0.027**	**0.026**	**0.048**	**0.021**
31	405313	511207	Bignall Banks SSSI	**0.052**	**0.078**	**0.074**	**0.022**	**0.018**	**0.018**	**0.042**	**0.017**
32	404288	511249	Bignall Banks SSSI	**0.035**	**0.052**	**0.051**	**0.014**	**0.013**	**0.013**	**0.033**	**0.013**
33	402819	513334	Kilmond Scar SSSI	**0.020**	**0.031**	**0.022**	0.005	0.009	0.009	**0.013**	0.004
34	401093	505981	Shaw Bank Gill SSSI	0.013	0.018	0.006	0.002	0.008	0.008	0.004	0.001
35	411836	502202	Lower Swaledale Woods And Grassland SSSI	0.010	**0.015**	0.005	0.002	0.006	0.006	0.003	0.001
36	412935	502474	Lower Swaledale Woods And Grassland SSSI	0.009	**0.015**	0.005	0.001	0.006	0.006	0.002	0.001

5.2 Detailed deposition modelling

In this case, detailed modelling has been carried out over a high resolution (100 m) domain that extends 5.2 km by 3.0 km around the site, focussing on Bignall Banks SSSI, where the results of the preliminary modelling show the potential for the exceedance of the Environment Agency's lower threshold percentage of the strict Critical Level of 1.0 µg/m³ or the Critical Load of 10.0 kg/ha, or 1% of the Critical Level/Load 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 this 5.2 km by 3.0 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 predicted maximum annual mean ground level ammonia concentrations and nitrogen deposition rates at the discrete receptors are shown in Table 6a, for the existing poultry houses and in Table 6b, for the proposed poultry houses. In these Tables, process contributions which are in excess of the Environment Agency's upper threshold percentage of the relevant Critical Level or Critical Load (50% for a SSSI or 100% for a non-statutory site) are coloured red. Process contributions which are in the range between the Environment Agency's lower and upper thresholds of the relevant Critical Level or Critical Load (20% and 50% for a SSSI or 100% and 100% for a non-statutory site) are coloured blue. In addition, process contributions which exceed 1% of the relevant Critical Level or Critical Load at a statutory site are highlighted with bold text.

Note, the modelling of the proposed poultry houses has been undertaken on the basis they would be accommodated by 74,000 egg-laying chickens. Predicted process contributions from the proposed poultry houses to ammonia concentrations and nitrogen deposition rates have been adjusted by a factor of 1.04 to correct for the proposed stocking of 77,000 egg-laying chickens. For convenience, cells referring to the LWS are shaded in yellow, cells referring to the AWs are shaded in olive and cells referring to the SSSIs are shaded green.

Contour plots of the predicted maximum annual mean ammonia concentration and the maximum annual nitrogen deposition rate are shown in Figures 7a and 7b, for the existing poultry houses and in Figures 8a and 8b, for the proposed poultry houses.

Table 6a. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors – existing 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	408855	513545	Unnamed LWS	0.03	1.0	10.0	0.092	9.2	0.71	7.1
2	407873	512067	Unnamed AW	0.03	1.0	10.0	0.117	11.7	0.91	9.1
3	407775	511914	Unnamed AW	0.03	1.0	10.0	0.113	11.3	0.88	8.8
4	407596	511765	Unnamed AW	0.03	1.0	10.0	0.091	9.1	0.71	7.1
5	408489	512505	Unnamed AW	0.03	1.0	10.0	0.289	28.9	2.25	22.5
6	408561	512696	Unnamed AW	0.03	1.0	10.0	0.217	21.7	1.69	16.9
7	407103	511321	Unnamed AW	0.03	1.0	10.0	0.055	5.5	0.43	4.3
8	408381	512472	Unnamed AW	0.03	1.0	10.0	0.252	25.2	1.96	19.6
9	408321	512460	Unnamed AW	0.03	1.0	10.0	0.226	22.6	1.76	17.6
10	408023	512436	Unnamed AW	0.03	1.0	10.0	0.115	11.5	0.89	8.9
11	407011	511586	Unnamed AW	0.03	1.0	10.0	0.043	4.3	0.33	3.3
12	407858	513088	Unnamed AW	0.03	1.0	10.0	0.079	7.9	0.61	6.1
13	408683	510194	Unnamed AW	0.03	1.0	10.0	0.120	12.0	0.93	9.3
14	409083	510129	Unnamed AW	0.03	1.0	10.0	0.086	8.6	0.67	6.7
15	408400	510102	Unnamed AW	0.03	1.0	10.0	0.097	9.7	0.75	7.5
16	408468	512435	Bignall Banks SSSI	0.03	1.0	10.0	0.328	**32.8**	2.56	**25.6**
17	408284	512412	Bignall Banks SSSI	0.03	1.0	10.0	0.223	**22.3**	1.74	**17.4**
18	408063	512357	Bignall Banks SSSI	0.03	1.0	10.0	0.133	**13.3**	1.04	**10.4**
19	408004	512306	Bignall Banks SSSI	0.03	1.0	10.0	0.120	**12.0**	0.93	**9.3**
20	407799	512182	Bignall Banks SSSI	0.03	1.0	10.0	0.089	**8.9**	0.69	**6.9**
21	407721	511994	Bignall Banks SSSI	0.03	1.0	10.0	0.094	**9.4**	0.73	**7.3**
22	407554	511830	Bignall Banks SSSI	0.03	1.0	10.0	0.081	**8.1**	0.63	**6.3**
23	407476	511684	Bignall Banks SSSI	0.03	1.0	10.0	0.077	**7.7**	0.60	**6.0**
24	407362	511505	Bignall Banks SSSI	0.03	1.0	10.0	0.071	**7.1**	0.55	**5.5**
25	407208	511355	Bignall Banks SSSI	0.03	1.0	10.0	0.061	**6.1**	0.47	**4.7**
26	406694	511349	Bignall Banks SSSI	0.03	1.0	10.0	0.024	**2.4**	0.19	**1.9**
27	406362	510917	Bignall Banks SSSI	0.03	1.0	10.0	0.021	**2.1**	0.16	**1.6**

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
28	406343	510547	Bignall Banks SSSI	0.03	1.0	10.0	0.020	**2.0**	0.16	**1.6**
29	406039	510115	Bignall Banks SSSI	0.03	1.0	10.0	0.013	**1.3**	0.11	**1.1**
30	406167	511292	Bignall Banks SSSI	0.03	1.0	10.0	0.016	**1.6**	0.12	**1.2**
31	405313	511207	Bignall Banks SSSI	0.03	1.0	10.0	0.009	0.9	0.07	0.7
32	404288	511249	Bignall Banks SSSI	0.03	1.0	10.0	0.005	0.5	0.04	0.4
33	402819	513334	Kilmond Scar SSSI	0.03	1.0	10.0	0.003	0.3	0.020	0.2
34	401093	505981	Shaw Bank Gill SSSI	-	-	-	0.001	-	-	-
35	411836	502202	Lower Swaledale Woods And Grassland SSSI	0.03	1.0	10.0	0.001	0.1	0.008	0.1
36	412935	502474	Lower Swaledale Woods And Grassland SSSI	0.03	1.0	10.0	0.001	0.1	0.008	0.1

Table 6b. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors – 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	408855	513545	Unnamed LWS	0.03	1.0	10.0	0.036	3.6	0.28	2.8
2	407873	512067	Unnamed AW	0.03	1.0	10.0	0.041	4.1	0.32	3.2
3	407775	511914	Unnamed AW	0.03	1.0	10.0	0.040	4.0	0.31	3.1
4	407596	511765	Unnamed AW	0.03	1.0	10.0	0.033	3.3	0.26	2.6
5	408489	512505	Unnamed AW	0.03	1.0	10.0	0.113	11.3	0.88	8.8
6	408561	512696	Unnamed AW	0.03	1.0	10.0	0.092	9.2	0.72	7.2
7	407103	511321	Unnamed AW	0.03	1.0	10.0	0.027	2.7	0.21	2.1
8	408381	512472	Unnamed AW	0.03	1.0	10.0	0.100	10.0	0.78	7.8
9	408321	512460	Unnamed AW	0.03	1.0	10.0	0.093	9.3	0.72	7.2
10	408023	512436	Unnamed AW	0.03	1.0	10.0	0.058	5.8	0.45	4.5

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
11	407011	511586	Unnamed AW	0.03	1.0	10.0	0.019	1.9	0.15	1.5
12	407858	513088	Unnamed AW	0.03	1.0	10.0	0.043	4.3	0.33	3.3
13	408683	510194	Unnamed AW	0.03	1.0	10.0	0.037	3.7	0.28	2.8
14	409083	510129	Unnamed AW	0.03	1.0	10.0	0.022	2.2	0.17	1.7
15	408400	510102	Unnamed AW	0.03	1.0	10.0	0.047	4.7	0.37	3.7
16	408468	512435	Bignall Banks SSSI	0.03	1.0	10.0	0.123	**12.3**	0.96	**9.6**
17	408284	512412	Bignall Banks SSSI	0.03	1.0	10.0	0.100	**10.0**	0.78	**7.8**
18	408063	512357	Bignall Banks SSSI	0.03	1.0	10.0	0.063	**6.3**	0.49	**4.9**
19	408004	512306	Bignall Banks SSSI	0.03	1.0	10.0	0.057	**5.7**	0.44	**4.4**
20	407799	512182	Bignall Banks SSSI	0.03	1.0	10.0	0.035	**3.5**	0.27	**2.7**
21	407721	511994	Bignall Banks SSSI	0.03	1.0	10.0	0.034	**3.4**	0.27	**2.7**
22	407554	511830	Bignall Banks SSSI	0.03	1.0	10.0	0.030	**3.0**	0.24	**2.4**
23	407476	511684	Bignall Banks SSSI	0.03	1.0	10.0	0.029	**2.9**	0.23	**2.3**
24	407362	511505	Bignall Banks SSSI	0.03	1.0	10.0	0.029	**2.9**	0.23	**2.3**
25	407208	511355	Bignall Banks SSSI	0.03	1.0	10.0	0.028	**2.8**	0.22	**2.2**
26	406694	511349	Bignall Banks SSSI	0.03	1.0	10.0	0.018	**1.8**	0.14	**1.4**
27	406362	510917	Bignall Banks SSSI	0.03	1.0	10.0	0.020	**2.0**	0.16	**1.6**
28	406343	510547	Bignall Banks SSSI	0.03	1.0	10.0	0.020	**2.0**	0.16	**1.6**
29	406039	510115	Bignall Banks SSSI	0.03	1.0	10.0	0.015	**1.5**	0.12	**1.2**
30	406167	511292	Bignall Banks SSSI	0.03	1.0	10.0	0.015	**1.5**	0.12	**1.2**
31	405313	511207	Bignall Banks SSSI	0.03	1.0	10.0	0.012	**1.2**	0.10	1.0
32	404288	511249	Bignall Banks SSSI	0.03	1.0	10.0	0.008	0.8	0.06	0.6
33	402819	513334	Kilmond Scar SSSI	0.03	1.0	10.0	0.003	0.3	0.024	0.2
34	401093	505981	Shaw Bank Gill SSSI	-	-	-	0.001	-	-	-
35	411836	502202	Lower Swaledale Woods And Grassland SSSI	0.03	1.0	10.0	0.001	0.1	0.008	0.1
36	412935	502474	Lower Swaledale Woods And Grassland SSSI	0.03	1.0	10.0	0.001	0.1	0.007	0.1

Figure 7a. Maximum annual ammonia concentration – existing poultry houses

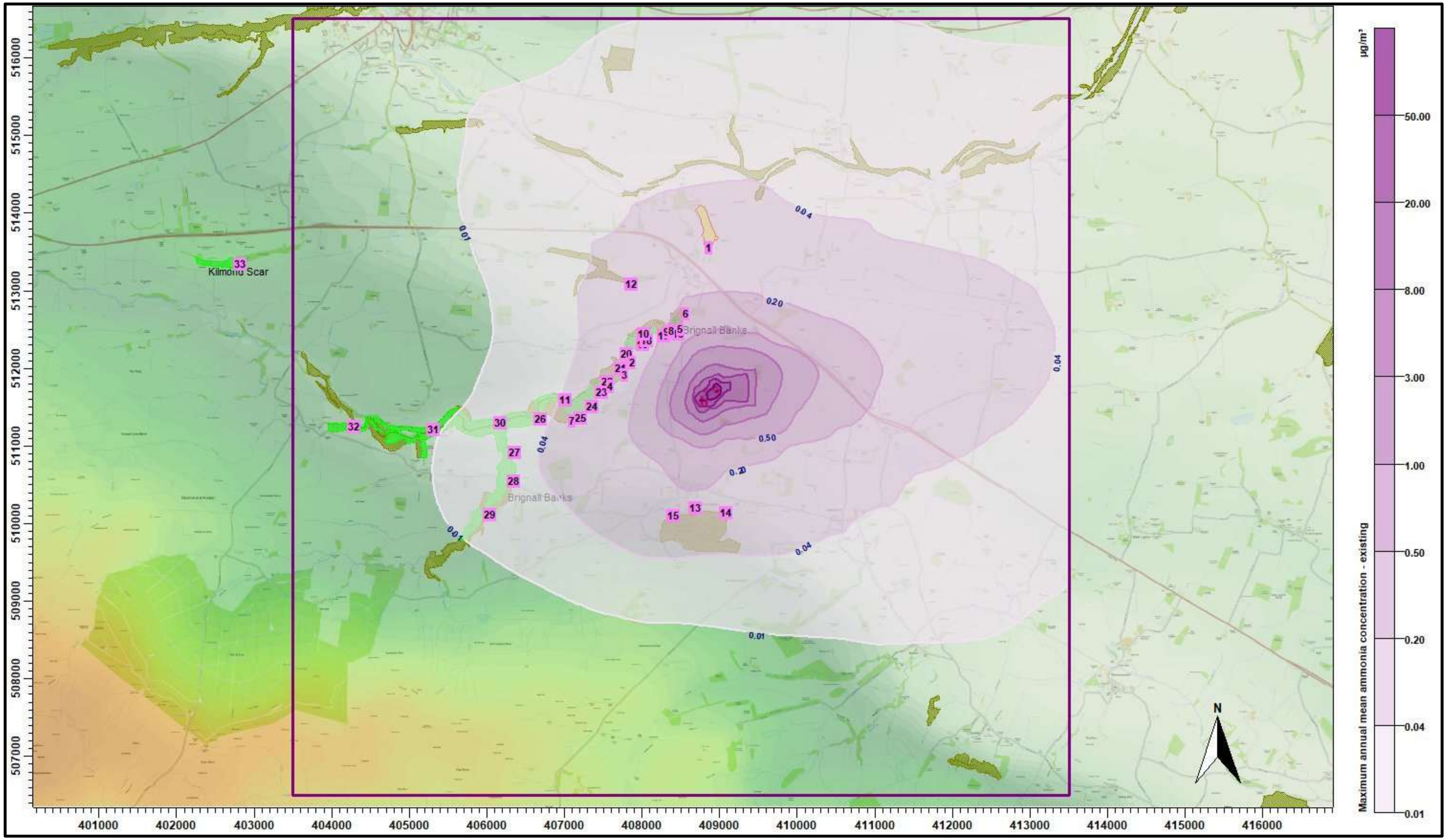


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Figure 7b. Maximum annual nitrogen deposition rate – existing poultry houses

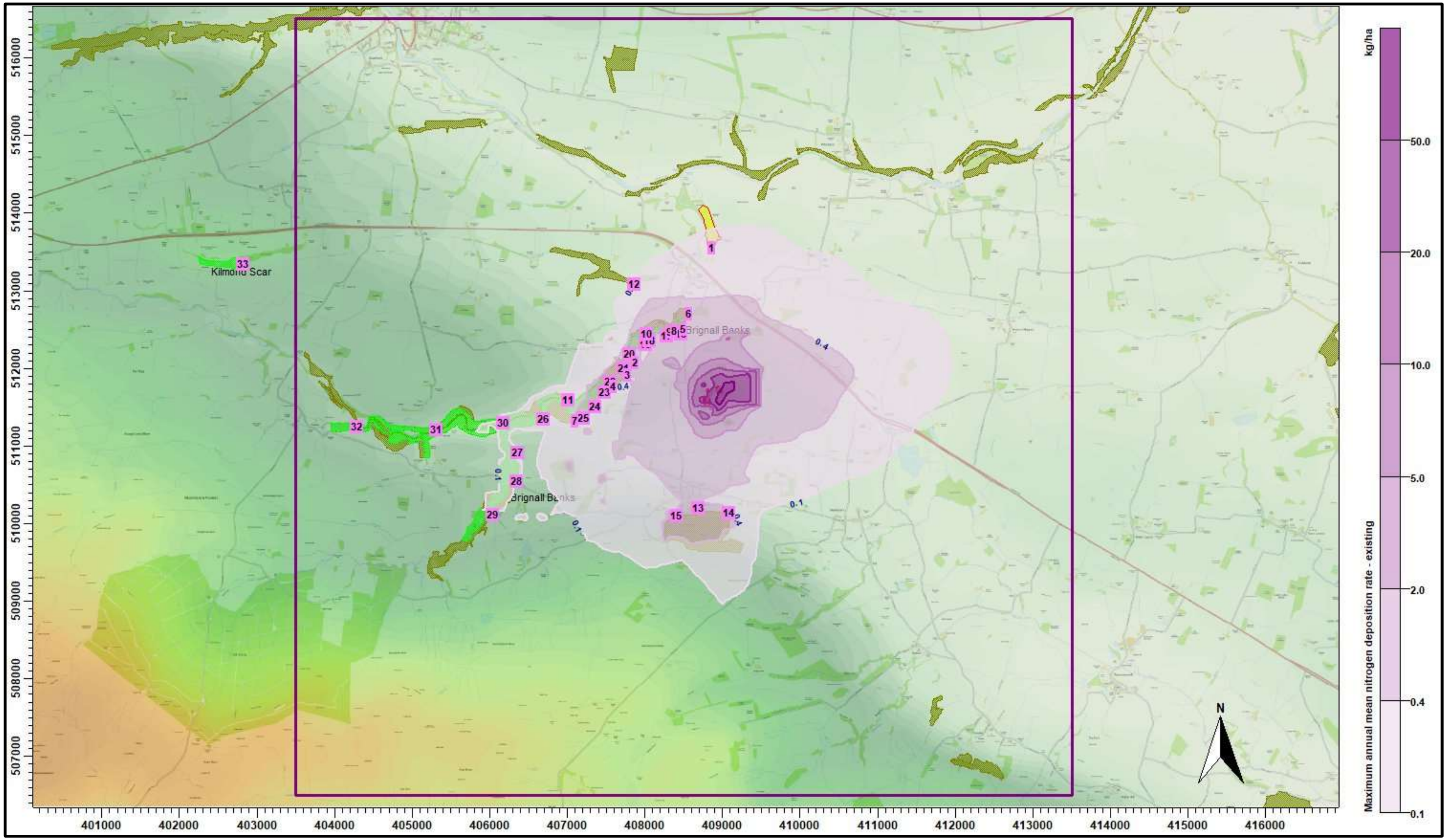


Figure 8a. Maximum annual ammonia concentration – proposed poultry houses

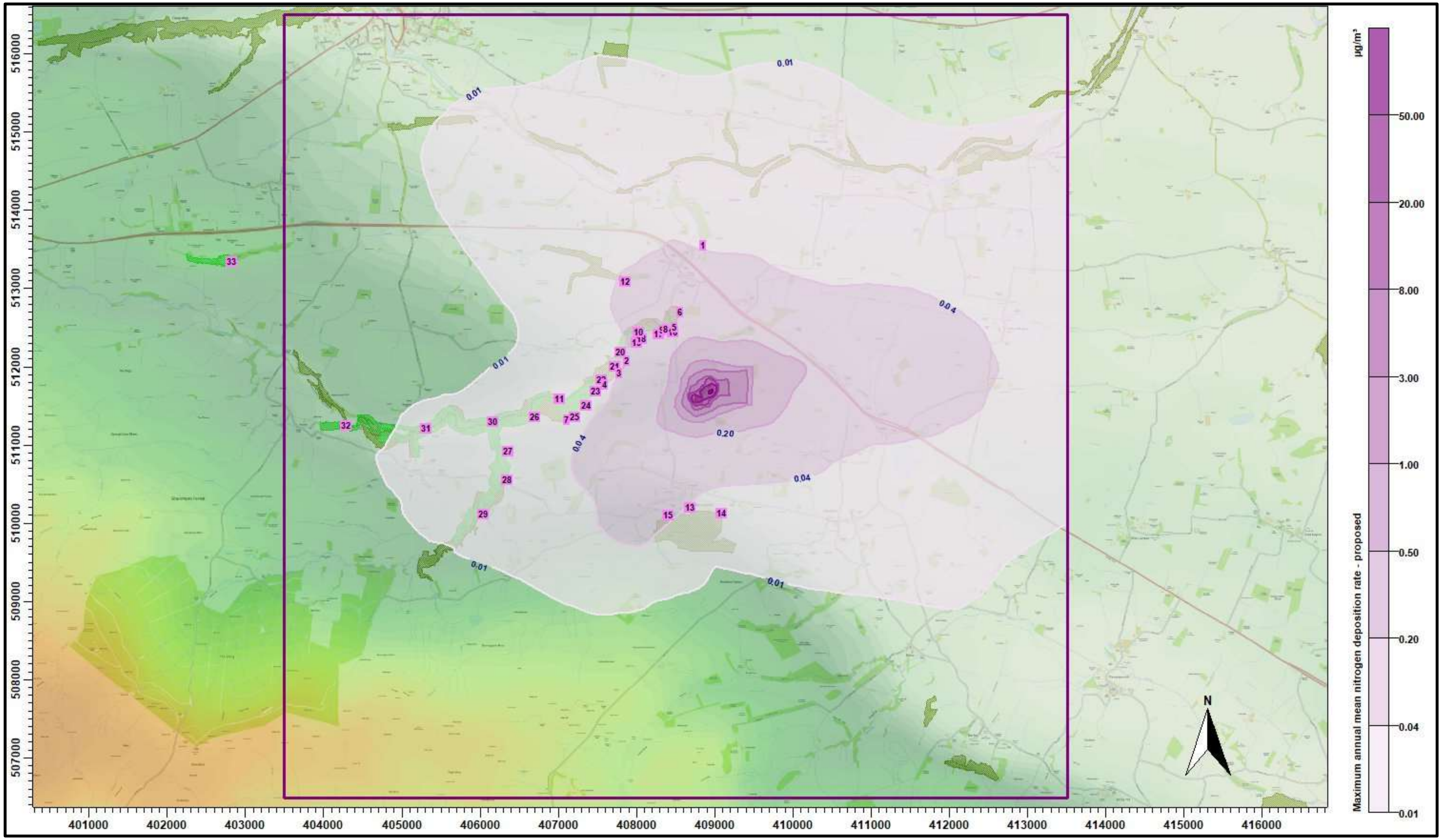
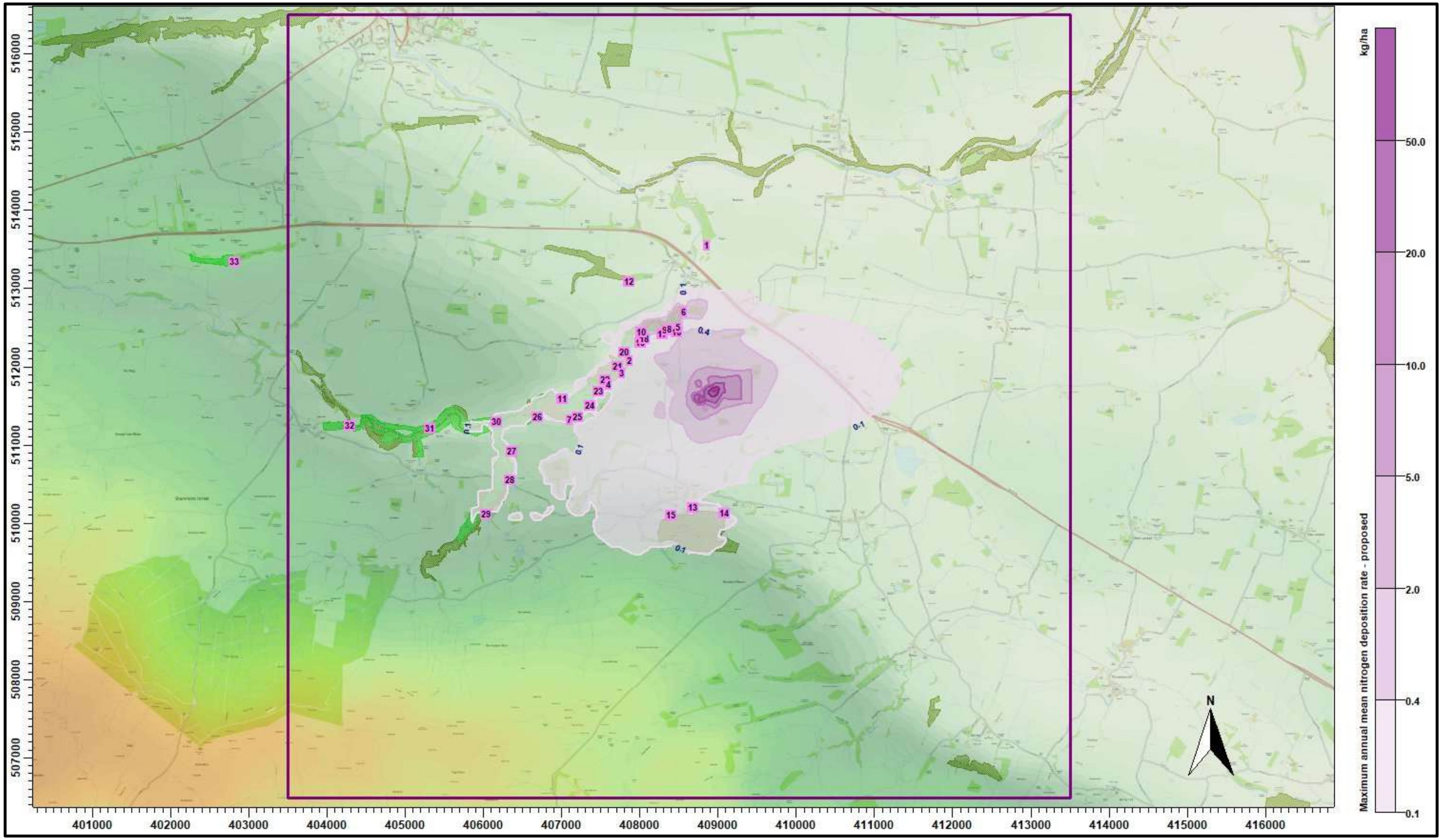


Figure 8b. Maximum annual ammonia concentration – proposed poultry houses



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Mr. Edward Bennett of AWSM Farming Ltd., on behalf of Saunders House Farm Ltd., to use computer modelling to assess the impact of ammonia emissions from the existing and proposed free range egg laying chicken houses at Saunders House Farm, Barningham, near to Barnard Castle, County Durham. DE11 7EB.

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

Existing poultry houses

The modelling predicts that:

- At the LWS and the AWs, process contributions from the existing poultry houses are below the Environment Agency's lower threshold percentage of both the precautionary Critical Level of 1.0 $\mu g/m^3$ and the Critical Load of 10.0 kg/ha.

- Process contributions from the existing poultry houses are greater than the Environment Agency's lower threshold percentage of both the Critical Level of 1.0 $\mu g/m^3$ and the Critical Load of 10.0 kg/ha over parts of Bignall Banks SSSI.

- Process contributions from the existing poultry houses exceed 1% of both the strict Critical Level of 1.0 $\mu g/m^3$ and the Critical Load of 10.0 kg/ha at Bignall Banks SSSI.

- At the other SSSIs, process contributions from the existing poultry houses to both ammonia concentrations and nitrogen deposition rates do not exceed 1% of the relevant Critical Level or Critical Load.

Proposed poultry houses

Should the proposed changes be undertaken at Saunders House Farm, the modelling predicts that:

- At the LWS and the AWs, process contributions from the proposed poultry houses would be below the Environment Agency's lower threshold percentage of both the precautionary Critical Level of 1.0 $\mu g/m^3$ and the Critical Load of 10.0 kg/ha and would be reduced significantly from existing levels.

- Process contributions from the proposed poultry houses would be below the Environment Agency's lower threshold percentage of both the Critical Level of 1.0 $\mu g/m^3$ and the Critical Load of 10.0 kg/ha at Bignall Banks SSSI.

- Process contributions from the proposed poultry houses would continue to exceed 1% of both the strict Critical Level of 1.0 µg/m³ and the Critical Load of 10.0 kg/ha at Bignall Banks SSSI. In most cases, the extent and magnitude of exceedances would be significantly reduced; however, at some of the more distant receptors (29, 31, 32 and 33) there is a very small (insignificant) increase predicted.

- At the other SSSIs identified for this study, process contributions from the proposed poultry houses to both ammonia concentrations and nitrogen deposition rates would be below 1% of the relevant Critical Level and the Critical Load.

7. References

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