

# 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 Hopes Ash Farm Poultry Unit, Hope Mansell, Ross-On-Wye in Herefordshire

# AS Modelling & Data Ltd.

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# Introduction

AS Modelling & Data Ltd. has been instructed by Mr. Steve Raasch, on behalf of Mr. Robert Davies, to use computer modelling to assess the impact of ammonia emissions from the existing turkey rearing houses and from the proposed broiler chicken rearing houses at Hopes Ash Farm Poultry Unit, Hope Mansell, Ross-On-Wye, Herefordshire. HR9 5TJ.

Ammonia emission rates from the poultry rearing houses have been estimated based upon the Environment Agency’s standard ammonia emission factors and figures obtained from the UK Ammonia Emissions Inventory (UKAEI). 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.

# Background Details

Hopes Ash Farm Poultry Unit is in a rural area approximately 0.8 km to the north of the small village of Hope Mansell and approximately 3.3 km to the south-east of the town of Ross-On-Wye, in Herefordshire. The surrounding land is used for arable cultivation, fodder production and pasture and there are extensive areas of semi-natural woodland in the area around the farm. The site is at an elevation of around 75 m in a steep valley formed by a tributary of the River Wye with hills and incised valleys characterising the area around the farm.

There are two turkey rearing houses at Hopes Ash Farm Poultry Unit, which provide accommodation for up to 9,300 stag turkeys and are ventilated by cowled side mounted fans. The houses are stocked with stag turkeys, at an age of around 41 days and weighing approximately 2 kg. The stag turkeys are reared for around 92 days, to a weight of approximately 19 kg and there is a period of 14 days between flocks when the houses are clean and empty. There are approximately three flocks per annum.

Under the proposals, the two poultry houses would be de-stocked of turkeys and would instead provide accommodation for up to 70,000 broiler chickens. The broiler chickens would be stocked as day old chicks and reared for around 38 days, with there being a period of ten days between flocks when the houses would be clean and left empty. There would be approximately 7.5 flocks per annum.

There are several areas that have been designated as Local Wildlife Sites (LWSs) and/or Ancient Woodlands (AWs) within 2 km (the normal screening distance for a non-statutory site) of the poultry houses. There are eight areas that have been designated as Sites of Special Scientific Interest (SSSIs) within 5 km (the normal screening distance for a SSSI) of the poultry houses, two of which are also designed as Special Areas of Conservation (SAC) in addition; namely Wye Valley And Forest of Dean Bat Sites SAC and River Wye SAC. There are an additional fourteen SSSIs and further constituent areas of River Wye SAC, Wye Valley Woodlands SAC and Wye Valley And Forest of Dean Bat Sites SAC within 10 km (the normal screening distance for a SAC) of the farm. Some further details of the SSSIs and the SACs that are likely to be sensitive to ammonia emissions are provided below:

**Wigpool Ironstone Mine SSSI (Wye Valley and Forest of Dean Bat Sites SAC)** - Approximately 2.5 km to the east-south-east -Notified for the lesser and greater horseshoe bat populations. This suite of sites includes both breeding and hibernation roosts and contributes to the conservation of bat populations of European importance.

**Coughton Wood and Marsh SSSI** - Approximately 3.5 km to the west - Selected as the largest remaining example of alder *Alnus glutinosa* woodland, which is one of the rarest types of woodland represented in the Wye Valley. Associated with the woodland is a small area of marsh which is a surviving fragment of the once extensive Coughton Marsh.

**River Wye SSSI/SAC** - Approximately 3.8 km to the south-west (closest) - The River Wye (Lower Wye) is a rare example of a near natural, large western eutrophic river which, unlike many rivers of a similar type, has not been subject to significant modification from human activities.

**Park Wood SSSI** - Approximately 4.7 km to the south-west - Park Wood lies on steep south facing slopes and cliffs above the River Wye. Its structure is very mixed and includes both standards and coppice. It is remarkable for the dominance of ash *Fraxinus excelsior* which is more common here than in any other Wye Valley woodland.

**Blaisdon Hall SSSI** - Approximately 8.0 km to the south-east - Notified for its nationally significant breeding population of lesser horseshoe bats.

**May Hill SSSI** - Approximately 6.5 km to the east - The acidic grassland and heath vegetation represented on this site is not found elsewhere in Herefordshire.

**Aston Ingham Meadows SSSI** - Approximately 6.8 km to the east-north-east - Two unimproved neutral hay meadows characterised by the presence of green-winged orchid *Orchis morio*. They are considered the finest known example of this type of habitat surviving in Herefordshire. The meadows are bordered by species-rich hedgerows, theses and a small area of wet woodland and scrub contribute to the overall value of the site.

**Dymock Woods SSSI** - Approximately 9.3 km to the north-east - The site contains the best areas of mature sessile oak *Quercus petraea* plantation that remain in the larger area of woodland known as Dymock Forest. Dymock Forest is important for butterflies and moths.

**Upper Wye Gorge SSSI** - Approximately 6.5 km to the south-west - One of the most extensive blocks of semi-natural broadleaved woodland in the whole of the Wye Valley. Other habitats represented include woodland streams, small areas of limestone grassland and limestone rock outcrops.

**Great Doward SSSI** - Approximately 9.0 km to the south-west - Two areas of limestone grassland, with associated scrub and woodland communities, situated on the south-west facing slopes of the Great Doward Hill, providing habitats for the rich insect fauna, particularly butterfly species.

**Brooks Head Grove SSSI** -Approximately 7.3 km to the south-west - Includes a number of types of seminatural woodland, selected as a representative of ancient broadleaved woodlands in the Wye Valley. Other habitats represented include an area of moderately species-rich permanent pasture which is integral with the woodland, some small limestone cliffs, a spring giving rise to a small stream, and two recently-created ponds.

**Speech House Oaks SSSI** - Approximately 8.3 km to the south - This linear stretch of open oak woodland in the centre of the Forest of Dean is the richest known site for epiphytic flora in the area and contains a number of uncommon lichens and bryophytes.

**Buckshraft Mine & Bradley Hill Railway Tunnel SSSI (Wye Valley and Forest of Dean Bat Sites SAC)** - Approximately 9.0 km to the south-south-east - One of the main British strongholds for the lesser horseshoe bat *Rhinolophus hipposideros* and greater horseshoe bat *Rhinolophus ferrumequinum*.

**Dean Hall Coach House & Cellar SSSI** - Approximately 8.9 km to the south-south-east - The site is notified as an important breeding roost for the nationally rare greater horseshoe bat *Rhinolophus ferrumequinum*.

**Soudley Ponds SSSI** - Approximately 9.7 km to the south-south-east - A series of ponds situated along the course of the Soudley Brook. They represent fine examples of a wetland habitat rich in wildlife and are bordered by damp woodland.

Maps of the surrounding area showing the positions of the turkey rearing houses, the LWSs, the SSSIs and the SAC are provided in Figures 1a and 1b. In the figures, the LWSs are shaded in yellow, the SSSIs are shaded in green, the SACs are shaded in purple and the positions of the existing and proposed poultry rearing houses are outlined in blue.

*Figure 1a. The area surrounding Hopes Ash Farm Poultry Unit, with circle radii 2.0 km (olive), 5.0 km (green) and 10.0 km (purple)*

*Map

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*Figure 1b. The area surrounding Hopes Ash Farm Poultry Unit, a closer view*

Map

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# 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-NH3/m3) 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 2022, source attribution data 2017 - 2019). It should be noted that the APIS background levels are an average over a 5 km grid square (they are also modelled values, they are not measured in any way and no particular farms are included explicitly in the sources attribution data). Ammonia levels vary markedly over relatively short distances and the APIS website itself notes that, the background values cannot be considered representative on any particular location within the 5 km grid square.

The most recent 1 km resolution data from APIS is not used as there is no proper documentation of the processes used to derive the data and AS Modelling & Data Ltd. has considerable doubts about the veracity of these data, particularly as there is no source data that could be used to derive 1 km resolution data; the source attribution data is stated to be at 0.1 degree resolution (approximately 10 km). It should be noted that ammonia levels vary markedly over relatively short distances and large sources that should be apparent at 1 km resolution (if the 1 km data were valid) are not apparent, indeed, it can be the case that minima in the data appear over large sources and maxima occur over semi-natural areas with no artificial sources of ammonia. There are also some unexplained and very marked differences to the 5 km data.

The APIS figure for background ammonia concentration (annual mean, at 5 km resolution) in the area around Hopes Ash Farm is 1.81 µg-NH3/m3. The background nitrogen deposition rate to woodland is 31.08 kg-N/ha/y and to short vegetation is 19.18 kg-N/ha/y. The background acid deposition rate to woodland is 2.35 keq/ha/y and to short vegetation is 1.48 keq/ha/y.

## 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 µg-NH3/m3 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-NH3/m3 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. Note, the citations for a number of the SSSIs identified for this study indicate that they have been designated due to their geology; therefore, these sites have not been considered further. Where the Critical Level of 1.0 µg-NH3/m3 is assumed, it is usually unnecessary to consider the Critical Load as the Critical Level provides the stricter test. Normally, the Critical Load for nitrogen deposition provides a stricter test than the Critical Load for acid deposition.

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

|  |  |  |  |
| --- | --- | --- | --- |
| Site | Critical Level  (µg-NH3/m3) | Critical Load Nitrogen Deposition  (kg-N/ha/y) | Critical Load  Acid Deposition  (keq/ha/y) |
| AWs/LWSs | 1.0 1 & 4 | 10.0 1 | - |
| River Wye SSSI/SAC, Soudley Ponds SSSI | 1.0 2 | n/a | - |
| Upper Wye Gorge SSSI/Wye Valley Woodlands SAC, Coughton Wood And Marsh SSSI, Brooks Head Grove SSSI, May Hill SSSI, Dymock Woods SSSI | 1.0 2 | 10.0 3 | - |
| Speech House Oaks SSSI | 1.0 2 | 15.0 3 | - |
| Wigpool Ironstone Mine SSSI/ Wye Valley & Forest of Dean Bat Sites SAC, Buckshaft Mine & Bradley Hill Railway Tunnel SSSI/ Wye Valley & Forest of Dean Bat Sites SAC, Blaisdon Hall SSSI, Dean Hall Coach House & Cellar SSSI. Westbury Brook Ironstone Mine SSSI/Edgehills Quarry SSSI | 3.0 2 | 10.0 3 | - |
| Great Doward SSSI | 3.0 2 | 15.0 3 | - |
| Aston Ingham Meadows SSSI | 3.0 2 | 20.0 3 | - |

1. A precautionary figure used where no details of the ecology of the site are available.
2. Based upon the citation for the site and information listed on APIS (December 2022).
3. The lower bound of the range of Critical Loads for the site/species, obtained from APIS (December 2022).
4. In their pre-application advice, the Environment Agency appear to have assumed a Critical Level of 3 µg-NH3/m3 for these sites, AS Modelling & Data Ltd. do not consider this to be a safe assumption in the area around Hopes Ash Farm.

## 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 in-combination with other developments) of Critical Level or Critical Load at a SSSI, SAC, SPA or Ramsar site, then the local authority should consider whether other farming installations1 might act in-combination or cumulatively with the farm and the sensitivities of the wildlife sites. However, Natural England advice has been contradictory and it should be noted that in other recent cases, Natural England are still applying a less strict threshold of 4% at SSSIs.

1. The process contribution from most farming installations is already included in the background ammonia concentrations and nitrogen and acid deposition rates (The APIS sources attribution data is from 2018). Therefore, it is normally only necessary to consider new installations and installations with extant planning permission and proposed developments when understanding the additional impact of a proposal upon nearby ecologies. However, established farms in close proximity may need to be considered given the background concentrations and deposition rates are derived as an average for a 5 km by 5 km grid.

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

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

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

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

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

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

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

## 3.5 Quantification of ammonia emissions

Ammonia emission rates from livestock housing depend on many factors and may 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 annual statistics it is not usually 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 Environment Agency provides an Intensive farming guidance note which lists standard ammonia emission factors for a variety of livestock, including male turkeys. However, it is understood that the Environment Agency’s figures for male turkeys assume that they are reared from day old chicks until they are fully grown; at Hopes Ash Farm Poultry Unit this is not the case. Therefore, AS Modelling and Data Ltd. has calculated an emission factor specifically for the turkeys reared at Hopes Ash Farm. The UKAEI has been used, which defines a figure of 64 g-N/livestock-unit/day (a livestock-unit is 500 kg) for turkeys, which equates to a specific emission factor of 0.05677 g-NH3/kg-live-weight/y.

Currently, male turkeys arrive at the farm at around 41 days old at a weight of approximately 2.0 kg and are reared to around 133 days old when they may weigh up to 19.0 kg. Assuming industry standard growth rates, the average weight of the turkeys (assuming numbers as initially stocked) is 9.7774 kg. Assuming the housing is cleaned and then empty for approximately fourteen days between crops, the derived site specific emission factor for the existing flock of male turkeys is 0.481747 kg-NH3/bird-place/y. For comparison, the Environment Agency figures are 0.45 kg-NH3/place/y for male turkeys it is understood that the Environment Agency figures are also derived using the figure of 64 g-N/livestock-unit/day from the UKAEI, but do not allow for empty and clean periods.

For the proposed broiler chicken rearing, the Environment Agency’s standard emission factor of 0.034 kg-NH3/place/y is used to estimate ammonia emissions.

Details of the turkey numbers and weights, emission factors used and calculated ammonia emission rates are provided in Table 2.

*Table 2. Details of turkey numbers and ammonia emission rates*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Source | Animal numbers | Type or weight | Emission factor  (kg-NH3/place/y) | Emission rate  (g-NH3/s) |
| Existing Turkey Rearing | 9,300 | Male turkeys ~2.0 kg to ~19 kg | 0.481757 | 0.141973 |
| Proposed Broiler Chicken Rearing | 70,000 | Standard broiler chickens | 0.034 | 0.075418 |

# 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; NOx 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 GFS1 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 GFS1 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 (FLOWSTAR2). The use of NWP data has advantages over traditional meteorological records because:

* Calm periods in traditional observational records may be over represented, this is because the instrumentation used may not record wind speeds below approximately 0.5 m/s and start up wind speeds may be greater than 1.0 m/s. In NWP data, the wind speed is continuous down to 0.0 m/s, allowing the calms module of ADMS to function correctly.
* Traditional records may include very local deviations from the broad-scale wind flow that would not necessarily be representative of the site being modelled; these deviations are difficult to identify and remove from a meteorological record. Conversely, local effects at the site being modelled are relatively easy to impose on the broad-scale flow and provided horizontal resolution is not too great, the meteorological records from NWP data may be expected to represent well the broad-scale flow.
* Information on the state of the atmosphere above ground level which would otherwise be estimated by the meteorological pre-processor may be included explicitly.

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 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 Hopes Ash Farm Poultry Unit is shown in Figure 2b. The resolution of the wind field in terrain runs is approximately 300 m. Please also note that FLOWSTAR2 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 amended3.

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 51.885 N, 2.542 W, 2018-2021*

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*Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 362700, 221000, 2018-2021*

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## 4.2 Emission sources

Emission from the cowled side fans that are used to ventilate the poultry houses are represented by a single volume source per house within ADMS (PH1v and PH2v). Details of the volume source parameters are shown in Table 3. The positions of the volume sources may be seen in Figure 3 (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-NH3/s) |
| PH1v | 18.0 | 74.0 | 3.0 | 0.0 | Ambient | 0.138753 1 |
| PH2v | 18.0 | 95.0 | 3.0 | 0.0 | Ambient | 0.178128 1 |

1. Based on a notional 10,000 birds for the two houses, with an emission factor of 1.0 kg-NH3/bird-place/y. The results of the modelling have then been scaled by factors of: 0.448034 for the turkey stocking regime and 0.238000 for the proposed broiler chicken stocking regime.

## 4.3 Modelled buildings

Not modelled.

## 4.4 Discrete receptors

Eighty-three discrete receptors have been defined at the wildlife sites. These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figures 4a and 4b (marked by enumerated pink rectangles).

## 4.5 Cartesian grid

To produce the contour plots presented in Section 5 of this report and to define the spatially varying deposition velocity field, a regular Cartesian grid has been defined within ADMS. The grid receptors are defined at ground level within ADMS. The position of the nested Cartesian grid receptors may be seen in Figure 4b (marked by grey gridlines).

## 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. The resolution of FLOWSTAR is 64 by 64 grid points; therefore, the effective resolution of the wind field is approximately 340 m.

## 4.7 Roughness Length

In this case, a spatially varying roughness length file has been defined, this is based upon the UK Centre for Ecology and Hydrology 25 m land use database, with permission1. The GFS meteorological data is assumed to have a roughness length of 0.38 m (the average over the modelling domain). The sample of the central area of the spatially varying roughness length field is shown in Figure 5.

1. Morton, R.D. ; Marston, C.G.; O’Neil, A.W.; Rowland, C.S. (2021). Land Cover Map 2020 (25m rasterised land parcels, GB). NERC EDS Environmental Information Centre. https://doi.org/10.5285/6c22cf6e-b224-414e-aa85-900325baed.

*Figure 3. The positions of the modelled sources and buildings*

Diagram

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*Figure 4a. The discrete receptors, a broad scale view*

*Map

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

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

Map

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## 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. Land use data used to derive deposition velocity is based upon the UK Centre for Ecology and Hydrology 25 m land use database, with permission1.

1. Morton, R.D. ; Marston, C.G.; O’Neil, A.W.; Rowland, C.S. (2021). Land Cover Map 2020 (25m rasterised land parcels, GB). NERC EDS Environmental Information Centre. https://doi.org/10.5285/6c22cf6e-b224-414e-aa85-900325baed.

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*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| NH3 concentration  (PC + background) (µg/m3) | < 10 | 10 - 20 | 20 - 30 | 30 - 80 | > 80 |
| Deposition velocity - woodland  (m/s) | 0.03 | 0.015 | 0.01 | 0.005 | 0.003 |
| Deposition velocity - short vegetation  (m/s) | 0.02 (0.010 to 0.015 over heavily grazed grassland) | 0.015 | 0.01 | 0.005 | 0.003 |
| Deposition velocity - arable farmland/rye grass  (m/s) | 0.005 | 0.005 | 0.005 | 0.005 | 0.003 |

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

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

Please note that, outside of the central grid, a fixed deposition at 0.005 m/s or 0.003 m/s is applied and similarly to not modelling deposition at all, the predicted ammonia concentrations (and nitrogen and acid deposition rates) are always equal to, or higher than if spatially varying deposition were modelled explicitly, particularly where there is some distance between the source and a receptor.

*Figure 6. The spatially varying deposition field*

*Map

Description automatically generated*

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# Details of the Model Runs and Results

## 5.1 Preliminary modelling and model sensitivity tests

ADMS was effectively run a totalof thirty-two times, once for each year of the meteorological record, for the existing stag turkey rearing and the proposed broiler chicken rearing 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 and surface roughness - GFS data.
* With terrain and surface roughness and a 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 for preliminary modelling runs 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 (20% for a SAC, 50% for a SSSI and 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 threshold percentages of the relevant Critical Level or Critical Load (4% and 20% for a SAC, 20% and 50% for a SSSI and 100% and 100% for a non-statutory site) are coloured blue. In addition, predicted ammonia concentrations (or concentrations equivalent to deposition rates) that exceed 1% of the relevant Critical Level or Critical Load are highlighted in emboldened text. For convenience, cells referring to the AWs are shaded olive, cells referring to the LWSs are shaded yellow, cells referring to the SSSIs are shaded green and cells referring to the SAC are shaded purple.

*Table 5. Predicted maximum annual mean ammonia concentration - preliminary modelling*

| Receptor number | X(m) | Y(m) | Designation | Maximum annual mean ammonia concentration - (µg/m3) | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Existing (9,300 stag turkeys) | | | | Proposed (70,000 broiler chickens) | | | |
| 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 Calms correction Terrain Fixed depo 0.003 m/s |
| 1 | 363000 | 220890 | LWS | **2.625** | **3.252** | **2.951** | **2.180** | **1.394** | **1.728** | **1.568** | **1.158** |
| 2 | 363031 | 221018 | LWS | **2.763** | **3.209** | **2.669** | **2.084** | **1.468** | **1.704** | **1.418** | **1.107** |
| 3 | 363057 | 221186 | AW | **2.072** | **2.386** | **2.509** | **1.999** | **1.101** | **1.268** | **1.333** | **1.062** |
| 4 | 363005 | 220759 | LWS | **2.140** | **2.656** | **2.717** | **1.914** | **1.137** | **1.411** | **1.443** | **1.017** |
| 5 | 363000 | 220667 | LWS | **1.591** | **1.988** | **2.492** | **1.739** | 0.845 | **1.056** | **1.324** | 0.924 |
| 6 | 363072 | 220473 | AW | 0.852 | **1.049** | **1.413** | 0.857 | 0.453 | 0.557 | 0.750 | 0.455 |
| 7 | 363064 | 221321 | AW | **1.328** | **1.561** | **1.710** | **1.400** | 0.705 | 0.829 | 0.908 | 0.744 |
| 8 | 362381 | 220922 | AW | **1.607** | **2.117** | **2.431** | **1.770** | 0.853 | **1.124** | **1.291** | 0.940 |
| 9 | 362353 | 221097 | AW | 0.868 | **1.340** | **1.212** | 0.839 | 0.461 | 0.712 | 0.644 | 0.446 |
| 10 | 362425 | 221312 | AW | 0.793 | **1.023** | 0.842 | 0.700 | 0.421 | 0.543 | 0.447 | 0.372 |
| 11 | 362360 | 220724 | AW | **1.289** | **1.774** | **2.228** | **1.503** | 0.685 | 0.943 | **1.183** | 0.798 |
| 12 | 362202 | 220885 | AW/LWS | 0.738 | 0.962 | **1.095** | 0.695 | 0.392 | 0.511 | 0.581 | 0.369 |
| 13 | 362247 | 221428 | AW | 0.381 | 0.509 | 0.450 | 0.340 | 0.202 | 0.270 | 0.239 | 0.181 |
| 14 | 361852 | 221529 | AW | 0.147 | 0.228 | 0.174 | 0.128 | 0.078 | 0.121 | 0.092 | 0.068 |
| 15 | 362028 | 221078 | AW | 0.326 | 0.473 | 0.450 | 0.297 | 0.173 | 0.251 | 0.239 | 0.158 |
| 16 | 362061 | 220535 | LWS | 0.407 | 0.560 | 0.695 | 0.387 | 0.216 | 0.297 | 0.369 | 0.206 |
| 17 | 363163 | 221477 | AW | 0.765 | 0.909 | 0.839 | 0.681 | 0.406 | 0.483 | 0.446 | 0.362 |
| 18 | 363238 | 220993 | LWS | **1.121** | **1.341** | **1.119** | 0.761 | 0.595 | 0.712 | 0.595 | 0.404 |
| 19 | 363323 | 220764 | AW | 0.700 | 0.884 | 0.857 | 0.515 | 0.372 | 0.470 | 0.455 | 0.274 |
| 20 | 363428 | 220434 | AW | 0.424 | 0.534 | 0.646 | 0.353 | 0.225 | 0.284 | 0.343 | 0.188 |
| 21 | 362973 | 220172 | LWS | 0.515 | 0.645 | 0.783 | 0.472 | 0.274 | 0.343 | 0.416 | 0.251 |
| 22 | 362672 | 221860 | AW | 0.261 | 0.341 | 0.276 | 0.214 | 0.139 | 0.181 | 0.147 | 0.114 |
| 23 | 362921 | 221925 | AW | 0.262 | 0.338 | 0.218 | 0.184 | 0.139 | 0.180 | 0.116 | 0.098 |
| 24 | 362293 | 220405 | AW | 0.723 | 0.927 | 0.971 | 0.642 | 0.384 | 0.493 | 0.516 | 0.341 |
| 25 | 362205 | 220101 | AW/LWS | 0.386 | 0.493 | 0.579 | 0.357 | 0.205 | 0.262 | 0.307 | 0.190 |
| 26 | 363054 | 222396 | AW | 0.137 | 0.176 | 0.105 | 0.084 | 0.073 | 0.094 | 0.056 | 0.045 |
| 27 | 362451 | 222433 | AW | 0.114 | 0.144 | 0.099 | 0.067 | 0.061 | 0.077 | 0.052 | 0.035 |
| 28 | 361995 | 222124 | AW | 0.129 | 0.166 | 0.113 | 0.078 | 0.069 | 0.088 | 0.060 | 0.041 |
| 29 | 362623 | 222824 | AW | 0.076 | 0.100 | 0.058 | 0.042 | 0.041 | 0.053 | 0.031 | 0.022 |
| 30 | 361219 | 222211 | AW | 0.053 | 0.075 | 0.047 | 0.031 | 0.028 | 0.040 | 0.025 | 0.016 |
| 31 | 361692 | 220917 | AW | 0.209 | 0.275 | 0.312 | 0.174 | 0.111 | 0.146 | 0.166 | 0.093 |
| 32 | 361049 | 221124 | LWS | 0.080 | 0.109 | 0.112 | 0.065 | 0.042 | 0.058 | 0.059 | 0.034 |
| 33 | 360812 | 220813 | LWS | 0.071 | 0.094 | 0.091 | 0.043 | 0.038 | 0.050 | 0.048 | 0.023 |
| 34 | 361551 | 220407 | LWS | 0.140 | 0.205 | 0.234 | 0.117 | 0.075 | 0.109 | 0.125 | 0.062 |
| 35 | 361980 | 219616 | AW | 0.180 | 0.230 | 0.287 | 0.153 | 0.096 | 0.122 | 0.152 | 0.081 |
| 36 | 362335 | 219083 | AW | 0.123 | 0.155 | 0.225 | 0.107 | 0.066 | 0.082 | 0.119 | 0.057 |
| 37 | 361736 | 219335 | AW | 0.122 | 0.157 | 0.160 | 0.081 | 0.065 | 0.083 | 0.085 | 0.043 |
| 38 | 361122 | 219778 | AW | 0.086 | 0.115 | 0.112 | 0.052 | 0.045 | 0.061 | 0.059 | 0.027 |
| 39 | 363207 | 219682 | AW | 0.206 | 0.260 | 0.376 | 0.192 | 0.109 | 0.138 | 0.200 | 0.102 |
| 40 | 363755 | 219970 | AW | 0.176 | 0.219 | 0.308 | 0.138 | 0.094 | 0.116 | 0.164 | 0.073 |
| 41 | 364028 | 220436 | LWS | 0.188 | 0.237 | 0.244 | 0.119 | 0.100 | 0.126 | 0.130 | 0.063 |
| 42 | 363732 | 219327 | AW | 0.114 | 0.142 | 0.201 | 0.083 | 0.060 | 0.075 | 0.107 | 0.044 |
| 43 | 364316 | 219860 | AW | 0.111 | 0.140 | 0.177 | 0.076 | 0.059 | 0.075 | 0.094 | 0.041 |
| 44 | 365107 | 219942 | Wigpool Ironstone Mine SSSI/Wye Valley & Forest of Dean Bat Sites SAC | **0.069** | **0.087** | **0.077** | **0.030** | **0.037** | **0.046** | **0.041** | **0.016** |
| 45 | 365592 | 220134 | Wigpool Ironstone Mine SSSI/Wye Valley & Forest of Dean Bat Sites SAC | **0.052** | **0.066** | **0.047** | **0.019** | **0.027** | **0.035** | **0.025** | 0.010 |
| 46 | 365524 | 219771 | Wigpool Ironstone Mine SSSI/Wye Valley & Forest of Dean Bat Sites SAC | **0.053** | **0.067** | **0.049** | **0.019** | **0.028** | **0.035** | **0.026** | 0.010 |
| 47 | 365572 | 219347 | Wigpool Ironstone Mine SSSI/Wye Valley & Forest of Dean Bat Sites SAC | **0.048** | **0.060** | **0.043** | **0.016** | **0.025** | **0.032** | **0.023** | 0.009 |
| 48 | 366005 | 216948 | Westbury Brook Ironside Mine SSSI/Edgehills Quarry SSSI/Wye Valley & Forest of Dean Bat Sites SAC | **0.022** | **0.027** | **0.019** | 0.006 | 0.012 | **0.014** | 0.010 | 0.003 |
| 49 | 359949 | 217902 | River Wye SSSI/SAC | **0.030** | **0.039** | **0.034** | **0.017** | **0.016** | **0.021** | **0.018** | 0.009 |
| 50 | 358389 | 219810 | River Wye SSSI/SAC | **0.016** | **0.023** | **0.020** | 0.009 | 0.009 | **0.012** | **0.010** | 0.005 |
| 51 | 359545 | 224159 | River Wye SSSI/SAC | **0.014** | **0.019** | **0.014** | 0.008 | 0.007 | **0.010** | 0.007 | 0.004 |
| 52 | 358158 | 223306 | River Wye SSSI/SAC | **0.010** | **0.016** | **0.011** | 0.005 | 0.005 | 0.009 | 0.006 | 0.003 |
| 53 | 356583 | 221702 | River Wye SSSI/SAC | 0.009 | **0.012** | **0.017** | 0.006 | 0.005 | 0.007 | 0.009 | 0.003 |
| 54 | 358187 | 216862 | River Wye SSSI/SAC | **0.015** | **0.019** | **0.020** | 0.009 | 0.008 | **0.010** | **0.011** | 0.005 |
| 55 | 355949 | 218361 | River Wye SSSI/SAC | 0.007 | **0.011** | **0.011** | 0.005 | 0.004 | 0.006 | 0.006 | 0.003 |
| 56 | 355624 | 214948 | River Wye SSSI/SAC | 0.007 | 0.010 | 0.009 | 0.004 | 0.004 | 0.005 | 0.005 | 0.002 |
| 57 | 358907 | 227691 | River Wye SSSI/SAC | 0.008 | 0.010 | 0.007 | 0.004 | 0.004 | 0.005 | 0.004 | 0.002 |
| 58 | 361638 | 229707 | River Wye SSSI/SAC | 0.006 | 0.008 | 0.005 | 0.003 | 0.003 | 0.004 | 0.003 | 0.001 |
| 59 | 356534 | 228017 | River Wye SSSI/SAC | 0.005 | 0.006 | 0.005 | 0.002 | 0.002 | 0.003 | 0.002 | 0.001 |
| 60 | 357829 | 216301 | Upper Wye Gorge SSSI/Wye Valley Woodlands SAC | **0.013** | **0.017** | **0.017** | 0.007 | 0.007 | 0.009 | 0.009 | 0.004 |
| 61 | 356620 | 216962 | Upper Wye Gorge SSSI/Wye Valley Woodlands SAC | 0.009 | **0.012** | **0.012** | 0.005 | 0.005 | 0.007 | 0.007 | 0.003 |
| 62 | 354902 | 215407 | Upper Wye Gorge SSSI/Wye Valley Woodlands SAC | 0.006 | 0.008 | 0.008 | 0.003 | 0.003 | 0.004 | 0.004 | 0.002 |
| 63 | 359483 | 223878 | Wilton Bluff, Ross on Wye SSSI | 0.014 | 0.020 | 0.014 | 0.008 | 0.007 | 0.011 | 0.007 | 0.004 |
| 64 | 359013 | 217789 | Parkwood SSSI | **0.021** | **0.027** | **0.025** | **0.012** | **0.011** | **0.014** | **0.013** | 0.007 |
| 65 | 364624 | 218413 | Puddlebrook Quarry SSSI | 0.050 | 0.061 | 0.061 | 0.021 | 0.026 | 0.033 | 0.032 | 0.011 |
| 66 | 365673 | 218739 | Scully Grove Quarry SSSI | 0.036 | 0.047 | 0.029 | 0.011 | 0.019 | 0.025 | 0.016 | 0.006 |
| 67 | 365861 | 218343 | Stenders Quarry SSSI | 0.030 | 0.038 | 0.025 | 0.009 | 0.016 | 0.020 | 0.013 | 0.005 |
| 68 | 367088 | 218591 | Land Grove Quarry, Mitcheldean SSSI | 0.024 | 0.030 | 0.021 | 0.008 | 0.013 | 0.016 | 0.011 | 0.004 |
| 69 | 359082 | 221035 | Coughton Wood And Marsh SSSI | **0.023** | **0.031** | **0.032** | **0.016** | **0.012** | **0.016** | **0.017** | 0.008 |
| 70 | 358641 | 214661 | Brooks Head Grove SSSI | **0.012** | **0.016** | **0.014** | 0.005 | 0.006 | 0.008 | 0.007 | 0.003 |
| 71 | 362699 | 212582 | Speech House Oaks SSSI | **0.011** | **0.013** | **0.010** | 0.004 | 0.006 | 0.007 | 0.005 | 0.002 |
| 72 | 365572 | 212292 | Buckshaft Minw & Badley Hill Railway Tunnel SSSI/Wye Valley & Forest of Dean Bat Sites SAC | 0.009 | 0.012 | 0.008 | 0.003 | 0.005 | 0.006 | 0.004 | 0.001 |
| 73 | 366227 | 211826 | Soudley Ponds SSSI | 0.008 | **0.010** | 0.007 | 0.002 | 0.004 | 0.005 | 0.004 | 0.001 |
| 74 | 369370 | 216726 | Wood Green Quarry & Railway Cutting SSSI | 0.011 | 0.014 | 0.008 | 0.003 | 0.006 | 0.008 | 0.004 | 0.002 |
| 75 | 369771 | 216977 | Blaisdon Hall SSSI | 0.011 | **0.014** | 0.007 | 0.003 | 0.006 | 0.007 | 0.004 | 0.002 |
| 76 | 369290 | 218590 | Longhope Hill SSSI | 0.013 | 0.017 | 0.009 | 0.004 | 0.007 | 0.009 | 0.005 | 0.002 |
| 77 | 369460 | 219352 | Hobb's Quarry, Longhope SSSI | 0.013 | 0.017 | 0.010 | 0.004 | 0.007 | 0.009 | 0.005 | 0.002 |
| 78 | 369190 | 221346 | May Hill SSSI | **0.016** | **0.020** | **0.015** | 0.006 | 0.009 | **0.011** | 0.008 | 0.003 |
| 79 | 368769 | 223871 | Aston Ingham Meadows SSSI | 0.021 | 0.025 | 0.019 | 0.010 | 0.011 | 0.013 | 0.010 | 0.005 |
| 80 | 367677 | 225685 | Linton Quarry SSSI | 0.020 | 0.023 | 0.017 | 0.009 | 0.010 | 0.012 | 0.009 | 0.005 |
| 81 | 368310 | 228532 | Dymock Woods SSSI | 0.010 | **0.012** | 0.008 | 0.005 | 0.005 | 0.006 | 0.004 | 0.002 |
| 82 | 354957 | 216291 | Great Doward SSSI | 0.006 | 0.008 | 0.009 | 0.003 | 0.003 | 0.004 | 0.005 | 0.002 |
| 83 | 367225 | 213113 | Dean Hall Coach House & Cellar SSSI | 0.009 | **0.011** | 0.007 | 0.002 | 0.005 | 0.006 | 0.004 | 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 5.0 km by 5.0 km and covers the poultry houses at Hopes Ash 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 this 5.0 km by 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 predicted process contribution from the stag turkey rearing and the broiler chicken rearing to maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors are shown in Table 6. In the Table, predicted ammonia concentrations or nitrogen deposition rates as a percentage of the relevant Critical Level or Critical Load that are in excess of the Environment Agency’s upper threshold (20% for a SAC, 50% for a SSSI and 100% for a non-statutory site) are coloured red. Percentages that are in the range between the Environment Agency’s upper threshold and lower threshold of the relevant Critical Level or Critical Load (4% and 20% for a SAC, 20% and 50% for a SSSI and 100% and 100% for a non-statutory site) are coloured blue. For convenience, cells referring to the AWs are shaded olive, cells referring to the LWSs are shaded yellow, cells referring to the SSSIs are shaded green and cells referring to the SAC are shaded purple.

Contour plots of the predicted process contributions to ground level maximum annual mean ammonia concentrations and nitrogen deposition rates are shown in Figures 7a and 7b (existing turkey rearing) and Figures 8a and 8b (proposed broiler chicken rearing).

*Table 6. Predicted process contribution to maximum annual mean ammonia and nitrogen deposition at the discrete receptors*

| Receptor number | X(m) | Y(m) | Designation | Site Parameters | | | Maximum annual ammonia concentration | | | | Maximum annual nitrogen deposition rate | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Existing (9,300 stag turkeys) | | Proposed (70,000 broiler chickens) | | Existing (9,300 stag turkeys) | | Proposed (70,000 broiler chickens) | |
| Deposition Velocity | CLe (µg/m3) | CLo (kg/ha) | PC (µg/m3) | %age of CLe | PC (µg/m3) | %age of CLe | PC (kg/ha) | %age of CLo | PC (kg/ha) | %age of CLo |
| 1 | 363000 | 220890 | LWS | 0.03 | 1.0 | 10.0 | 1.576 | **157.6** | 0.837 | 83.7 | 12.278 | **122.8** | 6.522 | 65.2 |
| 2 | 363031 | 221018 | LWS | 0.03 | 1.0 | 10.0 | 1.431 | **143.1** | 0.760 | 76.0 | 11.146 | **111.5** | 5.921 | 59.2 |
| 3 | 363057 | 221186 | AW | 0.03 | 1.0 | 10.0 | 1.336 | **133.6** | 0.710 | 71.0 | 10.411 | **104.1** | 5.531 | 55.3 |
| 4 | 363005 | 220759 | LWS | 0.03 | 1.0 | 10.0 | 1.443 | **144.3** | 0.767 | 76.7 | 11.243 | **112.4** | 5.972 | 59.7 |
| 5 | 363000 | 220667 | LWS | 0.03 | 1.0 | 10.0 | 1.367 | **136.7** | 0.726 | 72.6 | 10.648 | **106.5** | 5.656 | 56.6 |
| 6 | 363072 | 220473 | AW | 0.03 | 1.0 | 10.0 | 0.515 | 51.5 | 0.273 | 27.3 | 4.011 | 40.1 | 2.131 | 21.3 |
| 7 | 363064 | 221321 | AW | 0.03 | 1.0 | 10.0 | 0.921 | 92.1 | 0.489 | 48.9 | 7.177 | 71.8 | 3.812 | 38.1 |
| 8 | 362381 | 220922 | AW | 0.03 | 1.0 | 10.0 | 1.001 | **100.1** | 0.532 | 53.2 | 7.802 | 78.0 | 4.145 | 41.4 |
| 9 | 362353 | 221097 | AW | 0.03 | 1.0 | 10.0 | 0.500 | 50.0 | 0.266 | 26.6 | 3.895 | 39.0 | 2.069 | 20.7 |
| 10 | 362425 | 221312 | AW | 0.03 | 1.0 | 10.0 | 0.425 | 42.5 | 0.226 | 22.6 | 3.308 | 33.1 | 1.757 | 17.6 |
| 11 | 362360 | 220724 | AW | 0.03 | 1.0 | 10.0 | 0.882 | 88.2 | 0.468 | 46.8 | 6.868 | 68.7 | 3.648 | 36.5 |
| 12 | 362202 | 220885 | AW/LWS | 0.03 | 1.0 | 10.0 | 0.325 | 32.5 | 0.173 | 17.3 | 2.532 | 25.3 | 1.345 | 13.4 |
| 13 | 362247 | 221428 | AW | 0.03 | 1.0 | 10.0 | 0.176 | 17.6 | 0.094 | 9.4 | 1.372 | 13.7 | 0.729 | 7.3 |
| 14 | 361852 | 221529 | AW | 0.03 | 1.0 | 10.0 | 0.065 | 6.5 | 0.034 | 3.4 | 0.503 | 5.0 | 0.267 | 2.7 |
| 15 | 362028 | 221078 | AW | 0.03 | 1.0 | 10.0 | 0.137 | 13.7 | 0.073 | 7.3 | 1.069 | 10.7 | 0.568 | 5.7 |
| 16 | 362061 | 220535 | LWS | 0.03 | 1.0 | 10.0 | 0.174 | 17.4 | 0.093 | 9.3 | 1.357 | 13.6 | 0.721 | 7.2 |
| 17 | 363163 | 221477 | AW | 0.03 | 1.0 | 10.0 | 0.426 | 42.6 | 0.226 | 22.6 | 3.322 | 33.2 | 1.765 | 17.6 |
| 18 | 363238 | 220993 | LWS | 0.03 | 1.0 | 10.0 | 0.384 | 38.4 | 0.204 | 20.4 | 2.989 | 29.9 | 1.588 | 15.9 |
| 19 | 363323 | 220764 | AW | 0.03 | 1.0 | 10.0 | 0.204 | 20.4 | 0.108 | 10.8 | 1.590 | 15.9 | 0.845 | 8.4 |
| 20 | 363428 | 220434 | AW | 0.03 | 1.0 | 10.0 | 0.119 | 11.9 | 0.063 | 6.3 | 0.928 | 9.3 | 0.493 | 4.9 |
| 21 | 362973 | 220172 | LWS | 0.03 | 1.0 | 10.0 | 0.284 | 28.4 | 0.151 | 15.1 | 2.210 | 22.1 | 1.174 | 11.7 |
| 22 | 362672 | 221860 | AW | 0.03 | 1.0 | 10.0 | 0.122 | 12.2 | 0.065 | 6.5 | 0.952 | 9.5 | 0.506 | 5.1 |
| 23 | 362921 | 221925 | AW | 0.03 | 1.0 | 10.0 | 0.112 | 11.2 | 0.059 | 5.9 | 0.870 | 8.7 | 0.462 | 4.6 |
| 24 | 362293 | 220405 | AW | 0.03 | 1.0 | 10.0 | 0.399 | 39.9 | 0.212 | 21.2 | 3.107 | 31.1 | 1.650 | 16.5 |
| 25 | 362205 | 220101 | AW/LWS | 0.03 | 1.0 | 10.0 | 0.205 | 20.5 | 0.109 | 10.9 | 1.597 | 16.0 | 0.848 | 8.5 |
| 26 | 363054 | 222396 | AW | 0.03 | 1.0 | 10.0 | 0.049 | 4.9 | 0.026 | 2.6 | 0.382 | 3.8 | 0.203 | 2.0 |
| 27 | 362451 | 222433 | AW | 0.03 | 1.0 | 10.0 | 0.029 | 2.9 | 0.015 | 1.5 | 0.223 | 2.2 | 0.118 | 1.2 |
| 28 | 361995 | 222124 | AW | 0.03 | 1.0 | 10.0 | 0.035 | 3.5 | 0.019 | 1.9 | 0.274 | 2.7 | 0.145 | 1.5 |
| 29 | 362623 | 222824 | AW | 0.03 | 1.0 | 10.0 | 0.020 | 2.0 | 0.011 | 1.1 | 0.157 | 1.6 | 0.083 | 0.8 |
| 30 | 361219 | 222211 | AW | 0.03 | 1.0 | 10.0 | 0.013 | 1.3 | 0.007 | 0.7 | 0.105 | 1.0 | 0.056 | 0.6 |
| 31 | 361692 | 220917 | AW | 0.03 | 1.0 | 10.0 | 0.059 | 5.9 | 0.032 | 3.2 | 0.462 | 4.6 | 0.246 | 2.5 |
| 32 | 361049 | 221124 | LWS | 0.03 | 1.0 | 10.0 | 0.026 | 2.6 | 0.014 | 1.4 | 0.200 | 2.0 | 0.106 | 1.1 |
| 33 | 360812 | 220813 | LWS | 0.03 | 1.0 | 10.0 | 0.014 | 1.4 | 0.007 | 0.7 | 0.106 | 1.1 | 0.056 | 0.6 |
| 34 | 361551 | 220407 | LWS | 0.03 | 1.0 | 10.0 | 0.048 | 4.8 | 0.025 | 2.5 | 0.371 | 3.7 | 0.197 | 2.0 |
| 35 | 361980 | 219616 | AW | 0.03 | 1.0 | 10.0 | 0.075 | 7.5 | 0.040 | 4.0 | 0.586 | 5.9 | 0.311 | 3.1 |
| 36 | 362335 | 219083 | AW | 0.03 | 1.0 | 10.0 | 0.051 | 5.1 | 0.027 | 2.7 | 0.395 | 4.0 | 0.210 | 2.1 |
| 37 | 361736 | 219335 | AW | 0.03 | 1.0 | 10.0 | 0.039 | 3.9 | 0.020 | 2.0 | 0.300 | 3.0 | 0.160 | 1.6 |
| 38 | 361122 | 219778 | AW | 0.03 | 1.0 | 10.0 | 0.021 | 2.1 | 0.011 | 1.1 | 0.164 | 1.6 | 0.087 | 0.9 |
| 39 | 363207 | 219682 | AW | 0.03 | 1.0 | 10.0 | 0.079 | 7.9 | 0.042 | 4.2 | 0.615 | 6.2 | 0.327 | 3.3 |
| 40 | 363755 | 219970 | AW | 0.03 | 1.0 | 10.0 | 0.033 | 3.3 | 0.018 | 1.8 | 0.259 | 2.6 | 0.138 | 1.4 |
| 41 | 364028 | 220436 | LWS | 0.03 | 1.0 | 10.0 | 0.034 | 3.4 | 0.018 | 1.8 | 0.262 | 2.6 | 0.139 | 1.4 |
| 42 | 363732 | 219327 | AW | 0.03 | 1.0 | 10.0 | 0.022 | 2.2 | 0.012 | 1.2 | 0.169 | 1.7 | 0.090 | 0.9 |
| 43 | 364316 | 219860 | AW | 0.03 | 1.0 | 10.0 | 0.015 | 1.5 | 0.008 | 0.8 | 0.121 | 1.2 | 0.064 | 0.6 |
| 44 | 365107 | 219942 | Wigpool Ironstone Mine SSSI/Wye Valley & Forest of Dean Bat Sites SAC | 0.03 | 3.0 | 10.0 | 0.006 | 0.2 | 0.003 | 0.1 | 0.049 | 0.5 | 0.026 | 0.3 |
| 45 | 365592 | 220134 | Wigpool Ironstone Mine SSSI/Wye Valley & Forest of Dean Bat Sites SAC | 0.03 | 3.0 | 10.0 | 0.007 | 0.2 | 0.003 | 0.1 | 0.051 | 0.5 | 0.027 | 0.3 |
| 46 | 365524 | 219771 | Wigpool Ironstone Mine SSSI/Wye Valley & Forest of Dean Bat Sites SAC | 0.03 | 3.0 | 10.0 | 0.005 | 0.2 | 0.003 | 0.1 | 0.040 | 0.4 | 0.021 | 0.2 |
| 47 | 365572 | 219347 | Wigpool Ironstone Mine SSSI/Wye Valley & Forest of Dean Bat Sites SAC | 0.03 | 3.0 | 10.0 | 0.004 | 0.1 | 0.002 | 0.1 | 0.032 | 0.3 | 0.017 | 0.2 |
| 48 | 366005 | 216948 | Westbury Brook Ironside Mine SSSI/Edgehills Quarry SSSI/Wye Valley & Forest of Dean Bat Sites SAC | 0.03 | 3.0 | 10.0 | 0.002 | 0.1 | 0.001 | 0.0 | 0.013 | 0.1 | 0.007 | 0.1 |
| 49 | 359949 | 217902 | River Wye SSSI/SAC | - | 1.0 | - | 0.008 | 0.8 | 0.004 | 0.4 | - | - | - | - |
| 50 | 358389 | 219810 | River Wye SSSI/SAC | - | 1.0 | - | 0.004 | 0.4 | 0.002 | 0.2 | - | - | - | - |
| 51 | 359545 | 224159 | River Wye SSSI/SAC | - | 1.0 | - | 0.003 | 0.3 | 0.002 | 0.2 | - | - | - | - |
| 52 | 358158 | 223306 | River Wye SSSI/SAC | - | 1.0 | - | 0.002 | 0.2 | 0.001 | 0.1 | - | - | - | - |
| 53 | 356583 | 221702 | River Wye SSSI/SAC | - | 1.0 | - | 0.002 | 0.2 | 0.001 | 0.1 | - | - | - | - |
| 54 | 358187 | 216862 | River Wye SSSI/SAC | - | 1.0 | - | 0.005 | 0.5 | 0.002 | 0.2 | - | - | - | - |
| 55 | 355949 | 218361 | River Wye SSSI/SAC | - | 1.0 | - | 0.003 | 0.3 | 0.001 | 0.1 | - | - | - | - |
| 56 | 355624 | 214948 | River Wye SSSI/SAC | - | 1.0 | - | 0.002 | 0.2 | 0.001 | 0.1 | - | - | - | - |
| 57 | 358907 | 227691 | River Wye SSSI/SAC | - | 1.0 | - | 0.002 | 0.2 | 0.001 | 0.1 | - | - | - | - |
| 58 | 361638 | 229707 | River Wye SSSI/SAC | - | 1.0 | - | 0.002 | 0.2 | 0.001 | 0.1 | - | - | - | - |
| 59 | 356534 | 228017 | River Wye SSSI/SAC | - | 1.0 | - | 0.001 | 0.1 | 0.001 | 0.1 | - | - | - | - |
| 60 | 357829 | 216301 | Upper Wye Gorge SSSI/Wye Valley Woodlands SAC | 0.03 | 1.0 | 10.0 | 0.004 | 0.4 | 0.002 | 0.2 | 0.028 | 0.3 | 0.015 | 0.1 |
| 61 | 356620 | 216962 | Upper Wye Gorge SSSI/Wye Valley Woodlands SAC | 0.03 | 1.0 | 10.0 | 0.003 | 0.3 | 0.002 | 0.2 | 0.025 | 0.2 | 0.013 | 0.1 |
| 62 | 354902 | 215407 | Upper Wye Gorge SSSI/Wye Valley Woodlands SAC | 0.03 | 1.0 | 10.0 | 0.002 | 0.2 | 0.001 | 0.1 | 0.014 | 0.1 | 0.007 | 0.1 |
| 63 | 359483 | 223878 | Wilton Bluff, Ross on Wye SSSI | - | - | - | 0.003 | - | 0.002 | - | - | - | - | - |
| 64 | 359013 | 217789 | Parkwood SSSI | 0.03 | 1.0 | 10.0 | 0.007 | 0.7 | 0.003 | 0.3 | 0.051 | 0.5 | 0.027 | 0.3 |
| 65 | 364624 | 218413 | Puddlebrook Quarry SSSI | - | - | - | 0.005 | - | 0.003 | - | - | - | - | - |
| 66 | 365673 | 218739 | Scully Grove Quarry SSSI | - | - | - | 0.003 | - | 0.002 | - | - | - | - | - |
| 67 | 365861 | 218343 | Stenders Quarry SSSI | - | - | - | 0.003 | - | 0.001 | - | - | - | - | - |
| 68 | 367088 | 218591 | Land Grove Quarry, Mitcheldean SSSI | - | - | - | 0.002 | - | 0.001 | - | - | - | - | - |
| 69 | 359082 | 221035 | Coughton Wood And Marsh SSSI | 0.03 | 1.0 | 10.0 | 0.007 | 0.7 | 0.004 | 0.4 | 0.052 | 0.5 | 0.028 | 0.3 |
| 70 | 358641 | 214661 | Brooks Head Grove SSSI | 0.03 | 1.0 | 10.0 | 0.002 | 0.2 | 0.001 | 0.1 | 0.018 | 0.2 | 0.009 | 0.1 |
| 71 | 362699 | 212582 | Speech House Oaks SSSI | 0.03 | 1.0 | 15.0 | 0.001 | 0.1 | 0.001 | 0.1 | 0.011 | 0.1 | 0.006 | <0.0 |
| 72 | 365572 | 212292 | Buckshaft Minw & Badley Hill Railway Tunnel SSSI/Wye Valley & Forest of Dean Bat Sites SAC | 0.03 | 3.0 | 10.0 | 0.001 | <0.0 | 0.001 | <0.0 | 0.008 | 0.1 | 0.004 | <0.0 |
| 73 | 366227 | 211826 | Soudley Ponds SSSI | - | 1.0 | - | 0.001 | 0.1 | 0.000 | <0.0 | - | - | - | - |
| 74 | 369370 | 216726 | Wood Green Quarry & Railway Cutting SSSI | - | - | - | 0.001 | - | 0.001 | - | - | - | - | - |
| 75 | 369771 | 216977 | Blaisdon Hall SSSI | 0.03 | 3.0 | 10.0 | 0.001 | <0.0 | 0.001 | <0.0 | 0.011 | 0.1 | 0.006 | 0.1 |
| 76 | 369290 | 218590 | Longhope Hill SSSI | - | - | - | 0.002 | - | 0.001 | - | - | - | - | - |
| 77 | 369460 | 219352 | Hobb's Quarry, Longhope SSSI | - | - | - | 0.002 | - | 0.001 | - | - | - | - | - |
| 78 | 369190 | 221346 | May Hill SSSI | 0.02 | 1.0 | 10.0 | 0.003 | 0.3 | 0.002 | 0.2 | 0.015 | 0.1 | 0.008 | 0.1 |
| 79 | 368769 | 223871 | Aston Ingham Meadows SSSI | 0.03 | 3.0 | 20.0 | 0.006 | 0.2 | 0.003 | 0.1 | 0.045 | 0.2 | 0.024 | 0.1 |
| 80 | 367677 | 225685 | Linton Quarry SSSI | - | - | - | 0.006 | - | 0.003 | - | - | - | - | - |
| 81 | 368310 | 228532 | Dymock Woods SSSI | 0.03 | 1.0 | 10.0 | 0.003 | 0.3 | 0.002 | 0.2 | 0.023 | 0.2 | 0.012 | 0.1 |
| 82 | 354957 | 216291 | Great Doward SSSI | 0.02 | 3.0 | 15.0 | 0.002 | 0.1 | 0.001 | <0.0 | 0.009 | 0.1 | 0.005 | <0.0 |
| 83 | 367225 | 213113 | Dean Hall Coach House & Cellar SSSI | 0.03 | 3.0 | 10.0 | 0.001 | <0.0 | 0.000 | <0.0 | 0.006 | 0.1 | 0.003 | <0.0 |

*Figure 7a. Predicted process contribution to maximum annual mean ammonia concentration - existing turkey rearing*

Map

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*Figure 7b. Predicted process contribution to maximum annual nitrogen deposition rates - existing turkey rearing*

Map

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*Figure 8a. Predicted process contribution to maximum annual mean ammonia concentration - proposed broiler chicken rearing*

Map

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*Figure 8b. Predicted process contribution to maximum annual nitrogen deposition rates - proposed broiler chicken rearing*

Map

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# 6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Mr. Steve Raasch, on behalf of Mr. Robert Davies, to use computer modelling to assess the impact of ammonia emissions from the existing turkey rearing houses and from the proposed broiler chicken rearing houses at Hopes Ash Farm Poultry Unit, Hope Mansell, Ross-On-Wye, Herefordshire. HR9 5TJ.

Ammonia emission rates from the poultry rearing houses have been estimated based upon the Environment Agency’s standard ammonia emission factors and figures obtained from the UK Ammonia Emissions Inventory (UKAEI). 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 Scenario

The Modelling predicts that:

* At some of the closer non-statutory sites (receptors 1 to 5 and 8), there are currently exceedances of the Environment Agency’s upper threshold percentage of the precautionary Critical Level of 1.0 µg/m³. Nitrogen deposition rates do not exceed the Environment Agency’s lower threshold percentage of the assumed Critical Load of 10.0 kg/ha at any of the non-statutory wildlife sites.
* There are currently no exceedances of the Environment Agency’s lower threshold percentage of the Critical Level or Critical Load at the SSSIs and SACs considered
* There are currently no exceedances of 1% of the relevant Critical Level or Critical Load at the SSSIs and SACs considered.

## Proposed Scenario

The Modelling predicts that:

* At some of the closer non-statutory sites (receptors 1 to 5), there would be exceedances of the Environment Agency’s upper threshold percentage of the precautionary Critical Level of 1.0 µg/m³. Nitrogen deposition rates would not exceed the Environment Agency’s lower threshold percentage of the assumed Critical Load of 10.0 kg/ha at any of the non-statutory wildlife sites.
* There would be no exceedances of the Environment Agency’s lower threshold percentage of the Critical Level or Critical Load at the SSSIs and SACs considered.
* There would be no exceedances of 1% of the relevant Critical Level or Critical Load at the SSSIs and SACs considered.
* Should the proposed change to the rearing of broiler chickens at Hopes Ash Farm Poultry Unit proceed, there would be a reduction in ammonia concentration and nitrogen deposition rates at all of the wildlife sites considered.

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