A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Proposed Pig Rearing Houses at Hebrons Quarry Farm - Pig Unit, Quarry Farm, Sandsprunt Lane, near Ebberston in North Yorkshire

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Revision 1 – 10th February 2025 – Correction to Table 2a.

Introduction

AS Modelling & Data Ltd. has been instructed by Ms. Lizzie Bentley of Yorkshire Farmers, on behalf of Mr. Andrew Hebron, to use computer modelling to assess the impact of ammonia emissions from the proposed pig rearing houses at Hebrons Quarry Farm, Quarry Farm, Sandsprunt Lane, Ebberston, Scarborough, North Yorkshire. YO13 9PA.

Ammonia emission rates from the proposed pig rearing houses have been assessed and quantified based upon the Environment Agency 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.

1. Background Details

The site of the proposed pig rearing houses at Hebrons Quarry Farm is in an isolated rural area approximately 1.1 km to the north-east of the village of Ebberston in North Yorkshire. The surrounding land is used primarily for arable farming, but there are some areas of semi-natural woodland and isolated remnants of semi-natural grasslands. The site is at an elevation of around 145 m, with the land rising towards the North York Moors to the north and falling towards the Vale of Pickering to the south.

It is proposed that four pig rearing houses be constructed at Hebrons Quarry Farm. These houses would be used to accommodate up to 3,800 finisher pigs. The houses would have slatted floors with shallow slurry pits below and slurry would be transferred to a storage tank via a vacuum system. Ventilation would be provided by uncapped ridge/roof mounted fans, each with a short chimney.

There are some areas designated as Local Wildlife Sites (LWSs) within 2 km (the normal screening distance for non-statutory sites) of the farm. There are also fourteen Sites of Special Scientific Interest (SSSIs) within 10 km (the normal screening distance for a statutory site). No internationally designated sites have been identified within 10 km. Further details of the SSSIs are provided below:

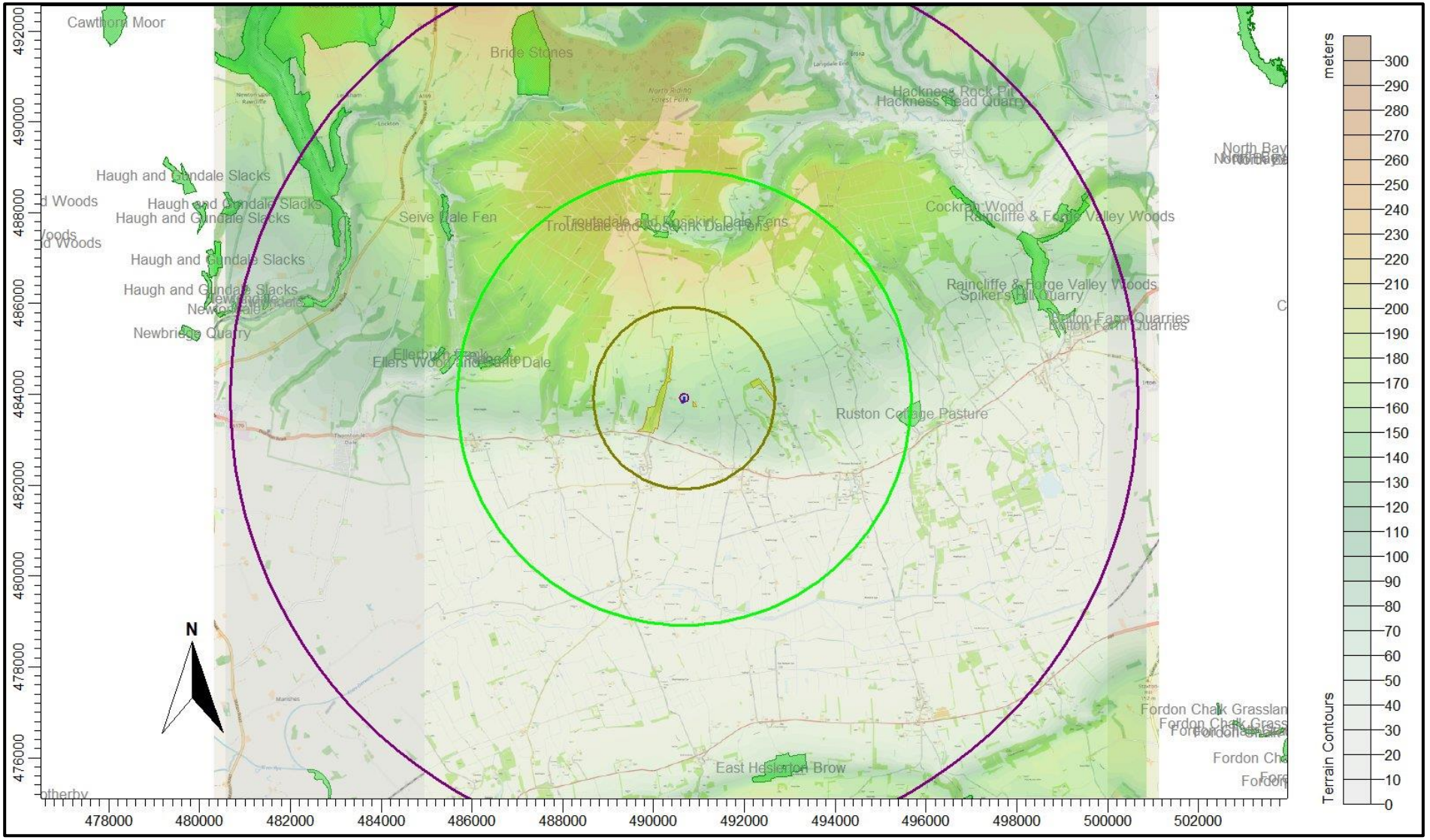
- **Troutsdale and Rosekirk Dale Fens SSSI** - Approximately 3.5 km to the north - Examples of spring and flush fen typical in the local area where base-rich springs emanate from the Corallian Limestone. In places mounds of bog mosses *Sphagnum* spp. allow some plants to grown in a more acidic environment above the influence of the calcareous flushes.
- **Nabgate SSSI** - Approximately 3.9 km to the west-north-west - Of interest for its species-rich calcareous grassland, developed on thin, stony soils and screes, in an area otherwise extensively afforested.
- **Eller's Wood and Sand Dale SSSI** - Approximately 4.6 km to the west-north-west - A remnant of formerly more extensive broadleaved woodland on the edge of extensive conifer plantations. In Sand Dale rich fen vegetation follows the seepage lines from springs and contains an impressive list of species. Between the flushes on raised banks there is a more acidic grassland amongst scattered gorse.
- **Ellerburn Bank SSSI** - Approximately 5.3 km to the west-north-west - A south-east facing slope on Oolitic Limestone, supporting a species-rich calcareous grassland flora. There is also considerable entomological interest with many lepidoptera recorded.
- **Ruston Cottage Pasture SSSI** - Approximately 4.6 km to the east - In addition to the main habitats of neutral and calcareous grassland, there is a strip of ash/hawthorn *Fraxinus excelsior/Crataegus monogyna* woodland around the north-western edge, gorse *Ulex europaeus* and hawthorn scrub of various ages on the valley sides and a small beck. The limestone pasture on the valley sides is very species-rich with several rare and local species. The grassland on the level ground is more neutral in character.
- **Spiker's Hill Quarry SSSI** - Approximately 6.5 km to the east-north-east - Geological.
- **Raincliffe & Forge Valley Woods SSSI** - Approximately 8.0 km to the east-north-east - One of the best examples known of mixed deciduous woodland in north-east England.
- **Betton Farm Quarries SSSI** - Approximately 9.5 km to the east-north-east - Geological.
- **Cockrah Wood SSSI** - Approximately 7.5 km to the north-east - The site was formerly on oakwood *Quercus* sp. situated on a steep slope with acid soils. It has been largely replanted with conifers but there remain populations of scarce plants.
- **Hackness Head Quarry SSSI and Hackness Rock Pit SSSI** - Approximately 8.6 km to the north-east - Geological.
- **Bride Stones SSSI** - Approximately 7.5 km to the north-north-west - A famous series of isolated stacks. The stones are surrounded by moorland which grades into woodland to the south.

- **Seive Dale Fen SSSI** - Approximately 6.2 km to the north-west - Fen vegetation extends over most of the site, but there are also areas of woodland and dry grassland.

- **Newtondale SSSI** - Approximately 7.9 km to the west-north-west - This site provides a fine example of the succession of habitats between the upland and lower valley regimes which includes woodland, grassland, fen, valley mire, marsh and moorland edge.
- **East Heslerton Brow SSSI** - Approximately 9.0 km to the south-south-east - The slopes support a chalk grassland community dominated by red rescue *Festuca rubra*.

A map of the surrounding area showing the positions of the pig houses and the wildlife sites is provided in Figure 1. In the figure, the LWSs are shaded in yellow, the SSSIs are shaded in green and the positions of the pig houses at Hebrons Quarry Farm are outlined in blue.

Figure 1. The area surrounding Hebrons Quarry Farm – concentric circles radii 2.0 km (olive), 5.0 km (green) and 10.0 km (purple)



2. 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, January 2025). It should be noted that the 1 km APIS database background levels are extrapolated from 5 km modelled data. Ammonia levels may vary markedly over relatively short distances and the APIS website itself notes that, the background values should be used only to assist the user in obtaining a broad indication of the likely pollutant impact at a specific location and cannot be considered representative of any particular location within the 5 km grid square; extrapolation to a 1 km grid does not alter this.

The background ammonia concentration (annual mean) in the area around Hebrons Quarry Farm and the wildlife sites is 2.07 $\mu g\text{-}NH_3/m^3$. The background nitrogen deposition rate to woodland is 33.26 kg-N/ha/y and to short vegetation is 18.46 kg-N/ha/y. The background acid deposition rate to woodland is 2.44 keq/ha/y and to short vegetation is 1.36 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 µg-NH_3/m^3 as an annual mean. For sites where there are sensitive lichens and bryophytes present, or where lichens and bryophytes are an integral part of the ecosystem, the Critical Level is 1.0 µg-NH_3/m^3 as an annual mean.

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

The Critical Levels and Critical Loads at the wildlife sites assumed in this study are provided in Table 1. Where the Critical Level of 1.0 µg-NH_3/m^3 is assumed, it is usually unnecessary to consider the Critical Load as the Critical Level provides the stricter test. 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 (µg-NH_3/m^3)	Critical Load - Nitrogen Deposition (kg-N/ha/y)	Critical Load - Acid Deposition (keq/ha/y)
Netherby Dale (Chafer Wood) LWS and Hazel Hall Farm Quarry LWS	3.0 [2]	10.0 [4&6]	-
Other LWSs	1.0 [1]	10.0 [4&6]	-
Troutsdale and Rosekirk Dale Fens SSSI	3.0 [3]	15.0 [3&4]	-
Nabgate SSSI, Eller's Wood and Sand Dale SSSI, Ellerburn Bank SSSI, Ruston Cottage Pasture SSSI, Raincliffe & Forge Valley Woods SSSI and Seive Dale Fen SSSI	1.0 [1&3]	10.0 [3&4]	-
Newtondale SSSI	1.0 [1&3]	5.0/10.0 [3&4]	-
Cockrah Wood SSSI	3.0 [3]	n/a [5]	-
East Heslerton Brow SSSI	1.0 [1&3]	10.0 [3&4]	-
Spiker's Hill Quarry SSSI, Betton Farm Quarries SSSI and Hackness Head Quarry SSSI and Hackness Rock Pit SSSI	n/a [5]	n/a [5]	n/a [5]

1. A precautionary figure used where no details of the ecology of the site are available, or the citation for the site contains reference to sensitive lichens and/or bryophytes.
2. As stated in Environment Agency pre-application report (EPR/UP3026ST/P001 dated 22/03/2024).
3. Based upon the citation for the site.
4. The lower bound of the range of Critical Loads (Review and revision of empirical critical loads of nitrogen for Europe 2022).
5. No Critical Load available.
6. The Environment Agency pre-application report (EPR/UP3026ST/P001 dated 22/03/2024) assumes a Critical load of 5.0 kg-N/ha/y; however, no habitat that might have a Critical Load of 5.0 kg-N/ha/y is likely to be present (Review and revision of empirical critical loads of nitrogen for Europe 2022).

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.

3.6 Quantification of ammonia emissions

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

The Environment Agency provides an Intensive Farming Guidance note which lists standard ammonia emission factors for a variety of livestock, including for pigs and slurry storage. The emission factors for Hebrons Quarry Farm have been obtained from: https://www.gov.uk/guidance/ammonia-emission-factors-for-pig-and-poultry-screening-modelling-and-reporting#ammonia-emission-factors-for-poultry.

Details of the pig numbers and types, manure storage, emission factors used and calculated ammonia emission rates are provided in Table 2a.

Table 2a. Details of pig numbers, slurry storage and ammonia emission rates

SOURCE	Number of Pigs	Type	Flooring	Ventilation	Emission Factor[1] ($kg\text{-}NH_3$/place/y)	Emission rate[1] ($g\text{-}NH_3$/s)
H1	950	Finisher Pigs	FSF/Shallow Pit	Ridge/Roof fans	2.11	0.063519
H2	950	Finisher Pigs	FSF/Shallow Pit	Ridge/Roof fans	2.11	0.063519
H3	950	Finisher Pigs	FSF/Shallow Pit	Ridge/Roof fans	2.11	0.063519
H4	950	Finisher Pigs	FSF/Shallow Pit	Ridge/Roof fans	2.11	0.063519
SOURCE	Area (m^2)	Type			Emission Factor[1] ($kg\text{-}NH_3/m^2$/y)	Emission rate[1] ($g\text{-}NH_3$/s)
TANK	550.0	Floating Cover			0.45	0.007843

1. Note for AQMAU - Modelling was conducted assuming 4,000 pigs, an emission factor of 2.0 $kg\text{-}NH_3$/place/y for the pig housing and 0.7 $kg\text{-}NH_3/m^2$/y for the slurry tank and modelling results are scaled post modelling. Details of the scaling factors are provided in Table 2b

Table 2b. Details of scaling factors applied post modelling

Source	Modelled Pig Numbers	Modelled EF	Actual Pig Numbers	Actual EF	Housing Scaling Factor
HOUSING	4,000	2	3,800	2.11	1.00225
TANK	346.4	0.7	346.4	0.45	0.64285714

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

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

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

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

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

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

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 2a.

Wind speeds 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 the location of the farm is shown in Figure 2b; it should be noted that elsewhere in the modelling domain the modified wind roses may differ more markedly, reflecting the local flow in that part of the domain. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is approximately 360 m. Please also note that FLOWSTAR 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.

Figure 2a. The wind rose. GFS derived data, for 54.242 N, 0.608 W, 2020 – 2024

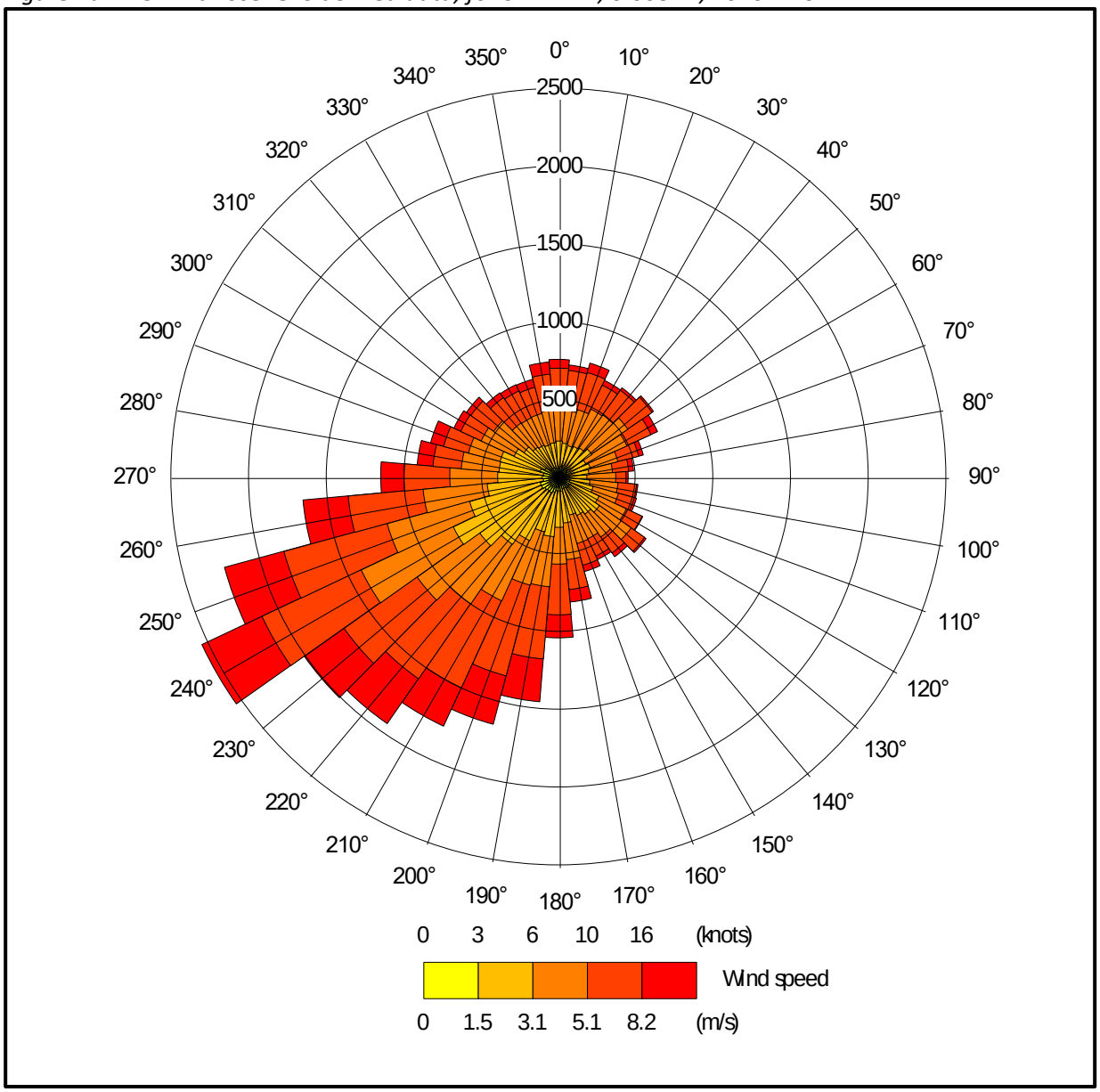
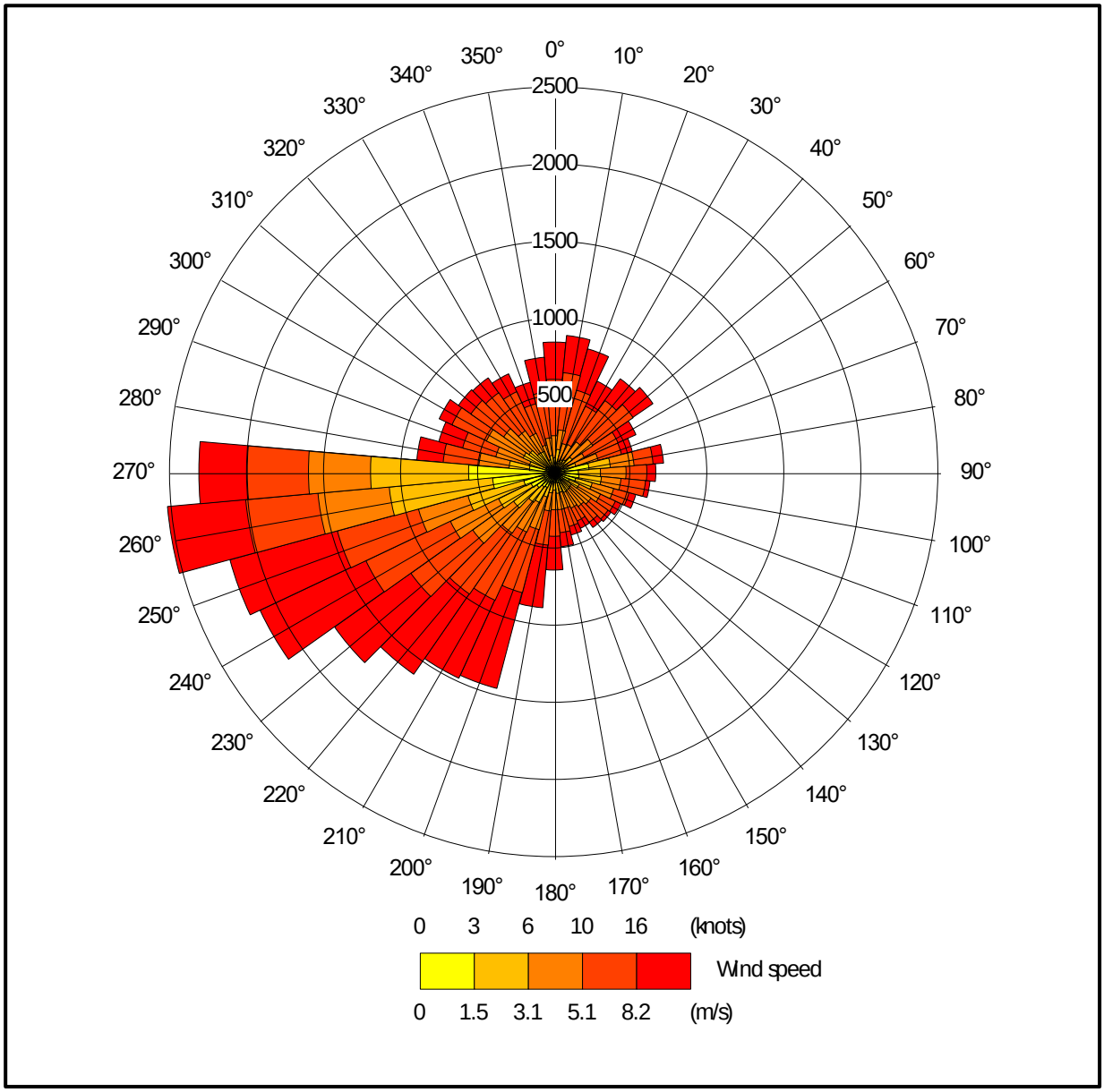


Figure 2b. The wind rose derived from FLOWSTAR output for NGR 490700,483900



4.2 Emission sources

Emissions from the ridge fans that would be used to ventilate the proposed pig houses at Hebrons Quarry Farm are represented by three point sources per building within ADMS. Details of the point source parameters are provided in Table 3a.

Table 3a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source[1] ($g\text{-}NH_3/s$)
H1 to H4: 1, 2 & 3	6.0	0.6	11.0	21.0	0.021125

Fugitive emissions from the slurry storage are represented by a volume source within ADMS. Details of the volume source parameters are given in Table 3b.

Table 3b. Volume source parameters

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate[1] ($g\text{-}NH_3/s$)
TANK	21.0	21.0	1.0	5.0	Ambient	0.012200

1. Note for AQMAU - Modelling was conducted assuming an emission factor of 2.0 $kg\text{-}NH_3$/place/y for the pig housing and 0.7 $kg\text{-}NH_3/m^2/y$ for the slurry tank and modelling results above are scaled post modelling.

The positions of the sources may be seen in Figure 3 (point sources – green circles and volume source – red shaded polygon).

4.3 Modelled buildings

The structure of the buildings may affect the plumes from the point sources. Therefore, the buildings are modelled within ADMS. The positions of the modelled buildings in the baseline and proposed scenarios may be seen in Figure 3 (marked by grey rectangles).

4.4 Discrete receptors

Twenty-seven 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 4 (marked by enumerated pink rectangles).

4.5 Cartesian grid

To produce the contour plots presented in Section 5 of this report and to define the spatially varying deposition velocity field, two regular Cartesian grids have been defined within ADMS. The individual grid receptors are defined at ground level within ADMS.

4.6 Terrain data

Terrain has been considered in the modelling. The terrain data are based upon the Ordnance Survey 50 m Digital Elevation Model. A 23.0 km x 23.0 domain has been resampled at 100 m horizontal resolution for use within ADMS. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is approximately 360 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 0.295 m (arithmetic average of the spatially varying roughness over the modelling domain). The sample of the central area of the spatially varying roughness length field is shown in Figure 5.

Figure 3. The positions of the modelled buildings and sources

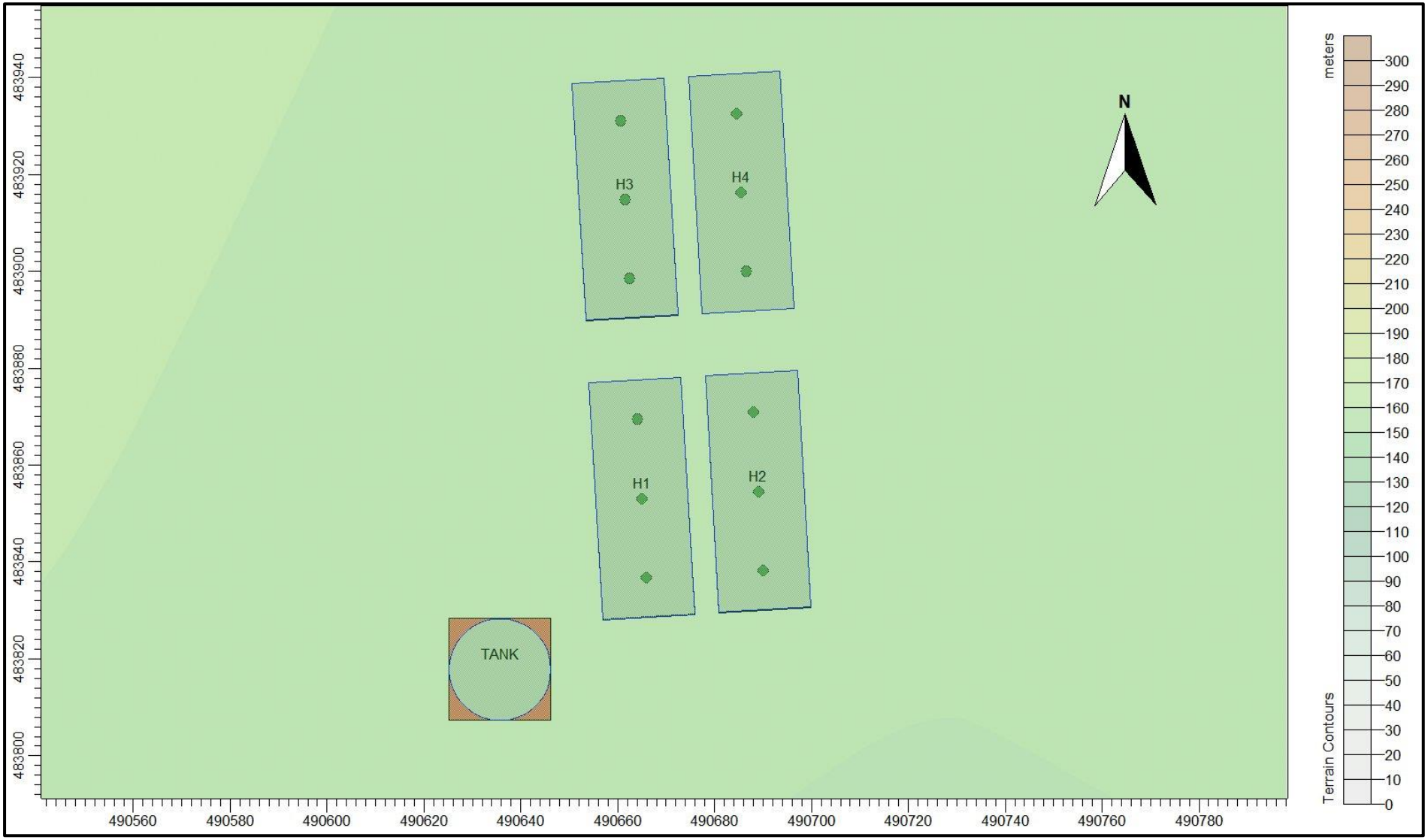


Figure 4. The discrete receptors and Cartesian grids

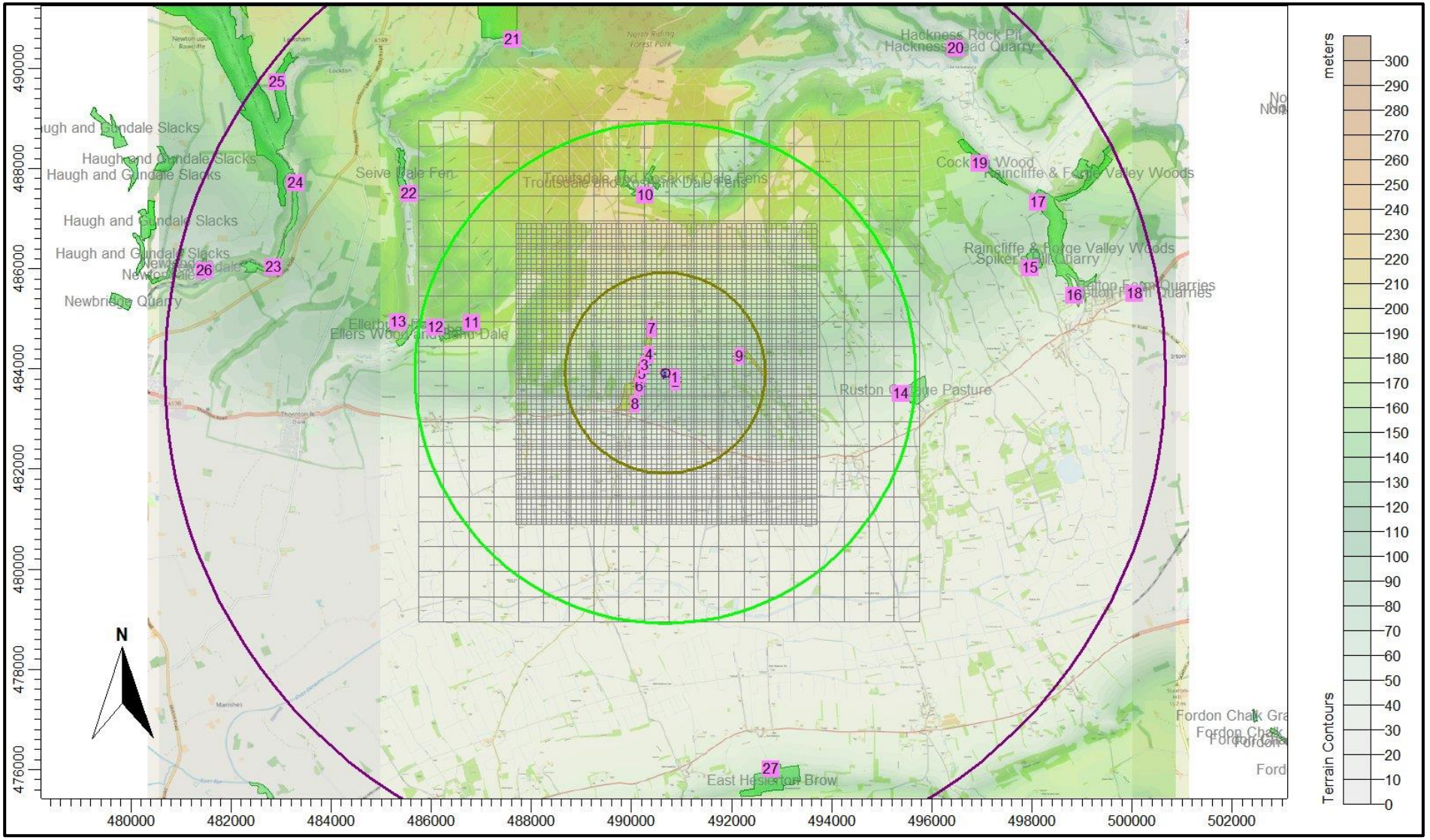
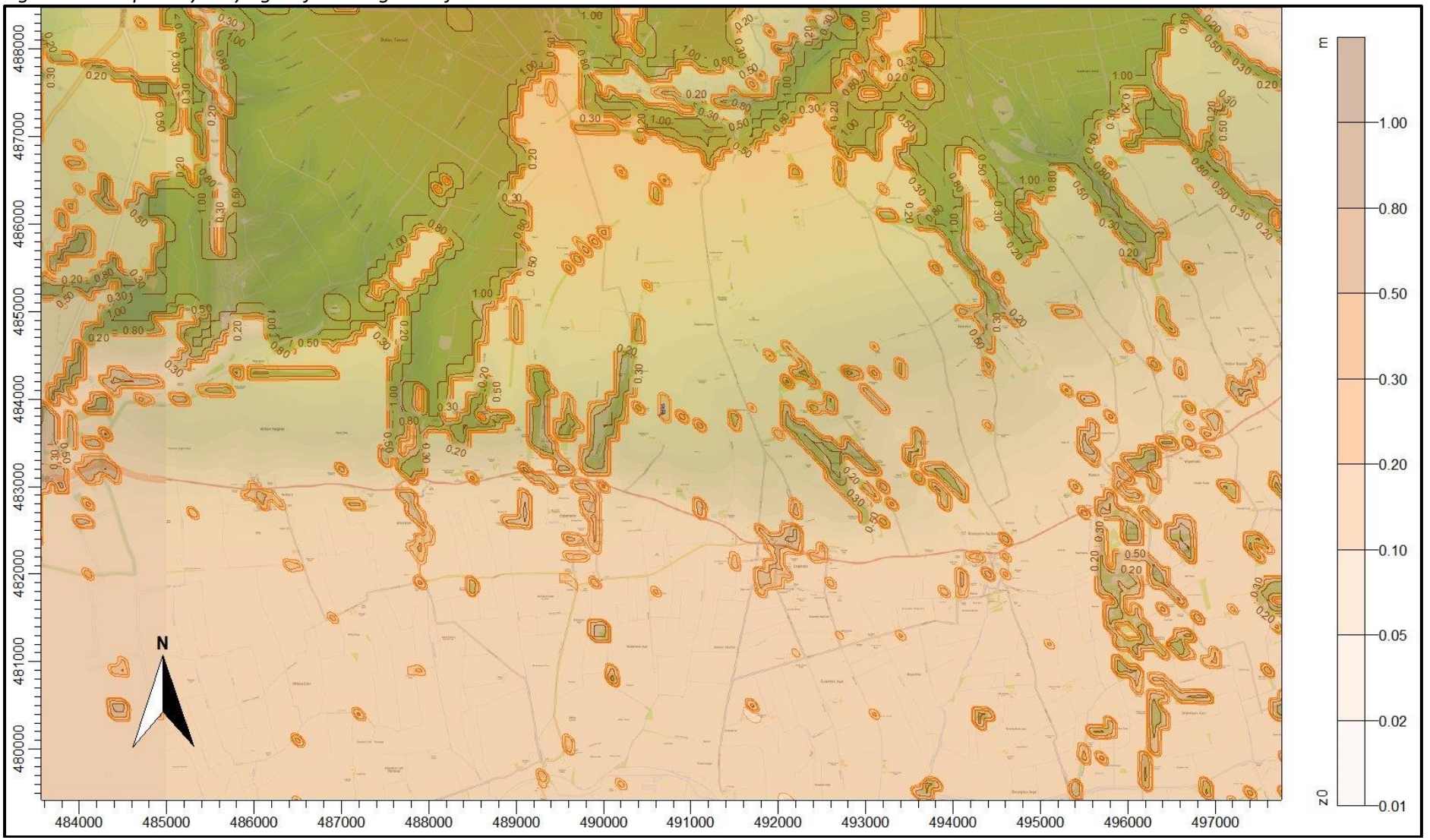


Figure 5. The spatially varying surface roughness field



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 livestock 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.

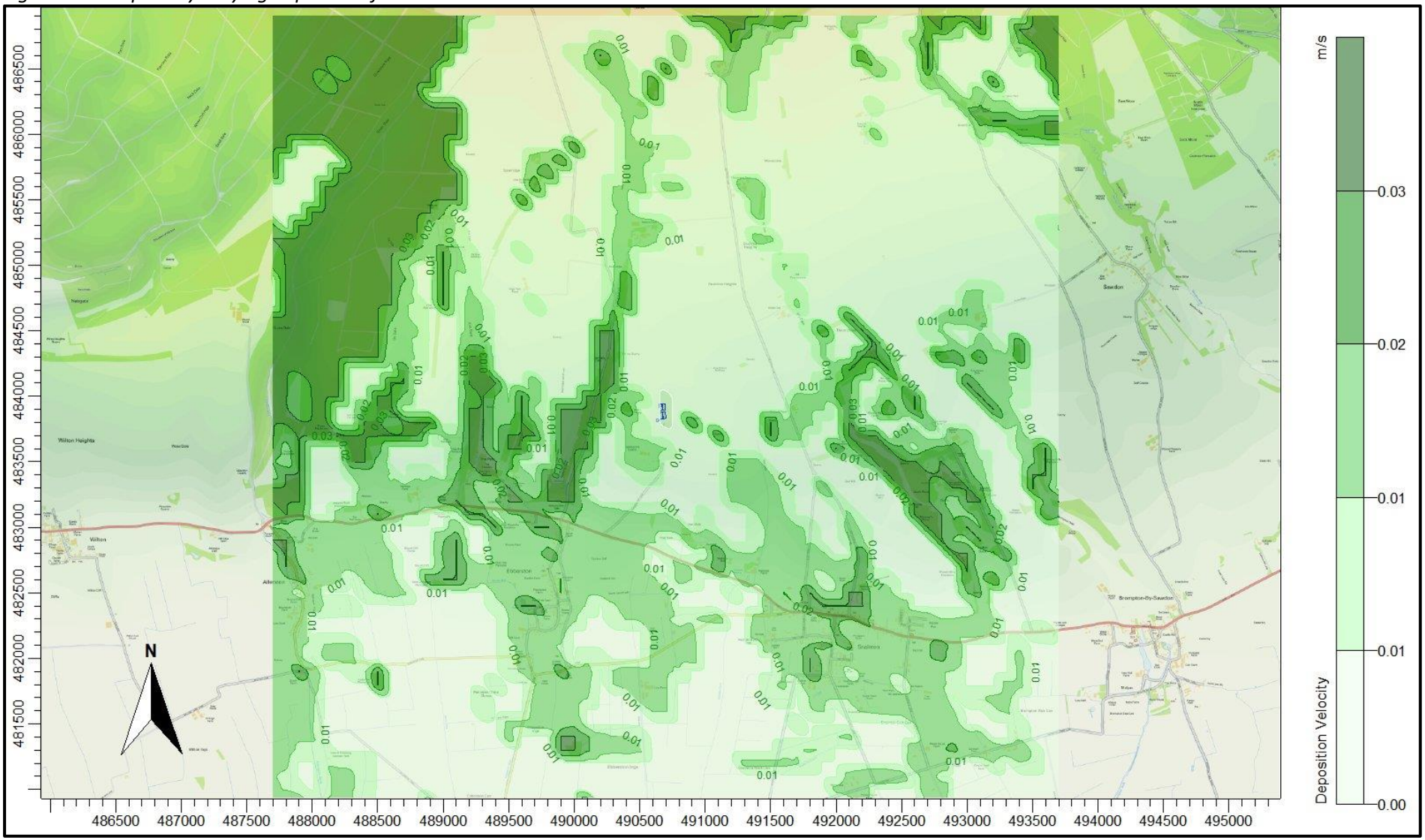
Table 4. Deposition velocities

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

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

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

Figure 6. The spatially varying deposition field



4. Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

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

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

For each mode, statistics for the maximum annual mean ammonia concentration at each receptor were compiled. Details of the predicted annual mean ammonia concentrations at each receptor are provided in Table 5. The primary purpose of the preliminary modelling is to assess the effect of calms on the results.

Table 5. Predicted maximum annual mean ammonia concentrations at the discrete receptors - preliminary modelling

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)	
				No Calms No Terrain	Calms No Terrain
1	490868	483833	LWS	1.319	1.319
2	490880	483734	LWS	0.780	0.782
3	490270	484082	LWS	0.310	0.313
4	490361	484291	LWS	0.281	0.282
5	490217	483898	LWS	0.240	0.246
6	490159	483646	LWS	0.186	0.190
7	490403	484794	LWS	0.119	0.120
8	490069	483303	LWS	0.129	0.131
9	492158	484248	LWS	0.128	0.127
10	490269	487462	Troutsdale and Rosekirk Dale Fens SSSI	0.023	0.023
11	486818	484927	Nabgate SSSI	0.017	0.017
12	486078	484845	Eller's Wood and Sand Dale SSSI	0.013	0.013
13	485352	484950	Ellerburn Bank SSSI	0.011	0.011
14	495386	483507	Ruston Cottage Pasture SSSI	0.024	0.024
15	497965	486020	Spiker's Hill Quarry SSSI	0.021	0.021
16	498843	485468	Raincliffe & Forge Valley Woods SSSI	0.017	0.016
17	498128	487337	Raincliffe & Forge Valley Woods SSSI	0.020	0.020
18	500046	485500	Betton Farm Quarries SSSI	0.014	0.013
19	496958	488101	Cockrah Wood SSSI	0.019	0.019
20	496486	490408	Hackness Head Quarry SSSI and Hackness Rock Pit SSSI	0.013	0.013
21	487629	490587	Bride Stones SSSI	0.009	0.009
22	485548	487499	Seive Dale Fen SSSI	0.013	0.013
23	482850	486036	Newtondale SSSI	0.008	0.008
24	483289	487727	Newtondale SSSI	0.009	0.009
25	482932	489726	Newtondale SSSI	0.008	0.008
26	481469	485971	Newtondale SSSI	0.006	0.006
27	492781	476025	East Heslerton Brow SSSI	0.006	0.006

5.2 Detailed deposition modelling

Detailed modelling has been carried out over a high resolution (100 m) domain that extends 6.0 km by 6.0 km around the site. 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 domain, a fixed deposition velocity of 0.005 m/s is assumed (with appropriate deposition velocities applied post-modelling at the discrete receptors).

The detailed deposition run was made with terrain. Calms cannot be used with terrain or spatially varying deposition, but in this case, the preliminary modelling indicates that the effects of calms, are not significant.

In this case, there are no predicted ammonia concentrations or nitrogen deposition rates that are in excess of the Environment Agency's upper threshold (100% of Critical level/Load for non-statutory sites, 50% a SSSI and 20% for an internationally designated site), nor in the range between the Environment Agency's upper threshold and lower threshold (100% and 100% of Critical level/Load for non-statutory sites, 20% and 50% a SSSI and 4% and 20% for an internationally designated site). Any exceedances of 1% of the relevant Critical Level or Load at statutory wildlife sites are highlighted with bold text in the Tables.

Contour plots of the predicted maximum annual mean ammonia concentration and the maximum annual nitrogen deposition rates are shown in Figures 7a and Figure 7b.

Table 6. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m^3)	Critical Load (kg/ha)	Process Contribution (µg/m^3)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	490868	483833	LWS	0.03	3.0	10.0	1.2214	40.71	9.516	95.16
2	490880	483734	LWS	0.03	3.0	10.0	0.6852	22.84	5.338	53.38
3	490270	484082	LWS	0.03	1.0	10.0	0.2779	27.79	2.165	21.65
4	490361	484291	LWS	0.03	1.0	10.0	0.2234	22.34	1.740	17.40
5	490217	483898	LWS	0.03	1.0	10.0	0.2403	24.03	1.872	18.72
6	490159	483646	LWS	0.03	1.0	10.0	0.1441	14.41	1.123	11.23
7	490403	484794	LWS	0.03	1.0	10.0	0.0731	7.31	0.569	5.69
8	490069	483303	LWS	0.02	3.0	10.0	0.0967	3.22	0.502	5.02
9	492158	484248	LWS	0.03	1.0	10.0	0.1506	15.06	1.174	11.74
10	490269	487462	Troutsdale and Rosekirk Dale Fens SSSI	0.02	1.0	15.0	0.0086	0.86	0.044	0.30
11	486818	484927	Nabgate SSSI	0.03	1.0	10.0	0.0056	0.56	0.044	0.44
12	486078	484845	Eller's Wood and Sand Dale SSSI	0.03	1.0	10.0	0.0046	0.46	0.036	0.36
13	485352	484950	Ellerburn Bank SSSI	0.02	1.0	10.0		0.00	0.000	0.00
14	495386	483507	Ruston Cottage Pasture SSSI	0.02	1.0	10.0	0.0129	**1.29**	0.067	0.67
15	497965	486020	Spiker's Hill Quarry SSSI	0.03	n/a	n/a	0.0157	-	0.122	-
16	498843	485468	Raincliffe & Forge Valley Woods SSSI	0.03	1.0	10.0	0.0140	**1.40**	0.109	**1.09**
17	498128	487337	Raincliffe & Forge Valley Woods SSSI	0.03	1.0	10.0	0.0118	**1.18**	0.092	0.92
18	500046	485500	Betton Farm Quarries SSSI	0.03	n/a	n/a	0.0112	-	0.087	-
19	496958	488101	Cockrah Wood SSSI	0.03	3.0	n/a	0.0084	0.28	0.065	-
20	496486	490408	Hackness Head Quarry SSSI and Hackness Rock Pit SSSI	0.02	n/a	n/a	0.0051	-	0.027	-
21	487629	490587	Bride Stones SSSI	0.03	1.0	10.0	0.0018	0.18	0.014	0.14
22	485548	487499	Seive Dale Fen SSSI	0.03	1.0	10.0	0.0034	0.34	0.027	0.27
23	482850	486036	Newtondale SSSI	0.03	1.0	10.0	0.0034	0.34	0.026	0.26
24	483289	487727	Newtondale SSSI	0.03	1.0	5.0	0.0028	0.28	0.022	0.44
25	482932	489726	Newtondale SSSI	0.03	1.0	5.0	0.0024	0.24	0.019	0.37
26	481469	485971	Newtondale SSSI	0.03	1.0	5.0	0.0033	0.33	0.026	0.51
27	492781	476025	East Heslerton Brow SSSI	0.03	3.0	10.0	0.0026	0.09	0.021	0.21

Figure 7a. Maximum annual ammonia concentration

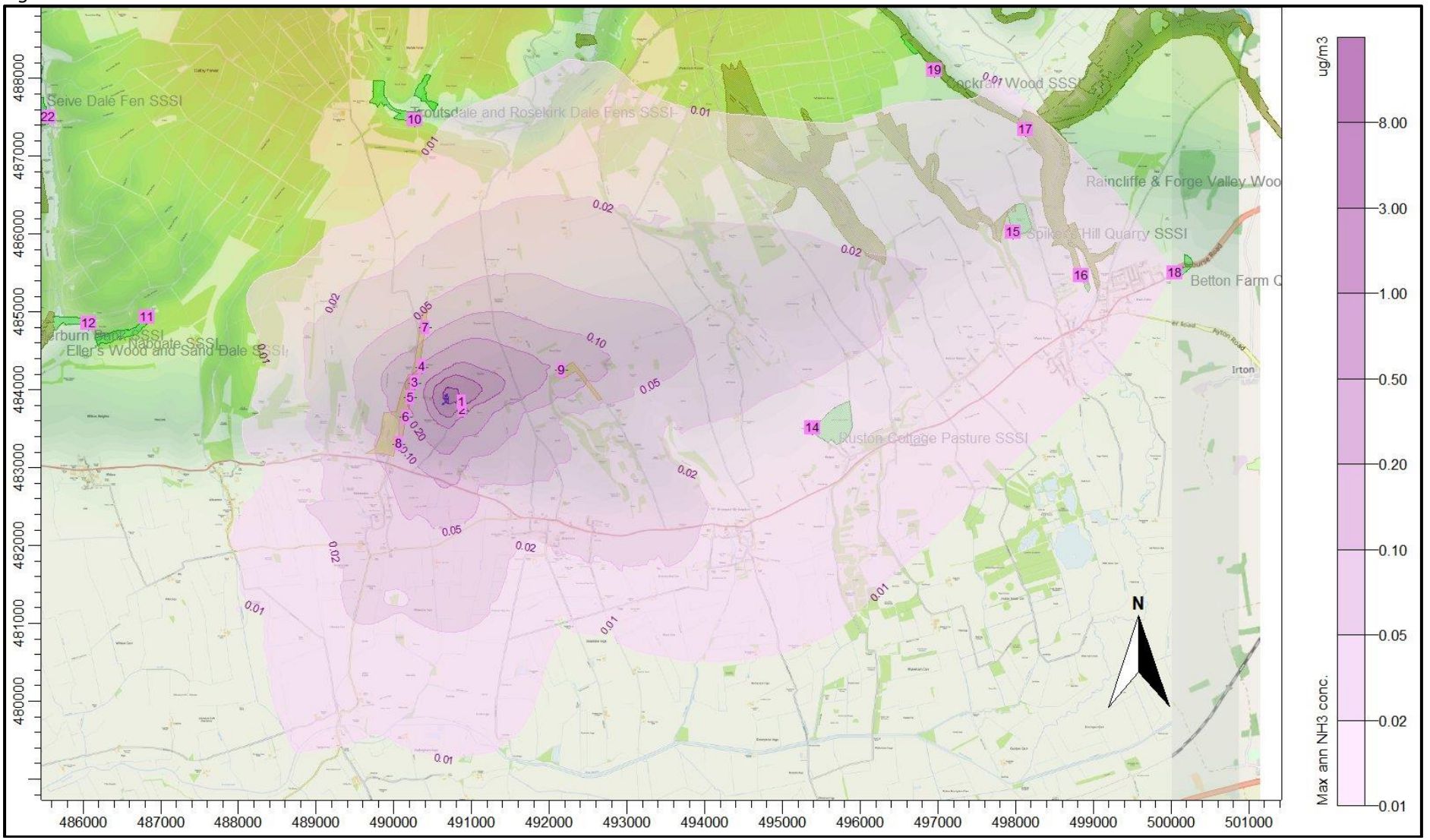
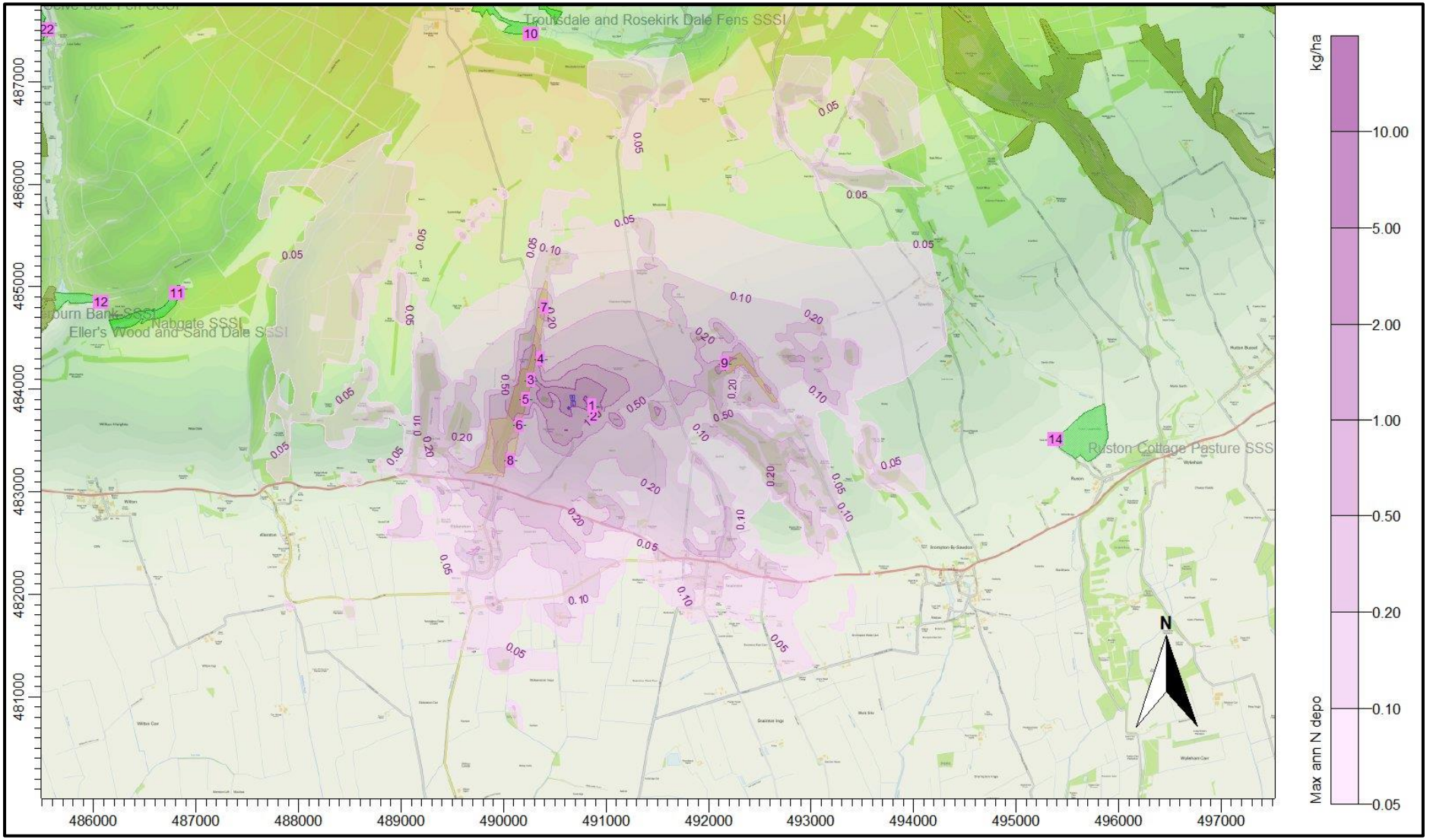


Figure 7b. Maximum annual nitrogen deposition rates



5. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Ms. Lizzie Bentley of Yorkshire Farmers, on behalf of Mr. Andrew Hebron, to use computer modelling to assess the impact of ammonia emissions from the proposed pig rearing houses at Hebrons Quarry Farm - Pig Unit, Quarry Farm, Sandsprunt Lane, Ebberston, Scarborough, North Yorkshire. YO13 9PA.

Ammonia emission rates from the proposed pig rearing houses have been assessed and quantified based upon: Environment Agency 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.

The modelling predicts that:

- At the LWSs, the process contribution to maximum annual ammonia concentration would be below the Environment Agency's lower threshold percentage of 100% (for a non-statutory site) of the Critical Level and Critical Load.

- Process contributions would be below the Environment Agency lower threshold percentage of 20% (for a SSSI) of the relevant Critical Level or Load at all of the SSSIs considered. However, there would be minor exceedances of 1% of the relevant Critical Level or Load at Ruston Cottage Pasture SSSI and Raincliffe & Forge Valley Woods SSSI.

6. References

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Frederik Schrader and Christian Brümmer. Land Use Specific Ammonia Deposition Velocities: a Review of Recent Studies (2004-2013).

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UK Air Pollution Information System (APIS) (website).