



A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Piggery at West Shaws, Westwick, near Barnard Castle in County Durham

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Mrs. Lizzie Bentley on behalf of GR Herbert & Sons, to use computer modelling to assess the impact on statutory wildlife sites of ammonia emissions from the piggery at West Shaws, Westwick, near Barnard Castle in County Durham. DL12 8UT.

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

This report is arranged in the following manner:

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

2. Background Details

West Shaws is in a rural area, approximately 2.2 km to the east-south-east of Barnard Castle in County Durham. The surrounding land is used almost exclusively for arable farming with several wooded areas nearby. The site is at an elevation of around 160 m above sea level, rising gently towards higher ground to the north and falling towards the River Tees to the south.

There is currently a single pig rearing building at West Shaws accommodating up to 1,800 pigs, which are reared from a weight of around 30 kg. The pigs are housed on a fully slatted floor system with deep pit, which has sufficient slurry storage for up to six months. The house is ventilated by side vents and roof inlets.

Under the proposal, a new pig rearing building would be constructed on land directly to the north of the existing building at West Shaws. The new building would be used to accommodate up to 1,500 production pigs (>30 kg) in addition to the 1,800 pigs in the existing building. The pigs in both the existing and proposed buildings would be housed on slatted floors under which slurry would collect, prior to frequent transfer (every twelve weeks) to a storage tank elsewhere. With the exception of the housing, no manure or slurry would be stored on site. The proposed building would be ventilated by high-speed ridge/roof fans, each with a short chimney.

Three scenarios are presented in this report:

- Baseline scenario – as permitted for 1,800 30+ kg pigs with slatted floor and deep pit.
- Proposed scenario – sought permit variation for 3,300 30+ kg pigs with slatted floor and frequent slurry removal.
- Proposed House Only – 1,600 30+ kg pigs with slatted floor and frequent slurry removal.

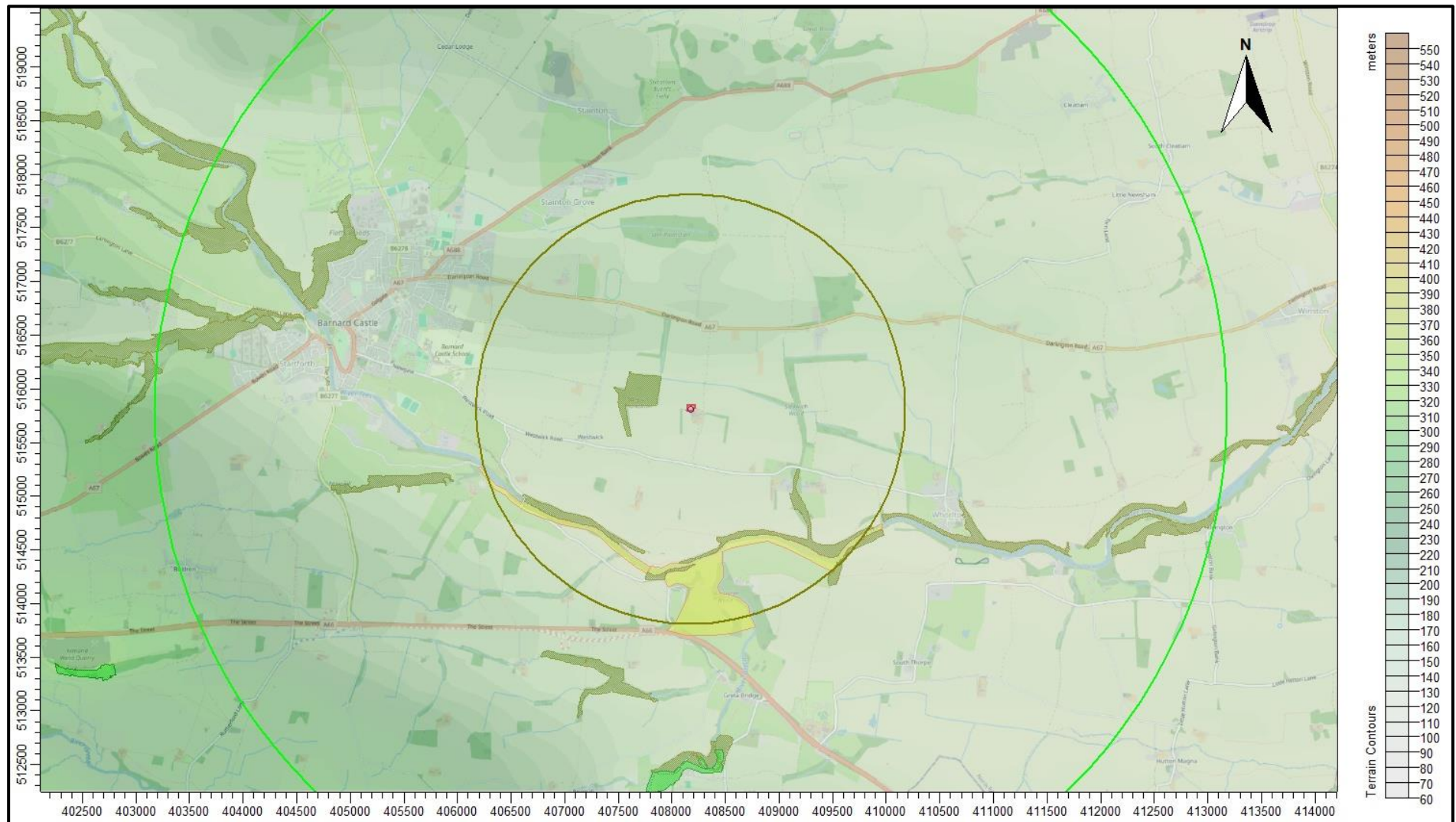
There are several areas designated as Ancient Woodlands (AWs) and Local Wildlife Sites (LWSs) within 2 km (the normal screening distance for non-statutory sites). There is one Site of Special Scientific Interest (SSSIs) within 5 km. There is also one Special Area of Conservation (SAC) and one Special Protection Area (SPA) within 10 km of the site. Further details of the statutory sites are provided below:

- **Brignall Banks SSSI** - Approximately 3.1 km to the south - One of the largest expanses of semi-natural woodland in North-East England containing a number of scarce species and supporting a varied bryophyte and lichen flora including several lichens sensitive to air pollution and rare in County Durham (*Thelotrema lepadinum*, *Graphis scripta* and various *Pertusaria* species).
- **North Pennine Moor SPA** - Approximately 8.2 km to the west (closest point) - Internationally important site for the Conservation of Wild Birds including *Falco peregrinus*, *Falco columbarius* and *Circus cyaneus*.
- **Helbeck and Swindale Woods SAC** - Approximately 8.2 km to the west (closest point) - Mixed woodland of ash, elm and a rich ground flora.

Maps of the surrounding area showing the positions of the piggery and the wildlife sites are provided in Figures 1a and 1b. The site of the pig rearing houses is outlined in red, the AWs are shaded olive, the LWSs are shaded yellow, the SSSIs are shaded green and the SPA/SAC is shaded orange.

The map displays the terrain contours of the Barnard Castle area. The elevation scale ranges from 60 to 550 meters. The map includes a north arrow and a color-coded elevation legend on the right. The map shows the River Ure flowing through the area, with several roads and settlements labeled. Three concentric circles are drawn around a central point marked with a red dot, representing the 100m, 200m, and 300m buffers. The purple circle (300m) is the largest, followed by the green circle (200m), and the yellow circle (100m) is the smallest. The map also shows the River Ure and several roads, including the A66 and A67.

Figure 1b. The area surrounding West Shaws – a closer view



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

3.1 Ammonia concentration and nitrogen and acid deposition

When assessing potential impact on ecological receptors, ammonia concentration is usually expressed in terms of micrograms of ammonia per metre cubed of air ($\mu\text{g-NH}_3/\text{m}^3$) as an annual mean. Ammonia in the air may exert direct effects on the vegetation, or indirectly affect the ecosystem through deposition which causes both hyper-eutrophication (excess nitrogen enrichment) and acidification of soils. Nitrogen deposition, specifically in this case the nitrogen load due to ammonia deposition/absorption is usually expressed in kilograms of nitrogen per hectare per year (kg-N/ha/y). Acid deposition is expressed in terms of kilograms equivalent (of H^+ ions) per hectare per year (keq/ha/y).

3.2 Background ammonia levels and nitrogen and acid deposition

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

The APIS figures for background ammonia concentration in the area around West Shaws is $1.41 \mu\text{g-NH}_3/\text{m}^3$. The background nitrogen deposition rate to woodland is 25.54 kg-N/ha/y and to short vegetation is 14.32 kg-N/ha/y . The background acid deposition rate to woodland is 1.93 keq/ha/y and to short vegetation is 1.09 keq/ha/y .

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

3.3 Critical Levels & Critical Loads

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

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

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

For ammonia concentration in air, the Critical Level for higher plants is 3.0 $\mu\text{g-NH}_3/\text{m}^3$ as an annual mean. For sites where there are sensitive lichens and bryophytes present, or where lichens and bryophytes are an integral part of the ecosystem, the Critical Level is 1.0 $\mu\text{g-NH}_3/\text{m}^3$ 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. N.B. Where the Critical Level of 1.0 $\mu\text{g-NH}_3/\text{m}^3$ is assumed, it is usually unnecessary to consider the Critical Load as the Critical Level provides the stricter test. However, it may be necessary to consider nitrogen deposition should a Critical Load of 5.0 kg-N/ha/y be appropriate. Normally, the Critical Load for nitrogen deposition provides a stricter test than the Critical Load for acid deposition.

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

Site	Critical Level ($\mu\text{g-NH}_3/\text{m}^3$)	Critical Load Nitrogen (kg-N/ha/y)	Critical Load Acid (keq/ha/y)
Sally Gill Plantation AW	1.0 ^{1 & 2}	10.0 ¹	1.73 ¹
Other AWs & LWSs	1.0 ²	10.0 ²	-
Brignall Banks SSSI	1.0 ³	10.0 ⁴	-
Helbeck and Swindale Woods SAC	1.0 ⁵	10.0 ⁴	-
North Pennine Moor SPA	n/a ⁵	5.0 ⁴	-

1. Critical Loads given in the EA pre-application report (23/04/2024).
2. A precautionary figure used where details of the site are unavailable.
3. The lower bound of the range of Critical Levels (1.0 $\mu\text{g}/\text{m}^3$) for habitats/species present at the site has been retained as a precaution as APIS/the citations of the sites indicate that sensitive lichens and/or bryophytes are/may be present.
4. The lower bound of the range of Critical Loads for habitats/species present at the site (APIS and the ‘Review and revision of empirical critical loads of nitrogen for Europe’, 2022).
5. No Critical Level for habitat given as stated in APIS.

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% (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 installations¹ might act in-combination or cumulatively with the farm and the sensitivities of the wildlife sites.

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

3.5 Quantification of ammonia emissions

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

Existing Scenario

AS Modelling & Data Ltd. understands that an ammonia emission factor based on the pre-November 2024 Environment Agency standard ammonia emission factors has been agreed to calculate emission rates from the aging, deep pit housing in the existing scenario at West Shaws.

Proposed Scenario

The emission factor used for the proposed piggery at West Shaws has been based upon the Environment Agency standard ammonia emission factors obtained from: <https://www.gov.uk/guidance/ammonia-emission-factors-for-pig-and-poultry-screening-modelling-and-reporting#ammonia-emission-factors-for-poultry>.

The Environment Agency emission factor for pigs with fully slatted flooring is 2.813 kg-NH₃/pig-place/y, this is based on assumed an occupancy rate of 87% and feed protein content of 18%. For the pigs at West Shaws, the occupancy rate would be 76% and the average protein content of the feed would be 15.1%; therefore, the standard emission factor for the proposed piggery has been adjusted to account for this. The adjusted emission factor is 1.966 kg-NH₃/pig-place/y (factors of 0.87 to account for occupancy and 0.8 to account for protein content have been applied).

Details of the pig numbers, emission factors used and calculated ammonia emission rates are provided in Tables 2a and 2b.

Table 2a. Details of slurry store and ammonia emission rates – existing scenario

Source	Animal numbers	Housing Type	Emission factor (kg-NH ₃ /place/y)	Emission rate (g-NH ₃ /s)
Existing pig rearing house	1,800	Slatted floor - deep pit	4.14	0.236140

Table 2b. Details of pig numbers and ammonia emission rates

Source	Animal numbers	Type or weight	Emission factor (kg-NH ₃ /place/y)	Emission rate (g-NH ₃ /s)
Existing pig rearing house	1,800	Fully slatted floor with a vacuum	1.966	0.112138
Proposed pig rearing house	1,500	Fully slatted floor with a vacuum	1.966	0.093448

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

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

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

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

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

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

4.1 Meteorological data

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

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

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

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

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 2a. Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and because terrain data is included in the modelling, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for the location of West Shaws is shown in Figure 2b; as might be expected, Figures 2a and 2b show little modification in this case, however, elsewhere in the modelling domain the modified wind roses may differ more markedly, reflecting the local flow in that part of the domain. The resolution of FLOWSTAR is 64 by 64 grid points and the effective resolution of the wind field is approximately 340 m. Please note that FLOWSTAR¹ 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 σ_z of the Gaussian plume model is overly constrained, which for elevated point sources emissions, may on occasion cause over prediction of ground level concentrations in stable weather conditions and light winds (Steven R. Hanna & Biswanath Chowdhury, 2013), conversely for low level emission sources, this will cause gross under prediction. Note that this becomes particularly important overnight and if calm and light wind conditions are not being ignored, as they often are when using traditional observational meteorological datasets. To reduce this behaviour, where terrain is modelled, AS Modelling & Data Ltd. have set a minimum turbulence length of 0.025 m in ADMS. This approximates the normal behaviour of ADMS with flat terrain.

Figure 2a. The wind rose. Raw GFS derived data for 54.537 N, 1.874 W, 2020-2023

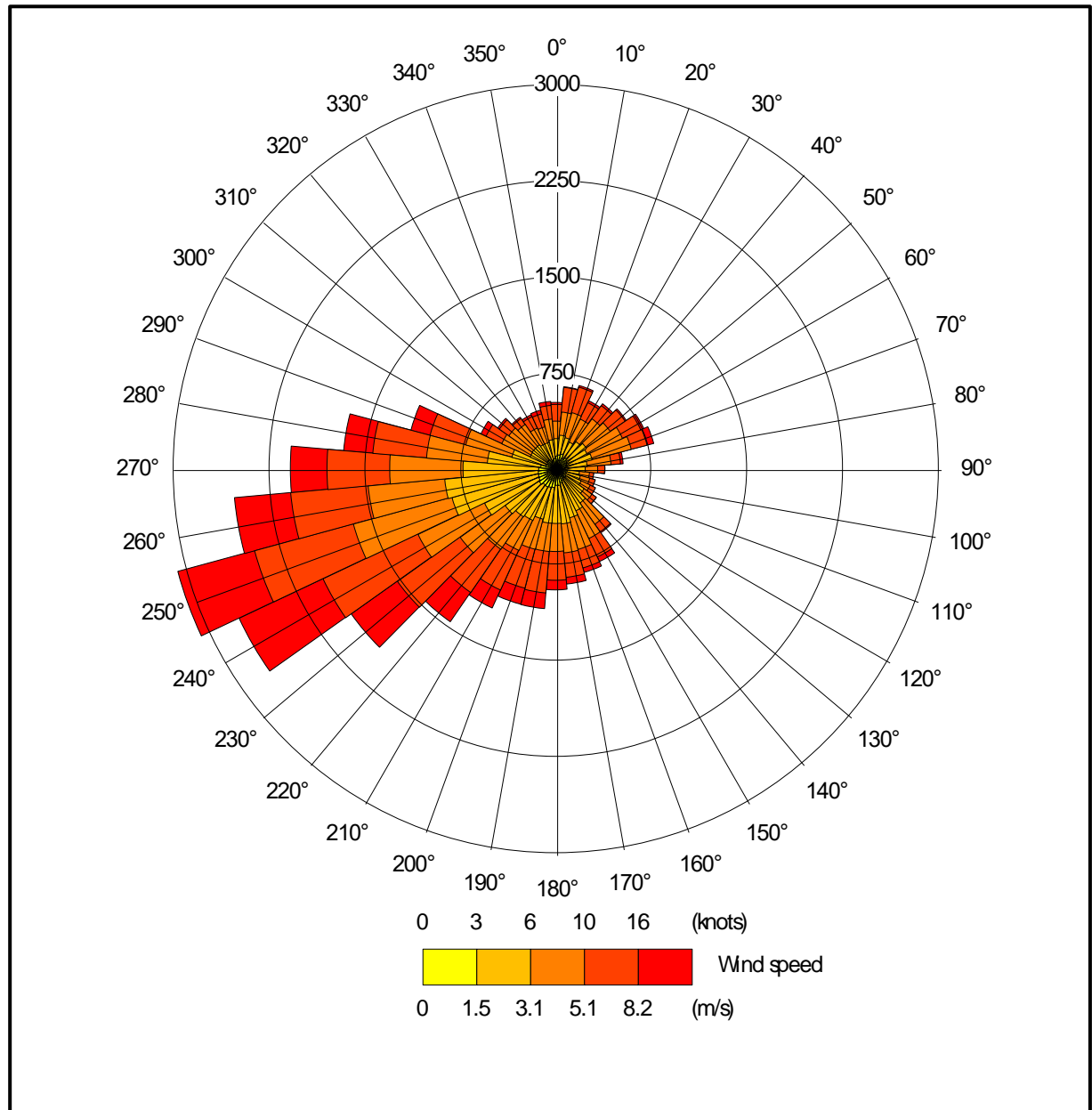
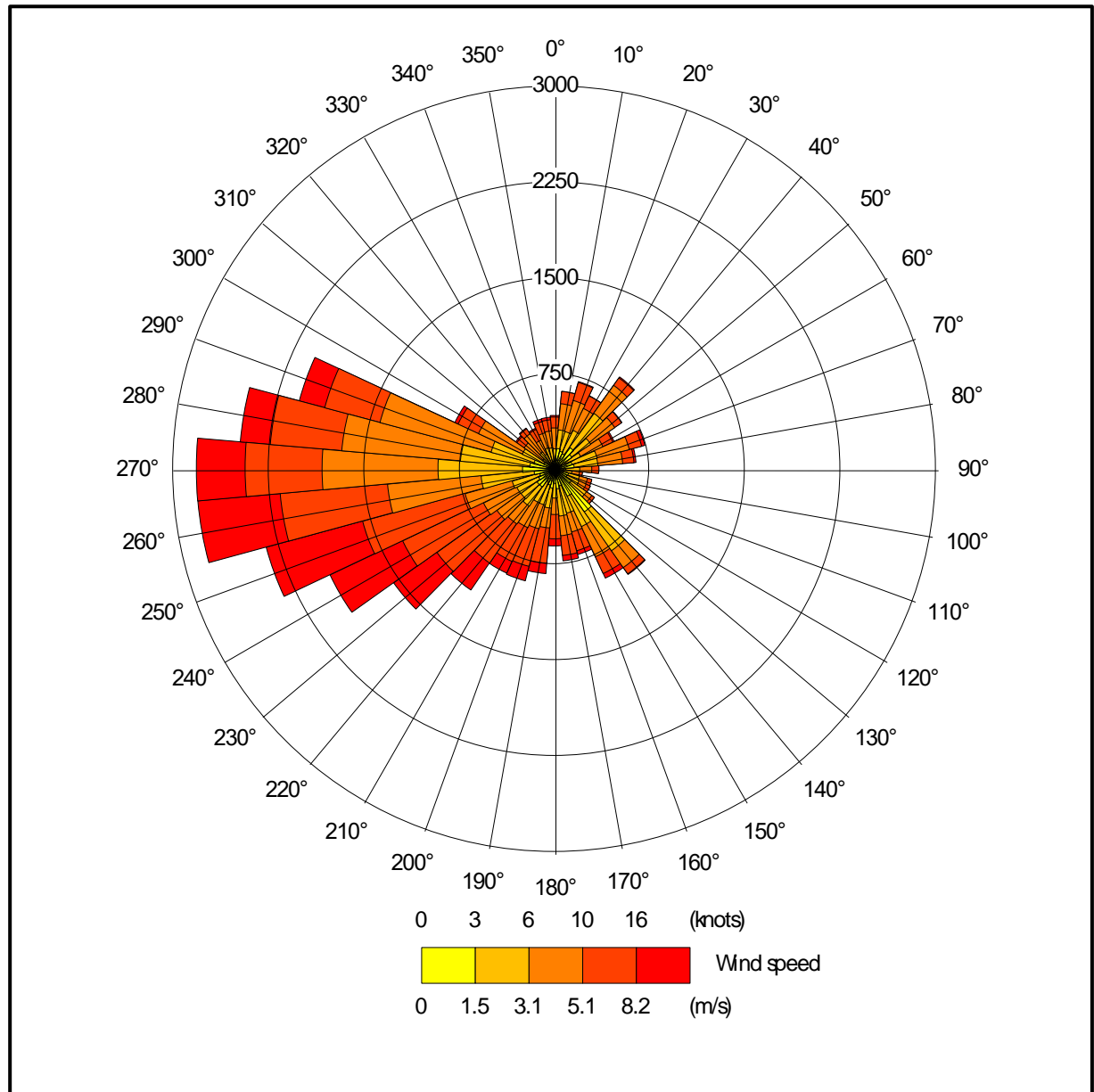


Figure 2b. The wind rose. FLOWSTAR derived data for NGR 408150, 515800, 2020-2023



4.2 Emission sources

Emissions from the uncapped high speed roof fans that would be used to ventilate the proposed new pig rearing houses are represented by point sources 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 (g-NH ₃ /s)
PR; 1, 2 & 3	6.0	0.8	11.0	21.0	0.031149

Emissions from side vents and roof inlets on the existing poultry house are represented by a single volume source within ADMS. Details of the volume source parameters are given in Table 3b.

Table 3b. Volume source parameters

Source ID (scenario)	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH ₃ /s)
EX (existing scenario)	55.6	19.4	2.0	3.0	Ambient	0.236140
EX (proposed scenario)	55.6	19.4	2.0	3.0	Ambient	0.112138

The positions of the sources may be seen in Figures 3a and 3b (point sources - green circles and volume source - red shaded rectangle).

4.3 Modelled buildings

The structure of the pig rearing houses and other farm buildings may affect the plumes from the proposed point sources. Therefore, these buildings are modelled within ADMS in the proposed scenario. The positions of the modelled buildings may be seen in Figure 3 (marked by grey rectangles).

4.4 Discrete receptors

Thirty-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 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 field used in the detailed modelling, two regular Cartesian grids have been defined at ground level within ADMS. The positions of the Cartesian grids may be seen in Figures 4a and 4b (marked by grey lines).

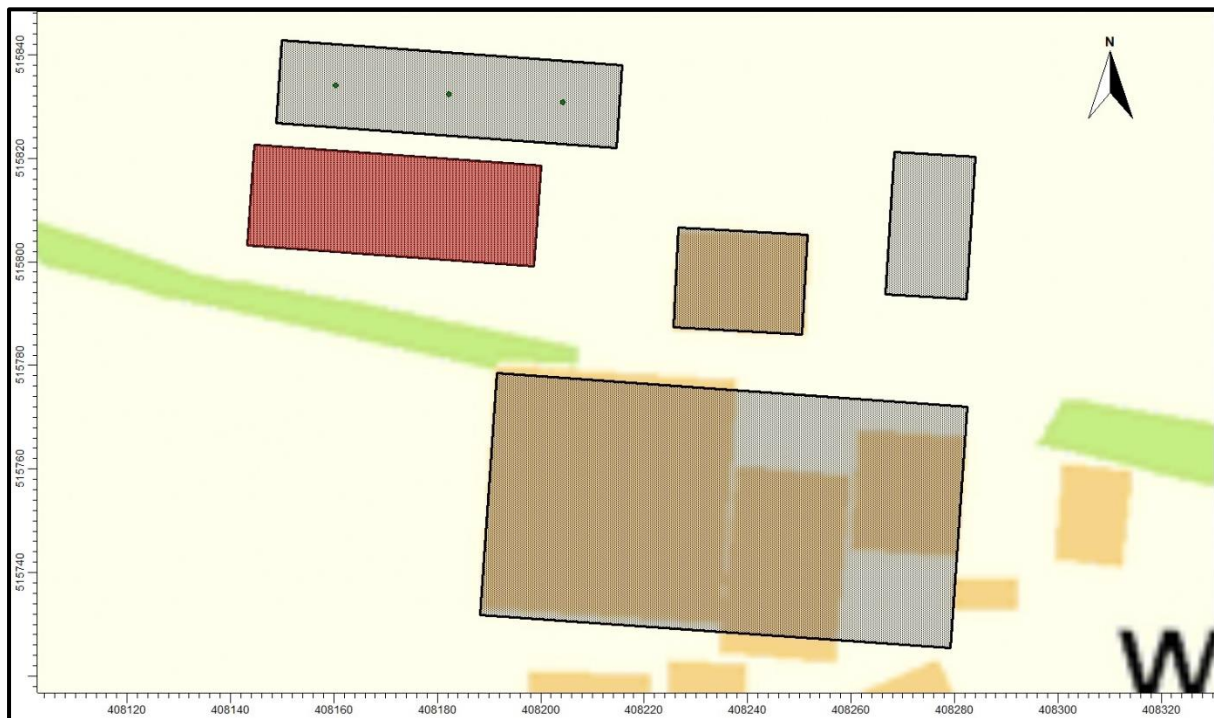
4.6 Terrain data

Terrain has been considered in the modelling. The terrain data are based upon the Ordnance Survey 50 m Digital Elevation Model. A 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 for the terrain runs is approximately 340 m.

4.7 Roughness Length

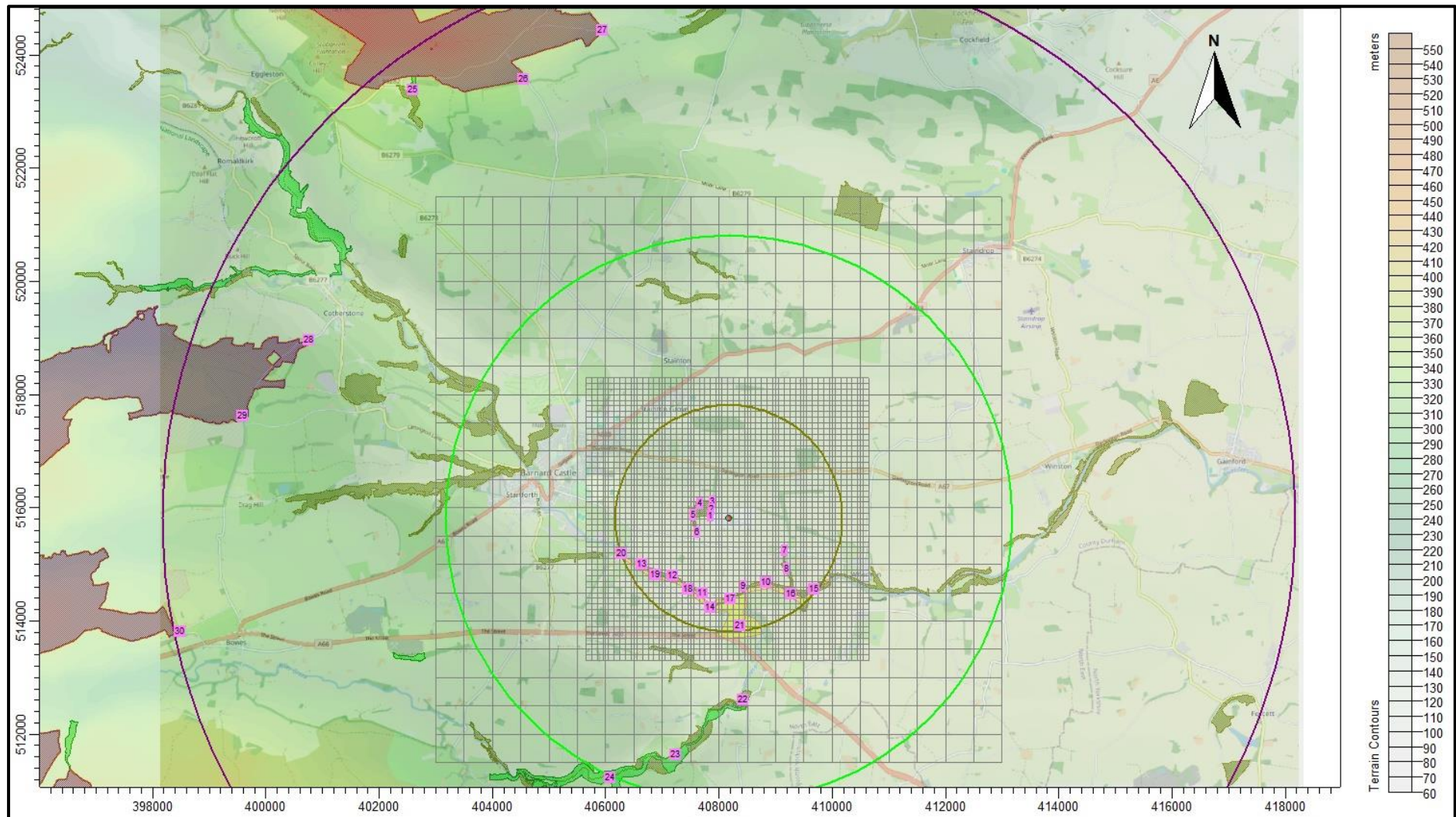
In this case, a spatially varying roughness length file has been defined, this is based upon the data provided in the UK Centre for Ecology and Hydrology Land Cover Maps. The GFS meteorological data is assumed to have a roughness length of 0.18 m (arithmetic average of the spatially varying roughness 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 at West Shaws



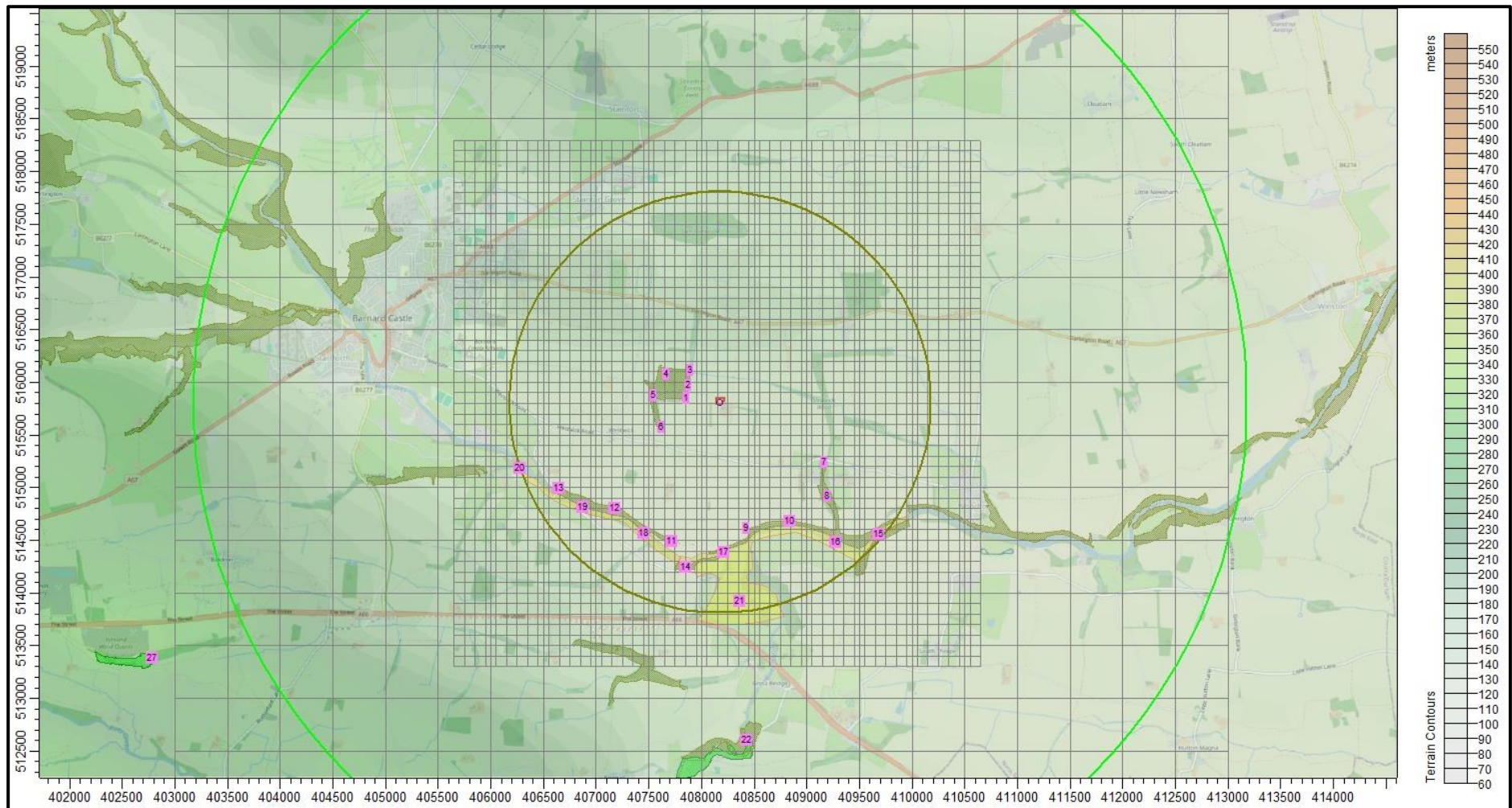
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Figure 4a. The discrete receptors and regular Cartesian grids



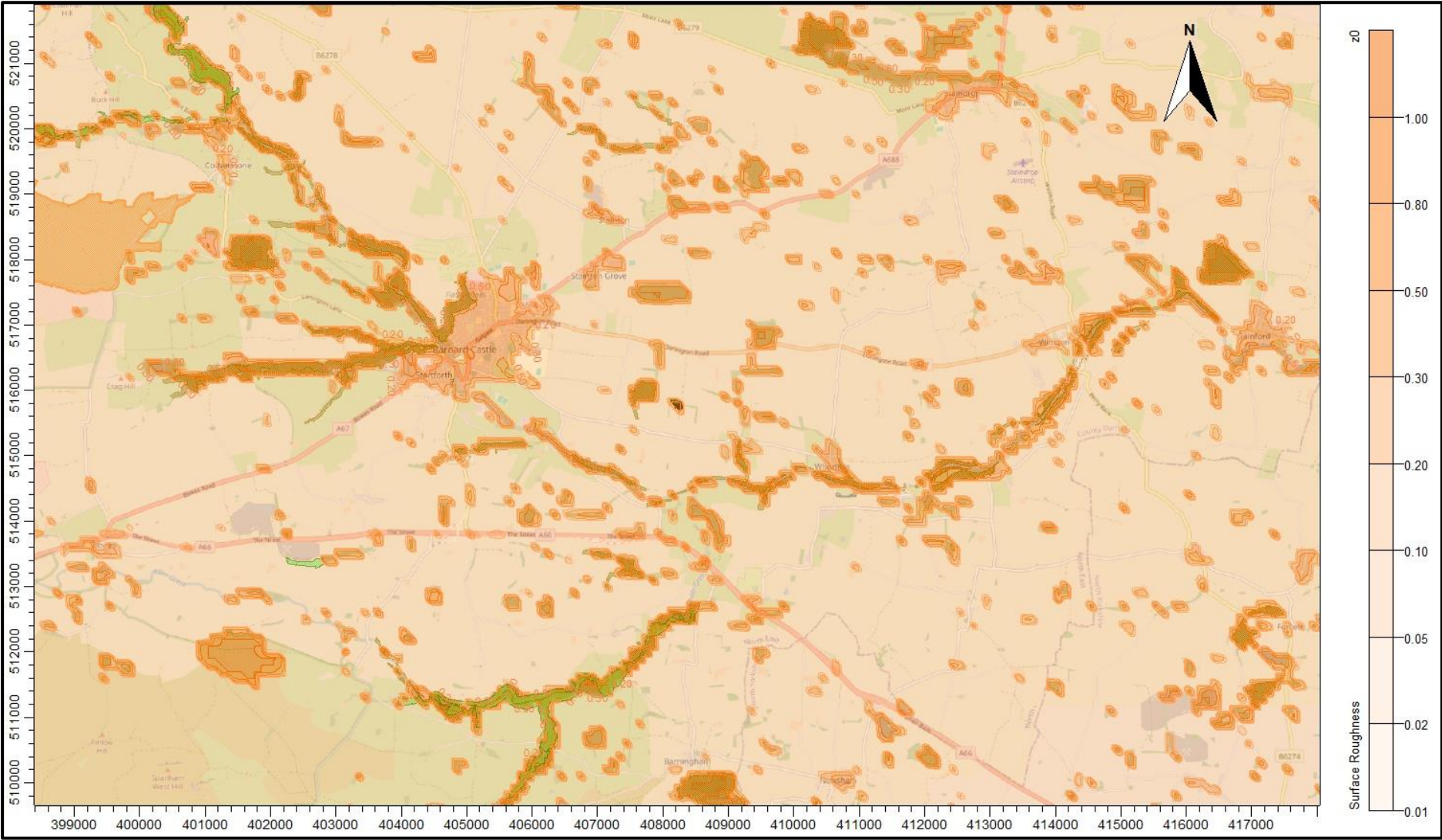
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Figure 4b. The discrete receptors and regular Cartesian grids – a closer view



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



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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 housing and 0.010 m/s to 0.015 m/s over heavily grazed grassland. Where deposition over water surfaces is calculated, a deposition velocity of 0.005 m/s is used.

In summary, the method is as follows:

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

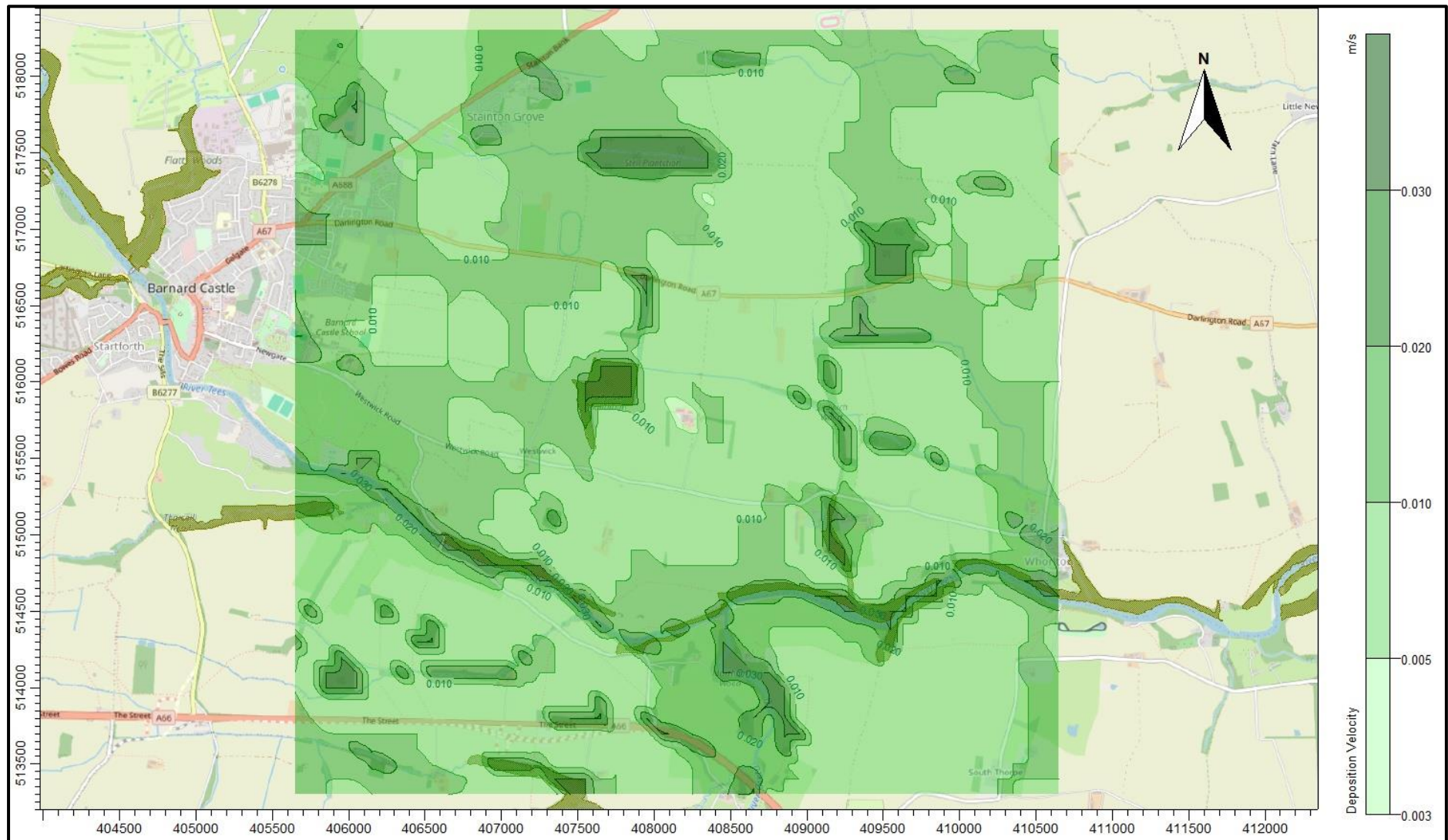
Table 4. Deposition velocities

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

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

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

Figure 6. The spatially varying deposition field



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5. Details of the Model Runs and Results

5.1 Preliminary modelling and 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 - ($\mu\text{g}/\text{m}^3$)			
				Existing		Proposed	
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms No Terrain	GFS Calms No Terrain
1	407854	515848	Sally Gill Plantation AW	2.032	3.301	0.106	0.105
2	407872	515972	Sally Gill Plantation AW	1.910	3.016	0.091	0.090
3	407894	516110	Sally Gill Plantation AW	1.577	2.471	0.099	0.098
4	407668	516073	Sally Gill Plantation AW	0.926	1.503	0.044	0.044
5	407541	515877	Sally Gill Plantation AW	0.795	1.323	0.036	0.036
6	407614	515571	Sally Gill Plantation AW	1.028	1.533	0.068	0.067
7	409169	515243	AW	0.392	0.602	0.028	0.028
8	409190	514920	AW	0.269	0.417	0.019	0.018
9	408425	514611	AW	0.312	0.484	0.022	0.021
10	408838	514680	AW	0.282	0.408	0.018	0.018
11	407715	514490	AW	0.326	0.473	0.019	0.018
12	407178	514800	AW	0.296	0.423	0.019	0.019
13	406640	514998	AW	0.202	0.300	0.017	0.016
14	407849	514245	AW	0.249	0.370	0.016	0.016
15	409680	514559	LWS	0.148	0.229	0.012	0.012
16	409276	514477	LWS	0.175	0.271	0.013	0.013
17	408210	514383	LWS	0.262	0.406	0.017	0.017
18	407453	514568	LWS	0.301	0.438	0.017	0.017
19	406868	514809	LWS	0.237	0.330	0.018	0.017
20	406279	515187	LWS	0.143	0.228	0.012	0.012
21	408365	513923	LWS	0.159	0.249	0.012	0.012
22	408426	512598	Brignall Banks SSSI	0.068	0.105	0.007	0.007
23	407229	511646	Brignall Banks SSSI	0.051	0.075	0.006	0.006
24	406069	511231	Brignall Banks SSSI	0.040	0.059	0.005	0.005
32	402595	523377	North Pennine Moors SPA/Helbeck and Swindale Woods SAC	0.013	0.019	0.003	0.003
33	404544	523570	North Pennine Moors SPA/Helbeck and Swindale Woods SAC	0.018	0.024	0.004	0.004
34	405940	524434	North Pennine Moors SPA/Helbeck and Swindale Woods SAC	0.019	0.026	0.004	0.004
35	400760	518961	North Pennine Moors SPA/Helbeck and Swindale Woods SAC	0.013	0.022	0.002	0.002
36	399588	517617	North Pennine Moors SPA/Helbeck and Swindale Woods SAC	0.012	0.020	0.002	0.002
37	398488	513806	North Pennine Moors SPA/Helbeck and Swindale Woods SAC	0.010	0.017	0.002	0.002

5.2 Detailed 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 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 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 detailed deposition run was made with terrain. Calms cannot be used with terrain or spatially varying deposition and in this case, the preliminary modelling indicates that the effects of calms are significant for the existing housing only. Therefore, a correction based upon the preliminary modelling results, is applied to receptors within 3 km of the existing housing. Note that this correction is not applied to the contour plots.

The predicted process contribution to maximum annual mean ground level ammonia concentrations and nitrogen deposition rates at the discrete receptors included within the detailed modelling are shown in Tables 6a (Existing Scenario), 6b (Proposed Scenario) and 6c (Proposed House Only). In the Tables, predicted nitrogen deposition rates that are in excess of the Environment Agency's upper threshold of 100% of the Critical Load of 10.0 kg-N/ha/yr for a non-statutory site are coloured red. There are no predicted ammonia concentrations nor nitrogen deposition rates that are in excess of the Environment Agency's lower or upper threshold (4% or 20% for an international site and 20% or 50% for a SSSI) of the relevant Critical Level or Critical Load at any statutory site. Process contributions which exceed 1% of the relevant Critical Level or Critical Load at a statutory site are highlighted with bold text.

Contour plots of the predicted process contributions to ground level maximum annual mean ammonia concentration and maximum annual nitrogen deposition rate for the Proposed House Only are shown in Figures 7a and 7b. Contour plots of other scenarios are available on request.

Table 6a. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors – Existing Scenario

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level ($\mu\text{g}/\text{m}^3$)	Critical Load (kg/ha)	Process Contribution ($\mu\text{g}/\text{m}^3$)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	407854	515848	Sally Gill Plantation AW	0.03	3.0	10.0	2.002	66.75	15.60	156.01
2	407872	515972	Sally Gill Plantation AW	0.03	3.0	10.0	1.914	63.81	14.91	149.14
3	407894	516110	Sally Gill Plantation AW	0.03	3.0	10.0	1.538	51.28	11.98	119.85
4	407668	516073	Sally Gill Plantation AW	0.03	3.0	10.0	0.548	18.28	4.27	42.73
5	407541	515877	Sally Gill Plantation AW	0.03	3.0	10.0	0.473	15.77	3.69	36.85
6	407614	515571	Sally Gill Plantation AW	0.03	3.0	10.0	0.792	26.41	6.17	61.73
7	409169	515243	AW	0.03	1.0	10.0	0.272	27.24	2.12	21.23
8	409190	514920	AW	0.03	1.0	10.0	0.118	11.77	0.92	9.17
9	408425	514611	AW	0.03	1.0	10.0	0.091	9.11	0.71	7.10
10	408838	514680	AW	0.03	1.0	10.0	0.077	7.72	0.60	6.01
11	407715	514490	AW	0.03	1.0	10.0	0.070	6.95	0.54	5.42
12	407178	514800	AW	0.03	1.0	10.0	0.075	7.47	0.58	5.82
13	406640	514998	AW	0.03	1.0	10.0	0.057	5.72	0.45	4.45
14	407849	514245	AW	0.03	1.0	10.0	0.059	5.85	0.46	4.56
15	409680	514559	LWS	0.03	1.0	10.0	0.048	4.82	0.38	3.76
16	409276	514477	LWS	0.03	1.0	10.0	0.048	4.78	0.37	3.73
17	408210	514383	LWS	0.03	1.0	10.0	0.070	6.96	0.54	5.42
18	407453	514568	LWS	0.03	1.0	10.0	0.061	6.08	0.47	4.74
19	406868	514809	LWS	0.03	1.0	10.0	0.064	6.39	0.50	4.98
20	406279	515187	LWS	0.03	1.0	10.0	0.041	4.11	0.32	3.20
21	408365	513923	LWS	0.03	1.0	10.0	0.060	6.04	0.47	4.70
22	408426	512598	Brignall Banks SSSI	0.03	1.0	10.0	0.039	3.87	0.30	3.01
23	407229	511646	Brignall Banks SSSI	0.03	1.0	10.0	0.012	1.15	0.09	0.90
24	406069	511231	Brignall Banks SSSI	0.03	1.0	10.0	0.005	0.50	0.04	0.39
32	402595	523377	North Pennine Moors SPA	0.02	n/a	5.0	0.002	-	0.01	0.24
33	404544	523570	North Pennine Moors SPA	0.02	n/a	5.0	0.003	-	0.02	0.35
34	405940	524434	North Pennine Moors SPA	0.02	n/a	5.0	0.003	-	0.02	0.36
35	400760	518961	North Pennine Moors SPA	0.02	n/a	5.0	0.003	-	0.01	0.27
36	399588	517617	North Pennine Moors SPA	0.02	n/a	5.0	0.002	-	0.01	0.20
37	398488	513806	North Pennine Moors SPA	0.02	n/a	5.0	0.002	-	0.01	0.18
32	402595	523377	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.002	0.23	0.02	0.18
33	404544	523570	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.003	0.34	0.03	0.27
34	405940	524434	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.003	0.35	0.03	0.27
35	400760	518961	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.003	0.26	0.02	0.21
36	399588	517617	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.002	0.19	0.02	0.15
37	398488	513806	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.002	0.18	0.01	0.14

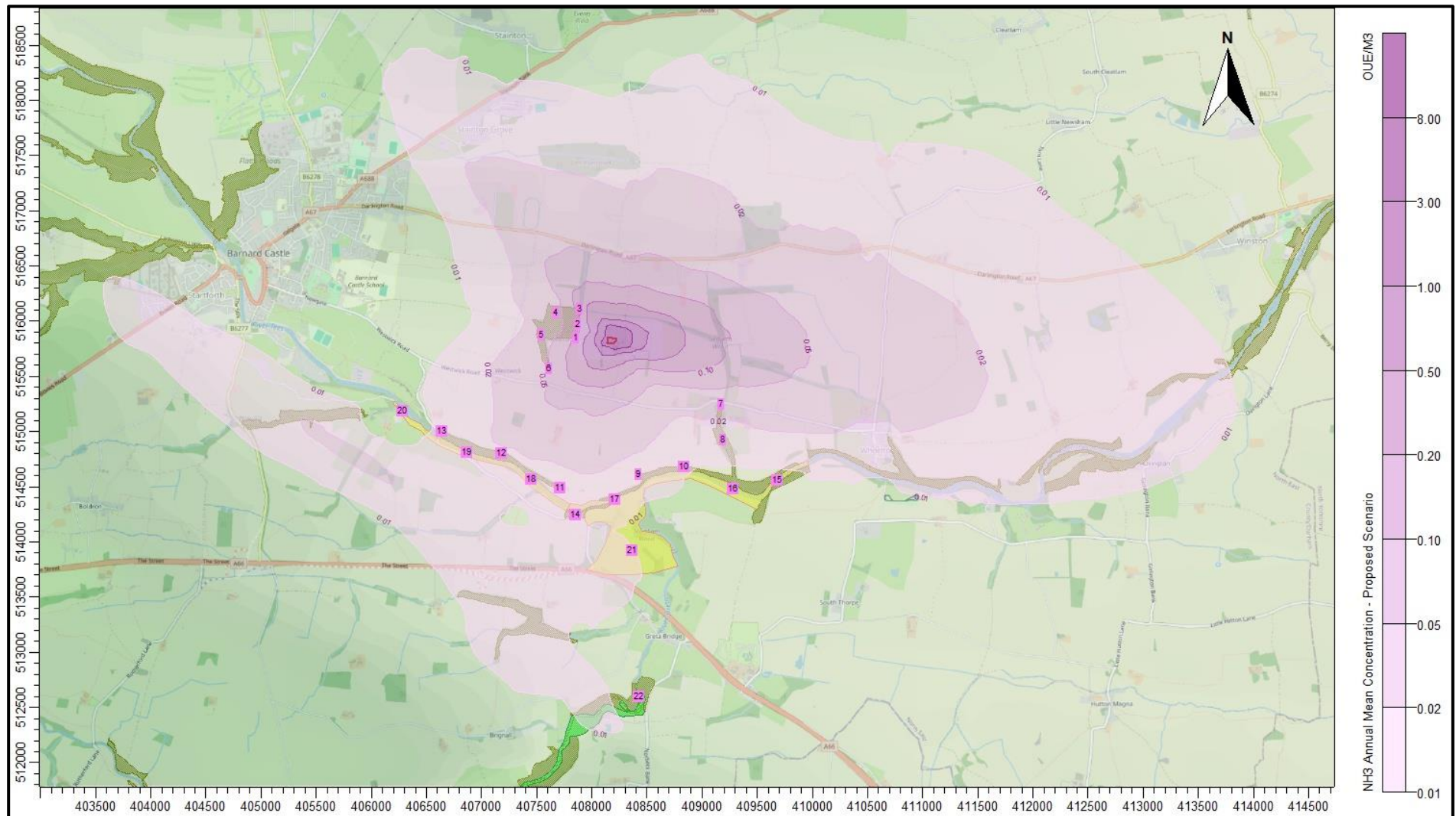
Table 6b. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors – Proposed Scenario

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	407854	515848	Sally Gill Plantation AW	0.03	3.0	10.0	1.052	35.05	8.19	81.93
2	407872	515972	Sally Gill Plantation AW	0.03	3.0	10.0	0.997	33.24	7.77	77.70
3	407894	516110	Sally Gill Plantation AW	0.03	3.0	10.0	0.856	28.54	6.67	66.72
4	407668	516073	Sally Gill Plantation AW	0.03	3.0	10.0	0.300	10.01	2.34	23.40
5	407541	515877	Sally Gill Plantation AW	0.03	3.0	10.0	0.254	8.47	1.98	19.80
6	407614	515571	Sally Gill Plantation AW	0.03	3.0	10.0	0.435	14.50	3.39	33.90
7	409169	515243	AW	0.03	1.0	10.0	0.157	15.73	1.23	12.26
8	409190	514920	AW	0.03	1.0	10.0	0.068	6.85	0.53	5.33
9	408425	514611	AW	0.03	1.0	10.0	0.057	5.75	0.45	4.48
10	408838	514680	AW	0.03	1.0	10.0	0.048	4.76	0.37	3.71
11	407715	514490	AW	0.03	1.0	10.0	0.048	4.76	0.37	3.71
12	407178	514800	AW	0.03	1.0	10.0	0.052	5.22	0.41	4.06
13	406640	514998	AW	0.03	1.0	10.0	0.038	3.79	0.30	2.95
14	407849	514245	AW	0.03	1.0	10.0	0.041	4.13	0.32	3.22
15	409680	514559	LWS	0.03	1.0	10.0	0.031	3.06	0.24	2.38
16	409276	514477	LWS	0.03	1.0	10.0	0.029	2.94	0.23	2.29
17	408210	514383	LWS	0.03	1.0	10.0	0.045	4.52	0.35	3.52
18	407453	514568	LWS	0.03	1.0	10.0	0.041	4.13	0.32	3.22
19	406868	514809	LWS	0.03	1.0	10.0	0.044	4.39	0.34	3.42
20	406279	515187	LWS	0.03	1.0	10.0	0.027	2.75	0.21	2.14
21	408365	513923	LWS	0.03	1.0	10.0	0.039	3.89	0.30	3.03
22	408426	512598	Brignall Banks SSSI	0.03	1.0	10.0	0.027	2.70	0.21	2.11
23	407229	511646	Brignall Banks SSSI	0.03	1.0	10.0	0.012	1.20	0.09	0.93
24	406069	511231	Brignall Banks SSSI	0.03	1.0	10.0	0.005	0.48	0.04	0.37
32	402595	523377	North Pennine Moors SPA	0.02	n/a	5.0	0.002	-	0.01	0.21
33	404544	523570	North Pennine Moors SPA	0.02	n/a	5.0	0.003	-	0.01	0.29
34	405940	524434	North Pennine Moors SPA	0.02	n/a	5.0	0.003	-	0.01	0.28
35	400760	518961	North Pennine Moors SPA	0.02	n/a	5.0	0.003	-	0.01	0.29
36	399588	517617	North Pennine Moors SPA	0.02	n/a	5.0	0.002	-	0.01	0.25
37	398488	513806	North Pennine Moors SPA	0.02	n/a	5.0	0.002	-	0.01	0.21
32	402595	523377	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.002	0.20	0.02	0.16
33	404544	523570	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.003	0.28	0.02	0.22
34	405940	524434	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.003	0.27	0.02	0.21
35	400760	518961	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.003	0.28	0.02	0.22
36	399588	517617	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.002	0.24	0.02	0.19
37	398488	513806	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.002	0.21	0.02	0.16

Table 6c. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors – Proposed House Only

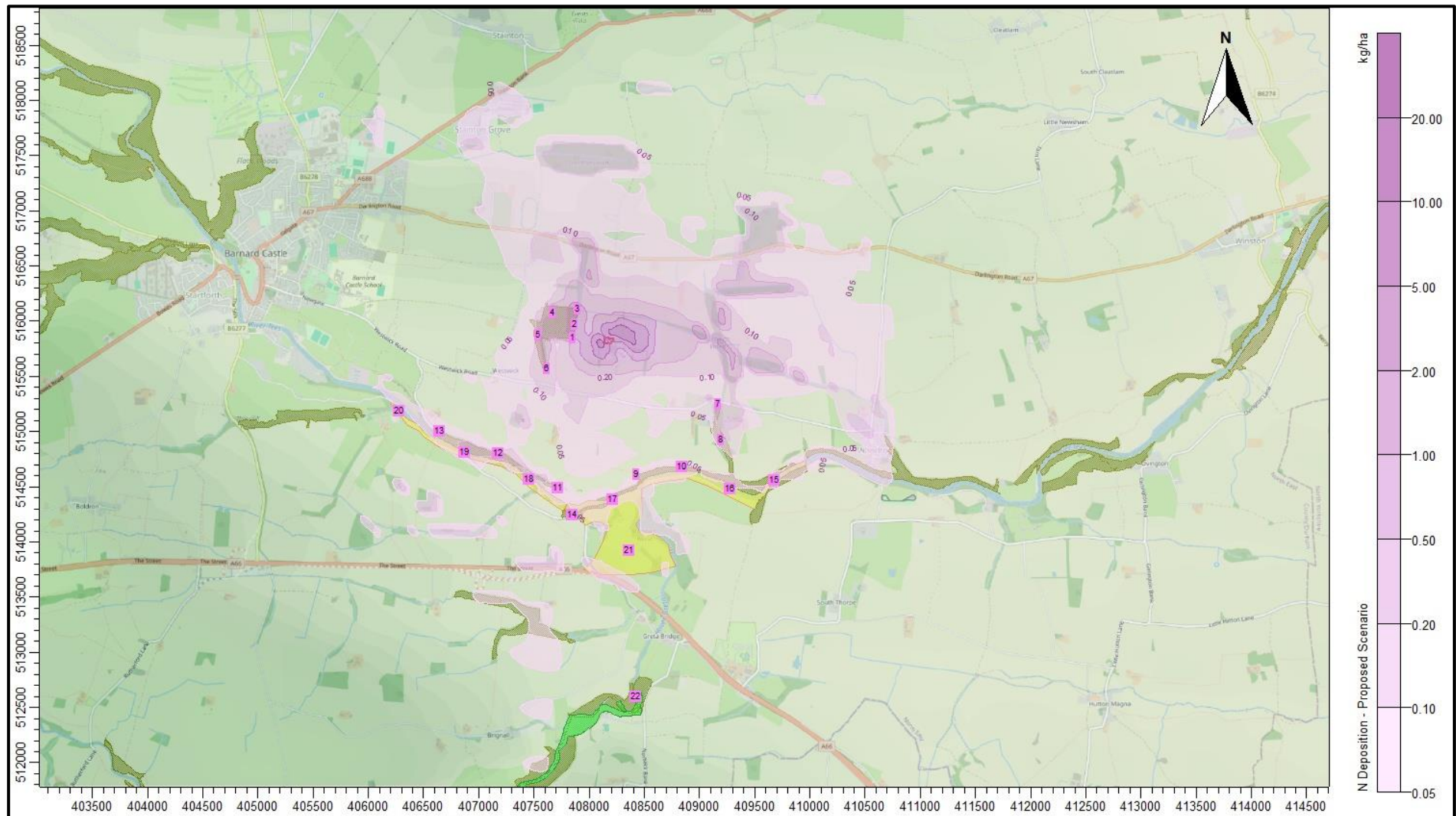
Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	407854	515848	Sally Gill Plantation AW	0.03	3.0	10.0	0.101	3.36	0.78	7.85
2	407872	515972	Sally Gill Plantation AW	0.03	3.0	10.0	0.088	2.94	0.69	6.88
3	407894	516110	Sally Gill Plantation AW	0.03	3.0	10.0	0.126	4.19	0.98	9.80
4	407668	516073	Sally Gill Plantation AW	0.03	3.0	10.0	0.040	1.33	0.31	3.11
5	407541	515877	Sally Gill Plantation AW	0.03	3.0	10.0	0.029	0.98	0.23	2.30
6	407614	515571	Sally Gill Plantation AW	0.03	3.0	10.0	0.059	1.96	0.46	4.58
7	409169	515243	AW	0.03	1.0	10.0	0.028	2.80	0.22	2.18
8	409190	514920	AW	0.03	1.0	10.0	0.013	1.26	0.10	0.98
9	408425	514611	AW	0.03	1.0	10.0	0.014	1.42	0.11	1.11
10	408838	514680	AW	0.03	1.0	10.0	0.011	1.10	0.09	0.86
11	407715	514490	AW	0.03	1.0	10.0	0.015	1.46	0.11	1.14
12	407178	514800	AW	0.03	1.0	10.0	0.017	1.67	0.13	1.30
13	406640	514998	AW	0.03	1.0	10.0	0.011	1.08	0.08	0.84
14	407849	514245	AW	0.03	1.0	10.0	0.014	1.35	0.11	1.05
15	409680	514559	LWS	0.03	1.0	10.0	0.008	0.77	0.06	0.60
16	409276	514477	LWS	0.03	1.0	10.0	0.007	0.67	0.05	0.52
17	408210	514383	LWS	0.03	1.0	10.0	0.012	1.21	0.09	0.94
18	407453	514568	LWS	0.03	1.0	10.0	0.012	1.24	0.10	0.97
19	406868	514809	LWS	0.03	1.0	10.0	0.014	1.36	0.11	1.06
20	406279	515187	LWS	0.03	1.0	10.0	0.008	0.80	0.06	0.62
21	408365	513923	LWS	0.03	1.0	10.0	0.010	1.02	0.08	0.79
22	408426	512598	Brignall Banks SSSI	0.03	1.0	10.0	0.009	0.87	0.07	0.67
23	407229	511646	Brignall Banks SSSI	0.03	1.0	10.0	0.006	0.65	0.05	0.51
24	406069	511231	Brignall Banks SSSI	0.03	1.0	10.0	0.002	0.24	0.02	0.18
32	402595	523377	North Pennine Moors SPA	0.02	n/a	5.0	0.001	-	0.00	0.10
33	404544	523570	North Pennine Moors SPA	0.02	n/a	5.0	0.001	-	0.01	0.12
34	405940	524434	North Pennine Moors SPA	0.02	n/a	5.0	0.001	-	0.01	0.11
35	400760	518961	North Pennine Moors SPA	0.02	n/a	5.0	0.002	-	0.01	0.16
36	399588	517617	North Pennine Moors SPA	0.02	n/a	5.0	0.002	-	0.01	0.16
37	398488	513806	North Pennine Moors SPA	0.02	n/a	5.0	0.001	-	0.01	0.13
32	402595	523377	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.001	0.09	0.01	0.07
33	404544	523570	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.001	0.12	0.01	0.09
34	405940	524434	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.001	0.10	0.01	0.08
35	400760	518961	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.002	0.15	0.01	0.12
36	399588	517617	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.002	0.15	0.01	0.12
37	398488	513806	Helbeck and Swindale Woods SAC	0.03	1.0	10.0	0.001	0.12	0.01	0.10

Figure 7a. Maximum annual mean ammonia concentration – Proposed House Only



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Figure 7b. Maximum annual nitrogen deposition rate – Proposed House Only



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6. Summary and Conclusions

Ammonia emission rates from the existing and proposed pig rearing housing at West Shaws have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors. The ammonia emission rates have then been used as inputs to an atmospheric dispersion and deposition model which calculates ammonia exposure levels and nitrogen deposition rates in the surrounding area.

Existing Scenario

The modelling predicts that:

- The process contributions to annual nitrogen deposition rates at closer parts of Sally Gill Plantation AW currently exceed the Environment Agency's lower threshold percentage of the Critical Load.
- The process contributions to annual mean ammonia concentrations and nitrogen deposition rates at all other non-statutory wildlife sites and all statutory wildlife sites are currently below the Environment Agency's lower threshold percentage of the Critical Level/Load.
- The process contributions exceed 1% of the relevant Critical Level and/or Load over north-eastern parts of Brignall Banks SSSI.
- The process contributions are well below 1% of the relevant Critical Level and/or Load at the internationally designated wildlife sites considered.

Proposed Scenario

The modelling predicts that:

- The process contributions to annual nitrogen deposition rates at Sally Gill Plantation AW would be reduced to below the Environment Agency's lower threshold percentage of the Critical Load.
- The process contributions to annual mean ammonia concentrations and nitrogen deposition rates at all other non-statutory wildlife sites and all statutory wildlife sites would remain below the Environment Agency's lower threshold percentage of the Critical Level/Load.
- The process contributions would remain in excess of 1% of the relevant Critical Level and/or Load over north-eastern parts of Brignall Banks SSSI, however they would be reduced at the closest parts. Over some small parts process contributions would increase by a small margin.
- The process contributions would remain well below 1% of the relevant Critical Level and/or Load at the internationally designated wildlife sites considered.

Proposed House Only

The modelling predicts that:

- The process contributions to annual mean ammonia concentrations and nitrogen deposition rates at all wildlife sites considered due to the proposed house only would be well below the Environment Agency's lower threshold percentage of the Critical Level/Load.
- Annual mean ammonia concentrations at Brignall Banks SSSI due to the proposed house only would be in excess of 1% of the relevant Critical Level and/or Load by a small margin over a very small part (not covered by a receptor) south of the village of Brignall.
- At the internationally designated wildlife sites the process contributions due to the proposed house alone would be well below 1% of the Critical Level/Load.

7. References

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