A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing Pig Rearing Houses at Locks Farm and Blackhall Farm, near Edgefield in Norfolk

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Eleanor Jackson of Dalehead Foods on behalf of North Farm Livestock Ltd., to use computer modelling to assess the impact of ammonia emissions from the existing pig rearing houses at Locks Farm and Blackhall Farm, near Edgefield in Norfolk. NR24 2AY.

Ammonia emission rates from the pig rearing houses at Locks Farm and Blackhall Farm, have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors and information from the recent Agriculture and Horticulture Development Board (AHDB) report, "Establishing ammonia emission factors for straw-based buildings". The ammonia emission rates have then been used as inputs to an atmospheric dispersion and deposition model which calculates ammonia exposure levels and nitrogen and acid deposition rates in the surrounding area.

This report is arranged in the following manner:

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

2. Background Details

Locks Farm is in an isolated rural location, approximately 1.9 km to the south-south-east of the village of Edgefield in Norfolk. The surrounding land is used largely for arable farming, although there are some wooded areas nearby. The site is at an altitude of around 55 m with the land rising towards higher ground to the north and falling towards the River Bure Valley to the south.

Blackhall Farm is approximately 750 m to the north-north-west of Locks Farm and is approximately 1.1 km to the south-south-east of Edgefield. Blackhall Farm is at an altitude of around 62 m with the land rising towards higher ground eo the north and falling towards the River Bure Valley to the south.

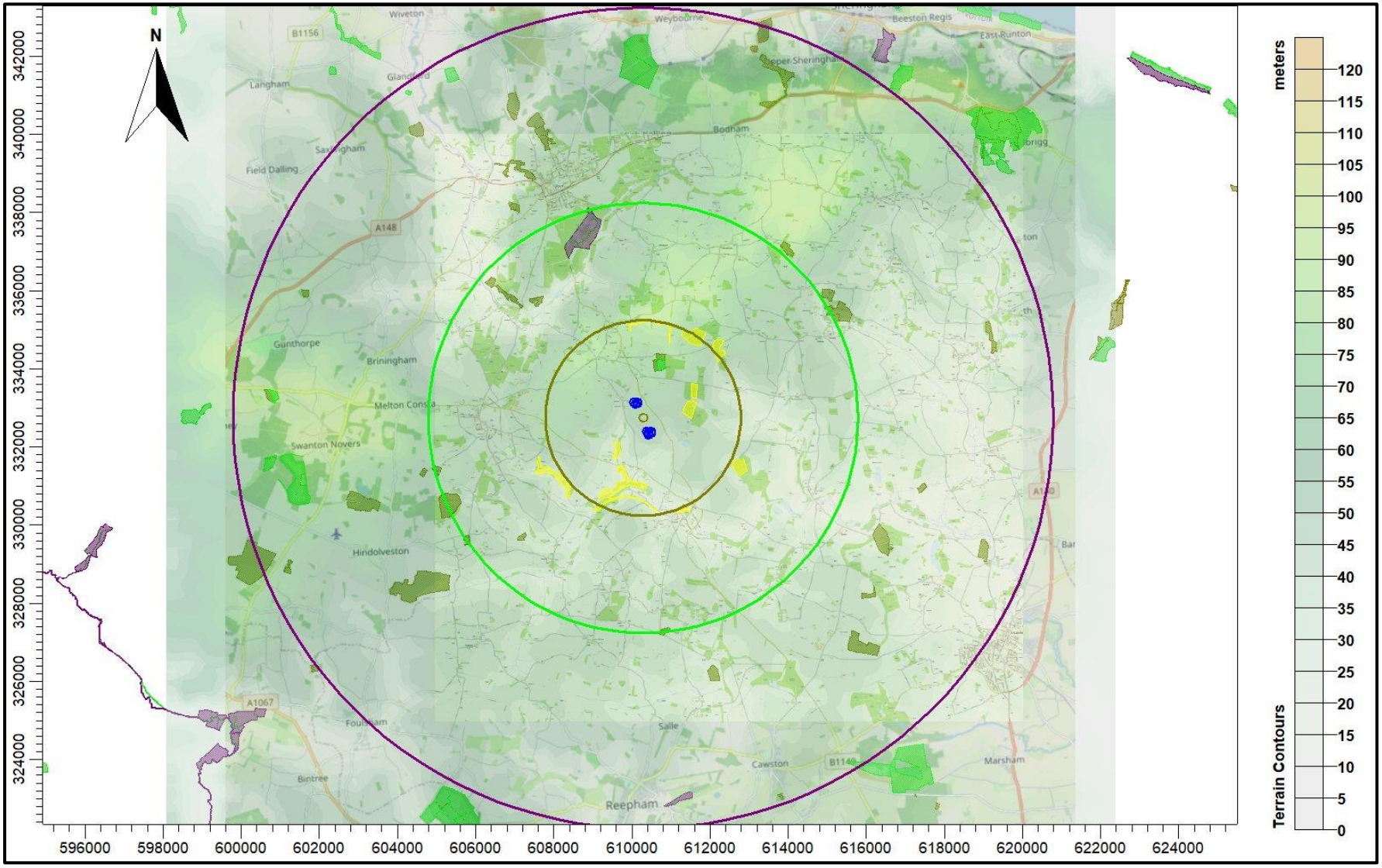
Under the proposal, the pig rearing house at Locks Farm and Blackhall Farm would be stocked with 3,292 and 1,008 pigs respectively. The pigs would be reared from around 7 kg to around 105 kg on a solid floor system with straw bedding/litter. Approximately 1,200 tonnes of manure in total would be stored in two middens, one at Locks Farm and one at Blackhall Farm.

There is one area designated as Ancient Woodland (AW) and several Local Wildlife Sites (LWSs) within 2 km (the normal screening distance for non-statutory sites) of the pig rearing houses at Locks farm and Blackhall Farm. There are two Sites of Special Scientific Interest (SSSIs), within 5 km (the normal screening distance for SSSIs) of the farm and there are several other SSSIs within 10 km. Two of the SSSIs are also designated as units of the Norfolk Valley Fens (NVF) Special Area of Conservation (SAC). Some further details of the SSSIs and the SAC are provided below; the distances given are from a central point between Locks Farm and Blackhill Farm.

- Edgefield Little Wood SSSI - Approximately 1.2 km to the north-north-east - A lowland sessile/pedunculate oakwood which is very rare in Norfolk.
- Holt Lowes SSSI/NVF SAC - Approximately 4.5 km to the north-north-west - an area of dry sandy heathland that grades into flushed slopes along the valley of the River Glaven.
- Kelling Heath SSSI - Approximately 8.4 km to the north - Kelling Heath provides perhaps the best example of a glacial outwash plain in England. A wide variety of heathland birds nest on the site, which also provides a good reptile habitat.
- Weybourne Town Pit SSSI - Approximately 10.3 km to the north - designated for geological features only.
- Briton's Lane Gravel Pit SSSI - Approximately 10.5 km to the north-east - designated for geological features only.
- Cawston and Marsham Heaths SSSI - Approximately 10.1 km to the south-west - The largest area of Heather-dominated heathland now remaining in east Norfolk. They represent a locally scarce type which shows affinities to the Atlantic coastal heaths found in western Britain.
- Booton Common SSSI/NVF SAC - Approximately 9.6 km to the south - a mosaic of wet calcareous fen grassland and acid heath communities which have developed due to the naturally undulating ground. Areas of tall fen and a strip of valley alder woodland occupy the lower ground adjacent to the stream.
- Swanton Novers Woods SSSI - Approximately 8.7 km to the west - One of the most important group of woods in the country, embracing between them an exceptional range of woodland stand-types, several of which are uncommon nationally. Bryophytes, fungi and epiphytic lichens are well represented with uncommon species present. There is a particularly diverse population of breeding birds and invertebrate fauna is also of considerable interest.
- Glandford (Letheringsett Road) SSSI - Approximately 10.2 km to the north-north-west - designated for geological features only.
- Glandford (Hurdle Lane) SSSI - Approximately 9.9 km to the north-north-west - designated for geological features only.

A map of the surrounding area showing the positions of the proposed pig rearing houses and the nearby wildlife sites are provided in Figure 1. In this figure, the LWSs are shaded in yellow, the AWs are shaded in olive, the SSSIs are shaded green, the SAC units are shaded purple and the site of the pig rearing houses are outlined in blue.

Figure 1. The area surrounding Locks Farm and Blackhall Farm – concentric circles radii at 2.5 km (olive), 5.5 km (green) and 10.5 km (purple)



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

3.1 Ammonia concentration and nitrogen and acid deposition

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

3.2 Background ammonia levels and nitrogen and acid deposition

The background ammonia concentration (annual mean) in the area around the farms and the wildlife sites is 3.35 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 47.60 kg-N/ha/y and to short vegetation is 27.72 kg-N/ha/y. The background acid deposition rate to woodland is 3.09 keq/ha/y and to short vegetation is 1.85 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS, July 2020).

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. N.B. 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, or lower, 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 (kg-N/ha/y)	Critical Load Acid (keq/ha/y)
AW and LWSs	1.0 [1 & 2]	-	-
Edgefield Little Wood SSSI	1.0 [1 & 2]	15.0 [2]	-
Holt Lowes SSSI/NVFs SAC	1.0 [1 & 2]	5.0 [2]	-
Kelling Heath SSSI and Cawston and Marsham Heaths SSSI, Booton Common SSSI/NVFs SAC and Swanton Novers Woods SSSI	1.0 [1 & 2]	10.0 [2]	-
Weybourne Town Pit SSSI, Briton's Lane Gravel Pit SSSI, Glandford (Letheringsett Road) SSSI and Glandford (Hurdle Lane) SSSI	n/a [2 & 3]	n/a [2 & 3]	n/a [2 & 3]

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. Based upon information from APIS and/or the citation for the site.
3. Designated for geological features.

3.4 Guidance on the significance of ammonia emissions

3.4.1 Environment Agency Criteria

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

If the predicted process contributions to Critical Level or Critical Load are below the lower threshold percentage, the impact is usually deemed acceptable.

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

3.5 Quantification of ammonia emissions

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

The emission factors used are based upon the Environment Agency's standard ammonia emission factors and information obtained from the recent Agriculture and Horticulture Development Board (AHDB) report, "Establishing ammonia emission factors for straw-based buildings". Details of the pig numbers and weights, manure storage, emission factors used and calculated ammonia emission rates are provided in Table 2.

Table 2. Details of poultry numbers and ammonia emission rates

Source	Animal numbers	Type or weight	Emission factor (kg-NH_3/place/y) or (kg-NH_3/tonne/y)	Emission rate (g-NH_3/s)
Locks Farm Housing	3,292	7 - 105 kg	1.398 (EA/AHDB time weighted)	0.145807
Locks Farm Manure storage		919 tonne	1.49 (EA)	0.043377
Blackhall Farm Housing	1,008		1.398 (EA/AHDB time weighted)	0.044646
Blackhall Farm Manure storage		281 tonne	1.49 (EA)	0.013282

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

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

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

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

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

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

4.1 Meteorological data

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

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

The GFS is a spectral model: the physics/dynamics model has an equivalent resolution of approximately 13 km (latterly 9km). Terrain is understood to be resolved at a resolution of approximately 2 km, with sub-13/9 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). The use of NWP data has advantages over traditional meteorological records because:

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

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

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

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

Wind speeds 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 roses for the farms are shown in Figures 2b (Locks Farm) and 2c (Blackhall Farm); although there is little modification in either case, elsewhere in the modelling domain the modified wind roses may differ more markedly, reflecting the local flow in that part of the domain. The resolution of FLOWSTAR is 64 x 64 grid points and the effective resolution of the wind field is approximately 370 m in the preliminary modelling and is approximately 180 m in the detailed modelling. Please 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. Raw GFS derived data, for 52.847 N, 1.125 E, 2016-2019

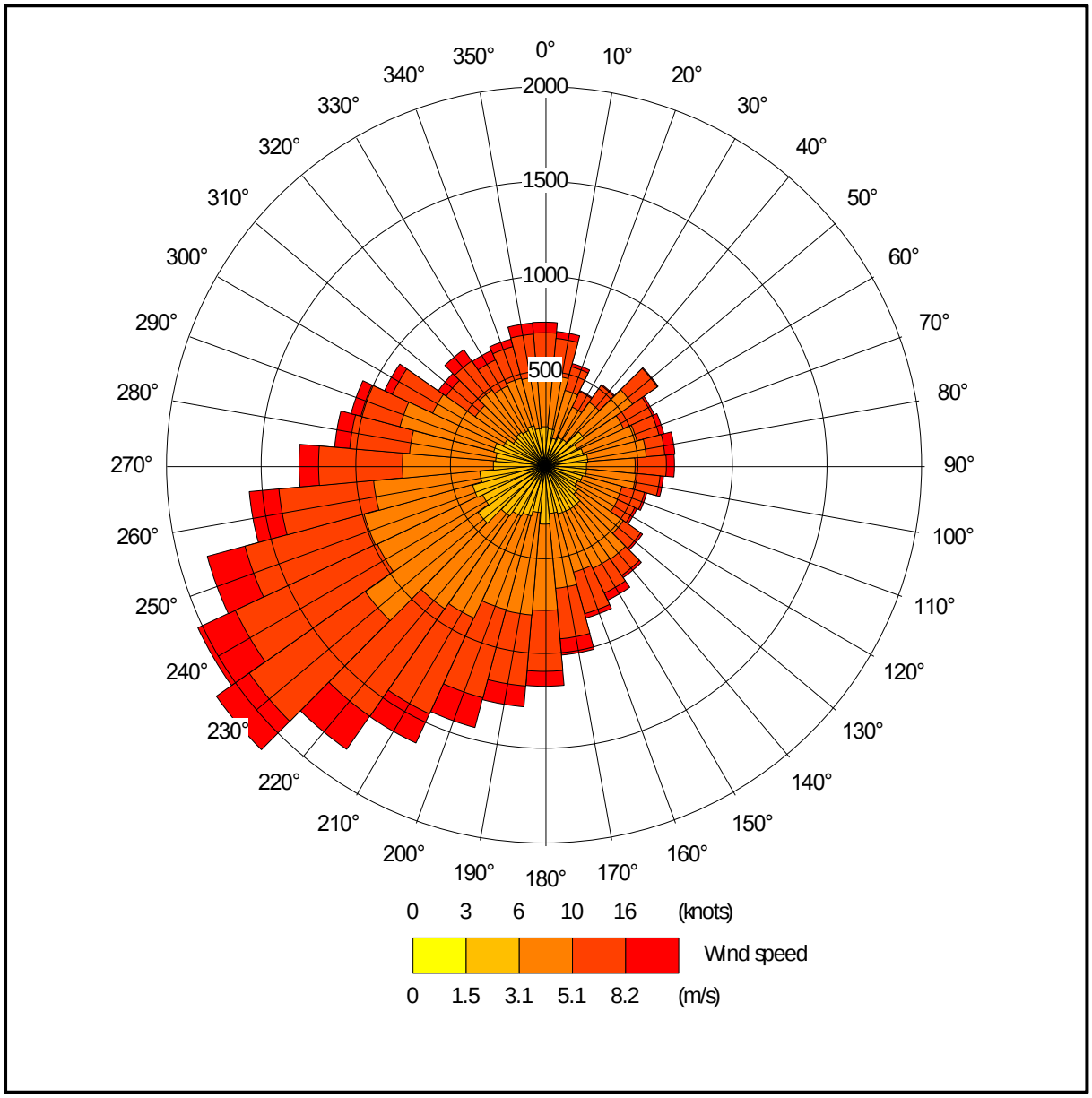


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 610450, 332400, 2016-2019

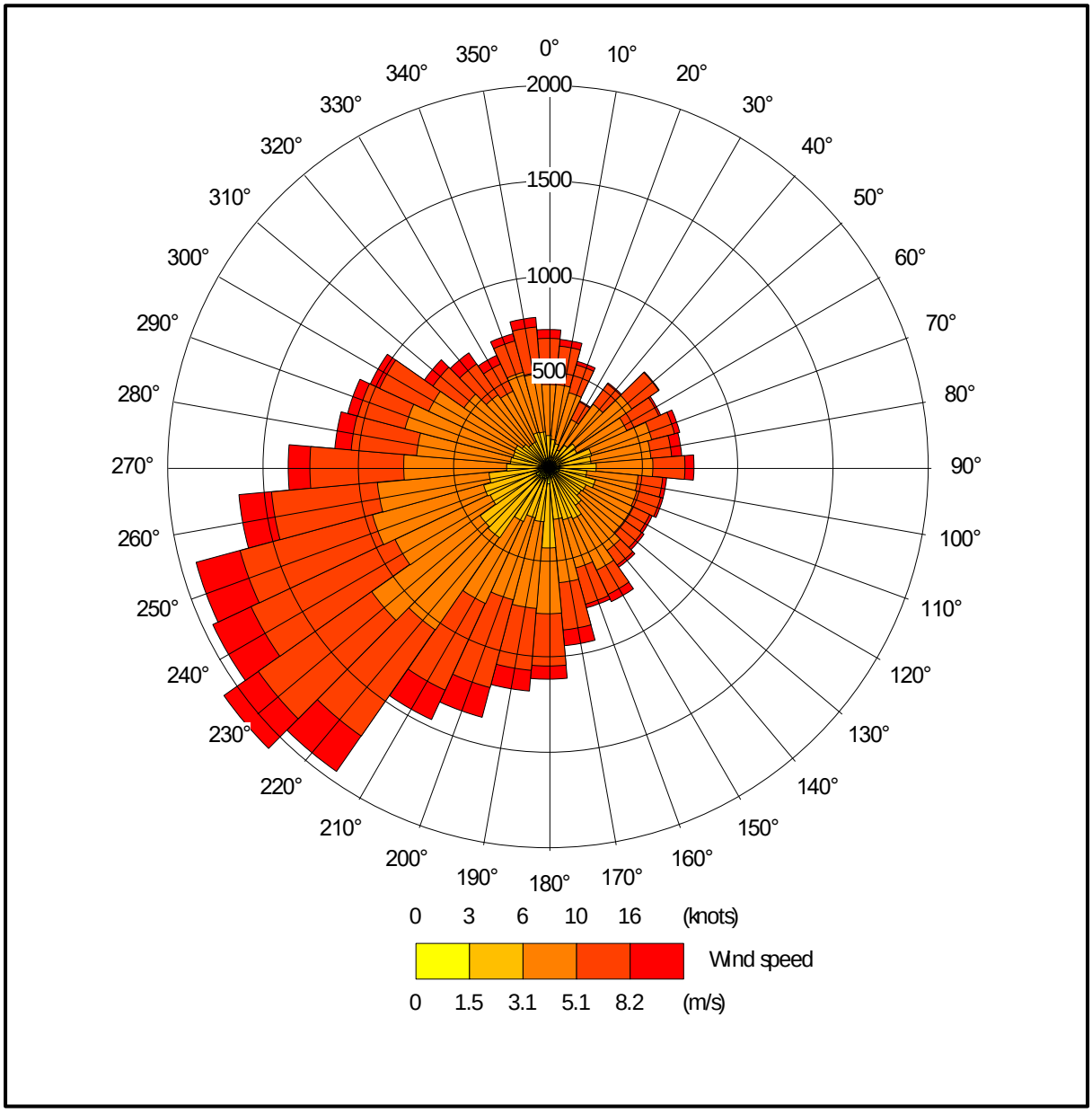
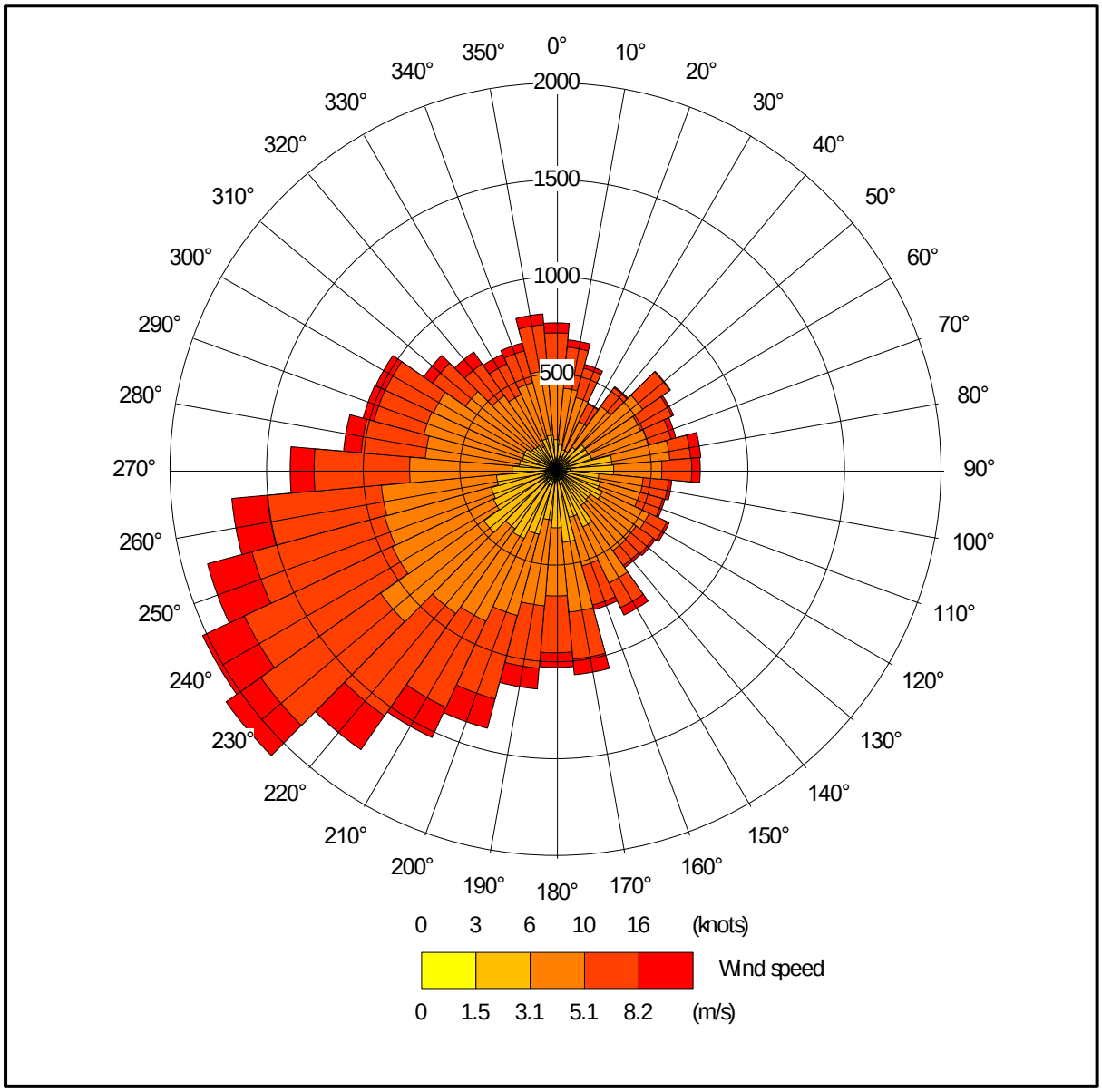


Figure 2c. The wind rose. FLOWSTAR modified GFS derived data for NGR 610100, 333100, 2016-2019



4.2 Emission sources

Emissions from the naturally ventilated pig rearing houses and the manure storage areas are represented by volume sources within ADMS (L1 to L5 & LMAN and BH1 & BMAN)). Details of the volume source parameters are shown in Table 3. The positions of the volume sources may be seen in Figures 3a and 3b, where they are indicated by blue rectangles.

Table 3. Volume source parameters

Source ID	Length Y (m)	Width X (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
L1 to L4	42.7	15.2	3.0	1.0	Ambient	0.033130
L5	36.6	15.2	3.0	1.0	Ambient	0.013287
LMAN	12.5	12.5	3.0	0.0	Ambient	0.043377
BH1	32.5	25.6	3.0	1.0	Ambient	0.044646
BMAN	6.0	27.0	3.0	0.0	Ambient	0.013282

4.3 Modelled buildings

Not modelled.

4.4 Discrete receptors

Thirty-six discrete receptors have been defined at the LWSs, the AW and the SSSIs/SAC. These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figures 4a and 4b, where they are 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 fields used in the detailed modelling, a regular Cartesian grid has been defined within ADMS. The individual grid receptors are defined at ground level within ADMS. The position of the Cartesian grid may be seen in Figures 4a and 4b, where it is 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 24.0 km x 24.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS in the preliminary modelling and a 12.0 km x 12.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS in the detailled modelling. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is approximately 370 m and 180 m, respectively.

4.7 Roughness Length

A fixed surface roughness length of 0.3 m has been applied over the entire modelling domain. As a precautionary measure, the GFS meteorological data is assumed to have a roughness length of 0.275 m. The effect of the difference in roughness length is precautionary as it increases the frequency of low wind speeds and stability and therefore increases predicted ground level concentrations.

Figure 3a. The positions of the modelled sources at Locks Farm

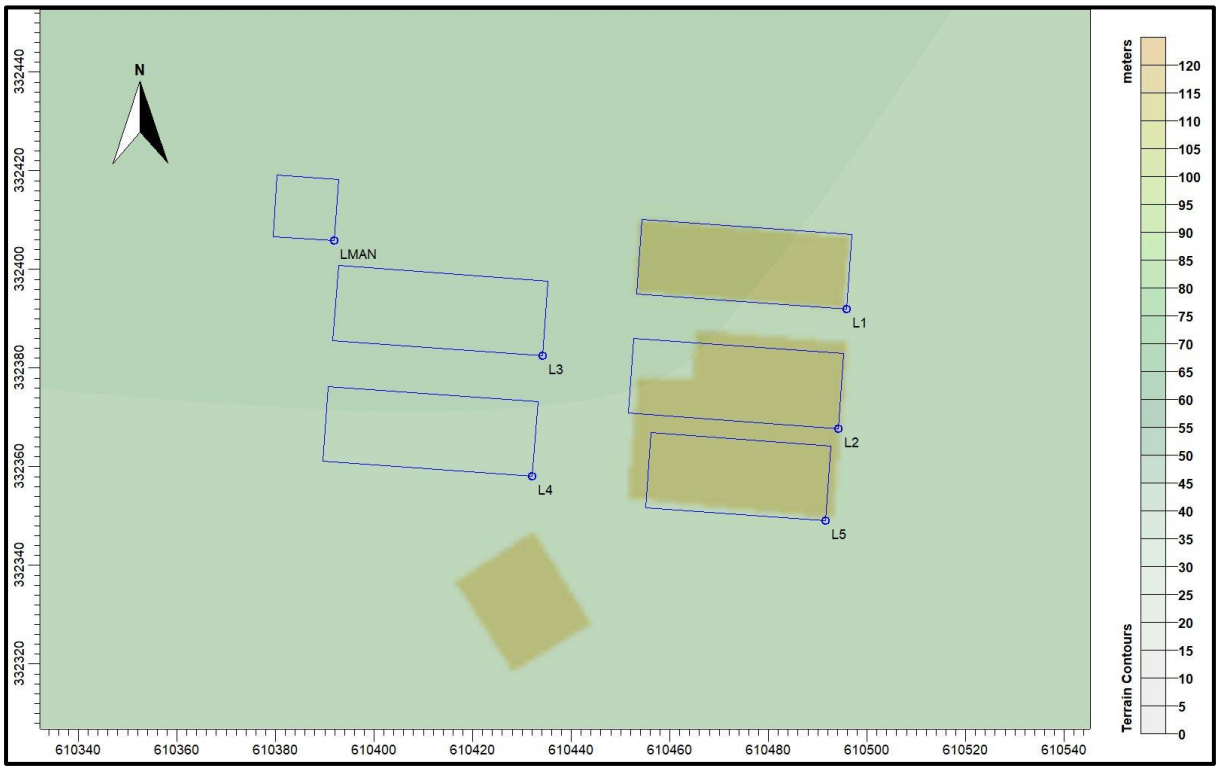


Figure 3b. The positions of the modelled sources at Blackhall Farm

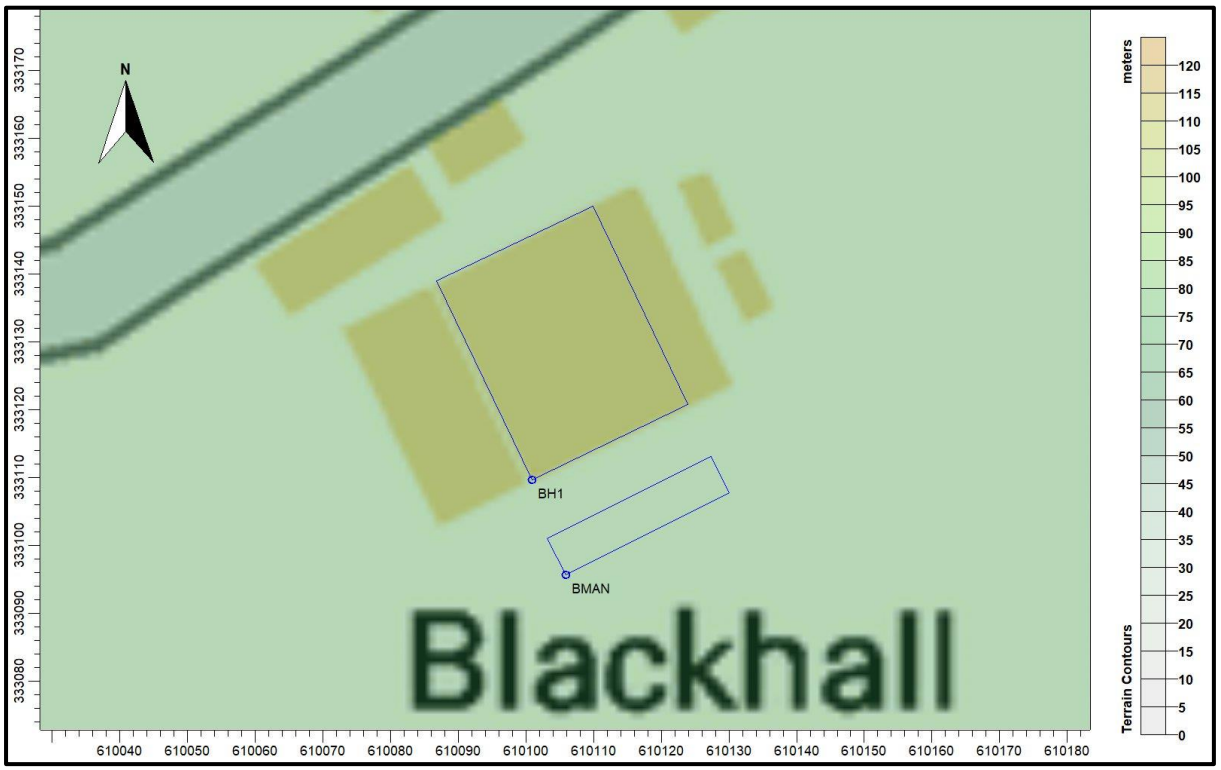


Figure 4a. The discrete receptors and regular Cartesian grid – a broad scale view

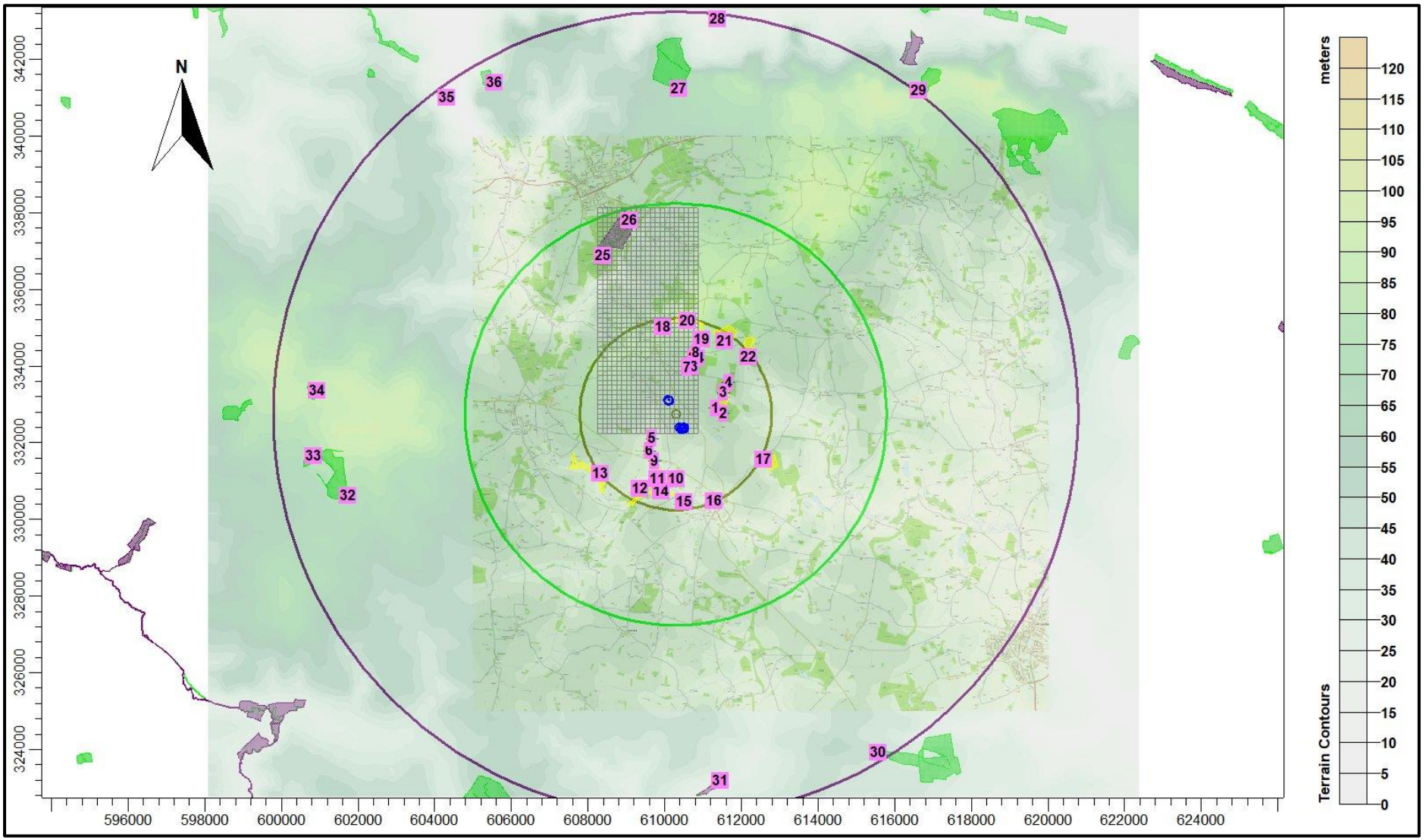
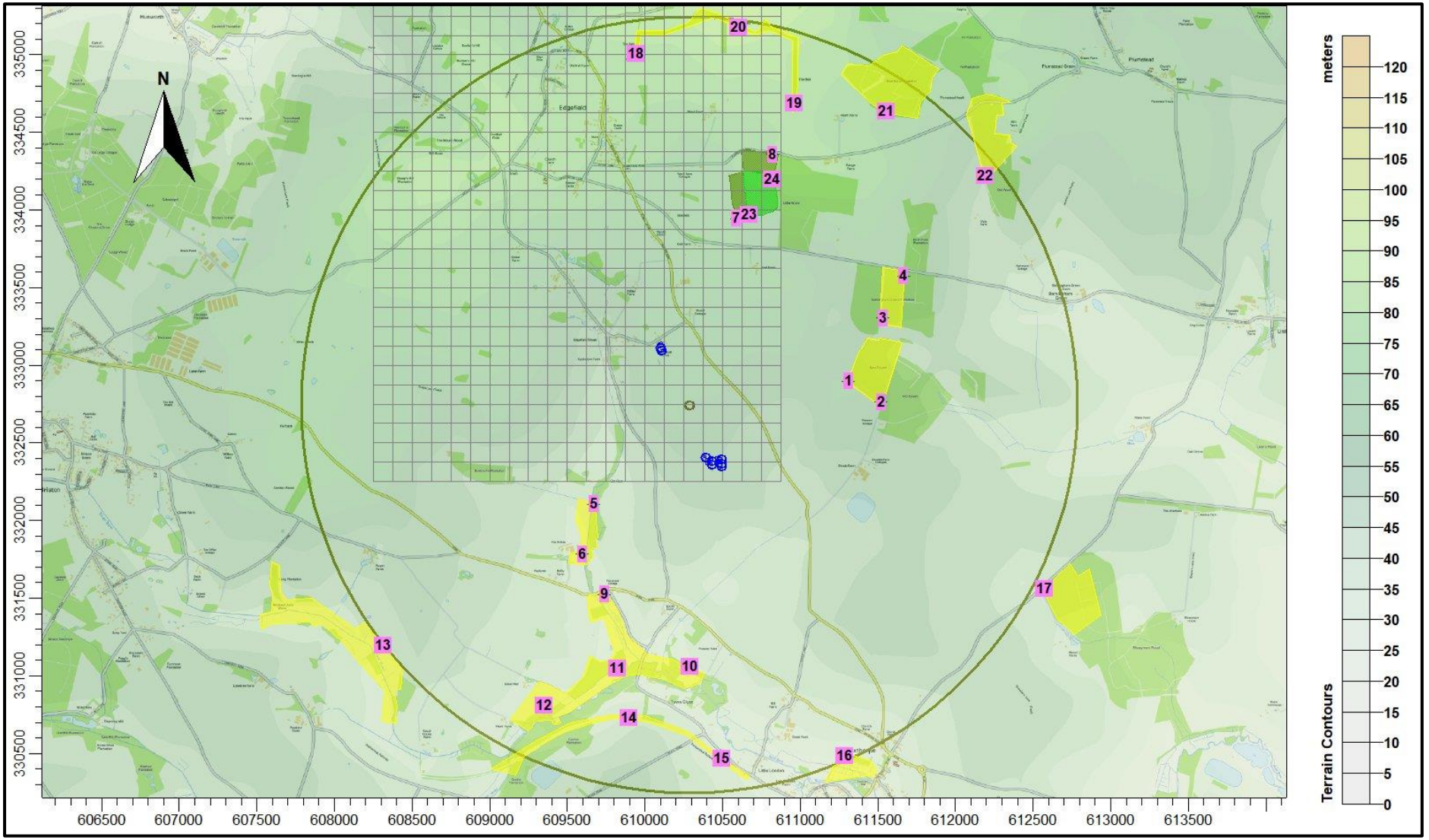


Figure 4b. The discrete receptors and regular Cartesian grid – a closer view



4.8 Deposition

The method used to model deposition of ammonia and consequent plume depletion is based on a document titled "Guidance on modelling the concentration and deposition of ammonia emitted from intensive farming" from the Environment Agency's Air Quality Modelling and Assessment Unit, 22 November 2010 and, because the Environment Agency guidance is somewhat incomplete, 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 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

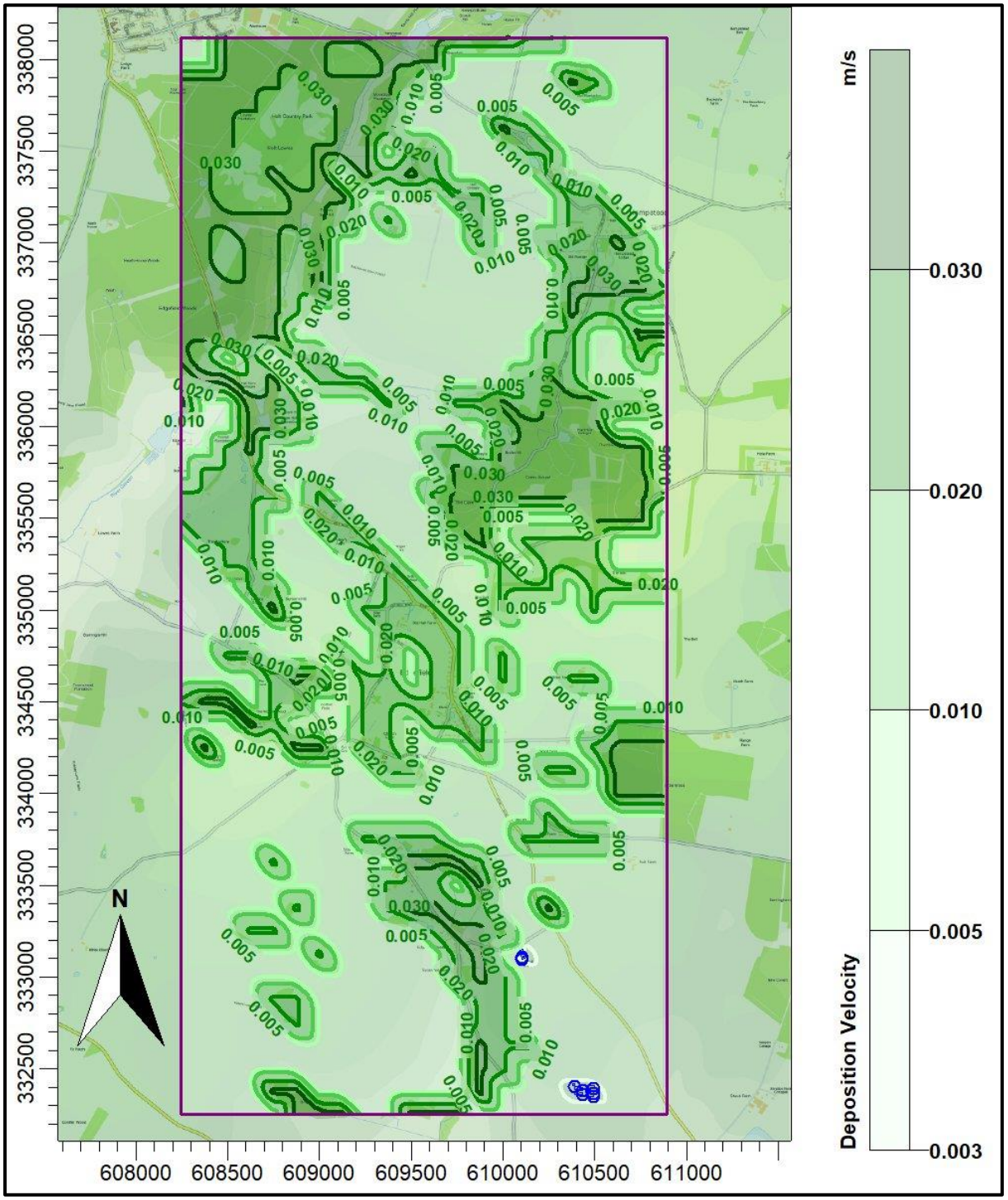
NH_3 concentration (PC + background) (µg/m^3)	< 10	10 - 20	20 - 30	30 – 80	> 80
Deposition velocity – woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity – short vegetation (m/s)	0.02 (0.010 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity – arable farmland/rye grass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

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

A contour plot of the spatially varying deposition fields is provided in Figure 5.

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

Figure 5. The spatially varying deposition field – low resolution



5. Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

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

- In basic mode without calms or terrain – GFS data.
- With calms and without terrain – GFS data.
- Without calms and with terrain – GFS data.
- With a calms correction, with terrain and with a fixed deposition velocity of 0.003 m/s – GFS data.

Details of the predicted annual mean ammonia concentrations at each receptor are provided in Table 5. In the Table, predicted ammonia concentrations that are in excess of the Environment Agency upper percentage threshold of the relevant Critical Level (20% for a SAC, 50% for a SSSI and 100% for a non-statutory site) are coloured red. Predicted ammonia concentrations that are in the range between the Environment Agency lower threshold and upper threshold (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 AW are shaded olive, cells referring to LWSs are shaded yellow, cells referring to the SSSIs are shaded green and cells referring to the SACs are shaded purple.

Table 5. Predicted process contribution to maximum annual mean ammonia at the discrete receptors - Preliminary modelling

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)											
				Locks Farm				Blackhall Farm				Both			
				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	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s
1	611311	332897	LWS	0.317	0.357	0.336	0.279	0.047	0.054	0.041	0.034	0.364	0.411	0.377	0.314
2	611521	332764	LWS	0.229	0.264	0.237	0.191	0.034	0.038	0.029	0.024	0.263	0.302	0.266	0.215
3	611533	333305	LWS	0.163	0.187	0.177	0.142	0.038	0.046	0.040	0.035	0.201	0.233	0.217	0.177
4	611666	333574	LWS	0.115	0.133	0.121	0.093	0.037	0.043	0.038	0.030	0.152	0.176	0.159	0.123
5	609671	332105	LWS	0.302	0.367	0.328	0.244	0.052	0.061	0.051	0.036	0.353	0.429	0.379	0.280
6	609597	331783	LWS	0.207	0.252	0.202	0.140	0.033	0.039	0.032	0.022	0.240	0.291	0.234	0.162
7	610590	333944	AW	0.106	0.125	0.104	0.072	0.091	0.105	0.086	0.068	0.197	0.230	0.189	0.140
8	610823	334356	AW	0.074	0.086	0.068	0.043	0.044	0.051	0.040	0.030	0.118	0.136	0.108	0.072
9	609739	331525	LWS	0.194	0.231	0.189	0.130	0.026	0.031	0.026	0.018	0.220	0.261	0.215	0.148
10	610290	331061	LWS	0.117	0.140	0.119	0.085	0.018	0.022	0.019	0.013	0.135	0.162	0.138	0.098
11	609823	331050	LWS	0.103	0.123	0.101	0.068	0.016	0.020	0.017	0.012	0.119	0.143	0.119	0.080
12	609351	330809	LWS	0.072	0.086	0.073	0.046	0.013	0.016	0.014	0.008	0.085	0.101	0.087	0.054
13	608314	331196	LWS	0.043	0.054	0.043	0.026	0.014	0.016	0.013	0.007	0.057	0.070	0.056	0.034
14	609899	330728	LWS	0.076	0.091	0.075	0.049	0.013	0.016	0.014	0.009	0.089	0.106	0.090	0.058
15	610495	330465	LWS	0.065	0.078	0.067	0.044	0.012	0.015	0.013	0.008	0.077	0.093	0.080	0.052
16	611287	330484	LWS	0.059	0.071	0.064	0.040	0.010	0.013	0.011	0.007	0.070	0.083	0.075	0.046
17	612573	331562	LWS	0.050	0.057	0.043	0.032	0.008	0.010	0.009	0.006	0.058	0.066	0.052	0.038
18	609940	335006	LWS	0.041	0.050	0.039	0.026	0.024	0.029	0.023	0.016	0.065	0.079	0.062	0.042
19	610963	334686	LWS	0.058	0.066	0.051	0.031	0.030	0.034	0.027	0.019	0.087	0.100	0.078	0.050
20	610603	335179	LWS	0.039	0.046	0.034	0.021	0.021	0.025	0.019	0.012	0.061	0.071	0.052	0.033
21	611553	334634	LWS	0.053	0.061	0.047	0.031	0.024	0.028	0.023	0.017	0.077	0.089	0.070	0.048
22	612189	334220	LWS	0.056	0.066	0.058	0.041	0.022	0.025	0.024	0.018	0.079	0.091	0.082	0.059
23	610672	333970	Edgefield Little Wood SSSI	0.106	0.123	0.102	0.068	0.082	0.094	0.077	0.062	0.188	**0.217**	0.179	0.129
24	610816	334199	Edgefield Little Wood SSSI	0.087	0.099	0.080	0.051	0.053	0.061	0.049	0.038	0.140	0.161	0.129	0.089
25	608381	336876	Holt Lowes SSSI/NVFs SAC	0.015	0.017	0.015	0.008	0.006	0.007	0.007	0.003	0.021	0.024	0.022	0.011
26	609081	337799	Holt Lowes SSSI/NVFs SAC	0.011	0.014	0.011	0.007	0.005	0.006	0.005	0.003	0.016	0.020	0.016	0.010
27	610363	341235	Kelling Heath SSSI	0.006	0.007	0.005	0.003	0.002	0.002	0.002	0.001	0.008	0.009	0.007	0.004
28	611387	343035	Weybourne Town Pit SSSI	0.004	0.005	0.004	0.002	0.001	0.002	0.001	0.001	0.006	0.007	0.005	0.003
29	616632	341173	Briton's Lane Gravel Pit SSSI	0.005	0.005	0.003	0.002	0.002	0.002	0.001	0.001	0.006	0.007	0.005	0.003
30	615577	323919	Cawston and Marsham Heaths SSSI	0.004	0.005	0.004	0.002	0.001	0.001	0.001	0.000	0.005	0.006	0.005	0.002
31	611449	323174	Booton Common SSSI/NVFs SAC	0.005	0.006	0.005	0.003	0.001	0.002	0.001	0.001	0.007	0.008	0.007	0.003
32	601736	330622	Swanton Novers Woods SSSI	0.006	0.007	0.005	0.002	0.002	0.002	0.002	0.001	0.007	0.009	0.007	0.003
33	600836	331646	Swanton Novers Woods SSSI	0.005	0.006	0.004	0.002	0.002	0.002	0.001	0.001	0.007	0.008	0.006	0.002
34	600929	333353	Swanton Novers Woods SSSI	0.005	0.006	0.004	0.002	0.002	0.002	0.001	0.001	0.006	0.008	0.005	0.002
35	604312	340987	Glandford (Letheringsett Road) SSSI	0.005	0.005	0.005	0.002	0.002	0.002	0.002	0.001	0.006	0.007	0.006	0.003
36	605553	341390	Glandford (Hurdle Lane) SSSI	0.005	0.005	0.005	0.002	0.002	0.002	0.002	0.001	0.007	0.007	0.007	0.003

5.2 Detailed deposition modelling

Detailed modelling has been carried out over a domain covering Locks Farm, Blackhall Farm, Edgefield Little Wood SSSI and Holt Lowes SSSI/NVFs SAC. Elsewhere, predicted exposures from the preliminary modelling are below 1% of the Critical level (and Critical Load) and would therefore normally be considered insignificant.

Calms cannot be modelled explicitly with spatially varying deposition, therefore a calms correction (based upon the difference between the basic mode and calms mode in the preliminary modelling) has been applied to the results.

The predicted maximum annual mean ground level ammonia concentrations at the discrete receptors within the detailed modelling domains are shown in Table 6a, (Locks Farm), Table 6b (Blackhall Farm) and Table 6c (both farms). In the Tables, predicted ammonia concentrations that are in excess of the Environment Agency's upper threshold percentage of the Critical Level or Load (20% for a Ramsar site, 50% for a SSSI and 100% for a non-statutory site) are coloured red. Ammonia concentrations that are in the range between the Environment Agency's lower and upper threshold percentage of the Critical Level or Load (4% and 20% for a Ramsar site, 20% and 50% for a SSSI and 100% and 100% for a non-statutory site) are coloured blue.

Contour plots of the predicted process contribution ground level maximum annual mean ammonia concentration and the maximum annual nitrogen deposition rate from both farms are shown in Figures 6a and 6b.

Table 6a. Predicted process contribution to maximum annual mean ammonia at the discrete receptors - Detailed modelling - Locks Farm

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
23	610672	333970	Edgefield Little Wood SSSI	0.030	1.0	10.0	0.058	5.8	0.45	4.5
24	610816	334199	Edgefield Little Wood SSSI	0.030	1.0	10.0	0.036	3.6	0.28	2.8
25	608381	336876	Holt Lowes SSSI/NVFs SAC	0.020	1.0	5.0	0.004	0.4	0.02	0.4
26	609081	337799	Holt Lowes SSSI/NVFs SAC	0.020	1.0	5.0	0.004	0.4	0.02	0.4

Table 6b. Predicted process contribution to maximum annual mean ammonia at the discrete receptors - Detailed modelling - Blackhall Farm

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
23	610672	333970	Edgefield Little Wood SSSI	0.030	1.0	10.0	0.055	5.5	0.43	4.3
24	610816	334199	Edgefield Little Wood SSSI	0.030	1.0	10.0	0.028	2.8	0.22	2.2
25	608381	336876	Holt Lowes SSSI/NVFs SAC	0.030	1.0	5.0	0.002	0.2	0.01	0.3
26	609081	337799	Holt Lowes SSSI/NVFs SAC	0.030	1.0	5.0	0.002	0.2	0.01	0.3

Table 6c. Predicted process contribution to maximum annual mean ammonia at the discrete receptors - Detailed modelling - Both Farms

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
23	610672	333970	Edgefield Little Wood SSSI	0.030	1.0	10.0	0.113	11.3	0.88	8.8
24	610816	334199	Edgefield Little Wood SSSI	0.030	1.0	10.0	0.064	6.4	0.50	5.0
25	608381	336876	Holt Lowes SSSI/NVFs SAC	0.030	1.0	5.0	0.006	0.6	0.05	0.96
26	609081	337799	Holt Lowes SSSI/NVFs SAC	0.030	1.0	5.0	0.005	0.5	0.04	0.8

Figure 6a. Maximum annual ammonia concentration - Both farms

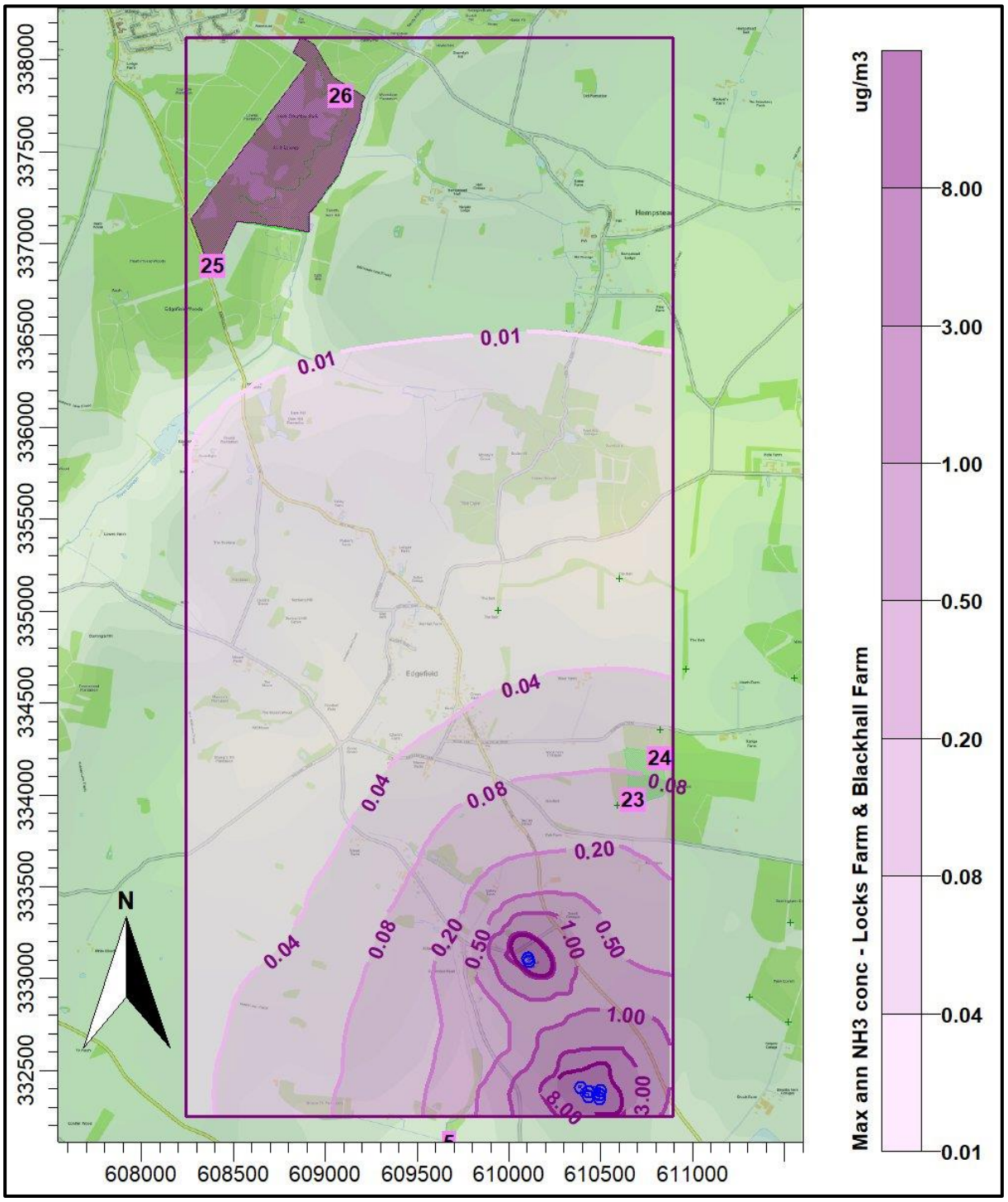
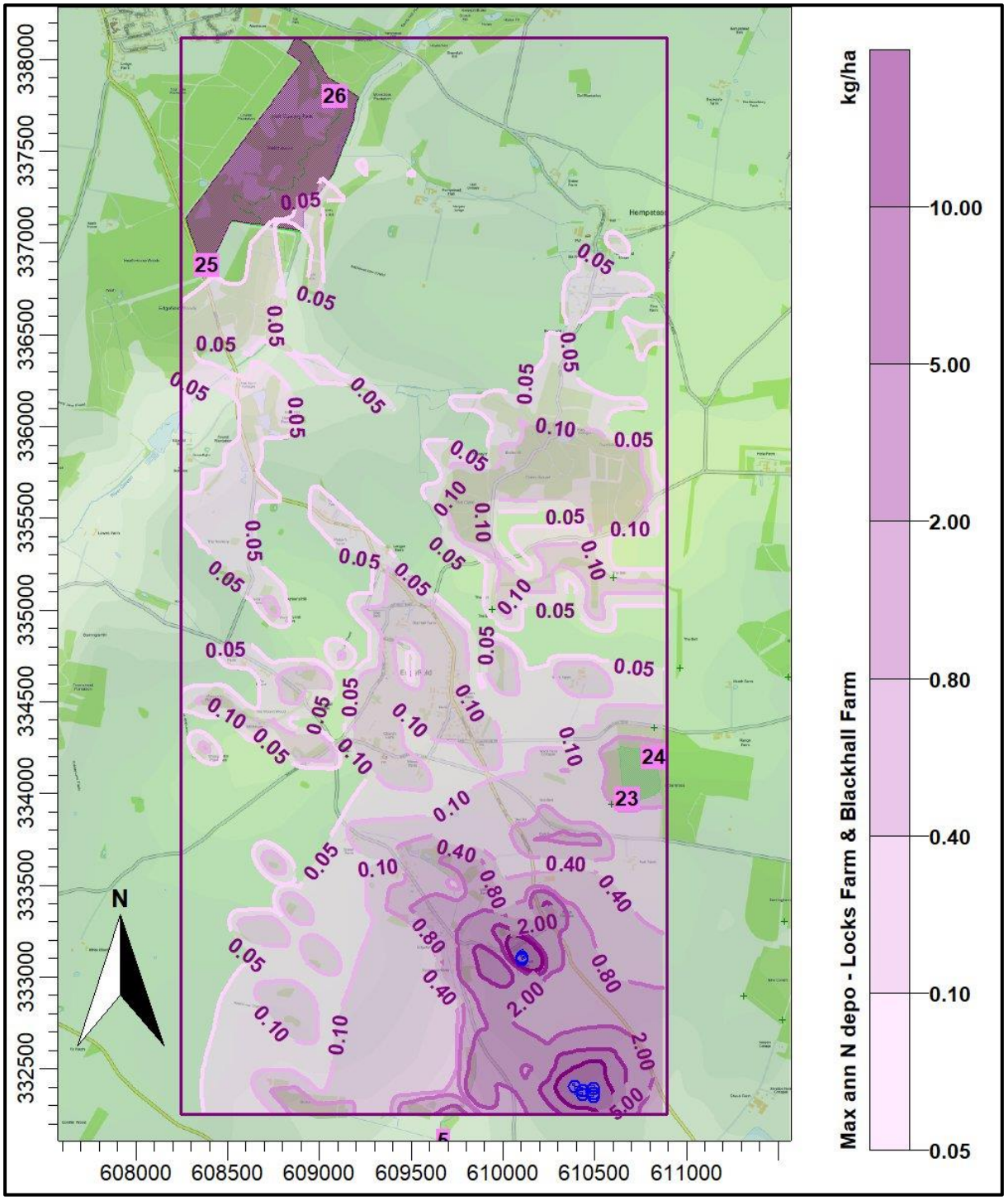


Figure 6b. Maximum annual nitrogen deposition rates - Both farms



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Eleanor Jackson of Dalehead Foods on behalf of North Farm Livestock Ltd., to use computer modelling to assess the impact of ammonia emissions from the existing pig rearing houses at Locks Farm and Blackhall Farm, near Edgefield in Norfolk. NR24 2AY.

Ammonia emission rates from the pig rearing houses at Locks Farm and Blackhall Farm, have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors and information from the recent Agriculture and Horticulture Development Board (AHDB) report, "Establishing ammonia emission factors for straw-based buildings". 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 the process contribution to ammonia concentrations and nitrogen deposition rates due to ammonia emissions from the pig rearing housing at Locks Farm and Blackhall Farm:

- Would be well below the Environment Agency's lower threshold percentage of the Critical Level and Critical Load (4% for a SAC, 20% for the SSSI and 100% for non-statutory sites) at all the wildlife sites considered.

7. References

Agriculture and Horticulture Development Board (AHDB) report, “Establishing ammonia emission factors for straw-based buildings”.

Cambridge Environmental Research Consultants (CERC) (website).

Environment Agency H1 Risk Assessment (website).

M. A. Sutton *et al*. Measurement and modelling of ammonia exchange over arable croplands.

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

United Nations Economic Commission for Europe (UNECE) (website).

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