A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Proposed Pullet Chicken Rearing House at Lynwood, near Church Stoke in Powys

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5th March 2018

1. Introduction

AS Modelling & Data Ltd. has been instructed by Rosina Bloor of Richard Parry & Partners LLP, on behalf of the applicant, to use computer modelling to assess the impact of ammonia emissions from the proposed pullet chicken rearing house at Lynwood, near Church Stoke in Powys.

Ammonia emission rates from the proposed poultry house have been assessed and quantified based upon the Environment Agency's 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

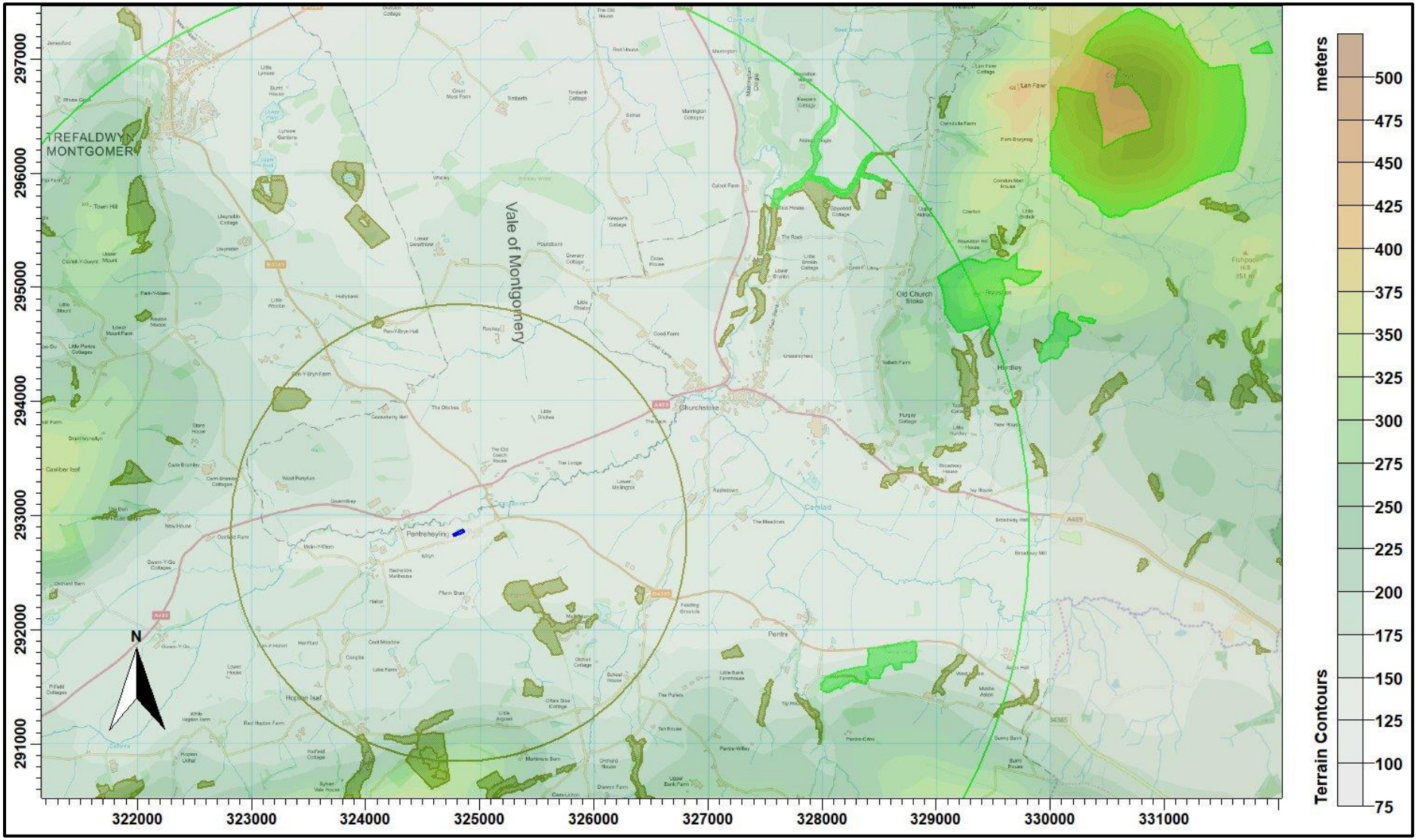
The site of the proposed pullet rearing house at Lynwood is in a rural area on the Welsh/English border, approximately 1.9 km to the south-west of the village of Church Stoke in Powys. The surrounding land is used largely for livestock and arable farming, although there are some isolated wooded areas. The site is at an altitude of around 150 m in the wide and relatively flat valley of the River Caebitra, a tributary of the River Camlad, with land rising to hilltops and mountains to the north-west and south.

The proposed poultry house would provide accommodation for up to 38,000 pullets, which would be reared from day old chicks to between 18 to 20 weeks old, prior to transfer to egg laying units elsewhere. The house would be ventilated by uncapped high speed ridge fans, each with a short chimney. Every four days, the birds' droppings would be removed by a belt collection system and stored temporarily on the farm, prior to being removed from site or spreading to land.

There are several Ancient Woodlands (AWs) within 2 km of Lynwood, including: Mellington Wood AW; Butcher's Wood AW; Lake Wood AW; Oak Coppice AW; Pentrenant Dingle AW; Weston Wood AW and three other unnamed sites. There are also three areas designated as Sites of Special Scientific Interest (SSSIs) within 5 km of the site, namely: Coed Pentre SSSI; Spy Wood & Aldress Dingle SSSI and Roundton Hill SSSI. There are no internationally designated sites within 5 km of the farm.

A map of the surrounding area showing the positions of the proposed poultry house and the nearby wildlife sites is provided in Figure 1. In the figure, the AWs are shaded in olive, the SSSIs are shaded green and the site of the proposed poultry house is outlined in blue.

Figure 1. The area surrounding the site – concentric circles radii at 2 km (olive) and 5 km (bright green)



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 Lynwood and the wildlife sites is 1.87 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 31.92 kg-N/ha/y and to short vegetation is 20.30 kg-N/ha/y. The background acid deposition rate to woodland is 2.40 keq/ha/y and to short vegetation is 1.57 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS, March 2018).

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 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)
AWs	1.0 [1]	-	-
Coed Pentre SSSI	1.0 [1]	5.0 [2]	-
Spy Wood & Aldress Dingle SSSI	n/a [3]	n/a [3]	-
Roundton Hill SSSI	1.0 [1]	5.0 [2]	-

1. A precautionary figure, used where the citation for the site contains reference to lichens or bryophytes, or no details of the ecology of the site are available, or have not been considered.
2. The lower bound of the range of Critical Loads obtained from APIS.
3. Designated for geological features – no Critical Level or Load.

3.4 Guidance on the significance of ammonia emissions

3.4.1 Natural Resources Wales criteria

In March 2017, Natural Resources Wales (Regulation and Permitting Department, EPP) published Operational Guidance Note 41 (OGN 41), "Assessment of ammonia and nitrogen impacts from livestock units when applying for an Environmental Permit or Planning Permission". This guidance was intended to update the way Natural Resources Wales (NRW) assessed emissions, in particular by changing the thresholds of insignificance and the upper threshold process contributions for designated sites. These designated sites include European sites, such as Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Ramsar sites as well as Sites of Special Scientific Interest (SSSIs).

Table 1 in OGN 41 describes the revised screening distance and thresholds for livestock developments; the threshold of insignificant percentage of the designated site Critical Level or Load is given as 1%; the upper threshold percentage of the designated site Critical Level or Load is given as 8%.

Table 2 in OGN 41 describes the possible outcomes of assessment and for detailed modelling of the application alone, where process contributions, considered in isolation, are up to 1% of the designated site Critical Level or Load, then it should be determined that there is no significant environmental effect/no likely significant effect/damage to scientific interest.

Where process contributions, considered in isolation, are between 1% and 8% of the designated site Critical Level or Load, an in-combination assessment is required. Should the in-combination process contributions be between 1% and 8% of the designated site Critical Level or Load then it should be

determined that the application would cause no significant environmental effect/likely significant effect/damage to scientific interest.

When considering process contributions, in isolation or in-combination, if they exceed 8% of the designated site Critical Level or Load it is necessary to consider background concentrations and whether the designated site Critical Level or Load is breached and whether additional controls may be necessary. The application will then be determined based on whether there will be significant environmental effect/adverse effect/damage to scientific interest.

For Local Nature Reserves (LNRs), Local Wildlife Sites (LWSs) and Ancient Woodlands (AWs), the current assessment procedure usually applied is based on the Environment Agency's horizontal guidance, H1 Environmental Risks Assessment, H1 Annex B - Intensive Farming. The following are taken from this document.

"An emission is insignificant where Process Contribution (PC) is <50% for local and national nature reserves (LNRs & NNRs), ancient woodland and local wildlife sites." And "Where modelling predicts a process contribution >100% at a NNR, LNR, ancient woodland or local wildlife site, your proposal may not be considered acceptable. In such cases, your assessment should include proposals to reduce ammonia emissions."

This document was withdrawn February 1st 2016 and replaced with a web-page titled "Intensive farming risk assessment for your environmental permit", which contains essentially the same criteria. It is assumed that the upper threshold and lower threshold on the web-page refers to the levels that were previously referred to as levels of insignificance and acceptability in Annex B– Intensive Farming.

Within the range between the lower and upper thresholds, whether or not the impact is deemed acceptable is at the discretion of the Environment Agency. N.B. 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 Environment Agency criteria

The following are obtained from the Environment Agency's horizontal guidance, H1 Environmental Risks Assessment, H1 Annex B - Intensive Farming.

"An emission is insignificant where Process Contribution (PC) is <4% of Critical Levels for SACs, SPAs and Ramsars, <20% for SSSIs, and <50% for local and national nature reserves (LNRs & NNRs), ancient woodland and local wildlife sites." And, "Where modelling predicts a process contribution >20% of the Critical Level/Load at a SAC, SPA or Ramsar, >50% at a SSSI or >100% at a NNR, LNR, ancient woodland or local wildlife site, your proposal may not be considered acceptable. In such cases, your assessment should include proposals to reduce ammonia emissions."

This document was withdrawn February 1st 2016 and replaced with a web-page titled "Intensive farming risk assessment for your environmental permit", which contains essentially the same criteria. It is assumed that the upper threshold and lower threshold on the web-page refers to the levels that were previously referred to as levels of insignificance and acceptability in Annex B– Intensive Farming.

Within the range between the lower and upper thresholds; 4% to 20% for SACs, SPAs and Ramsars; 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. N.B. 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 IAQM Position Statement on the use of the 1% criterion

A Position Statement issued by the Institute of Air Quality Management (IAQM) in January 2016 further clarifies the use of the 1% criterion for the determination of an '*insignificant*' effect of air quality impacts on sensitive habitats. The Position Statement states: "*the use of a criterion of 1% of an environmental standard or assessment level in the context of habitats should be used only to screen out impacts that will have an insignificant effect. It should not be used as a threshold above which damage is implied.*" Furthermore, if the impacts are plainly above 1% then this should be regarded as potentially significant; where impacts are just slightly greater than 1% then a degree of professional judgement should be applied with regards to the theoretical risk.

3.6 Quantification of ammonia emissions

Ammonia emission rates from poultry 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.

AS Modelling & Data Ltd. understand that the Environment Agency and Natural Resources Wales have agreed to an ammonia emission factor of 0.04 kg-NH_3/bird place/y, which is based on the Environment Agency pullet rearing figure of 0.06 kg-NH_3/bird place/y, reduced by one third to account for the effect of the manure belt system which would remove a significant proportion of the manure from the building.

Details of the poultry numbers and types and emission factors used and calculated ammonia emission rates are provided in Table 2.

Table 2. Details of animal numbers and ammonia emission rates

Source	Animal numbers	Type or weight	Emission factor (kg-NH_3/place/y)	Emission rate (g-NH_3/s)
Proposed Housing	38,000	Pullet Rearing	0.04	0.048166

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 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).

The GFS is a spectral model and data are archived at a horizontal resolution of 0.25 degrees, which is approximately 25 km over the UK (formerly 0.5 degrees, or approximately 50 km). 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 observational records may be over represented, this is because the instrumentation used may not record wind speeds below approximately 0.5 m/s and start up wind speeds may be greater than 1.0 m/s. In NWP data, the wind speed is continuous down to 0.0 m/s, allowing the calms module of ADMS to function correctly.

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

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

The wind rose for the raw GFS data is shown in Figure 2a.

Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and where terrain data is included in the modelling, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for the location of the proposed poultry house at Lynwood is shown in Figure 2b. The resolution of the wind field in terrain runs is approximately 300 m.

Figure 2a. The wind rose. Raw GFS derived data for 52.528 N, 3.109 W, 2014-2017

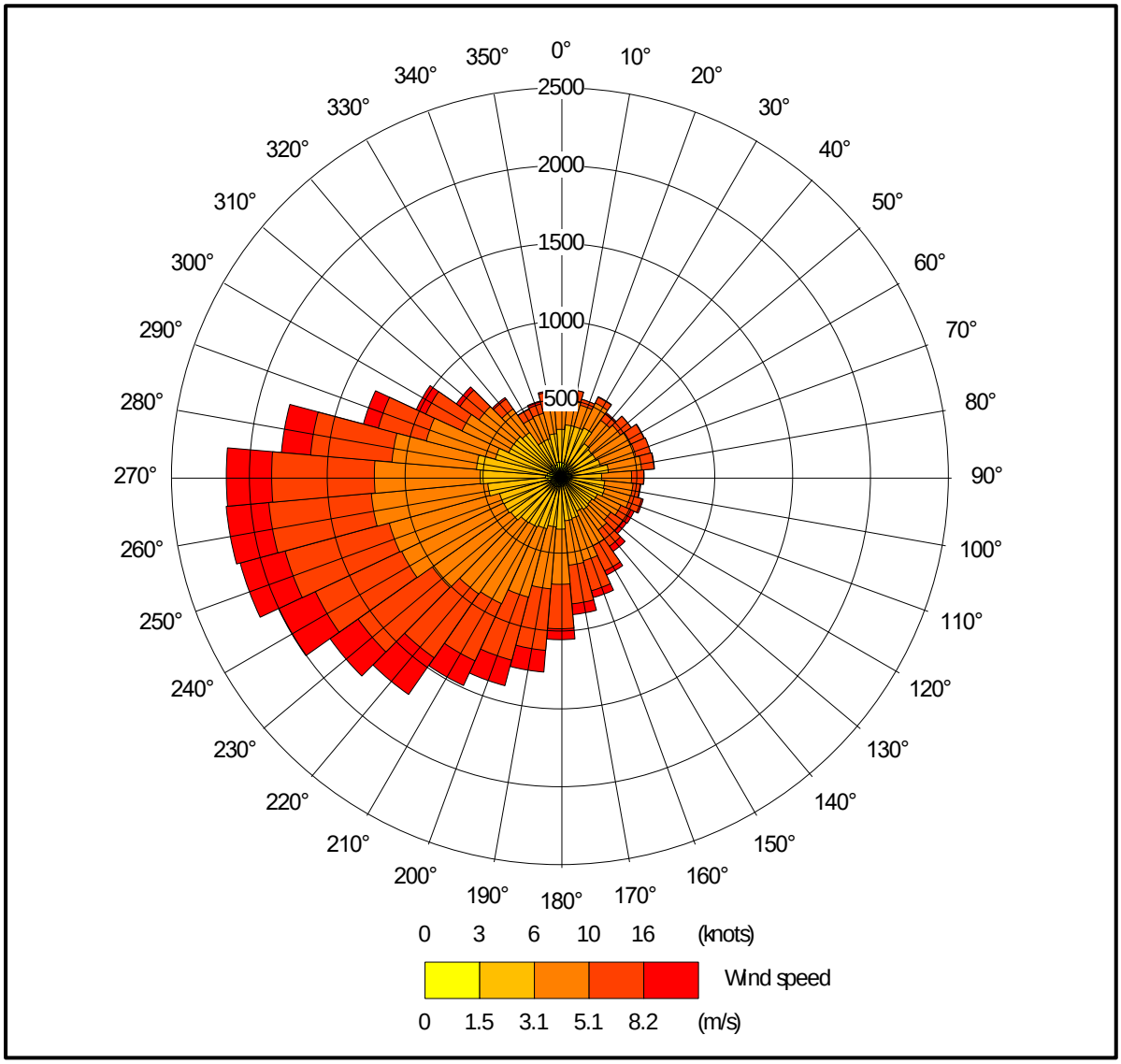
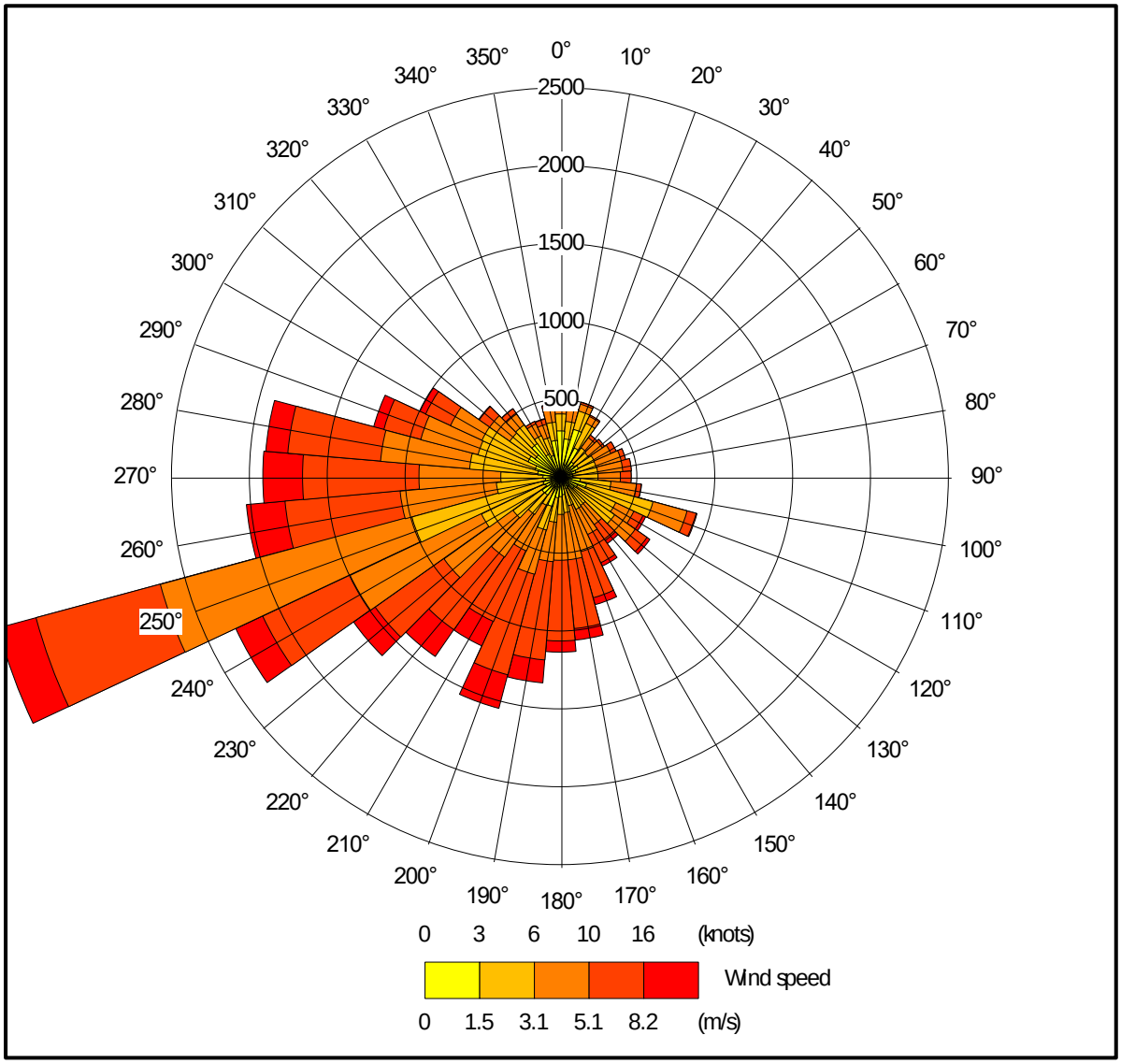


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 324800, 292850, 2014-2017



4.2 Emission sources

Emissions from the chimneys of the uncapped high speed ridge or roof fans that would be used for the ventilation of the poultry house are represented by three point sources within ADMS (PR a, b & c). Details of the point source parameters are shown in Table 3 and their positions may be seen in Figure 3, where they are marked by red stars.

Table 3. Point source parameters

Source ID (Scenario)	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source (g-NH_3/s)
PR1 a, b & c	6.5	0.8	11.0	21.0	0.016055

4.3 Modelled buildings

The structure of the proposed poultry house may affect the plumes from the point sources. Therefore, the building is modelled within ADMS. The position of the modelled building may be seen in Figure 3, where it is marked by a grey rectangle.

4.4 Discrete receptors

Twenty-two discrete receptors have been defined: fourteen at the AWs (1 to 14) and eight at the SSSIs (15 to 22). These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figure 4, where they are marked by enumerated pink rectangles.

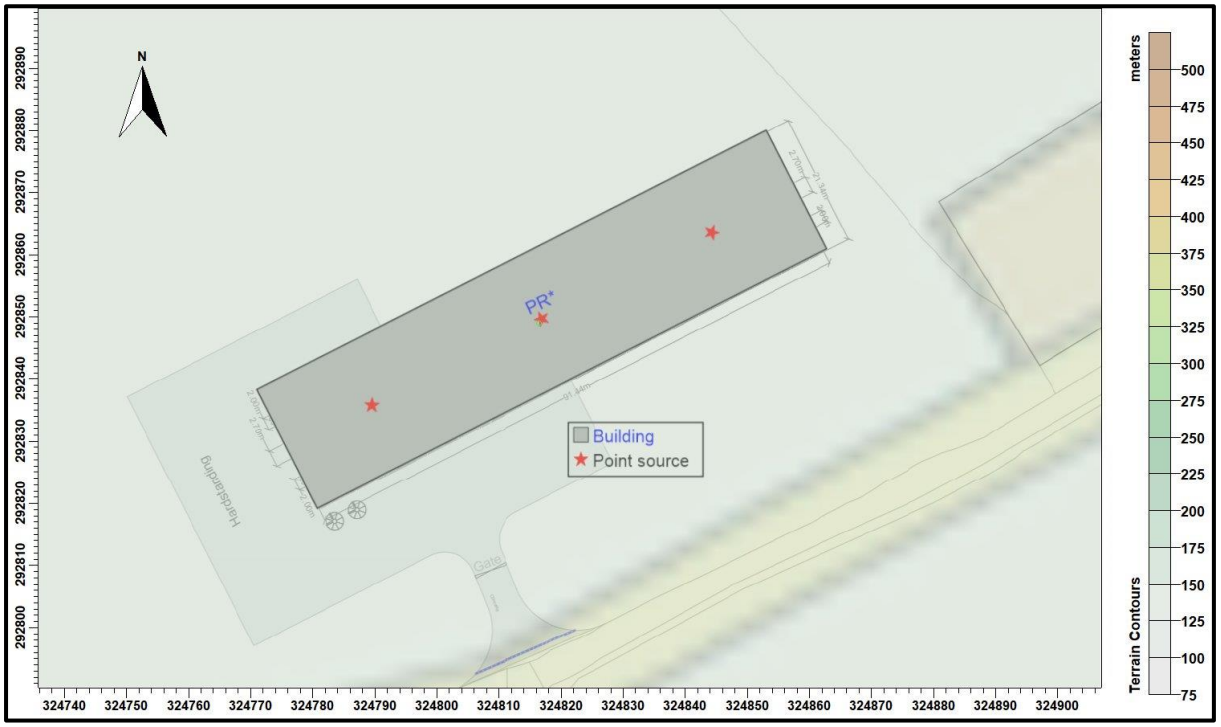
4.5 Cartesian grid

Not used.

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 20.0 km x 20.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS for the preliminary modelling. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is approximately 300 m.

Figure 3. The position of the modelled building and sources



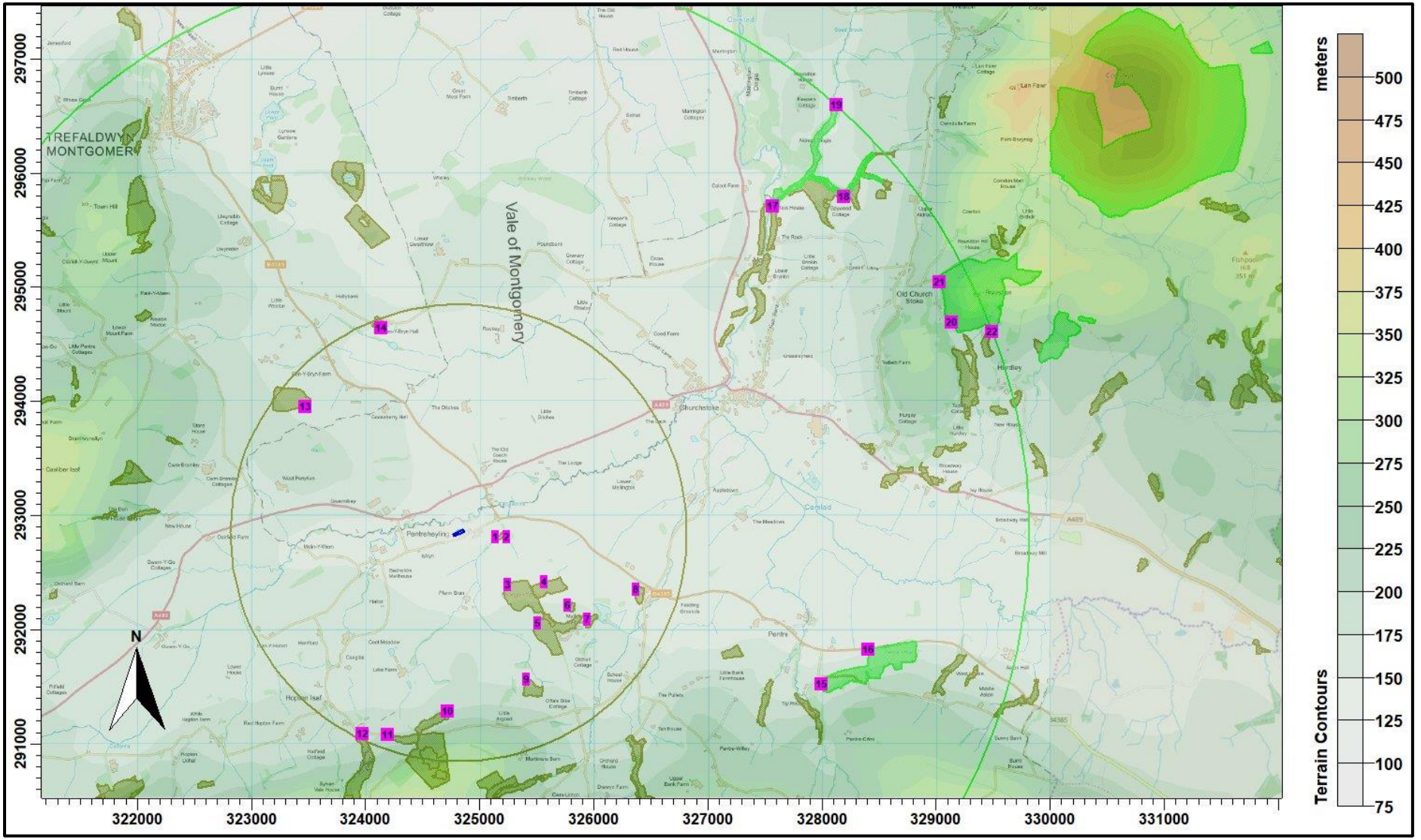
4.7 Roughness Length

A fixed surface roughness length of 0.25 has been applied over the entire modelling domain. As a precautionary measure, the GFS meteorological data is assumed to have a roughness length of 0.225 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.

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. In this case, it proves unnecessary to model deposition of ammonia explicitly and where deposition figures are quoted, these are obtained by multiplying the predicted ammonia concentration by an appropriate deposition velocity and a factor of 259.7 to convert units. Please note that, because deposition of ammonia and the consequent plume depletion are not accounted for, this is a precautionary approach. Therefore, predicted ammonia concentrations (and nitrogen and acid deposition rates) are always higher than if deposition were modelled explicitly, particularly where there is some distance between the source and a receptor.

Figure 4. The discrete receptors



5. Details of the Model Runs and Results

5.1 Preliminary modelling

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

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

For each mode, statistics for the maximum annual mean ammonia concentration at each receptor were compiled.

Details of the predicted annual mean ammonia concentrations at each receptor are provided in Table 4. In the Table, predicted ammonia concentrations (or concentrations equivalent to deposition rates) that are in excess of the Natural Resources Wales upper threshold (8% of Critical Level/Load for a SSSI and 50%[1] of Critical Level/Load for a non-statutory wildlife site) are coloured red. Concentrations in the range between the Natural Resources Wales lower and upper thresholds (1% and 8% for a SSSI and 50%[1] and 100% for a non-statutory wildlife site) are coloured blue.

1. The pre-February 2016 value is used.

Table 4. Predicted maximum annual mean ammonia concentration at the discrete receptors

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration (µg/m³)			
				GFS No Calms No terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed Dep 0.003 m/s
1	325136	292808	Unnamed AW	0.296	0.293	0.286	0.273
2	325239	292816	Unnamed AW	0.206	0.203	0.192	0.183
3	325245	292394	Mellington Wood AW	0.040	0.040	0.036	0.030
4	325563	292418	Mellington Wood AW	0.040	0.040	0.035	0.030
5	325508	292058	Mellington Wood AW	0.019	0.019	0.040	0.022
6	325772	292215	Mellington Wood AW	0.024	0.024	0.030	0.019
7	325942	292087	Mellington Wood AW	0.019	0.019	0.029	0.016
8	326368	292349	Unnamed AW	0.023	0.023	0.023	0.019
9	325408	291560	Butcher's Wood AW	0.010	0.010	0.017	0.010
10	324720	291289	Lake Wood AW	0.011	0.011	0.019	0.007
11	324192	291081	Oak Coppice AW	0.011	0.011	0.018	0.008
12	323973	291084	Pentrenant Dingle AW	0.010	0.010	0.028	0.009
13	323469	293955	Weston Wood AW	0.009	0.009	0.015	0.010
14	324132	294643	Unnamed AW	0.009	0.009	0.011	0.008
15	327998	291523	Coed Pentre SSSI	0.008	0.008	0.009	0.005
16	328407	291826	Coed Pentre SSSI	0.009	0.008	0.009	0.006
17	327565	295711	Spy Wood & Aldress Dingle SSSI	0.005	0.005	0.005	0.003
18	328190	295789	Spy Wood & Aldress Dingle SSSI	0.005	0.005	0.005	0.003
19	328123	296598	Spy Wood & Aldress Dingle SSSI	0.004	0.004	0.004	0.002
20	329134	294694	Roundton Hill SSSI	0.005	0.005	0.007	0.003
21	329029	295041	Roundton Hill SSSI	0.005	0.005	0.004	0.002
22	329485	294608	Roundton Hill SSSI	0.005	0.005	0.005	0.003

6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Rosina Bloor of Richard Parry & Partners LLP, on behalf of the applicant, to use computer modelling to assess the impact of ammonia emissions from the proposed pullet chicken rearing house at Lynwood, near Church Stoke in Powys.

Ammonia emission rates from the proposed poultry house have been assessed and quantified based upon the Environment Agency's 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.

At all sites considered, the modelling predicts that the process contribution to the annual ammonia concentration and the nitrogen deposition rate would be below the Natural Resources Wales lower threshold percentage of Critical Level or Critical Load for the site (1% for a SSSI and 100% for a non-statutory wildlife site).

7. References

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