An Assessment using Dispersion Modelling of the Impact of Emissions of Ammonia from the Stacks Serving the Existing and Proposed Ammonia Scrubbing Units at the Befesa Salt Slags Ltd. Aluminium Recycling Facility at Fenn's Bank near Whitchurch, Shropshire

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Mr S Filkin of Filkin & Co. EHS Limited, on behalf of Befesa Salt Slags Ltd., to use computer modelling to assess the impact of ammonia emissions from existing and proposed stacks serving the ammonia scrubbing units at Befesa Salt Slags Ltd., at Fenn's Bank (postal address, Befesa Salt Slags Ltd. Fenn's Bank, Whitchurch, Shropshire. SY13 3PA).

Emissions of ammonia (NH_3) from the stacks serving the three existing ammonia scrubbing units have been assessed and quantified based upon data from Stack Reports compiled by ESG and supplied to AS Modelling & Data Ltd. by Befesa Salt Slags Ltd.

Emissions of ammonia (NH_3) from the stacks serving the proposed ammonia scrubbing unit have been assessed and quantified based upon data on likely performance provided by the manufacturers of the ammonia scrubbing unit, Chemical Process Solutions Ltd.

This report is arranged in the following manner:

- Section 2 provides relevant details of the proposed development and potentially sensitive receptors in the area.

- Section 3 provides some general information on NO_x and details of the method used to determine emission rates; relevant guidelines and legislation on exposure limits and where relevant, details of likely background levels of the pollutants.

- 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

Befesa is an international company specialising in environmental services, offering integrated solutions in industrial residues treatment. The activities of the company are divided into three main areas: Industrial environmental solutions (IES), aluminium residues recycling and Recycling of Steel Dust. The aluminium recycling facility at Fenn's Bank is in a rural area on the Welsh/English border approximately 3.3 km to the south-west of the town of Whitchurch in Shropshire. The site is at an altitude of around 90 m above mean sea level on fairly level ground at the north-eastern end of Fenn's & Whixall Moss with the land rising towards hillier ground to the east.

This report seeks to establish a baseline of the impact from the three stacks that currently emit residual ammonia, known as A2, A5 and A6(GT10). The proposed changes from this baseline involve installation of a new ammonia scrubber unit and an associated stack (A7); the increased capacity to scrub ammonia would allow additional extraction of air from the oxide storage area and would also allow the loading of the existing scrubbers to be reduced.

There are potential human health receptors at residential, commercial and industrial premises in the surrounding area. A map of the surrounding area is provided in Figure 1a; in this figure the site of the main processing facility is outlined in blue.

There are three Ancient Woodlands (AWs) within 2 km of the stacks at Befesa Salt Slags. There are two Sites of Special Scientific Interest (SSSIs) within 5 km, namely; Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses SSSI and Llyn Bedydd SSSI. Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses SSSI is also designated as a Special Area of Conservation (SAC) and a Ramsar site and Llyn Bedydd SSSI is designated as part of the Midland Meres & Mosses Ramsar sites. There are two other SACs within 10 km; Brown Moss SAC and the West Midlands Mosses SAC and also four other units of the Midland Meres & Mosses Ramsar sites.

A map of the surrounding area showing the positions of the wildlife sites is provided in Figure 1b; in this figure, the AWs are shaded olive, SSSIs are shaded in green, the SAC/Ramsar sites are shaded in purple, Ramsar sites are shaded blue and the site of the main processing facility is outlined in blue.

Figure 1a. The area surrounding Befesa Salt Slags

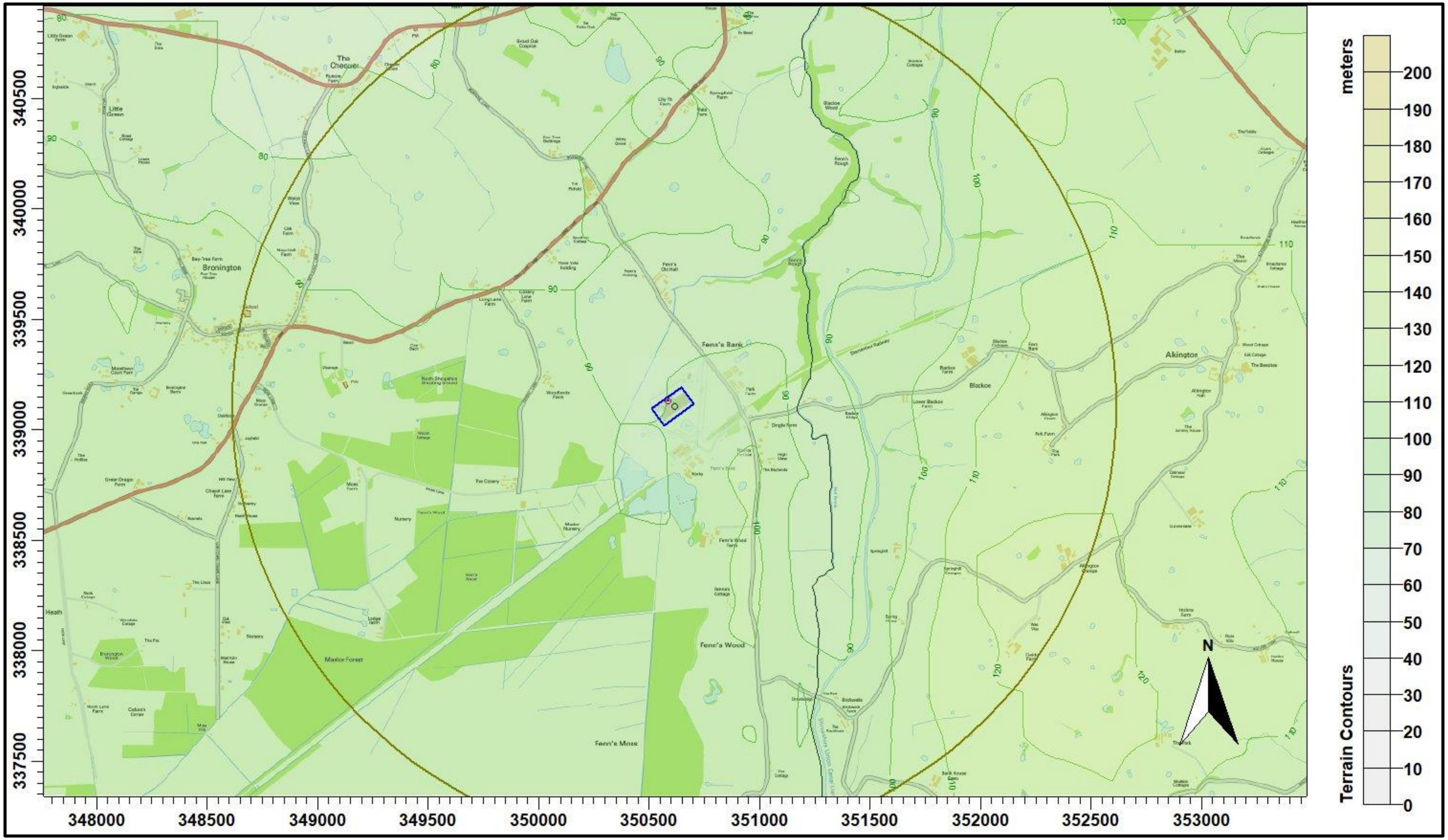

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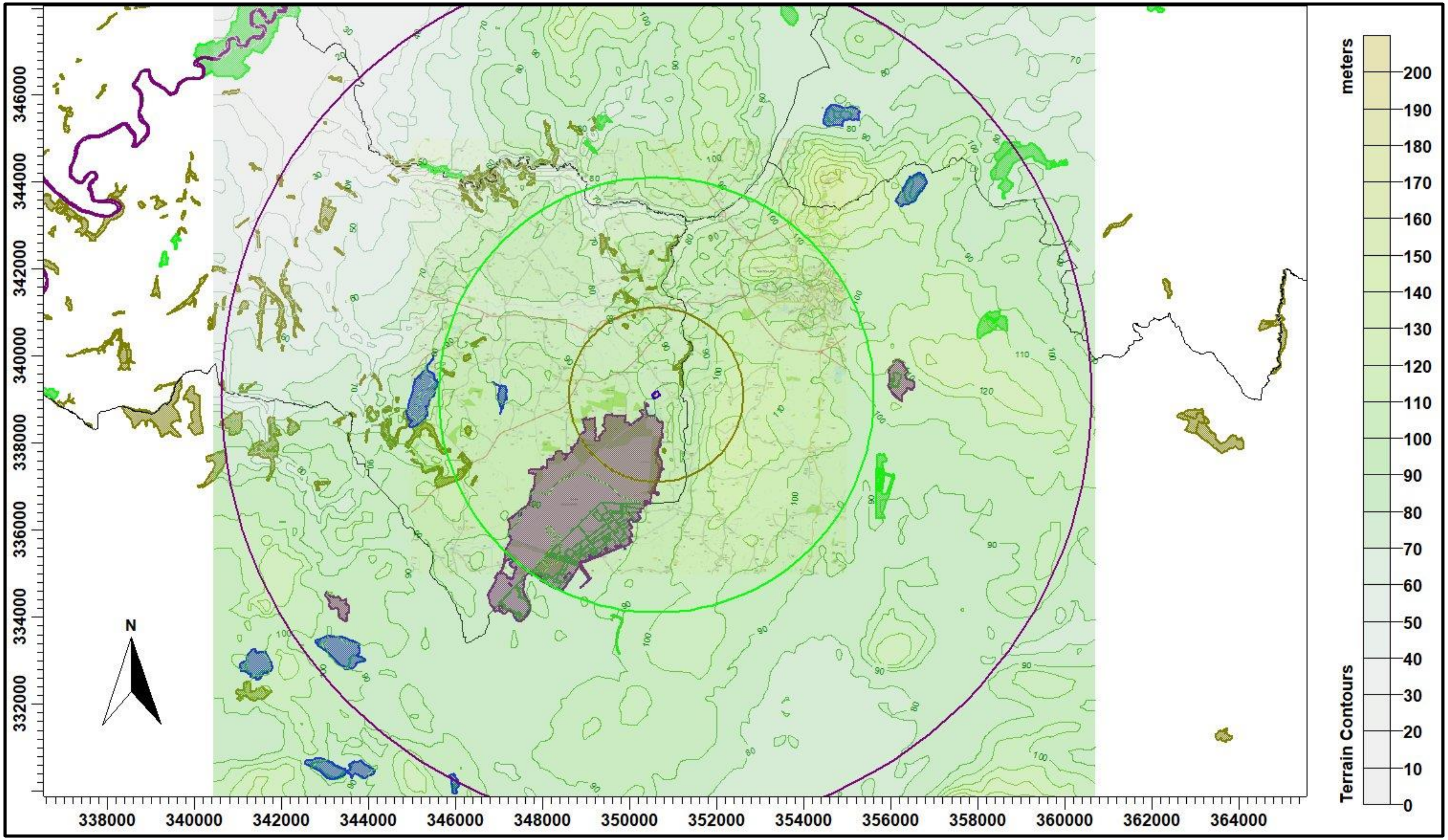
Figure 1b. Wildlife sites in the area surrounding Befesa Salt Slags – concentric circles radii 2 km (olive), 5 km (green) and 10 km (purple)



3. Air Quality Legislation, Regulation, Background Levels & Emission Rates

3.1 Air Quality Strategy and Air Quality Standards Regulations

The current UK Air Quality Strategy (AQS) was published in July 2007 and set out objectives for local authorities for undertaking their Local Air Quality Management (LAQM) duties. The AQS establishes the framework for air quality improvements. The strategy is based upon measures agreed at the national and international level. The requirements of the Local Air Quality Management process as set out in Part IV of the Environment Act (1995), the Air Quality Strategy for England, Scotland, Wales and Northern Ireland 2007 and the relevant Policy and Technical Guidance documents. The LAQM process places an obligation on all local authorities to regularly review and assess air quality in their areas, and to determine whether or not the air quality objectives are likely to be achieved. Where exceedances are considered likely, the local authority must then declare an Air Quality Management Area (AQMA) and prepare an Air Quality Action Plan (AQAP) setting out the measures it intends to put in place in pursuit of the objectives.

The air quality objectives applicable to LAQM in Wales are set out in the Air Quality (Wales) Regulations 2010. The Air Quality Regulations transpose into Welsh law the requirements of the European Directive 2008/50/EC on ambient air quality and cleaner air for Europe, Council Directive 1999/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air, Council Directive 2000/69/EC relating to limit values for benzene and carbon monoxide in ambient air, Council Directive 2002/3/EC relating to ozone in ambient air and Directive 2004/107/EC relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air. Air quality objectives relating to ammonia are provided in Table 1a.

Table 1a. Air Quality Objectives included in Regulations for the purpose of LAQM in Wales

Pollutant	Air Quality Objective Concentration	Averaging period
Ammonia (human health)	180 µg/m^3	Annual mean
Ammonia (human health)	2,500 µg/m^3	Hourly mean
Ammonia (ecological receptors)	1.0 µg/m^3 where lichens or bryophytes (including mosses, landworts and hornwarts) are present, 3.0 µg/m^3 where they are not present.	Annual mean

3.2 Guidance on the Significance of the Impact of Emissions

Where comment on the significance of the impact of emission is made in this report, it is based upon guidance contained in an Environmental Protection UK publication titled Land Use Planning & Development Control: Planning For Air Quality (May 2015). It should be noted; however, that the final judgment on significance is made by the local authority's air quality specialist. The definitions of impact of magnitude for changes in pollutant concentration as a percentage of the assessment level and predicted concentration for an annual mean are provided in Table 1b.

Table 1b. Air quality impact descriptors for changes to annual mean concentrations

Average concentration (as percentage of Predicted Environmental Concentration)	Change in concentration (Process Contribution as percentage of Environmental Assessment Level)			
	<1	>=1 and <5	>=5 and <10	>10
<75	Negligible	Negligible	**Slight**	**Moderate**
>=75 to <95	Negligible	**Slight**	**Moderate**	**Moderate**
>=95 to <103	**Slight**	**Moderate**	**Moderate**	**Substantial**
>=103 to <110	**Moderate**	**Moderate**	**Substantial**	**Substantial**
>=110	**Moderate**	**Substantial**	**Substantial**	**Substantial**

3.3 Background Ammonia Levels

The background concentrations used in this report are obtained from the Air Pollution Information System (APIS) website (2013-2015 data), and measured data from Fenn's Moss (2016 data).

The background concentrations of ammonia from APIS are provided in Table 2. The table contains the concentration for the centroid of the 1 km Ordnance Survey grid square around the site and the concentration for the centroids of adjacent 1 km Ordnance Survey grid squares. The Average concentration at Fenn's Moss (exact location not given) is 2.98 µg/m^3.

Table 2. Background ammonia concentrations - APIS figures

OS easting & northing	346500	347500	348500	349500	350500	351500	352500	353500	354500
343500	3.03	3.03	3.03	3.03	3.3	3.3	3.3	3.3	3.3
342500	3.03	3.03	3.03	3.03	3.3	3.3	3.3	3.3	3.3
341500	3.03	3.03	3.03	3.03	3.3	3.3	3.3	3.3	3.3
340500	3.03	3.03	3.03	3.03	3.3	3.3	3.3	3.3	3.3
339500	2.42	2.42	2.42	2.42	3.53	3.53	3.53	3.53	3.53
338500	2.42	2.42	2.42	2.42	3.53	3.53	3.53	3.53	3.53
337500	2.42	2.42	2.42	2.42	3.53	3.53	3.53	3.53	3.53
336500	2.42	2.42	2.42	2.42	3.53	3.53	3.53	3.53	3.53
335500	2.42	2.42	2.42	2.42	3.53	3.53	3.53	3.53	3.53

3.5 Quantification of Emissions of Ammonia and Stack Parameters

Emissions of ammonia from stacks A2, A5 and A6 and stack efflux velocity and temperatures are based upon data from quarterly Stack Reports compiled by ESG and supplied to AS Modelling & Data Ltd. by Befesa Salt Slags Ltd. The data for stacks A2, A5 and A6 are summarised in Tables 3a, 3b and 3c, respectively.

Table 3a. ESG recorded ammonia emissions and efflux parameters – Stack A2.

	Ammonia (mg/m^3)	Ammonia (g/h)	Water Vapour (%)	Temperature (°C)	Volume (m^3/h)	Volume at STP wet (m^3/h)	Volume at STP (dry) (m^3/h)	Volume REF (m^3/h)	Velocity (m/s)	Diameter (m)
Mar-16	2.1	37	5	47	20295	17229	16363	17229	11.8	0.78
Jun-16	0.46	6.4	4.6	47	16415	13921	13287	139210	9.5	0.78
Aug-16	0.07	0.69	1.9	19	11328	10597	10376	10579	6.6	0.78
Sep-16	7.6	116	6.6	53	18502	15354	14341	15354	10.8	0.78
Dec-16	13	160	14.3	53	15169	12641	10835	12641	8.8	0.78
Feb-17	0.14	1.3	1.8	51	11247	9425	9253	9425	6.5	0.78
Average	3.895	53.565	5.7	45	15493	13195	12409	34073	9	0.78
Maximum	13	160	14.3	53	20295	17229	16363	139210	11.8	0.78
Minimum	0.07	0.69	1.8	19	11247	9425	9253	9425	6.5	0.78

Table 3b. ESG recorded ammonia emissions and efflux parameters – Stack A5.

	Ammonia (mg/m^3)	Ammonia (g/h)	Water Vapour (%)	Temperature (°C)	Volume (m^3/h)	Volume at STP wet (m^3/h)	Volume at STP (dry) (m^3/h)	Volume REF (m^3/h)	Velocity (m/s)	Diameter (m)
Mar-16	0.24	0.61	1.1	15	2724	2561	2532	2561	7.5	0.35
Jun-16	1.6	4.4	3	16	2996	2783	2699	2783	8.5	0.35
*	0.35	0.96								
Sep-16	1.9	5.2	1.1	15	2926	2744	2713	2744	8.4	0.35
Dec-16	3.7	6.3	1.1	11	1790	1713	1694	1713	5.2	0.35
*	8.7	15								
Feb-17	1.5	1.5	0.83	12	1044	993	985	993	3	0.35
*	1.4	1.4								
Average	2.424	4.421	1.426	13.8	2296	2159	2125	2159	6.52	0.35
Maximum	8.700	15.000	3	16	2996	2783	2713	2783	8.5	0.35
Minumum	0.240	0.610	0.83	11	1044	993	985	993	3	0.35

** Same sample for the month previous but analysed by different methods*

Table 3c. ESG recorded ammonia emissions and efflux parameters – Stack A6.

	Ammonia (mg/m^3)	Ammonia (g/h)	Water Vapour (%)	Temperature (°C)	Volume (m^3/h)	Volume at STP wet (m^3/h)	Volume at STP (dry) (m^3/h)	Volume REF (m^3/h)	Velocity (m/s)	Diameter (m)
Jun-16	0.85	5.8	2.1	23	7511	6880	6733	6880	4.2	0.8
Aug-16	0.08	1.9	1.8	15	24348	23019	22609	23019	13.5	0.8
*	0.86	20								
Nov-16	0.05	0.99	3.3	27	20835	18857	18232	12275	11.5	0.8
*	2	38								
Nov-16	0.08	1.15	1.4	25	16153	14781	14518	14781	8.9	0.8
*	2.5	36								
Feb-17	0.42	4.7	2.9	25	12390	11284	10957	11284	6.8	0.8
*	0.59	6.7								
Average	0.826	12.804	2.3	23	16247	14964	14610	13648	8.98	0.8
Maximum	2.5	38	3.3	27	24348	23019	22609	23019	13.5	0.8
Minimum	0.05	0.99	1.4	15	7511	6880	6733	6880	4.2	0.8

** Same sample for the month previous but analysed by different methods*

3.6 Choice of Receptors

Guidance on the choice of receptors is available in the Environmental Protection UK publication titled Development Control: Planning For Air Quality (2010 Update). The descriptions from Development Control: Planning For Air Quality are reproduced in Table 4.

In this case, it would be rather impractical to place receptors at all qualifying locations. Therefore, a high resolution grid of receptors has been defined and the maximum concentrations predicted at all receptors are presented. Discrete receptors have been defined based on professional experience.

Table 4. Choice of receptors (Development Control: Planning For Air Quality)

Averaging period of objective	Where the objective should apply	Where the objective should not generally apply
Annual	All locations where members of the public might be regularly exposed. Building facades, residential properties, schools, hospitals, care homes etc.	Building facades of offices or other places of work where members of the public do not have regular access. Hotels, unless people live there as their permanent residence. Gardens of residential properties. Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.
8 hours to 24 hours	All locations where the annual mean objectives would apply. Gardens of residential properties.	Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.
1 hour	All locations where the annual mean and 24 and 8-hour mean objectives would apply. Kerbside sites (e.g. pavements of busy shopping streets). Those parts of car parks, bus stations and railway stations etc. which are not fully enclosed, where the public might reasonably be expected to spend one hour or more. Any outdoor locations at which the public may be expected to spend one hour or longer.	Kerbside sites where the public would not be expected to have regular access.
15 minutes	All locations where members of the public might reasonably be expected to spend a period of 15 minutes or longer.	

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

4.1 ADMS

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 (that 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.

4.2 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). Data from RAF Shawbury, has also been considered.

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 records may be over represented, this is 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 that 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, wind speeds and directions will be modified. The terrain and roughness length modified wind rose is shown in Figure 2b. Note that elsewhere in the modelling domain, modified wind roses may differ more markedly and that the resolution of the wind field is approximately 300 m.

The weather data from RAF Shawbury, which, although it quite possibly includes some effects local to the airfield at Shawbury that are not present in the Fenn’s Moss area, should also provide a reasonably good representation of the weather around Befesa Salt Slags. However; it should be noted that whilst Shawbury data shows a west-south-westerly prevailing wind; all other weather data available, GFS, Befesa and the weather data from the Environment Agency/Natural Resources

Wales monitoring show a south-westerly or south-south-westerly prevailing wind. All available met records or data, show a secondary prevailing wind from the north-west.

The wind rose for RAF Shawbury is shown in Figure 2c and a comparison of wind speeds and directions is presented in Annex 1 of this report.

Figure 2a. The wind rose. Raw GFS derived data for 52.947 N, 2.735 W, 2013 – 2016

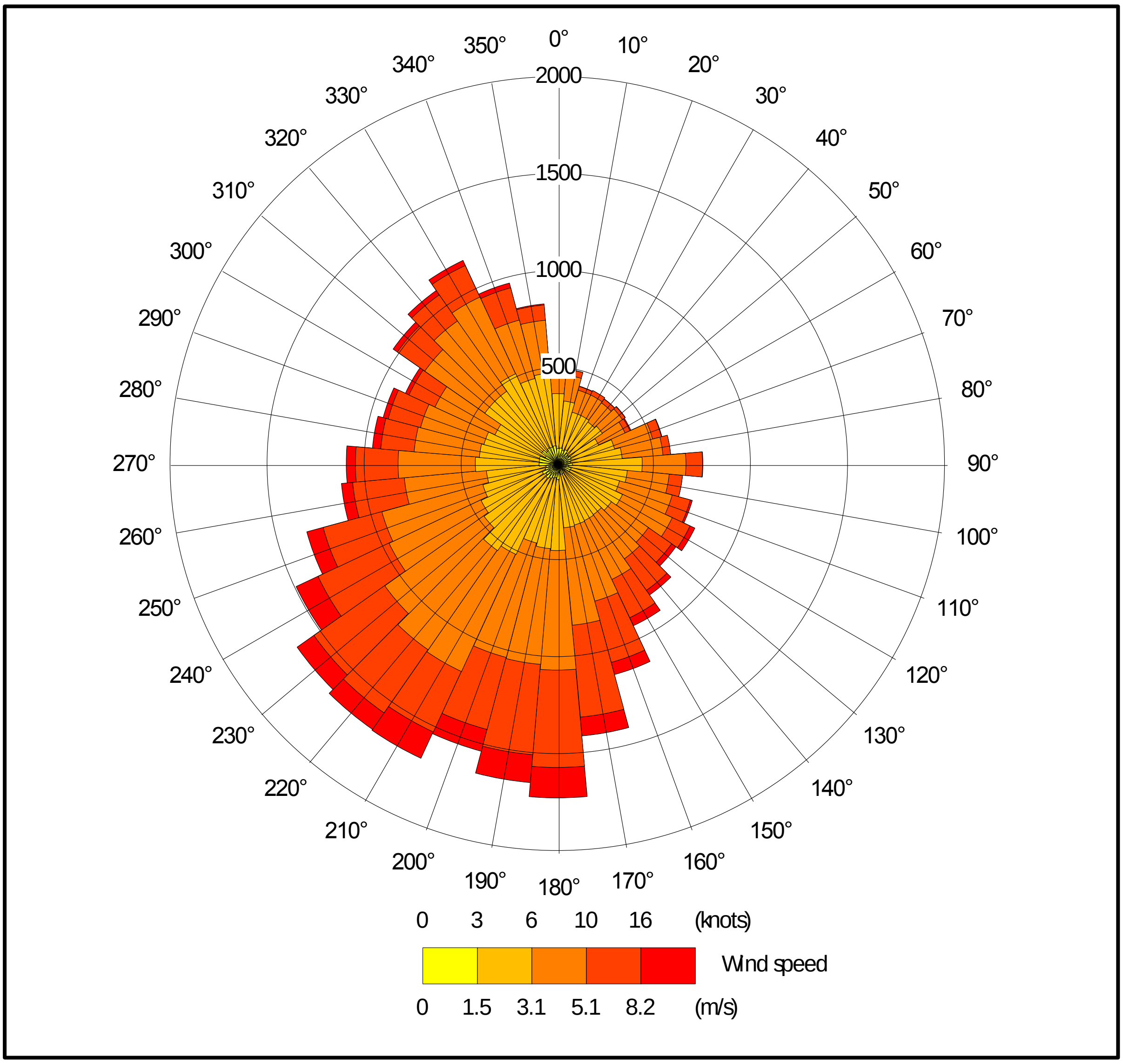


Figure 2b. The wind rose. FLOWSTAR modified GFS data for NGR 350600, 339100, 2013 – 2016

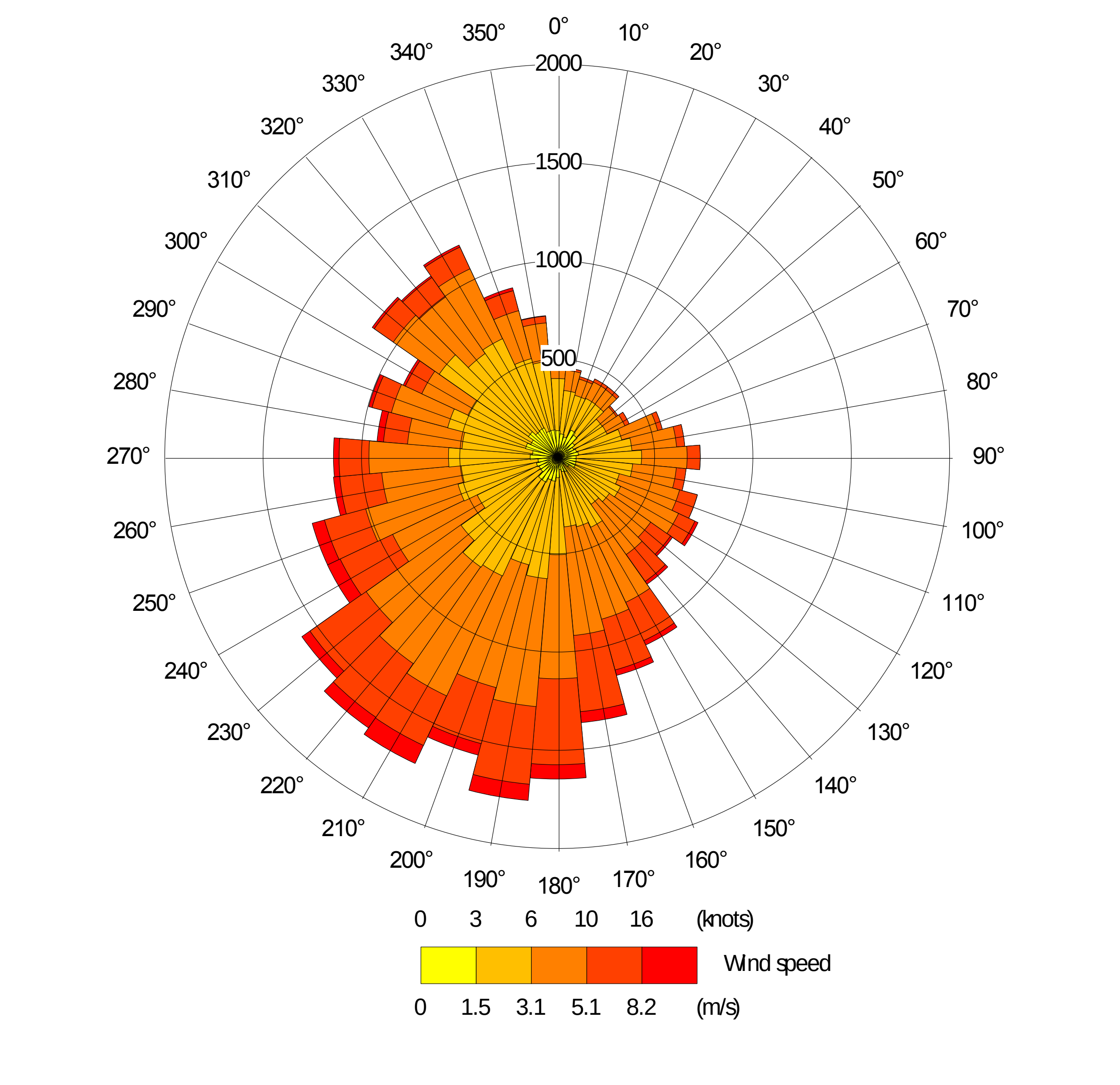
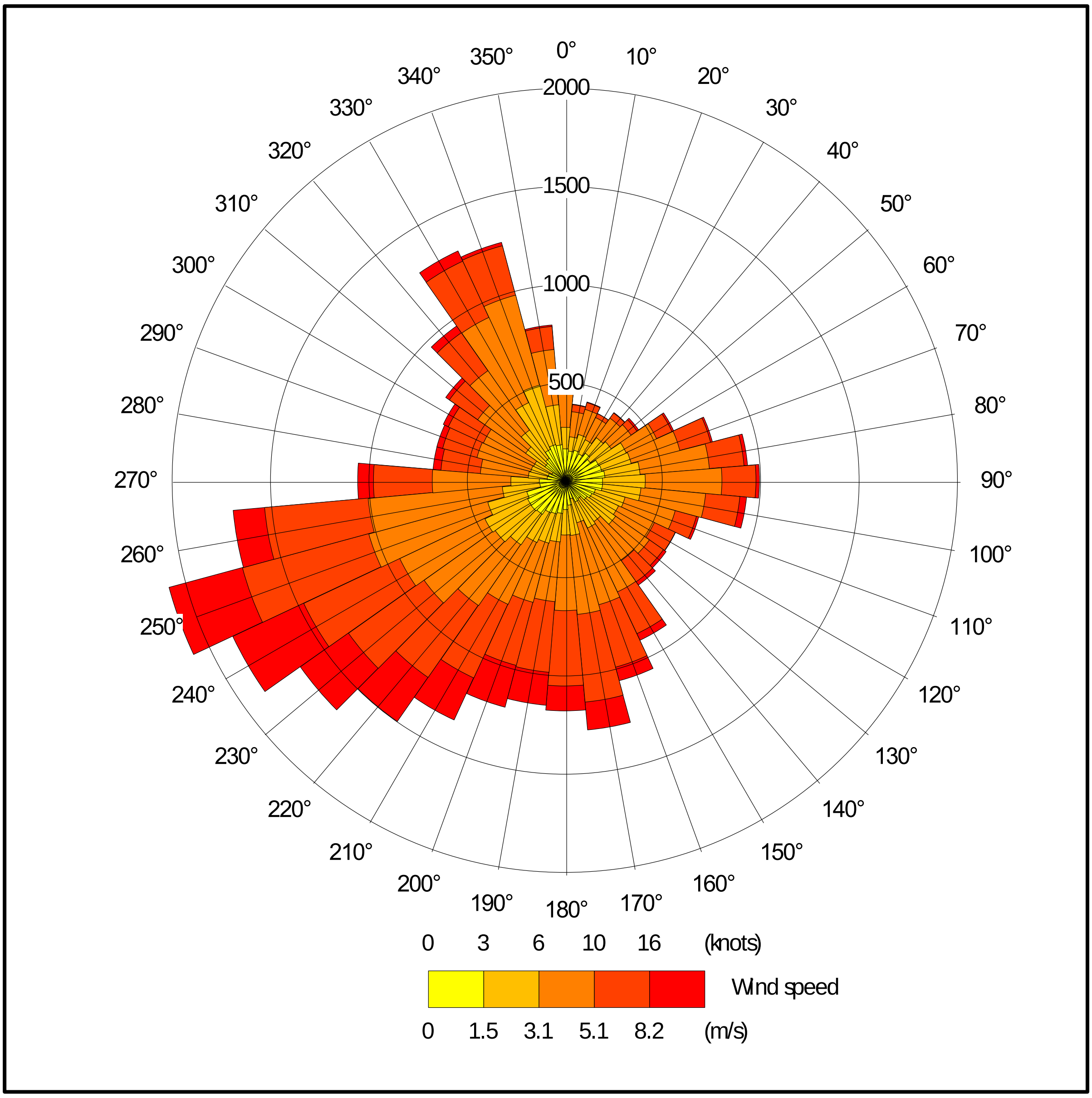


Figure 2c. The wind rose. RAF Shawbury data, 2013 – 2016



4.3 Emission Sources

Emissions of ammonia from the stacks A2, A5, A6 and A7 are modelled using four point sources. The combined stacks are assumed to operate constantly. Three scenarios have been modelled:

- Existing realistic emissions, which use averaged parameters obtained from the ESG reports.
- Existing worst case emissions, which use maximum ammonia emission rates from the ESG reports and the stack parameters likely to lead to the poorest dispersion.
- Proposed realistic emissions, which uses the data supplied by the manufacturers of the ammonia scrubbing unit, Chemical Process Solutions Ltd., for stack A7 and a simple reduction in ammonia emissions from Stacks A2, A5 and A6, based on the estimated reductions provided by Befesa.

Details of the modelled stack parameters are provided in Tables 5a, 5b and 5c. The positions of the combined stacks may be seen in Figure 3, where they are marked by red star symbols.

Table 5a. Point source emission parameters – Existing Realistic

Source ID	X (m)	Y (m)	Height (m)	Diameter (m)	Velocity (m/s)	Temperature (C)	Ammonia Emission Rate (g/s)
A2	350555	339114	15.50	0.78	9.0	45.0	0.014879
A5	350557	339110	6.50	0.35	6.5	14.0	0.001228
A6	350547	339105	12.83	0.80	9.0	23.0	0.003557

Table 5b. Point source emission parameters – Existing Worst Case

Source ID	X (m)	Y (m)	Height (m)	Diameter (m)	Velocity (m/s)	Temperature (C)	Ammonia Emission Rate (g/s)
A2	350555	339114	15.50	0.78	6.5	19.0	0.044444
A5	350557	339110	6.50	0.35	3.0	11.0	0.004167
A6	350547	339105	12.83	0.80	4.2	15.0	0.010556

Table 5c. Point source emission parameters - Proposed

Source ID	X (m)	Y (m)	Height (m)	Diameter (m)	Velocity (m/s)	Temperature (C)	Ammonia Emission Rate (g/s)
A2	350555	339114	15.50	0.78	6.5	19.0	0.013391
A5	350557	339110	6.50	0.35	3.0	11.0	0.000000
A6	350547	339105	12.83	0.80	4.2	15.0	0.000889
A7	350530	339095	16.50	0.98	18.5	23.0	0.052820

4.4 Modelled Buildings

The structure of the various buildings at and around the site may affect the plumes from the point sources. Therefore, the major buildings are modelled within ADMS. The positions of the modelled buildings may be seen in Figure 3, where they are marked by grey rectangles.

4.5 Discrete receptors

4.5.1 Human health receptors

In this case, it would be rather impractical to place receptors at all qualifying locations. Therefore; a high resolution grid of receptors have been defined and the maximum concentrations predicted at all receptors are presented. Discrete receptors have been defined based on professional experience. The positions of the discrete receptors may be seen in Figure 4a, where they are marked by blue circles.

4.5.3 Ecological Receptors

Forty-five discrete receptors have been defined at nearby wildlife sites: seven at the AWs (1 to 7); thirty at the SAC/Ramsar sites (8 to 38) and seven at the Ramsar sites (39 to 45). These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figures 4b and 4c, where they are marked by enumerated pink rectangles.

4.6 The Nested Cartesian Grid

To produce the contour plots presented in this report and to obtain the maximum predicted concentrations, a nested regular Cartesian grid has been defined within ADMS. The individual grid receptors are defined at a height of 1.5 m above ground level within ADMS. The positions of the individual grid points of the nested Cartesian grid may be seen in Figure 4a, where they are marked by green crosses.

4.7 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 use in the 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.

4.8 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 the stability and therefore increases predicted ground level concentrations.

4.9 Deposition

Not modelled.

Figure 3. The positions of modelled point sources and buildings

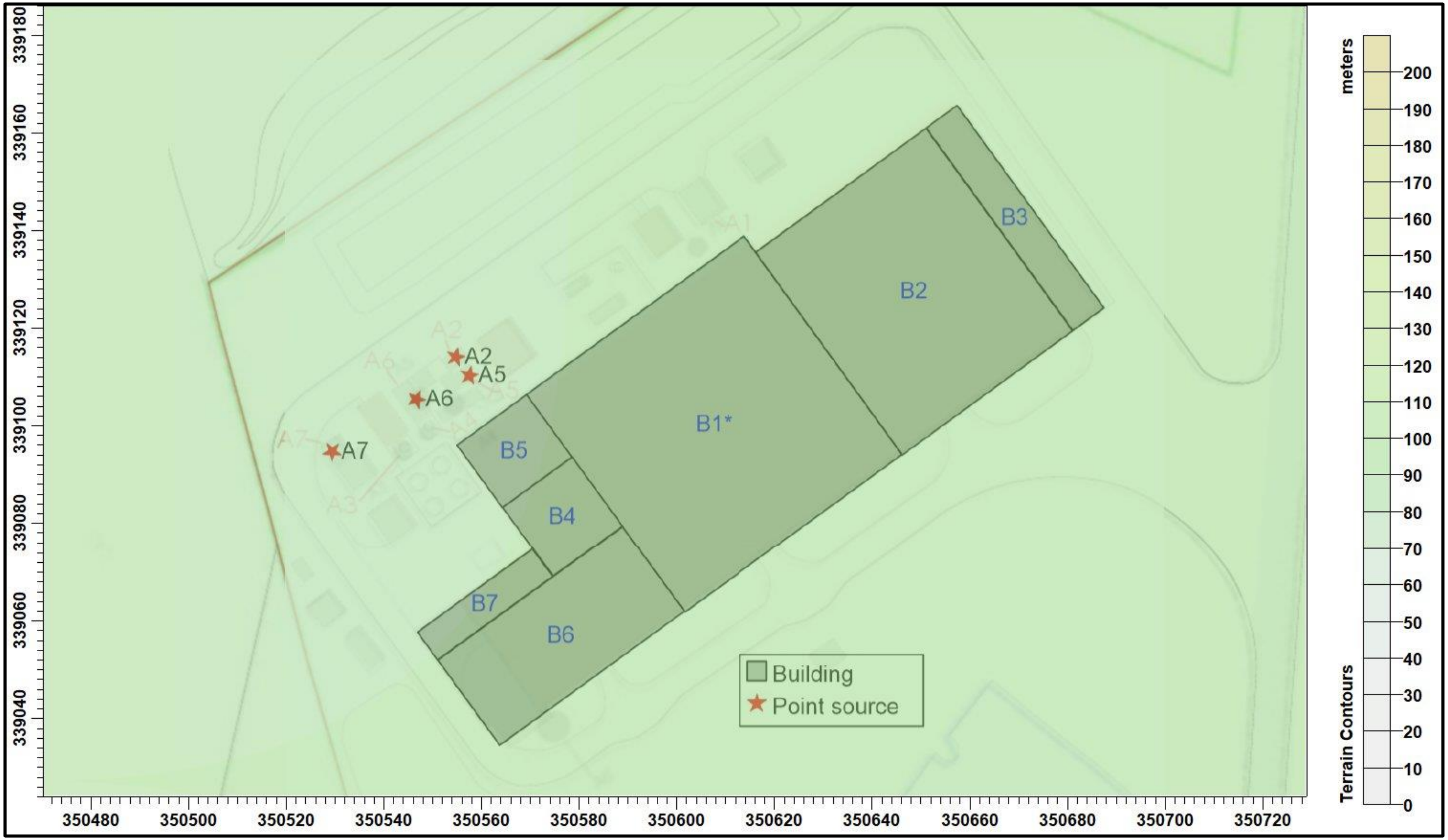


Figure 4a. The nested Cartesian grid

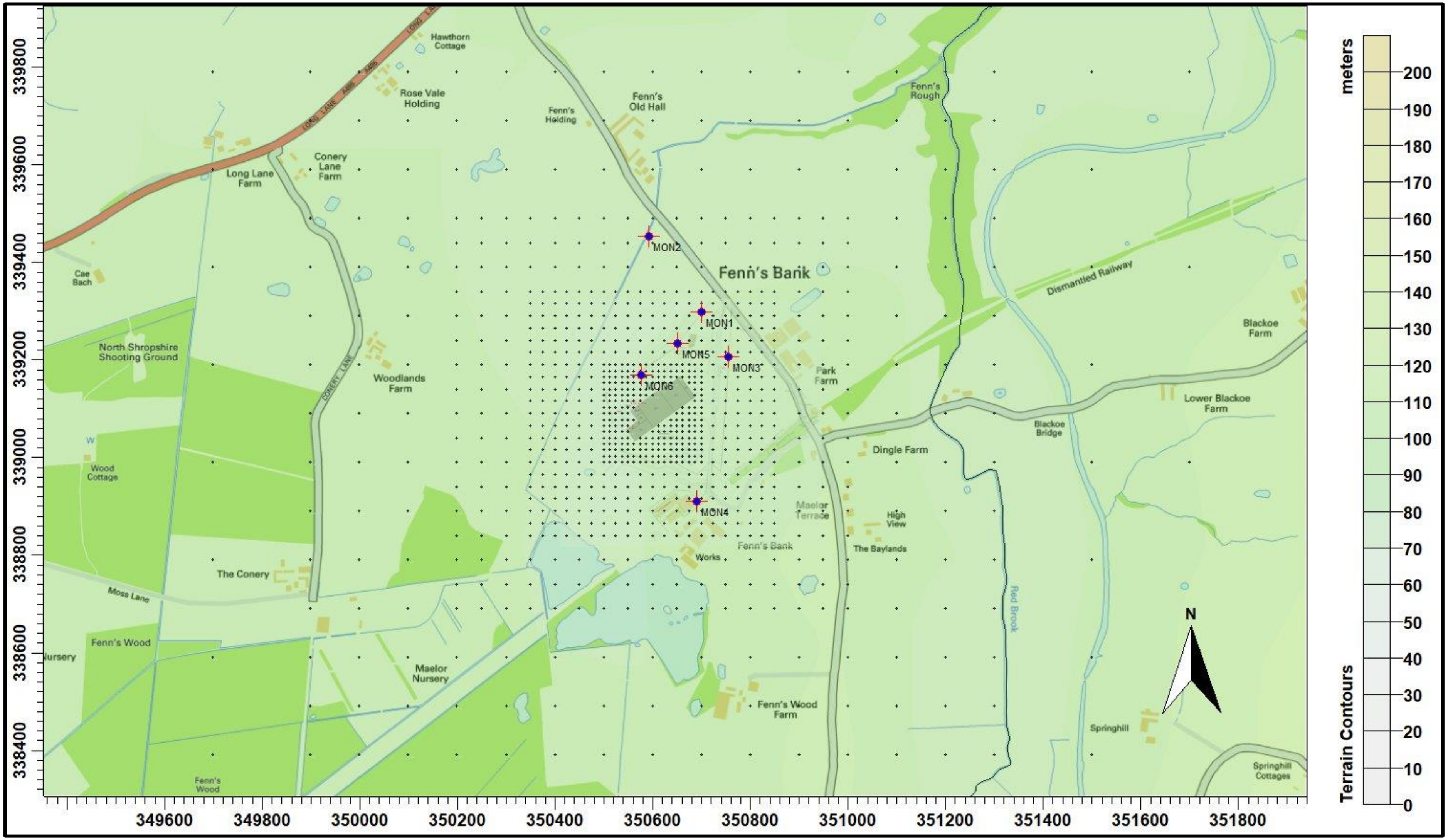


Figure 4b. The discrete receptors at the wildlife sites – a broad scale view

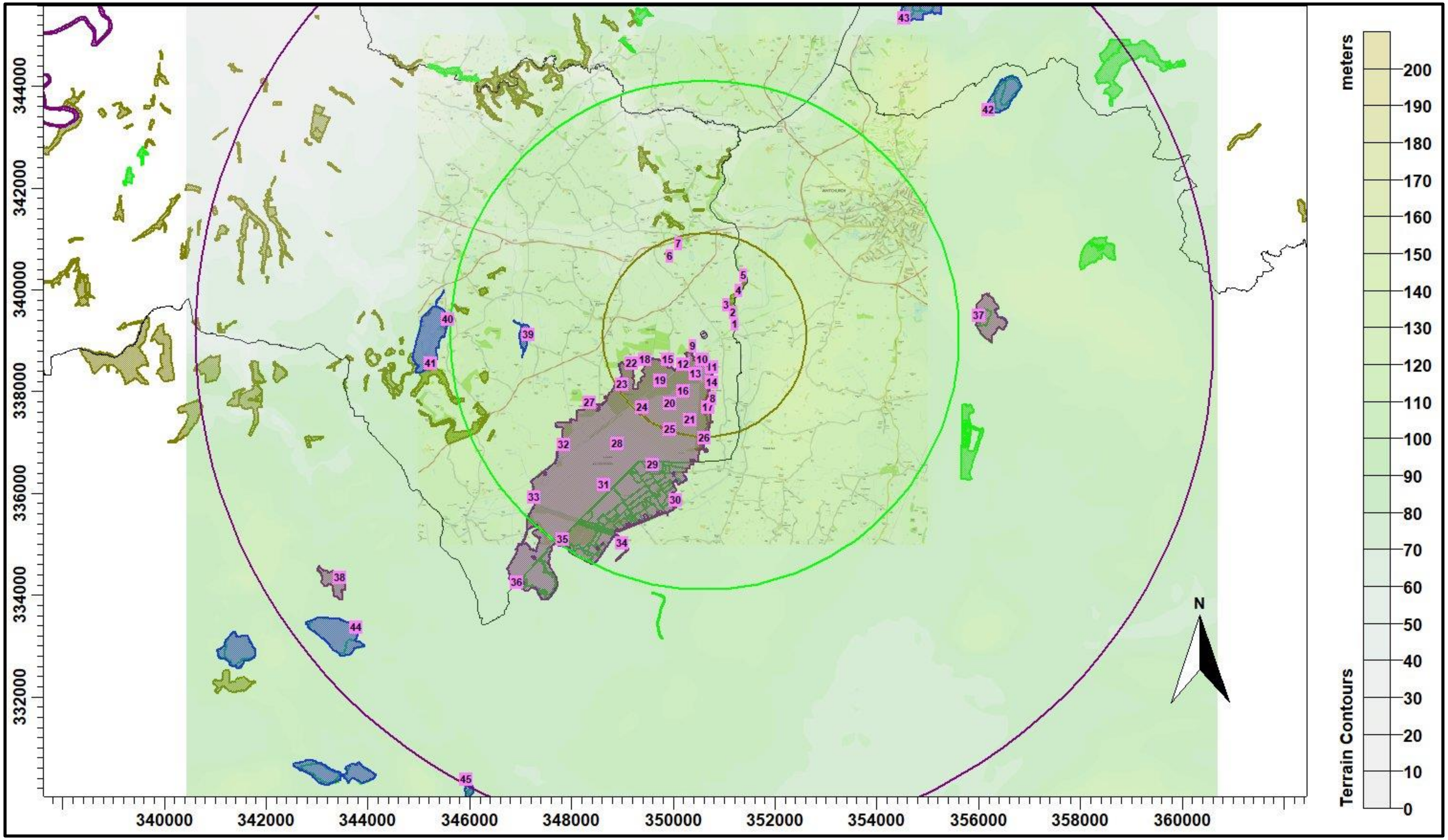
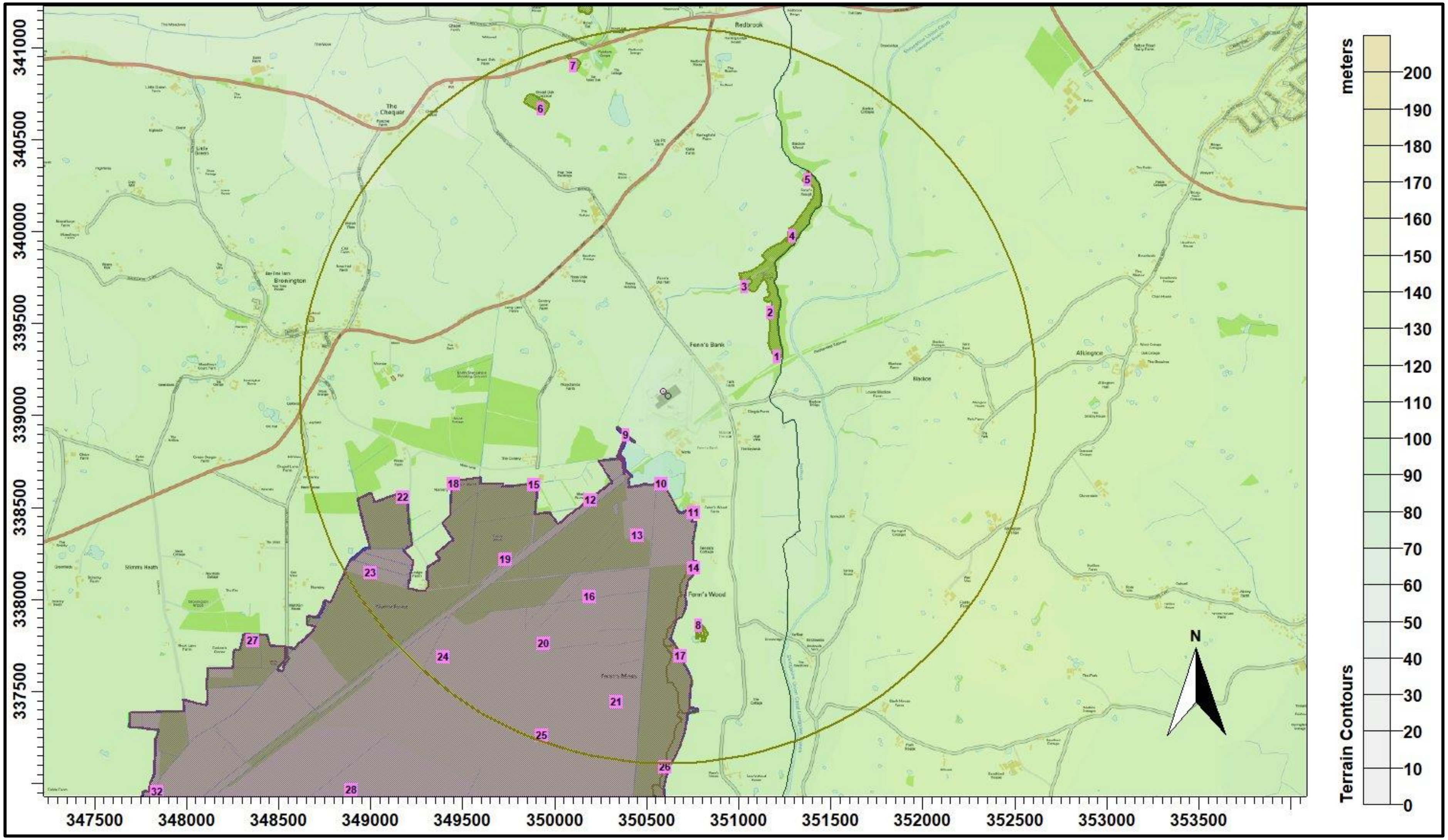


Figure 4c. The discrete receptors at the wildlife sites – a closer view



5. Details of the Model Runs and Results

5.1 Model sensitivity to meteorological data

ADMS was run four times, once for each year of the meteorological datasets (GFS and Shawbury), using the realistic scenario emission parameters, in the following modes:

- GFS data, without calms and without terrain.
- GFS data with calms and without terrain.
- GFS data, without calms and with terrain.
- Shawbury data, without calms and without terrain.

For each receptor at the internal monitoring points and the ecological receptors, statistics for the maximum annual mean ammonia concentration and the maximum hourly mean concentration were compiled. The results are provided in Table 6.

There is little difference between the four modes. The modelling using GFS data and terrain tends to give slightly higher results than other modes at closer receptors; however, it should be noted that this is because the minimum turbulence length is constrained in ADMS [1] when modelling complex terrain. Therefore, for simplicity, all further modelling present uses the GFS data, without calms and without terrain; however, results for other modes can be made available upon request.

1. 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). Whist this might be appropriate over hill/mountain tops in terrain with slopes > 1:10 in lesser terrain it introduces model behaviour that is not desirable where FLOWSTAR is simply being used to modify the upwind flow. Specifically, the parameter sigma z of the Gaussian plume model is overly constrained, which may cause over prediction of ground level concentrations in stable weather conditions and light winds (Steven R. Hanna & Biswanath Chowdhury, 2013). Note that this becomes particularly important 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 approximated the normal behaviour of ADMS with flat terrain.

Table 6. Predicted maximum annual mean and maximum hourly mean ammonia concentration for each of the modes

Receptor number	X(m)	Y(m)	Maximum annual mean ammonia concentration - (μg/m^3)				Maximum hourly mean ammonia concentration - (μg/m^3)			
			Realistic Emissions (averages)				Realistic Emissions (averages)			
			GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	Shawbury No Calms No Terrain	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	Shawbury No Calms No Terrain
mon1	350700	339299	0.091	0.090	**0.093**	0.078	0.997	0.997	1.015	**1.019**
mon2	350592	339455	**0.059**	0.058	**0.059**	0.038	**1.342**	**1.342**	1.309	1.328
mon3	350754	339207	0.100	0.099	0.096	**0.118**	1.296	1.296	**1.302**	1.252
mon4	350689	338910	0.081	0.080	**0.083**	0.080	1.502	1.502	1.492	**1.599**
mon5	350651	339234	0.133	0.132	**0.137**	0.117	1.449	1.449	**1.463**	1.439
mon6	350576	339170	0.318	0.314	**0.322**	0.228	**3.679**	3.607	3.637	3.484
E1	351208	339320	0.018	0.018	0.017	**0.024**	**0.720**	**0.720**	0.694	0.592
E2	351170	339557	**0.017**	**0.017**	**0.017**	**0.017**	0.385	0.385	**0.396**	0.331
E3	351033	339696	**0.019**	0.018	**0.019**	0.016	**0.404**	**0.404**	0.394	0.400
E4	351292	339972	**0.010**	**0.010**	**0.010**	0.008	0.277	0.277	0.286	**0.290**
E5	351374	340282	**0.007**	**0.007**	**0.007**	0.006	**0.217**	**0.217**	0.216	0.193
E6	349926	340665	0.004	0.004	0.004	0.004	0.457	0.457	0.433	**0.467**
E7	350101	340897	0.004	0.004	0.004	0.004	**0.414**	**0.414**	0.400	0.403
E8	350779	337860	0.006	0.006	0.006	0.006	0.573	0.573	**0.611**	0.564
E9	350388	338895	0.019	0.019	0.019	**0.020**	0.793	0.793	0.796	**0.893**
E10	350578	338630	**0.018**	**0.018**	**0.018**	0.017	**1.060**	**1.060**	1.055	0.816
E11	350753	338471	0.017	0.016	0.017	**0.018**	1.121	1.121	1.222	**1.298**
E12	350196	338538	0.006	0.006	**0.007**	0.006	0.407	0.397	**0.442**	0.410
E13	350447	338345	**0.007**	**0.007**	0.006	0.006	**0.484**	**0.484**	0.470	0.384
E14	350756	338172	0.009	0.009	0.009	**0.010**	0.766	0.766	**0.859**	0.699
E15	349888	338621	0.005	0.005	0.005	**0.006**	**0.350**	0.339	0.323	0.329
E16	350191	338017	**0.003**	**0.003**	**0.003**	**0.003**	0.251	0.251	0.250	**0.255**
E17	350681	337691	0.004	0.004	0.004	**0.005**	0.413	0.413	**0.451**	0.408
E18	349450	338626	0.004	0.004	0.004	**0.005**	0.389	0.389	0.375	**0.442**
E19	349733	338217	**0.003**	**0.003**	**0.003**	**0.003**	**0.382**	0.229	0.347	0.225
E20	349938	337762	0.002	0.002	**0.003**	0.002	0.203	0.203	**0.216**	0.170
E21	350333	337441	0.002	0.002	0.002	0.002	**0.241**	**0.241**	0.227	0.189
E22	349177	338553	0.003	0.003	0.003	**0.004**	0.338	0.338	0.335	**0.387**
E23	348998	338143	**0.002**	**0.002**	**0.002**	**0.002**	0.168	0.168	0.168	**0.182**
E24	349392	337686	**0.002**	**0.002**	**0.002**	**0.002**	**0.257**	0.169	0.251	0.168
E25	349928	337264	**0.002**	**0.002**	**0.002**	0.001	0.152	0.152	0.151	**0.181**
E26	350600	337092	0.002	0.002	0.002	**0.003**	**0.275**	**0.275**	0.266	0.241
E27	348357	337777	0.001	0.001	0.001	**0.002**	0.121	0.121	0.123	**0.138**
E28	348894	336966	**0.001**	**0.001**	**0.001**	**0.001**	0.175	0.110	**0.182**	0.115
E29	349597	336564	**0.001**	**0.001**	**0.001**	**0.001**	0.115	0.115	0.116	**0.144**
E30	350040	335874	**0.001**	**0.001**	**0.001**	**0.001**	**0.115**	**0.115**	0.109	0.101
E31	348639	336162	**0.001**	**0.001**	**0.001**	**0.001**	0.107	0.087	**0.126**	0.082
E32	347841	336953	**0.001**	**0.001**	**0.001**	**0.001**	0.105	0.094	0.096	**0.115**
E33	347265	335928	**0.001**	**0.001**	**0.001**	**0.001**	**0.105**	0.067	0.089	0.077
E34	348987	335016	**0.001**	**0.001**	**0.001**	**0.001**	0.072	0.072	0.083	**0.093**
E35	347834	335090	**0.001**	**0.001**	**0.001**	**0.001**	0.083	0.071	**0.095**	0.064
E36	346923	334256	**0.001**	**0.001**	**0.001**	0.000	**0.076**	0.055	0.054	0.056
E37	355995	339492	**0.001**	**0.001**	**0.001**	**0.001**	**0.123**	**0.123**	0.122	0.107
E38	343437	334338	**0.000**	**0.000**	**0.000**	**0.000**	0.044	0.044	**0.051**	0.040
E39	347144	339123	**0.002**	**0.002**	**0.002**	**0.002**	0.217	0.217	0.198	**0.228**
E40	345566	339414	**0.001**	**0.001**	**0.001**	**0.001**	0.135	0.135	0.122	**0.141**
E41	345236	338547	**0.001**	**0.001**	**0.001**	**0.001**	0.122	0.122	0.111	**0.124**
E42	356193	343529	**0.001**	**0.001**	**0.001**	**0.001**	0.052	0.052	0.054	**0.056**
E43	354543	345341	**0.001**	**0.001**	**0.001**	**0.001**	0.050	0.050	**0.055**	0.050
E44	343763	333365	**0.000**	**0.000**	**0.000**	**0.000**	0.046	0.040	0.043	**0.046**
E45	345924	330378	**0.000**	**0.000**	**0.000**	**0.000**	0.037	0.037	**0.051**	0.039

5.2 Human Health receptors

ADMS was run four times, once for each year of the meteorological dataset (GFS) without calms and without terrain for the following three scenarios:

- Existing realistic emission parameters.
- Existing worst case emission parameters.
- Proposed emissions parameters.

From the model output, the following statistics for each grid point (discrete and nested Cartesian) have been complied:

- Maximum annual mean ammonia concentration.
- Maximum hourly mean ammonia concentration.

Summaries of the maximum predicted concentrations for each of these statistics (at any receptor point, discrete or nested Cartesian) are presented in Tables 6a and 6b. The concentrations predicted at the internal monitoring points are shown in Tables 6c and 6d. The abbreviations EAL, PC and PEC used in the Tables mean: Environmental Assessment Level (EAL), Process Contribution (PC) and Predicted Environmental Concentration (PEC), respectively.

Contour plots of the predicted maximum annual mean ammonia concentration for each scenario are shown in Figures 5a, 5b and 5c.

Contour plots of the predicted maximum hourly mean ammonia concentration for each scenario are shown in Figures 6a, 6b and 6c.

Table 6a. Maximum predicted annual mean ammonia concentration

	Maximum annual mean ammonia concentration		
	Realistic Scenario	Worst Case Scenario	Proposed Scenario
X(m)	350562	350562	350499
Y(m)	339103	339103	339141
Maximum PC (μg/m^3)	1.35	5.06	0.59
EAL (μg/m^3)	180	180	180
APIS Background (μg/m^3)	3.53	3.53	3.53
Maximum PEC (μg/m^3)	4.88	8.59	4.12
Maximum PC as %age of EAL	0.8	2.8	0.3
Percentage change (from background)	27.7	58.9	14.4
IAQM descriptor	Moderate	Moderate	Moderate
Exceedances of EAL	None	None	None

Table 6b. Maximum predicted hourly mean ammonia concentration

	Maximum hourly mean ammonia concentration		
	Realistic Scenario	Worst Case Scenario	Proposed Scenario
X(m)	350549	350512	350574
Y(m)	339066	339128	339003
Maximum PC (μg/m^3)	17.90	71.79	20.37
EAL (μg/m^3)	2500	2500	2500
APIS Background x 2 (μg/m^3)	7.06	7.06	7.06
Maximum PEC (μg/m^3)	24.96	78.85	27.43
Maximum PC as %age of EAL	0.7	2.9	0.8
Percentage change (from background)	71.7	91.0	74.3
IAQM descriptor	n/a	n/a	n/a
Exceedances of EAL	None	None	None

Table 6c. Maximum predicted annual mean ammonia concentrations at the internal monitoring points

Monitoring point number	X(m)	Y(m)	EAL ($\mu g-NH_3/m^3$)	APIS background concentration ($\mu g-NH_3/m^3$)	Maximum annual mean ammonia concentration								
					Realistic Scenario			Worst Case Scenario			Proposed Scenario		
					PC ($\mu g-NH_3/m^3$)	PEC ($\mu g-NH_3/m^3$)	PC as %age of EAL	PC ($\mu g-NH_3/m^3$)	PEC ($\mu g-NH_3/m^3$)	PC as %age of EAL	PC ($\mu g-NH_3/m^3$)	PEC ($\mu g-NH_3/m^3$)	PC as %age of EAL
mon1	350700	339299	180	3.53	0.09	3.62	0.05	0.34	3.87	0.19	0.19	3.72	0.11
mon2	350592	339455	180	3.53	0.06	3.59	0.03	0.21	3.74	0.12	0.14	3.67	0.08
mon3	350754	339207	180	3.53	0.10	3.63	0.06	0.37	3.90	0.20	0.22	3.75	0.12
mon4	350689	338910	180	3.53	0.08	3.61	0.04	0.31	3.84	0.17	0.19	3.72	0.11
mon5	350651	339234	180	3.53	0.13	3.66	0.07	0.53	4.06	0.30	0.23	3.76	0.13
mon6	350576	339170	180	3.53	0.32	3.85	0.18	1.30	4.83	0.72	0.23	3.76	0.13

Table 6d. Maximum predicted hourly mean ammonia concentrations at the internal monitoring points

Monitoring point number	X(m)	Y(m)	EAL ($\mu g-NH_3/m^3$)	APIS background concentration ($\mu g-NH_3/m^3$)	Maximum annual mean ammonia concentration								
					Realistic Scenario			Worst Case Scenario			Proposed Scenario		
					PC ($\mu g-NH_3/m^3$)	PEC ($\mu g-NH_3/m^3$)	PC as %age of EAL	PC ($\mu g-NH_3/m^3$)	PEC ($\mu g-NH_3/m^3$)	PC as %age of EAL	PC ($\mu g-NH_3/m^3$)	PEC ($\mu g-NH_3/m^3$)	PC as %age of EAL
mon1	350700	339299	2500	7.06	1.00	4.53	0.55	6.09	9.62	3.39	2.34	5.87	1.30
mon2	350592	339455	2500	7.06	1.34	4.87	0.75	9.16	12.69	5.09	1.67	5.20	0.93
mon3	350754	339207	2500	7.06	1.30	4.83	0.72	11.66	15.19	6.48	2.80	6.33	1.56
mon4	350689	338910	2500	7.06	1.50	5.03	0.83	10.51	14.04	5.84	3.16	6.69	1.75
mon5	350651	339234	2500	7.06	1.45	4.98	0.81	10.10	13.63	5.61	3.12	6.65	1.73
mon6	350576	339170	2500	7.06	3.68	7.21	2.04	20.42	23.95	11.34	6.23	9.76	3.46

Figure 5a. Maximum annual mean ammonia concentration – Realistic Scenario

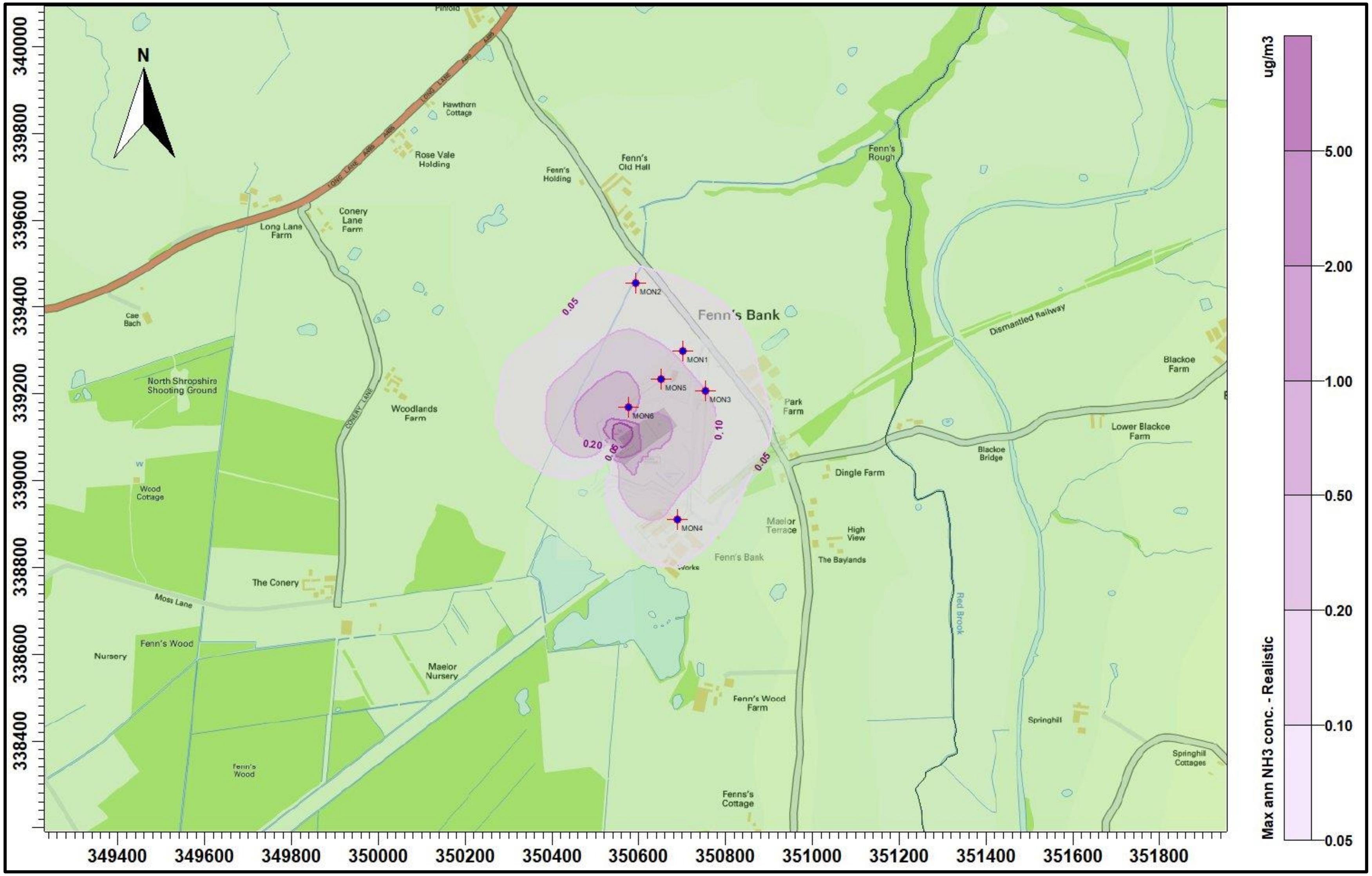


Figure 5b. Maximum annual mean ammonia concentration – Worst Case Scenario

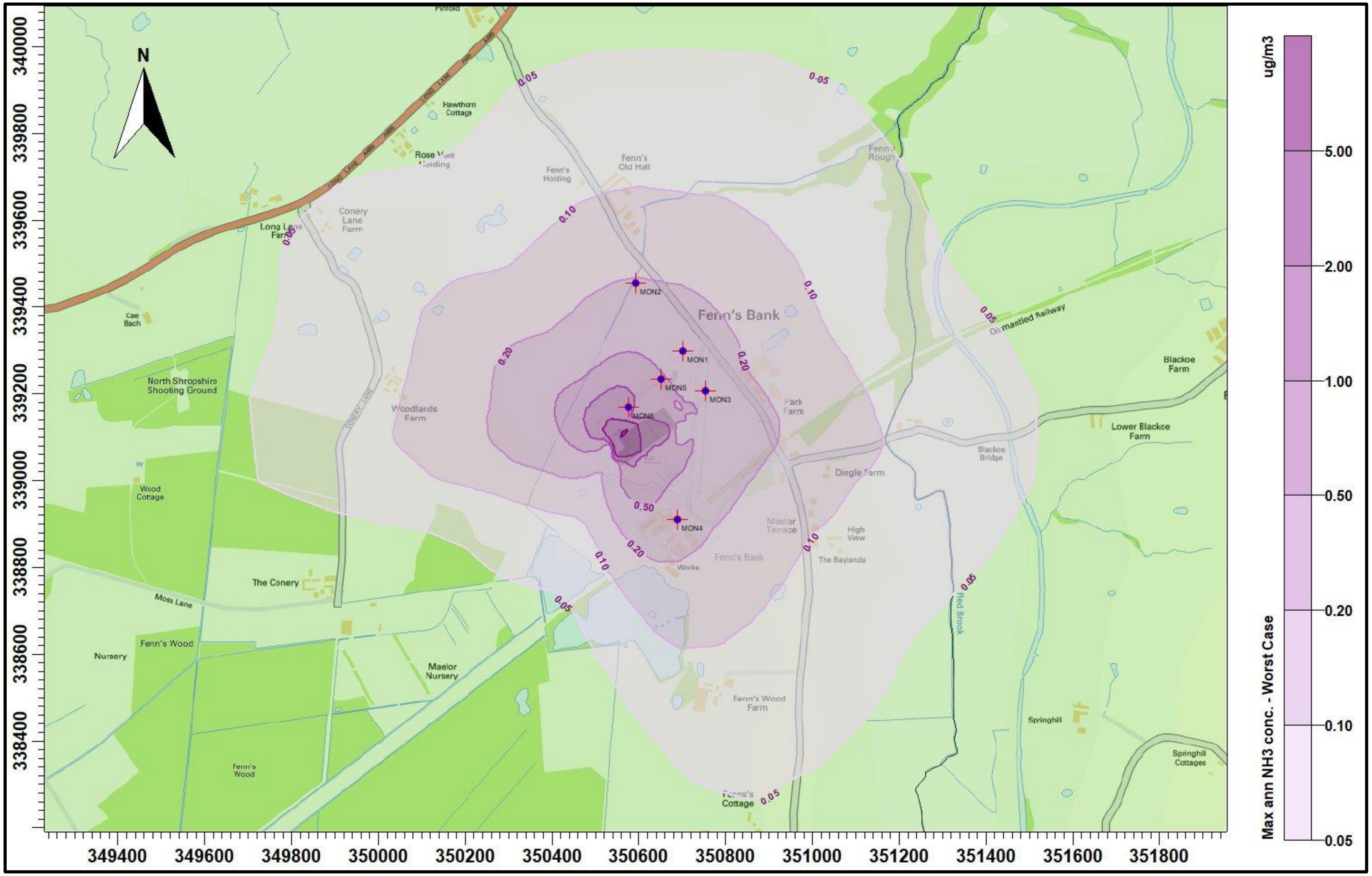


Figure 5c. Maximum annual mean ammonia concentration – Proposed Scenario

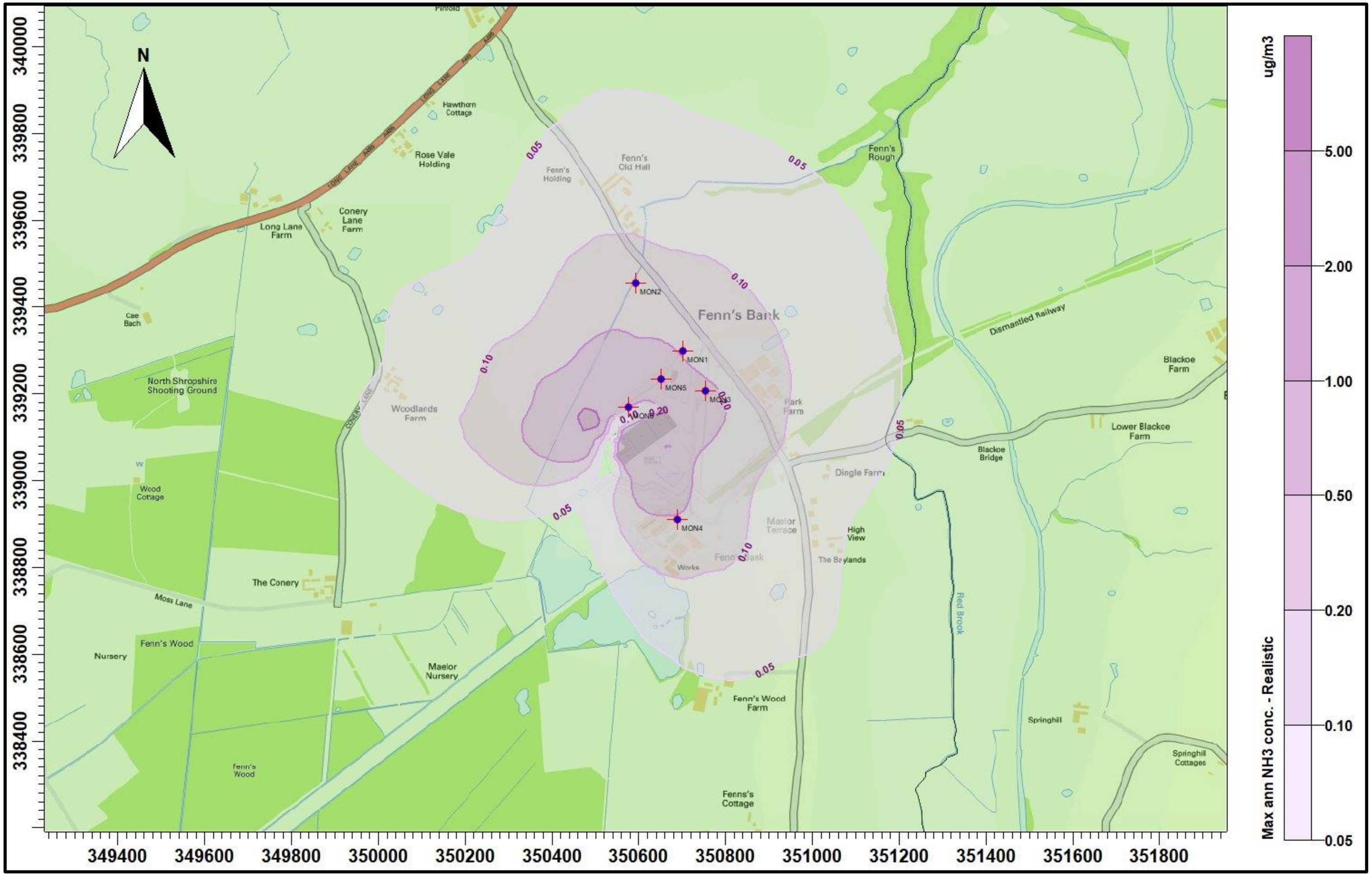


Figure 6a. Maximum hourly mean ammonia concentration – Realistic Scenario

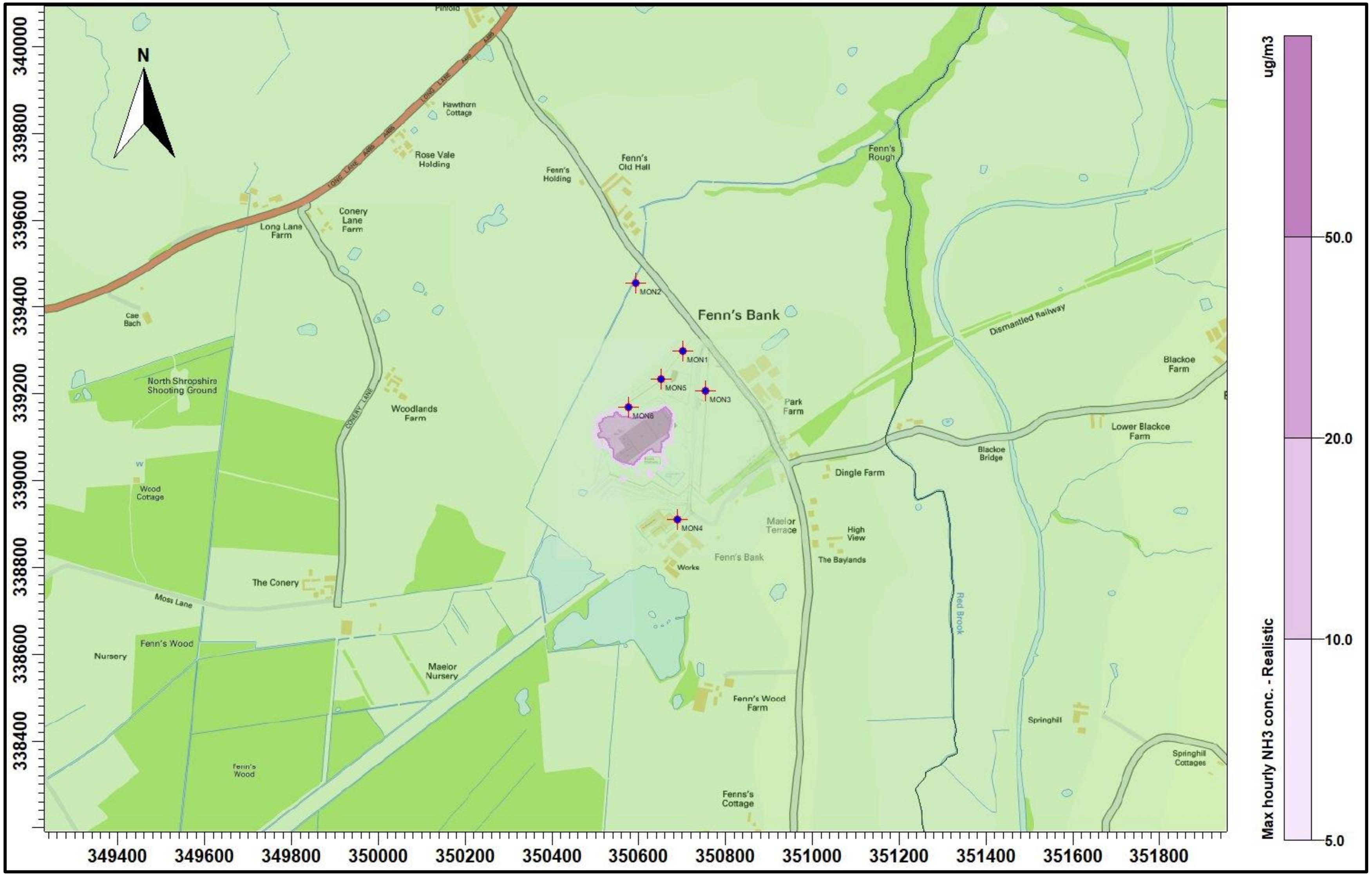


Figure 6b. Maximum hourly mean ammonia concentration – Worst Case Scenario

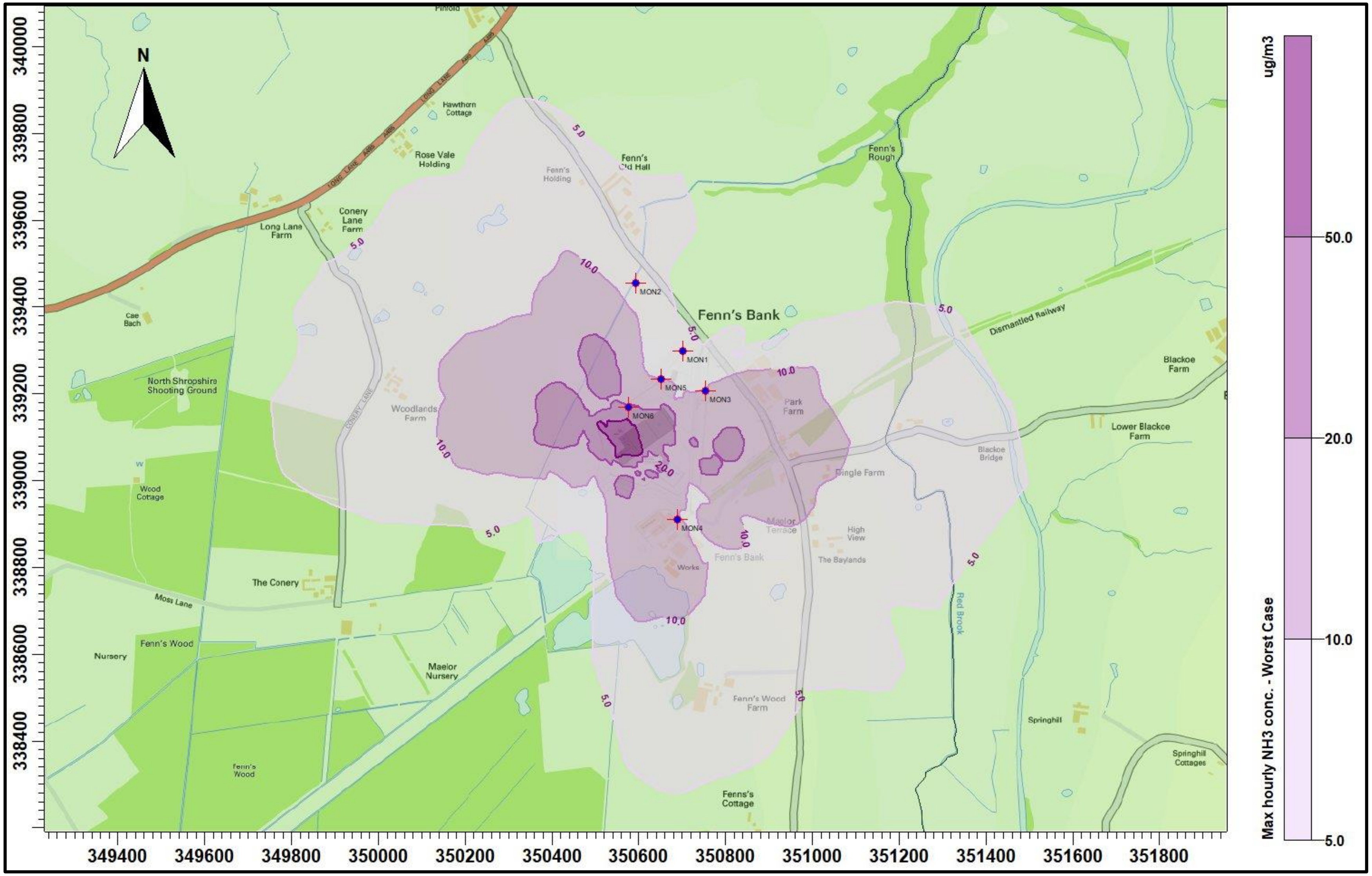
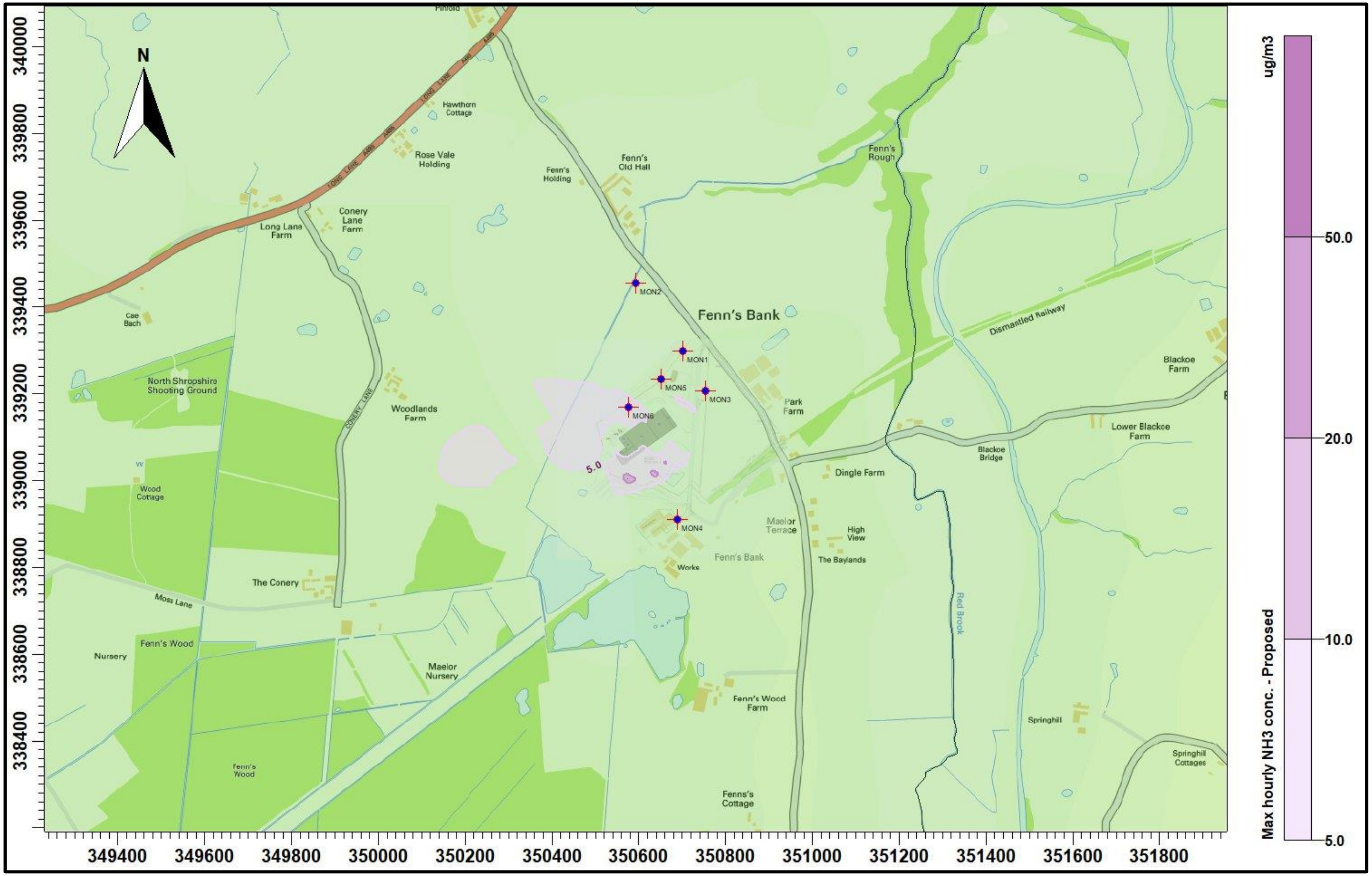


Figure 6c. Maximum hourly mean ammonia concentration – Proposed Scenario



5.2 Ecological Receptors

ADMS was run four times, once for each year of the meteorological dataset (GFS) without calms and without terrain for the following three scenarios:

- Existing realistic emission parameters.
- Existing worst case emission parameters.
- Proposed emissions parameters.

From the model output, the following statistics for each discrete receptor point have been complied:

- Maximum annual mean ammonia concentration.

The predicted concentrations are presented in Table 7. In the Table, Process contributions in excess of 1% of the precautionary Critical Level of 1.0 µg-NH_3/m^3 are highlighted in bold blue text.

Table 7. Predicted annual mean ammonia concentrations at the discrete receptors.

Receptor number	X(m)	Y(m)	Maximum annual mean ammonia concentration - (μg/m³)		
			Realistic Scenario	Worst Case Scenario	Proposed Scenario
			GFS No Calms No Terrain	GFS No Calms No Terrain	GFS No Calms No Terrain
E1	351208	339320	**0.018**	**0.072**	**0.049**
E2	351170	339557	**0.017**	**0.062**	**0.047**
E3	351033	339696	**0.019**	**0.068**	**0.049**
E4	351292	339972	**0.010**	**0.036**	**0.028**
E5	351374	340282	0.007	**0.026**	**0.020**
E6	349926	340665	0.004	**0.017**	**0.011**
E7	350101	340897	0.004	**0.016**	**0.012**
E8	350779	337860	0.006	**0.026**	**0.013**
E9	350388	338895	**0.019**	**0.084**	**0.043**
E10	350578	338630	**0.018**	**0.073**	**0.041**
E11	350753	338471	**0.017**	**0.072**	**0.041**
E12	350196	338538	0.006	**0.027**	**0.015**
E13	350447	338345	0.007	**0.028**	**0.015**
E14	350756	338172	0.009	**0.040**	**0.021**
E15	349888	338621	0.005	**0.020**	**0.014**
E16	350191	338017	0.003	**0.013**	0.007
E17	350681	337691	0.004	**0.019**	0.010
E18	349450	338626	0.004	**0.016**	**0.010**
E19	349733	338217	0.003	**0.013**	0.008
E20	349938	337762	0.002	0.010	0.005
E21	350333	337441	0.002	**0.011**	0.005
E22	349177	338553	0.003	**0.013**	0.008
E23	348998	338143	0.002	0.007	0.004
E24	349392	337686	0.002	0.008	0.004
E25	349928	337264	0.002	0.007	0.004
E26	350600	337092	0.002	**0.012**	0.005
E27	348357	337777	0.001	0.005	0.003
E28	348894	336966	0.001	0.005	0.003
E29	349597	336564	0.001	0.005	0.003
E30	350040	335874	0.001	0.005	0.002
E31	348639	336162	0.001	0.004	0.002
E32	347841	336953	0.001	0.004	0.002
E33	347265	335928	0.001	0.003	0.002
E34	348987	335016	0.001	0.003	0.002
E35	347834	335090	0.001	0.003	0.002
E36	346923	334256	0.001	0.002	0.001
E37	355995	339492	0.001	0.004	0.003
E38	343437	334338	0.000	0.001	0.001
E39	347144	339123	0.002	0.008	0.006
E40	345566	339414	0.001	0.005	0.004
E41	345236	338547	0.001	0.004	0.003
E42	356193	343529	0.001	0.003	0.002
E43	354543	345341	0.001	0.003	0.002
E44	343763	333365	0.000	0.001	0.001
E45	345924	330378	0.000	0.001	0.001

6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Mr S Filkin of Filkin & Co. EHS Limited, on behalf of Befesa Salt Slags Ltd., to use computer modelling to assess the impact of ammonia emissions from existing and proposed stacks serving the ammonia scrubbing units at Befesa Salt Slags Ltd., at Fenn's Bank (postal address, Befesa Salt Slags Ltd. Fenns Bank, Whitchurch, Shropshire. SY13 3PA).

Emissions of ammonia (NH_3) from the stacks serving the three existing ammonia scrubbing units have been assessed and quantified based upon data from Stack Reports compiled by ESG and supplied to AS Modelling & Data Ltd. by Befesa Salt Slags Ltd.

Emissions of ammonia (NH_3) from the stacks serving the proposed ammonia scrubbing unit have been assessed and quantified based upon data on likely performance provided by the manufacturers of the ammonia scrubbing unit, Chemical Process Solutions Ltd.

6.1 Assessment of the impact of the stack emissions of ammonia against Human Health EALs

Using APIS background levels to calculate the PEC, there are no predicted exceedances of the long term EAL of 180 $\mu g/m^3$ for ammonia as an annual mean. At the maximum point, the magnitude of the PC is 0.8% of the EAL for the existing realistic scenario, 2.8% of the EAL for the existing worst case scenario and 0.3% of the EAL for the proposed scenario.

Using twice the APIS background levels to calculate the PEC, there are no predicted exceedances of the short term EAL of 2,500 $\mu g/m^3$ for ammonia as an hourly mean. At the maximum point, the magnitude of the PC is 0.7% of the EAL for the existing realistic scenario, 2.9% of the EAL for the existing worst case scenario and 0.8% of the EAL for the proposed scenario.

6.2 Assessment of the impact of the stack emissions of ammonia against the Critical Level of 1.0 $\mu g\text{-}NH_3/m^3$ at nearby AWs, SSSIs, SACs and Ramsar sites

It is assumed that any PC greater than 1% of Critical Level would be considered significant.

6.2.1 Existing Realistic Scenario

Exceedances of 1% of the Critical Level are predicted at the remnant of AW at Fenn's Rough to the north-east (Receptors E1 to E4) of Befesa Salt Slags and also over north-easternmost parts of Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses SSSI (Receptors E9 to E11), which is also designated as a Special Area of Conservation (SAC) and a Ramsar site.

6.2.2 Existing Worst Case Scenario

Exceedances of 1% of the Critical Level are predicted at the remnant of AW at Fenn's Rough to the north-east (Receptors E1 to E5), two small areas of AW to the north-north-west (Receptors E6 and E7) and another small area of AW to the south (Receptor 8) and also over north-eastern parts of

Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses SSSI (Receptors E9 to E19; E21, E22 and E26), the area covered by the predicted exceedances is approximately 1,400 ha).

6.2.3 Proposed Scenario

Exceedances of 1% of the Critical Level are predicted at the remnant of AW at Fenn's Rough to the north-east (Receptors E1 to E5), two small areas of AW to the north-north west (Receptors E6 and E7) and another small area of AW to the south (Receptor 8) and also over north-eastern parts of Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses SSSI (Receptors E9 to E16 and E18), the area covered by the predicted exceedances is approximately 560 ha).

7. References

Cambridge Environmental Research Consultants (CERC) (website).
http://www.cerc.co.uk/environmental-software/ADMS-model.html

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Steven R. Hanna & Biswanath Chowdhury, 2013. Minimum turbulence assumptions and u* and L estimation for dispersion models during low-wind stable conditions. Journal of the Air & Waste Management Association.

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http://www.apis.ac.uk/

Annex 1. Analysis of meteorological datasets

There is a meteorological recording station at Befesa Salt Slags. However, although entirely adequate for its intended purpose, the data from the station are not of suitable quality for the purposes of dispersion modelling; chiefly because the wind direction is only recorded to a resolution of 22.5 degrees, the anemometer is at a non-standard exposure height (4 m), the available record is less than two years in length and the parameters required to determine Monin-Obukhov length or stability class (cloud cover or radiation fluxes) are not present.

The wind speed and direction from RAF Shawbury, the raw GFS data and FLOWSTAR modified GFS data have been compared against the records from February 2016 to December 2016 from the recording station at Befesa Salt Slags. Statistics of the mean and standard deviation of the x and y components of the wind direction (normalised) and the mean and standard deviation of the wind speed are provided in Table A1a and Table A1b, respectively. As an example, graphs of the wind directions and wind speeds for February 2016 are presented in Figures A1a and A1b, respectively. Note that the FLOWSTAR modified data is absent only because it is very similar to the raw GFS data and therefore only serves to further clutter the graphs. Graphs for other months can be made available upon request

Note that the Befesa Salt Slags wind direction is recorded to the nearest 22.5 degrees and that the wind speed has been adjusted to be comparable with the 10 m anemometer height in the Shawbury and GFS records. Also note that the RAF Shawbury wind directions are recorded to the nearest 10 degrees and the wind speed is a 10 minute average, whereas the GFS day wind directions are continuous and wind speeds are probably more likely to reflect an hourly average. Additionally, both the Befesa Salt Slags and RAF Shawbury data have discontinuities between calm and the start-up speed of their anemometers; therefore, there are periods recorded as calm with no wind direction where in reality wind speeds should be light, but non-zero and there may be a definite wind direction; with in the GFS and FLOWSTAR data this is not the case and winds are continuous with a defined direction down to zero.

Table A1a.Wind direction

Dataset	Mean difference from Befesa Salt Slags data		Standard deviation of difference from Befesa Salt Slags data	
	x component	y component	x component	y component
Raw GFS	0.0236	0.0200	0.4342	0.4297
FLOWSTAR modified GFS	0.0274	0.0219	0.4350	0.4294
RAF Shawbury data	0.0031	0.0200	0.4485	0.5334

Table A2b. Wind Speed

Dataset	Mean difference from Befesa Salt Slags data	Standard deviation of difference from Befesa Salt Slags data
Raw GFS	-1.3755	1.3237
FLOWSTAR modified GFS	-0.8415	1.2036
RAF Shawbury data	-1.4105	1.4351

Figure A1a. Wind direction comparison February 2016

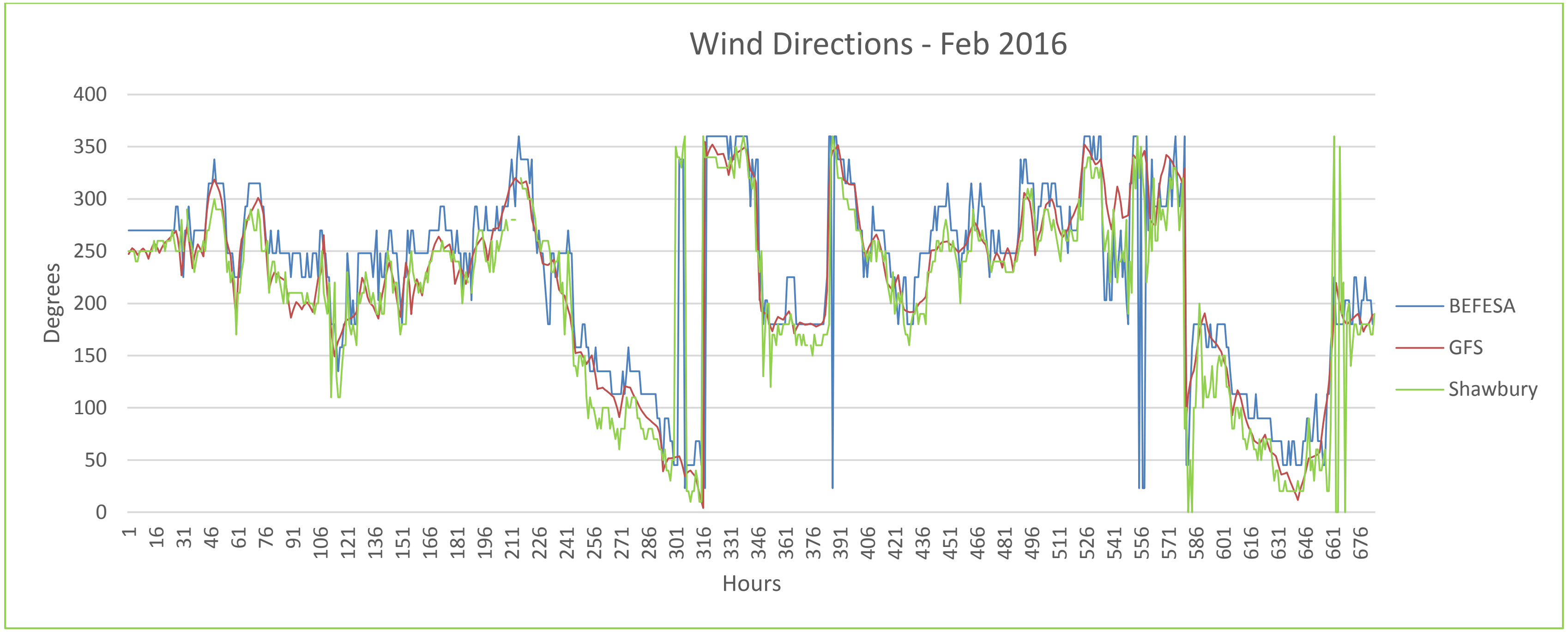

Figure A1b. Wind speed comparison February 2016