COGEO

planning and environmental expertise

AIR QUALITY IMPACT ASSESSMENT

BROXTY FARM

Applicant: Mr. Kevin Buckle

Version 1.5

EXPERTISE | KNOWLEDGE | SUPPORT

Document Version Control

Revision Control Table

Issue	Date	Change	Prepared	Approved
1.0	25/03/21	Reporting for Internal Review	MP	CPE
1.1	01/04/21	Updated Report for Submission	MP	BL
1.2	17/05/21	Updated additional work as per J. Pinder	MP	DA
1.3	11/08/21	Updated revision with mitigation measures	MP	EC
1.4	01/02/22	Updated revision as per EA comments	MP	BL
1.5	22/07/22	Updated revision as per EA comments	MP	

Proprietary Statement

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2. INTRODUCTION

This report describes an Air Quality Impact Assessment (AQIA) study conducted by Cogeo Planning & Environmental Services Ltd. commissioned by the applicant, Mr. Kevin Buckle; owner of Broxty Farm. This AQIA is undertaken for the proposed development of a single 32,000 capacity free-range hen shed and chicken range as an extension of existing farming operations at Broxty Farm, Kaber, Kirkby Stephen, Cumbria, CA17 4ER. The assessment will be conducted using atmospheric dispersion modelling and aims to provide information to support the environmental permitting application.

The main aims of the assessment are to:

- Quantify current (baseline) air quality by modelling emissions associated with the existing hen sheds at Broxty Farm.
- Cumulative impacts upon air quality arising through existing structures and the proposed shed and ranging area shall be assessed.
- Assess impacts upon designated habitats.

This assessment will consider the atmospheric pollutants of ammonia (NH_3) and total nitrogen deposition from the proposed development.

The approach taken in this study was to:

- Collect and interpret the proposed project specifications and emissions data for input to an atmospheric dispersion model.
- Obtain local background pollutant concentrations in the study area from either local measurements or background mapping.
- Using five consecutive years of relevant meteorological data, model concentrations of NH_3 and total nitrogen deposition in the study area.
- Assess and describe air quality impacts at nearby sensitive habitats. The impact assessment will consider both critical loads and levels; and will follow the method specified in the Environment Agency (EA) AQTAG (06) guidance and the information provided by the UK government Intensive farming risk assessment for your environmental permit Guidance [1].
- Report the predicted annual mean concentrations at nearby sensitive receptor locations; and present the predicted spatial variation in pollutant concentrations across the study area using contour plots.

[1]Guidance: Intensive farming risk assessment for your environmental permit, https://www.gov.uk/guidance/intensive-farming-risk-assessment-for-your-environmental-permit#ammonia-emissions

3. AIR QUALITY STANDARDS AND GUIDELINES

3.1. Assessment of Impacts on Vegetation and Ecosystems

3.1.1. Calculation of Contribution to Critical Loads

Deposition rates were calculated using empirical methods recommended by the EA AQTAG06[2]. Dry deposition flux was calculated using the following equation:

Dry deposition flux (µg/m2/s) = ground level concentration (µg/m^3) x deposition velocity (m/s)

Wet deposition occurs via the incorporation of the pollutant into water droplets which are then removed in rain or snow and is not considered significant over short distances compared with dry deposition and therefore for the purposes of this assessment (in accordance with AQTAG06), wet deposition has not been considered.

The applied deposition velocities for the relevant chemical species are as shown in Table 3.1.

Table 3.1 Applied Deposition Velocities

Chemical Species	Recommended deposition velocity (m/s)	
NH_3	Grassland	0.02
	Woodland	0.03

3.1.2. Critical Loads - Eutrophication

The critical loads for nitrogen and ammonia deposition (N) are recorded in units of kgN/ha/yr. The deposition PC is converted from µg/m^2/s to units of kgN/ha/year by multiplying the dry deposition flux by the standard conversion factor of 95.9 and 259.7 respectfully.

3.1.3. Critical Loads – Acidification

The deposition PC is converted to units of equivalents (keq/ha/year), which is a measure of how acidifying the chemical species can be, by multiplying the µg/m^2/s by standard conversion factor of 18.5.

3.1.4. Calculation of PC as a percentage of Acid Critical Load Function

The calculation of the process contribution of N to the critical load function has been carried out according to the guidance on APIS, which is as follows:

'The potential impacts of additional sulphur and/or nitrogen deposition from a source are partly determined by PEC, because only if PEC of nitrogen deposition is greater than CLminN will the additional nitrogen deposition from the source contribute to acidity. Consequently, if PEC is less that CLminN only the acidifying effects of sulphur from the process need to be considered:

[2] AQTAG06 – Technical Guidance on detailed modelling approach for an appropriate assessment for emissions to air. Environment Agency, March 2014 version.

- Where PEC N Deposition < CLminN

PC as % CL function = (PC S deposition/CLmaxS) *100

- Where PEC N Deposition > CLminN

PC as %CL function = ((PC of S+N deposition)/CLmaxN) *100'

- Where PEC is greater than CLminN (the majority of cases), the combined inputs of sulphur and nitrogen need to be considered. In such cases, the total acidity input should be calculated as a proportion of the CLmaxN

3.1.5. Assessment of Impact and Significance

Predicted ammonia concentrations will further be evaluated against critical levels/loads specified for the protection of natural ecosystems at internationally designated habitat sites (SPAs, SACs, SSSIs, and Ramsar Sites) within 5km and nationally designated habitat sites (AW and LNRs) within 2km of the development site. The critical loads for nitrogen/ammonia are expressed as the rate of deposition per unit area per year which can be tolerated by the habitat site. These values vary by site. Site-specific critical loads are presented from the UK Air Pollution Information System (APIS)[3] in Section 4.2.2.

In accordance with the Environment Agency's(EA) Air Emissions Risk Assessment Guidance[1] and consultation from the EA permitting department, where the site contribution is less than 4% for SSSI sites and 1% for SAC sites of the relevant long-term critical level, and less than 20% for SAC sites and 50% for SSSI sites of the relevant short-term critical level, the process contribution of the site can be considered as insignificant. This applies to the following types of designated sites:

- Sites of Special Scientific Interest (SSSI);
- Special Protection Areas (SPA);
- Special Areas of Conservation (SAC); and
- Ramsars.

The threshold for local nature sites is much less sensitive, with process contributions below 100% of the short and long-term critical levels classified as insignificant. The following designations fall under local nature sites:

- Ancient Woodlands;
- Local Wildlife Sites (LWS); and
- Local Nature Reserves (LNR).

[3] Air Pollution Information System, http://www.apis.ac.uk/

4. STUDY AREA

4.1. Site Description and Location

The proposed hen sheds are located on agricultural farmland (Grade 3: Good to Moderate) at Broxty Farm. The existing development consists of two free-range hen sheds with a cumulative capacity of 32,000 hens. The proposed development is for an additional free-range hen shed with a capacity of 32,000 hens; this will be an extension of the existing farm operations at Broxty Farm, located west of the existing shed.

The site location relative to the surrounding area is presented in Appendix 4.1.

4.2. Baseline Air Quality

4.2.1. Background Concentrations

The Defra background maps[4] were compared to the measured concentrations of NO_2 in the study area. This resource provides estimated annual mean background concentrations of key pollutants at a resolution of 1x1km for the UK. Annual mean NO_2 background concentrations at the site for 2020 are presented in Table 4.1.

Table 4.1 Annual Mean Background Concentrations

Grid square		Mapped concentrations (µg/m^{-3})
X	Y	NO_2
382500	510500	3.9

The impact concentrations from the existing and proposed hen sheds will be significantly lower than the measured concentrations at the urban monitors, and as such the background map data represents a more appropriate estimate of background NO_2 concentrations at the development site. In accordance with this analysis, the mapped concentrations for the grid square containing the proposed development have been used for this study.

4.2.2. Background Ammonia Levels and Nitrogen Deposition

The APIS website[3] , a support tool for the assessment of potential effects of air pollutants on habitats and species, has been used to provide information on background pollutant concentrations. Current Critical Loads/Levels are presented in Table 4.2 and location specific background concentrations and depositions are presented in Table 4.3.

[4] Background Mapping data for local authorities - 2018. https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html

Table 4.2 Nitrogen, Ammonia, and Acidity Critical Loads/ Levels

Site	Critical Load (kg N/ha/yr)	NH_3 Critical Level (μ/m^3)	Acidity Critical Loads CLmaxN (keq/ha/yr)
Belah Woods and Pastures	10	1	2.06
Holme and Blackscar Woods	10	3	2.06
Coldkeld Wood	10	3	2.071
River Eden & Tributaries	10	3	0.536
River Eden	3	1	**
Argill Woods & Pastures	10	1	1.328
Augill Valley Pasture	20	3	1.328
Swindale Wood	15	3	1.933
Helbeck and Swindale Woods	15	1	1.923
Birkett Hill & High Out Wood	15	1	2.203

*** denotes no values/data available*

Table 4.3 Background Acid, Nitrogen and Ammonia Concentrations

Site	APIS Acid Deposition (keq/ha/yr)	APIS Total Nitrogen Background Concentration (kg N/ha/yr)	APIS Ammonia Background Concentration ($\mu g/m^3$)
Belah Woods and Pastures	1.58	4.83	1.82
Coldkeld Wood	1.58	4.83	1.82
Holme and Blackscar Woods	1.58	4.87	1.82
River Eden & Tributaries	1.58	5.00	1.82
River Eden	1.58	5.00	1.82
Argill Woods & Pastures	1.06	5.06	1.82
Augill Valley Pasture	1.06	6.77	1.82
Swindale Wood	1.78	5.51	0.98
Helbeck and Swindale Woods	1.78	5.51	0.98
Birkett Hill & High Out Wood	1.87	4.81	1.54

5. MODELLING METHODOLOGY

5.1. Model Description

The air quality impact assessment will be conducted using the American Meteorological Regulatory Model, AERMOD View 10.0.1. Plume depletion will be considered in this assessment.

The AERMOD model will be applied; this model is widely used and accepted by the EA for undertaking such assessments and its predictions have been validated against real-time monitoring data by the United States (US) Environmental Protection Agency (EPA).

New generation dispersion models describe the atmospheric boundary layer in terms of the boundary layer depth, the Monin-Obukhov length and a skewed Gaussian distribution to calculate dispersion under convective meteorological conditions. The model is applicable up to approximately 20km downwind of the source.

5.2. Model Input Data

5.2.1. Model Domain

The dispersion modelling study aimed to assess the cumulative impacts of NH_3 emissions from the existing and proposed hen sheds and chicken range on the designated habitats in the area surrounding Broxty Farm. Pollutant dispersion will be calculated over a regular Cartesian grid pattern and at a selection of specified receptor points. The modelled domain covers an area of approximately 5km x 5km grid which predicts pollutant concentrations at a resolution of 60m centred on the hen shed fans' locations. A grid height of 0m was modelled to represent ground level exposure.

5.2.2. Designated Nature Conservation Sites

As per DEFRA and EA guidance[1], internationally designated habitat sites (SSSIs, SPAs, SACs, and Ramsar Sites) within 5km of the site, and nationally designated habitat sites (AW and LNRs) within 2km of the site should be considered. It should be noted that both internationally and nationally designated sites within 5km have been included within this AQIA in line with the SCAIL model completed for the PPC permit, providing a transparent assessment. Distances were measured from the closest point on the designated habitat site to the site boundary. Although emissions from the site could potentially affect designated sites further away from the site, any impacts would be less significant than those forecast at sites within the 5km zone and have therefore been scoped out of this assessment. No further assessment was carried out in relation to Mousegill Beck SSSI as it is designated solely for its geological interest. Low Out and High Out Woods, Redgategill Wood 2, Peasah, Snouthill and High Woods, and Stepping Stones Wood Ancient Woodlands sites have also been omitted from assessment as they are outwith the 2km radius from the development site reference point. The designated sites identified are set out in Table 5.1 and Appendix 4.2. Nearby locally designated sites were identified using data published by APIS[3].

Table 5.1 Modelled Sensitive Receptor Locations

Receptor ID	Receptor Name	OS Grid reference		Description	Distance from site (km)
		X	Y		
Belah 1	Belah Woods and Pastures 1	383110	511508	SSSI	0.25
Belah 2	Belah Woods and Pastures 2	382863	511143	SSSI	0.26
Holme Blks	Holme and Blackscar Woods	383097	511380	AW	0.26
Belah 3	Belah Woods and Pastures 3	383097	511383	SSSI	0.27
Belah 4	Belah Woods and Pastures 4	382723	511663	SSSI	0.29
Belah 5	Belah Woods and Pastures 5	382905	511630	SSSI	0.31
Coldkeld	Coldkeld Wood	382943	511050	AW	0.35
Belah 6	Belah Woods and Pastures 6	383053	511667	SSSI	0.42
Riv E&T	River Eden & Tributaries	382020	512266	SSSI	1.15
Riv Eden	River Eden	382020	512266	SAC	1.15
Argill	Argill Woods & Pastures	383290	513376	SSSI	2.14
Augill	Augill Valley Pasture	381758	514570	SSSI	3.37
Swindale	Swindale Wood	380291	515288	SSSI	4.63
Helbeck	Helbeck and Swindale Woods	380293	515291	SAC	4.63
Birkett	Birkett Hill & High Out Wood	379621	507792	SSSI	4.68

5.2.3. Meteorology

Hourly sequential meteorological data for the nearest suitable meteorological station with adequate data capture, Warcop meteorological station, was obtained for five calendar years 2016 - 2020. Examination of the wind roses indicates that winds are predominantly observed to be from the directions of between 300° and 150°, i.e., predominantly south-westerly winds. This is typical of the conditions experienced generally in this part of the UK.

A minimum Monin-Obukhov Length of 1m will be used for both the site domain and meteorological site location as the modelling guidance, is appropriate for rural areas. The Monin-Obukhov Length is the height above ground, where mechanically produced (by vertical shear) turbulence is in balance with the dissipative effect of negative buoyancy.

This assessment will include a sensitivity analysis of meteorological conditions measured at Warcop meteorological station over five consecutive years. The sensitivity analysis will be used to determine the meteorological dataset that predicted the worst-case ambient pollutant concentrations and to assess the variability in predicted concentrations attributable to inter-year variability in meteorological data sets.

5.2.4. Terrain and Land Use

The topographical features surrounding a site will have an influence on the dispersion of pollution within the area. This is accounted for in the surface roughness length specified in the model input.

A z_0 of 1m was used as the model guidance indicated that this is appropriate for woodlands, due to the hen shed site being located at Broxty Farm and surrounding large woods and farmland. A z_0 of 0.5m was used to describe the meteorological site. This value of z_0 is considered appropriate for the morphology of the area and

is suggested within AERMOD as being suitable for 'parkland, open suburbia'. Model default values were used for surface albedo (0.23) and the Priestley Taylor parameter (1).

Slopes with a gradient of greater than 1:10 can impact on this dispersion. Therefore, complex terrain effects were included in the model set up using Shuttle Radar Topography Mission/Digital Elevation Model (SRTM/DEM) topography data[5].

5.2.5. Building Parameters

AERMOD contains an option to model algorithms that account for building downwash effects. Nearby buildings (within five stack heights from the stack; and with a height of more than one third of the stack height) can affect the dispersion of emissions from a stack. The main effect can be to increase concentrations in the immediate vicinity of the building, while reducing concentrations further away.

For this assessment, the client's agent[6] provided dimensions for all surrounding buildings meeting the criteria for inclusion in the modelling. The model requires the height, length, width and orientation of the buildings as input data. Building locations and dimensions were added using the AERMOD Mapper utility using a base map to ensure correct location and orientation. The buildings included in the model and the relevant input data are presented in Table 5.2. A plan view of the buildings modelled superimposed on a map of the study area is presented in Appendix 5.1

Table 5.2 Buildings Included Within Model

Building	X	Y	Height (m)	Width (m)	Length (m)	Angle (°)
Shed 1 (existing 1a)	382798	511323	5.4	15.3	84.5	124
Shed 2 (existing1b)	382750	511352	5.4	15.3	84.5	214
Proposed sheds (sheds 3 & 4)	382446	511332	5.4	30.6	169	214

5.2.1. Uncertainty

Dispersion modelling is affected by a number of inherent uncertainties, which include:

- Model uncertainty - associated with model formulations;
- Data uncertainty – associated with uncertainties and assumptions of the input data (e.g., emissions estimates, meteorology, and surface roughness);
- Variability – associated with the inherent randomness of measurements used.

When considering air dispersion, a major source of uncertainty relates to the choice of emission rates as many factors can influence the rate of a particular process at a specific time.

[5] SRTM data Download Manager: https://srtm.csi.cgiar.org/srtmdata/
[6] JJP Environmental Services, "Yew Trees", Hackthorpe, Penrith, CA10 2HX; 07554 070 105; johnpinder@aol.com

To manage the uncertainty associated with the modelling process, several steps have been taken. These include:

- The use of the most recent version of USEPA AERMOD;
- The use of five years of the most recent, consecutive meteorological data to account for variability in the meteorological conditions;
- Sensitivity testing, investing the effects of complex terrain; and
- The application of standardised emission factors from the EA and SCAIL guidance.

5.3. Installation Details

5.3.1. Installation Specifications

The proposed development is for an additional hen shed with a total capacity of 32,000 free-range hens to be installed on farmland, east of Kaber, Cumbria. The site plan, Appendix 5.1 details the proposed location and layout of the hen sheds and chicken range at Broxty Farm. The design specifications of the existing and proposed hen sheds are displayed in Table 5.3.

It should be noted that although the existing hen shed 1a has 10 roof fans as per the client's agent[7], only two fans are operational. Therefore, the modelling will only include the two operational roof fans for shed 1a.

Table 5.3 Installation Specifications

Specification		Existing shed 1a (2 roof fans)	Existing shed 1b (1 Duty fan)	Existing shed 1b (4 auxiliary fans)	Proposed shed 2a and b (2 Duty fans)	Proposed shed 2a and b (8 auxiliary fans)	Range 1 and 2
Flue location grid reference	Easting	382798	382716	382716	382446	382446	396021
	Northing	511323	511376	511376	511332	511332	524651
Stack height (m)		6.4	2.5	1.5	3.2	1.5	-
Inner flue diameter (m)		0.71	0.91	1.2	0.91	1.2	-
Exit temp. (°C)		Ambient	Ambient	Ambient	Ambient	Ambient	Ambient
Actual exit velocity (m/s)		11.5	8.5	7.0	8.5	7.0	
Cumulative Site Area		Approx. 1293m^2	Approx. 1293m^2	Approx. 1293m^2	Approx. 2586m^2	Approx. 2586m^2	Approx. 6856 m^2 and 3762 m^2
Hen Shed Capacity		16,000 Hens	16,000 Hens	16,000 Hens	32,000 Hens	32,000 Hens	32,000 Hens each

[7] JJP Environmental Services, "Yew Trees", Hackthorpe, Penrith, CA10 2HX; 07554 070 105; johnpinder@aol.com

5.4. Source Operational Hours and Emissions Data

The hen sheds are ventilated via roof inlet vents and duty gable end extraction fans, which on warm days, would be augmented with auxiliary gable end fans for sheds 1b, 2a and 2b. To be conservative, the assessment assumed that all the hens would be placed into the farm on the same day and all of the auxiliary fans in poultry sheds will be in continuous operation.

Where appropriate, the emissions data for the hen shed exhaust fans were provided by the Environment Agency (EA) SCAIL-Agriculture guidance [8] and Environment Agency's Intensive farming risk assessment for your environmental permit guidance[9].The EA provides an Intensive Farming guidance note which lists standard ammonia emission factors for a variety of livestock, including poultry. For the free-range egg laying chickens, in an aviary system, where manure is removed frequently using a belt system, the Environment Agency emission factor is 0.08 kg NH_3/bird/year for the hen sheds where the chickens will be housed for 80% of the time and an emission factor of 0.21 kg NH_3/animal place/year for outdoor ranging where the birds will be ranging outside for 20% of the time.

As per the client, the development will be without a manure store, removing manure as and when produced to recipient farmers outside of the permitted site. Details of the poultry numbers and types, emission factors used, and calculated ammonia emission rates are provided in Table 5.4.

Table 5.4 Details of Poultry Numbers and Ammonia Emission Rates

Source	Animal numbers	Type	Emission factor	
			(kg NH_3/place/y) hen shed	(kg NH_3/place/y) range
Proposed hen sheds	32,000	Egg laying chickens, aviary system	0.08(EA figure)	0.21 (EA figure)
Existing hen sheds	32,000	Egg laying chickens, aviary system	0.08(EA figure)	0.21 (EA figure)

The Department for Environment, Food & Rural Affairs (Defra) Ammonia mitigation guidance[10] suggests:

- Ammonia emission reduction efficiency (%) - 30% Poultry litter drying (e.g., Heat exchangers). This will apply to both existing and the proposed houses.

That means the existing houses (32,000 birds) may emit 30% less ammonia and also the proposed houses (32,000 birds) 30% less. As per the client's agent[6], these mitigation measures are to be employed onsite; therefore, the mitigating percentages will be applied to modelling emission rates.

[8] SCAIL Screening Guidance, Emission Factors http://nora.nerc.ac.uk/id/eprint/506087/1/N506087CR.pdf
[9] Environment Agency (2013): Intensive farming guidance note. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/296993/LIT_7807_d074d7.pdf
[10] Defra (2019): Reduction efficiencies for ammonia emission mitigation methods and an indication of their impacts on nitrous oxide and methane emissions –Submission Report Feb. 2019

5.4.1. Hen Sheds

Exhaust velocity will be taken from the manufacturer, emission factors from EA Intensive Farming Risk Assessment Guidelines[1], and screening air quality modelling carried out as part of the application for the permit.

The calculation equations for the emissions of the pollutants of concern from the hen sheds and ranges to be put into the model are the following:

- Hen Sheds 1a and 1b for NH_3 and PM_{10}

(Emission factor 0.08 kg/place/year *number of hens*1000g per kg)/8760 hours per year/ 60 minutes per hour/ 60 seconds per minute = g/second; Applying 30% reduction * 0.7; Applying 20% reduction for ranging birds * 0.8; Dividing by 2 duty fans for shed 1a and 5 exhaust fans for shed 1b

- Hen Sheds 2a and 2b for NH_3 and PM_{10}

(Emission factor 0.08 kg/place/year *number of hens*1000g per kg)/8760 hours per year/ 60 minutes per hour/ 60 seconds per minute = g/second; Applying 30% reduction * 0.7; Applying 20% reduction for ranging birds * 0.8; Dividing by 10 fans

- External ranges

(Emission factor kg/place/year * 0.2*number of hens*1000g per kg)/8760 hours per year/ 60 minutes per hour/ 60 seconds per minute/ area of range m_2 = g/second/m^2

Data for the proposed and existing shed sources are presented in Table 5.5.

Table 5.5 Hen Shed Emissions

Source ID	Emission rate (g/s)	Emission rate (g/s-m^2)	Emission rate (g/s-m^2)
	NH_3 shed	NH_3 Range 1	NH_3 Range 2
Shed 1a flue 1	0.0114	0.000006214	0.0000108
Shed 1a flue 2	0.0114	-	
Shed 1b flue 1-5	0.0045	-	
Shed 2a flue 1	0.0045	-	
Shed 2a flue 2	0.0045	-	
Shed 2a flue 3	0.0045	-	
Shed 2a flue 4	0.0045	-	
Shed 2a flue 5	0.0045	-	
Shed 2b flue 1	0.0045	-	
Shed 2b flue 2	0.0045	-	
Shed 2b flue 3	0.0045	-	
Shed 2b flue 4	0.0045	-	
Shed 2b flue 5	0.0045	-	

6. MODEL RESULTS: PROTECTION OF VEGETATION AND ECOSYSTEMS

6.1. Critical Levels for the Protection of Vegetation and Ecosystems

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 hyper-eutrophication (excess nitrogen enrichment).

For the ammonia concentration in air, the Critical Level for higher plants is 3.0 µg-NH_3/m^3 as an annual mean and for sites where there are sensitive lichens and bryophytes present, or if 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. 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.

Concentrations of NH_3 were predicted at all designated habitat sites identified in Section 5.2.2 for comparison with critical levels for the protection of vegetation and ecosystems. Concentrations of NH_3 were predicted at all designated habitat sites identified in the EA's screening report (Ref: EPR/GP3001LP/A001) and SCAIL model for comparison with critical levels for the protection of vegetation and ecosystems. Concentrations were calculated along the closest edge of each site using the 5 years of meteorological data described in Section 5.2.3; in this section, the maximum predicted concentrations across all modelled years are presented.

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). Normally the Critical Load for nitrogen deposition provides a stricter test than does the Critical Load for acid deposition. Deposition of nitrogen was predicted at the SSSIs identified in Section 3.1.1 for comparison with site specific critical loads for nutrient nitrogen and acidity, following "AQTAG (06) Technical guidance on detailed modelling approach for an appropriate assessment for emissions to air", published by the EA. Concentrations were calculated over a 100m resolution grid covering each site; the maximum calculated value across each site is presented. Critical Loads and background deposition rates for each site were taken from the APIS[3].

6.1.1. Scenario 1: Proposed Hen Sheds and Chicken Range - NH_3 Critical Levels

The location of each habitat site relative to Broxty Farm are presented on Appendix 4.2. The Process Contribution (PC) from the prosed hen sheds and chicken range is predicted, the existing background air quality (i.e. arising from other sources) is then added to calculate the Predicted Environmental Concentrations (PEC).

The maximum modelled process contributions (PCs) over 5 years of meteorological data for comparison with the annual mean NH_3 Critical Level (1.0 µg/m^3) are presented in Table 6.1 and presents the maximum modelled PCs and PECs from the proposed hen sheds for comparison with the Critical Level for annual mean ammonia concentrations. A contour plot showing the predicted spatial variation in predicted NH_3 annual mean concentrations is presented in Appendix 6.1.

The site's PC cannot be screened out as less than 4% of the Critical Level and 1% criteria for the River Eden SAC at all the designated sites except for River Eden & Tributaries SSSI, Argill Woods & Pastures, Augill Valley Pasture SSSI, Swindale Wood SSSI, Helbeck and Swindale Woods SSSI, and Birkett Hill & High Out Wood SSSI.

While the site's PC cannot be screened out at these habitats as insignificant, no exceedances of the critical levels from the hen shed emissions are predicted to occur at any of these locations.

Table 6.1 Maximum Modelled Process Contributions to the Annual Mean NH_3 Concentrations at Designated Habitat Sites from the Proposed Hen Sheds

Receptor ID	Designated site	CL ($\mu g/m^3$)	Site PC, ($\mu g/m^3$)	Site PC as % of CL	PEC, ($\mu g/m^3$)	PEC as % of CL
Belah 1	Belah Woods and Pastures 1	1	0.11	11%	1.93	193%
Belah 2	Belah Woods and Pastures 2	1	0.25	25%	2.07	207%
Holme Blks	Holme and Blackscar Woods	3	0.10	3.3%	1.92	64%
Belah 3	Belah Woods and Pastures 3	1	0.10	10%	1.92	192%
Belah 4	Belah Woods and Pastures 4	1	0.39	39%	2.21	221%
Belah 5	Belah Woods and Pastures 5	1	0.25	25%	2.07	207%
Coldkeld	Coldkeld Wood	3	0.17	5.6%	1.99	66%
Belah 6	Belah Woods and Pastures 6	1	0.14	14%	1.96	196%
Riv E&T	River Eden & Tributaries	3	0.06	2.1%	1.88	63%
Riv Eden	River Eden	1	0.06	6.2%	1.88	188%
Argill	Argill Woods & Pastures	1	0.02	1.9%	1.84	184%
Augill	Augill Valley Pasture	3	0.01	0.3%	1.83	61%
Swindale	Swindale Wood	3	0.01	0.2%	0.99	33%
Helbeck	Helbeck and Swindale Woods	1	0.01	0.7%	0.99	99%
Birkett	Birkett Hill & High Out Wood	1	0.002	0.2%	1.54	154%

6.1.2. Scenario 1: Proposed Hen Sheds and Chicken Range - Critical Loads for Nutrient Nitrogen and Acidity

The maximum modelled process contribution (PC) to total nutrient nitrogen deposition at designated sites is presented in Table 6.2. The PC is assessed against the minimum critical load for Nitrogen for the designated sites obtained from the site-specific information from the APIS website[3].

The proposed hen sheds and chicken range process contributions (PC) to the total nutrient nitrogen deposition flux are above 4% of the site-specific Critical Loads; with the exception of River Eden & Tributaries SSSI, Argill Woods & Pastures, Augill Valley Pasture SSSI, Swindale Wood SSSI, Helbeck and Swindale Woods SSSI, and Birkett Hill & High Out Wood SSSI. While the site's PC cannot be screened out at these habitats as insignificant, no exceedances of the critical loads from the hen shed emissions are predicted to occur at any of these locations.

Table 6.3 presents the maximum modelled site PC and PEC acid deposition impacts at the designated sites for which acid critical load functions were specified. The PC and PEC are assessed against the minimum CLmaxN critical load function for each site.

The site process contributions to acid deposition are less than 4% of critical load function with the exception of Belah Woods and Pastures SSSI and River Eden & Tributaries SSSI site. While the site's PC cannot be screened out at these habitats as insignificant, no exceedances of the critical loads from the hen shed emissions are predicted to occur at any of these locations.

Table 6.2 Modelled proposed Nutrient Nitrogen Deposition at Habitat Sites using minimum CLs

Receptor ID	Designated site	Critical load	Site PC N Dry deposition flux (kg N/ha/year)	Site PC % of minimum Critical load	Background total N deposition (kg N/ha/year)	Site PEC Dry deposition flux (kg N/ha/year)	Site PEC % of minimum Critical load
Belah 1	Belah Woods and Pastures 1	10	0.56	5.6%	4.83	5.39	54%
Belah 2	Belah Woods and Pastures 2	10	1.29	13%	4.83	6.12	61%
Holme Blks	Holme and Blackscar Woods	10	0.52	5.2%	4.87	5.39	54%
Belah 3	Belah Woods and Pastures 3	10	0.52	5.2%	4.83	5.35	54%
Belah 4	Belah Woods and Pastures 4	10	2.03	20%	4.83	6.86	69%
Belah 5	Belah Woods and Pastures 5	10	1.32	13%	4.83	6.15	61%
Coldkeld	Coldkeld Wood	10	0.87	8.7%	4.83	5.70	57%
Belah 6	Belah Woods and Pastures 6	10	0.71	7.1%	4.83	5.54	55%
Riv E&T	River Eden & Tributaries	10	0.32	3.2%	5.00	5.32	53%
Riv Eden	River Eden	3	0.32	11%	5.00	5.32	177%
Argill	Argill Woods & Pastures	10	0.10	1.0%	5.06	5.16	52%
Augill	Augill Valley Pasture	20	0.05	0.3%	6.77	6.82	34%
Swindale	Swindale Wood	15	0.03	0.2%	5.51	5.54	37%
Helbeck	Helbeck and Swindale Woods	15	0.03	0.2%	5.51	5.54	37%
Birkett	Birkett Hill & High Out Wood	15	0.01	0.1%	4.81	4.82	32%

Table 6.3 Modelled Acid Deposition at Habitat Sites, Compared to Acid Critical Load Functions

Receptor ID	Designated site	Critical load	Site PC Annual mean acidity PC (keq/ha/yr)	Site PC % of minimum Critical load	Background Annual mean acidity PC (keq/ha/yr)	Site PEC Annual mean acidity (keq/ha/yr)	Site PEC % of minimum Critical load
Belah 1	Belah Woods and Pastures 1	2.06	0.04	1.9%	1.58	1.62	79%
Belah 2	Belah Woods and Pastures 2	2.06	0.092	4.5%	1.58	1.67	81%
Holme Blks	Holme and Blackscar Woods	2.071	0.037	1.8%	1.58	1.62	78%
Belah 3	Belah Woods and Pastures 3	2.06	0.037	1.8%	1.58	1.62	78%
Belah 4	Belah Woods and Pastures 4	2.06	0.145	7.0%	1.58	1.73	84%
Belah 5	Belah Woods and Pastures 5	2.06	0.094	4.6%	1.58	1.67	81%
Coldkeld	Coldkeld Wood	2.06	0.062	3.0%	1.58	1.64	80%
Belah 6	Belah Woods and Pastures 6	2.06	0.051	2.5%	1.58	1.63	79%
Riv E&T	River Eden & Tributaries	0.536	0.023	4.3%	1.58	1.60	299%
Argill	Argill Woods & Pastures	1.328	0.007	0.5%	1.06	1.07	80%
Augill	Augill Valley Pasture	1.328	0.004	0.3%	1.06	1.06	80%
Swindale	Swindale Wood	1.933	0.002	0.1%	1.78	1.78	92%
Helbeck	Helbeck and Swindale Woods	1.923	0.002	0.1%	1.78	1.78	93%
Birkett	Birkett Hill & High Out Wood	2.203	0.001	0.0%	1.87	1.87	85%

6.1.3. Scenario 2: Cumulative Impacts – Existing and Proposed Hen Sheds and Chicken Ranges - NH_3 Critical Levels

Scenario 2 represents the combined impacts from the existing and proposed hen sheds and chicken ranges. To quantify the cumulative air quality attributable to both the existing and proposed hen sheds, and surrounding background sources; the Process Contribution (PC) is predicted, then the existing background air quality (i.e., arising from other sources) is added to calculate the Predicted Environmental Concentrations (PEC).

The maximum modelled process contributions (PCs) over 5 years of meteorological data for comparison with the annual mean NH_3 Critical Level (1.0 µg/m^3) are presented in with the exception of the Belah Woods and Pastures SSSI site.

Table 6.4 and details the maximum modelled PCs and PECs from the proposed and existing hen sheds and chicken ranges for comparison with the Critical Level for annual mean ammonia concentrations. A contour plot illustrating the predicted spatial variation in predicted NH_3 annual mean concentrations is presented in Appendix 6.2

The cumulative process contributions (PC) to the Critical Level for annual mean ammonia concentrations are above 4% of the site-specific Critical Loads for SSSI sites and 1% criteria for the River Eden SAC site. While the site's cumulative PC cannot be screened out at these habitats as insignificant, no exceedances of the critical loads from the hen shed emissions are predicted to occur at the locations with the exception of the Belah Woods and Pastures SSSI site.

Table 6.4 Maximum Modelled Process Contributions to the Cumulative Maximum Annual Mean NH_3 Concentration at Designated Habitat Sites

Receptor ID	Designated site	CL (µg/m^3)	Site PC, (µg/m^3)	Site PC as % of CL	PEC, (µg/m^3)	PEC as % of CL
Belah 1	Belah Woods and Pastures 1	1	0.49	49%	2.31	231%
Belah 2	Belah Woods and Pastures 2	1	1.69	169%	3.51	351%
Holme Blks	Holme and Blackscar Woods	3	0.48	16%	2.30	77%
Belah 3	Belah Woods and Pastures 3	1	0.48	48%	2.30	230%
Belah 4	Belah Woods and Pastures 4	1	1.05	105%	2.87	287%
Belah 5	Belah Woods and Pastures 5	1	0.94	94%	2.76	276%
Coldkeld	Coldkeld Wood	3	0.82	27%	2.64	88%
Belah 6	Belah Woods and Pastures 6	1	0.43	43%	2.25	225%
Riv E&T	River Eden & Tributaries	3	0.12	4.0%	1.94	65%
Riv Eden	River Eden	1	0.12	12%	1.94	194%
Argill	Argill Woods & Pastures	1	0.04	4.3%	1.86	186%
Augill	Augill Valley Pasture	3	0.02	0.7%	1.84	61%
Swindale	Swindale Wood	3	0.01	0.5%	0.99	33%
Helbeck	Helbeck and Swindale Woods	1	0.01	1.4%	0.99	99%
Birkett	Birkett Hill & High Out Wood	1	0.004	0.4%	1.54	154%

6.1.4. Scenario 2: Cumulative Impacts – Existing and Proposed Hen Sheds and Chicken Ranges - Critical Loads for Nutrient Nitrogen and Acidity

The maximum modelled process contribution (PC) to total nutrient nitrogen deposition at designated sites is presented in Table 6.5.

The PC is assessed against the minimum critical load for Nitrogen for the designated sites obtained from the site-specific information from the APIS website[3].

The cumulative process contributions (PC) to the total nutrient nitrogen deposition flux are above 4% of the site-specific Critical Loads; with the exception of Argill Woods & Pastures SSSI, Augill Valley Pasture SSSI, Swindale Wood SSSI, Helbeck and Swindale Woods SSSI, and Birkett Hill & High Out Wood SSSI. While the site's PC cannot be screened out at these habitats as insignificant, no exceedances of the critical loads from the hen shed emissions are predicted to occur at any of these locations.

Table 6.6 presents the maximum modelled site PC and PEC acid deposition impacts at the designated sites for which acid critical load functions were specified. The PC and PEC are assessed against the minimum CLmaxN critical load function for each site.

The cumulative process contributions to acid deposition are above 4% of the site-specific Critical Loads; with the exception of Argill Woods & Pastures SSSI, Augill Valley Pasture SSSI, Swindale Wood SSSI, Helbeck and Swindale Woods SSSI, and Birkett Hill & High Out Wood SSSI. While the site's PC cannot be screened out at these habitats as insignificant, no exceedances of the critical loads from the hen shed emissions are predicted to occur at any of these locations.

Table 6.5 Modelled Cumulative Nutrient Nitrogen Deposition at Habitat Sites, using minimum CLs

Receptor ID	Designated site	Critical load	Site PC N Dry deposition flux (kg N/ha/year)	Site PC % of minimum Critical load	Background total N deposition (kg N/ha/year)	Site PEC Dry deposition flux (kg N/ha/year)	Site PEC % of minimum Critical load
Belah 1	Belah Woods and Pastures 1	10	2.565	26%	4.83	7.4	74%
Belah 2	Belah Woods and Pastures 2	10	8.805	88%	4.83	13.6	136%
Holme Blks	Holme and Blackscar Woods	10	2.501	25%	4.87	7.4	74%
Belah 3	Belah Woods and Pastures 3	10	2.521	25%	4.83	7.4	74%
Belah 4	Belah Woods and Pastures 4	10	5.436	54%	4.83	10.3	103%
Belah 5	Belah Woods and Pastures 5	10	4.898	49%	4.83	9.7	97%
Coldkeld	Coldkeld Wood	10	4.262	43%	4.83	9.1	91%
Belah 6	Belah Woods and Pastures 6	10	2.249	22%	4.83	7.1	71%
Riv E&T	River Eden & Tributaries	10	0.629	6.3%	5.00	5.6	56%
Riv Eden	River Eden	3	0.629	21%	5.00	5.6	188%
Argill	Argill Woods & Pastures	10	0.223	2.2%	5.06	5.3	53%
Augill	Augill Valley Pasture	20	0.115	0.6%	6.77	6.9	34%
Swindale	Swindale Wood	15	0.073	0.5%	5.51	5.6	37%
Helbeck	Helbeck and Swindale Woods	15	0.073	0.5%	5.51	5.6	37%
Birkett	Birkett Hill & High Out Wood	15	0.023	0.2%	4.81	4.8	32%

Table 6.6 Modelled Acid Deposition at Habitat Sites, Compared to Acid Critical Load Functions

Receptor ID	Designated site	Critical load	Site PC Annual mean acidity PC (keq/ha/yr)	Site PC % of minimum Critical load	Background Annual mean acidity PC (keq/ha/yr)	Site PEC Annual mean acidity (keq/ha/yr)	Site PEC % of minimum Critical load
Belah 1	Belah Woods and Pastures 1	2.06	0.183	8.9%	1.58	1.76	86%
Belah 2	Belah Woods and Pastures 2	2.06	0.629	31%	1.58	2.209	107%
Holme Blks	Holme and Blackscar Woods	2.071	0.179	8.6%	1.58	1.759	85%
Belah 3	Belah Woods and Pastures 3	2.06	0.18	8.7%	1.58	1.760	85%
Belah 4	Belah Woods and Pastures 4	2.06	0.388	19%	1.58	1.968	96%
Belah 5	Belah Woods and Pastures 5	2.06	0.35	17%	1.58	1.930	94%
Coldkeld	Coldkeld Wood	2.06	0.304	15%	1.58	1.884	91%
Belah 6	Belah Woods and Pastures 6	2.06	0.161	7.8%	1.58	1.741	85%
Riv E&T	River Eden & Tributaries	0.536	0.045	8.4%	1.58	1.625	303%
Argill	Argill Woods & Pastures	1.328	0.016	1.2%	1.06	1.076	81%
Augill	Augill Valley Pasture	1.328	0.008	0.6%	1.06	1.068	80%
Swindale	Swindale Wood	1.933	0.005	0.3%	1.78	1.785	92%
Helbeck	Helbeck and Swindale Woods	1.923	0.005	0.3%	1.78	1.785	93%
Birkett	Birkett Hill & High Out Wood	2.203	0.002	0.1%	1.87	1.872	85%

7. DISCUSSION AND CONCLUSION

An AQIA of the proposed and cumulative impacts of ammonia (NH_3) emissions from the hen sheds at Broxty Farm has been carried out. The assessment assumed operation of the proposed and existing hen shed exhaust fans.

The impact of NH_3 emissions from the proposed and cumulative impacts of the existing and proposed hen sheds at Broxty Farm was assessed against the relevant annual mean NH_3 critical levels, nitrogen and acidity deposition critical loads for the protection of vegetation and ecosystems at sensitive habitats.

The following conclusions are drawn in relation to impacts at designated nature conservation sites:

- The process contributions from the proposed scenario, with the exception of River Eden & Tributaries SSSI, Argill Woods & Pastures, Augill Valley Pasture SSSI, Swindale Wood SSSI, Helbeck and Swindale Woods SSSI, and Birkett Hill & High Out Wood SSSI, will contribute above the 4% increase to the NH_3 critical levels. While the site's PC cannot be screened out at these habitats as insignificant, no exceedances of the critical levels from the hen shed emissions are predicted to occur at any of these locations.
- The site contributions from the proposed scenario to the total nitrogen deposition are predicted to contribute more than 4% increase to the total nitrogen deposition Critical loads, with the exception of River Eden & Tributaries SSSI, Argill Woods & Pastures, Augill Valley Pasture SSSI, Swindale Wood SSSI, Helbeck, Swindale Woods SSSI, and Birkett Hill & High Out Wood SSSI. While the site's PC cannot be screened out at these habitats as insignificant, no exceedances of the critical loads from the hen shed emissions are predicted to occur at any of these locations.
- The site process contributions from the proposed scenario to the acid deposition are not predicted to contribute more than 4% increase to the Critical load functions at any of the identified habitat sites, with the exception of Belah Woods and Pastures SSSI and River Eden & Tributaries SSSI. While the site's PC cannot be screened out at these habitats as insignificant, no exceedances of the critical loads from the hen shed emissions are predicted to occur at any of these locations.
- The cumulative process contributions from the site were predicted to contribute less than 4% increase to the NH_3 critical level, with the exception of Belah Woods and Pastures SSSI and River Eden & Tributaries SSSI. Therefore, these sites can be screened out at these habitats as insignificant. The site's cumulative PC show no exceedances of the NH_3 critical levels from the hen shed emissions at the specified locations with the exception of the Belah Woods and Pastures SSSI site.
- The cumulative site process contributions to the total nitrogen deposition are predicted to contribute more than 4% increase to the total nitrogen deposition Critical loads, with the exception of River Eden & Tributaries SSSI, Argill Woods & Pastures, Augill Valley Pasture SSSI, Swindale Wood SSSI, Helbeck, Swindale Woods SSSI, and Birkett Hill & High Out Wood SSSI. While the site's PC cannot be screened out at these habitats as insignificant, no exceedances of the critical loads from the hen shed emissions are predicted to occur at any of these locations.
- The cumulative site process contributions to the acid deposition are predicted to contribute more than 4% increase to the Critical load functions with the exception of River Eden & Tributaries SSSI, Argill

Woods & Pastures, Augill Valley Pasture SSSI, Swindale Wood SSSI, Helbeck, Swindale Woods SSSI, and Birkett Hill & High Out Wood SSSI. While the site's PC cannot be screened out at these habitats as insignificant, no exceedances of the critical loads from the hen shed emissions are predicted to occur at any of these locations.

On this basis it is concluded that with the existing and additional mitigation measures installed, as well as enhanced air drying on the proposed buildings, on the cumulative impacts from the hen sheds and external range development to air pollution at all relevant protected nature conservation site can be lowered to below the 50% critical level/ load increment limit.

APPENDIX 1 - SENSITIVITY ANALYSIS AND METEOROLOGICAL DATA

A1.1 Sensitivity analysis of meteorological effects on dispersion

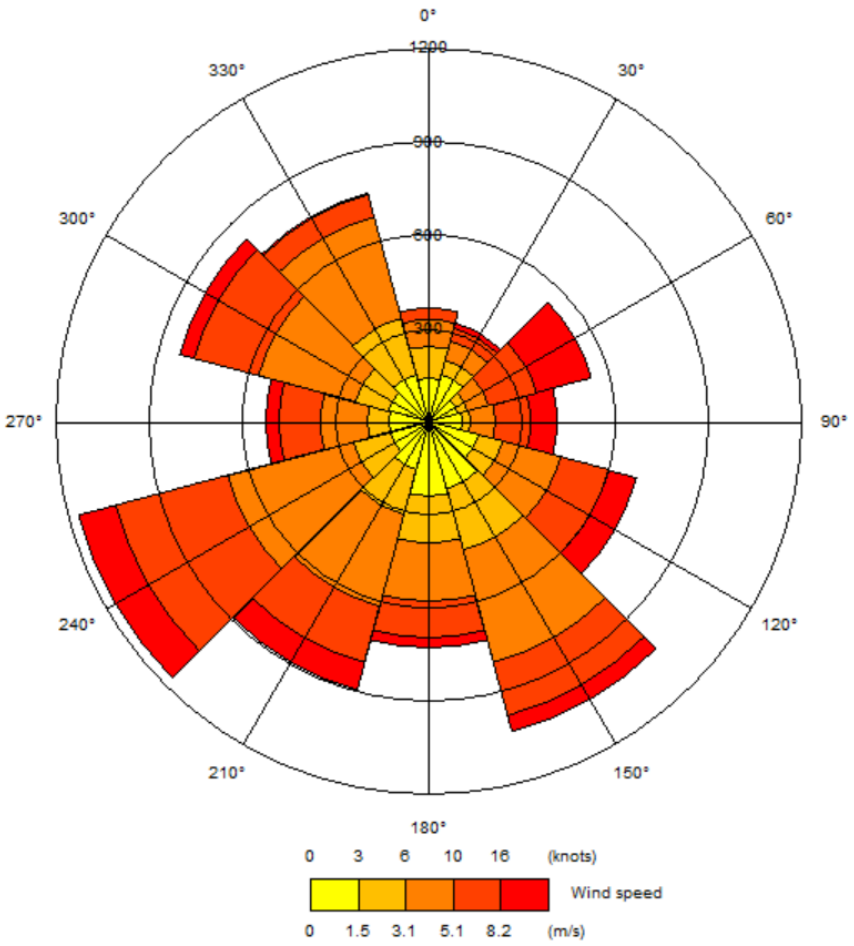
Table A1 1: Maximum Process Contributions to Concentrations for each Annual Met Dataset

Year	Maximum NO_2 Annual mean PC ($\mu g/m^{-3}$)	Maximum NH_3 annual mean PC ($\mu g/m^{-3}$)
2016	0.440	0.587
2017	**0.446**	**0.595**
2018	0.424	0.565
2019	0.409	0.545
2020	0.439	0.585
Year Max PC	2017	2017

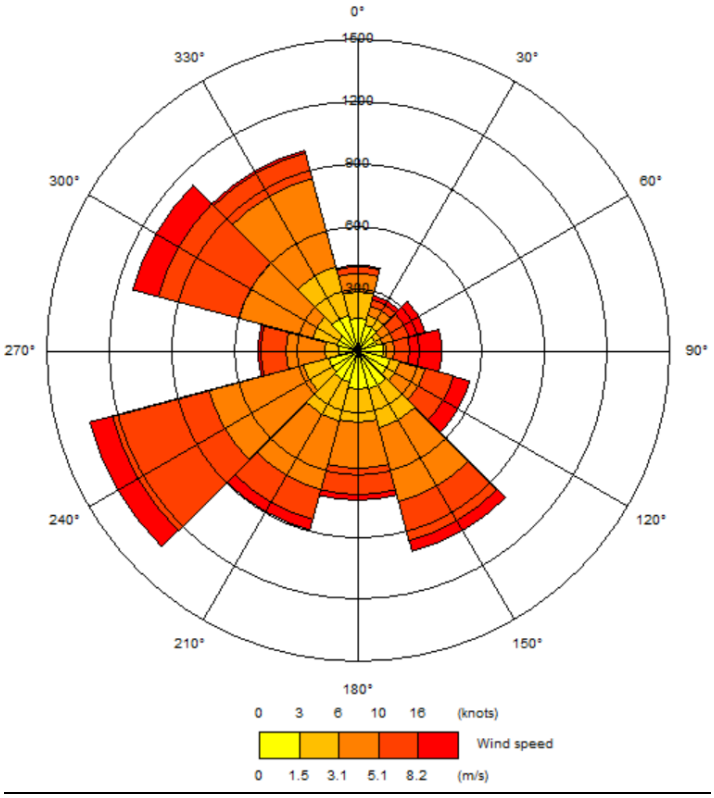
A1. 2 Warcop years 2016 to 2020

Wind Roses

2016



2017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Wind speed
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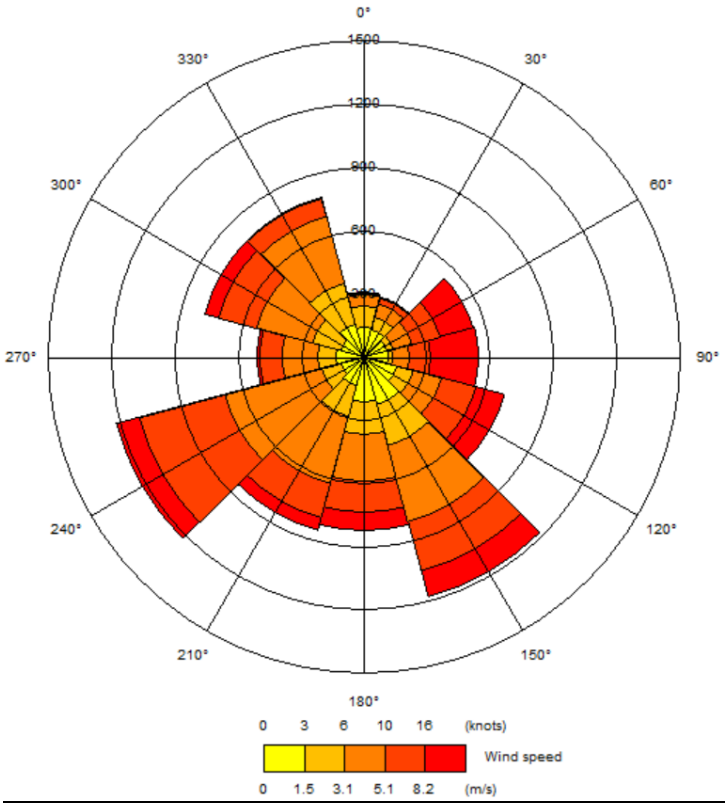
2018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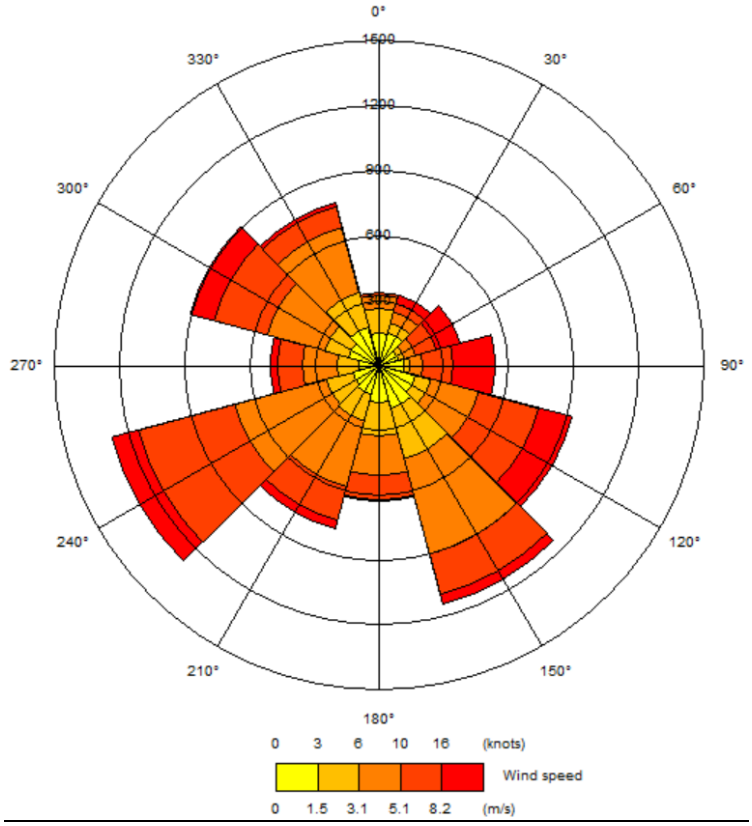
0 3 6 10 16 (knots)
Wind speed
0 1.5 3.1 5.1 8.2 (m/s)

2019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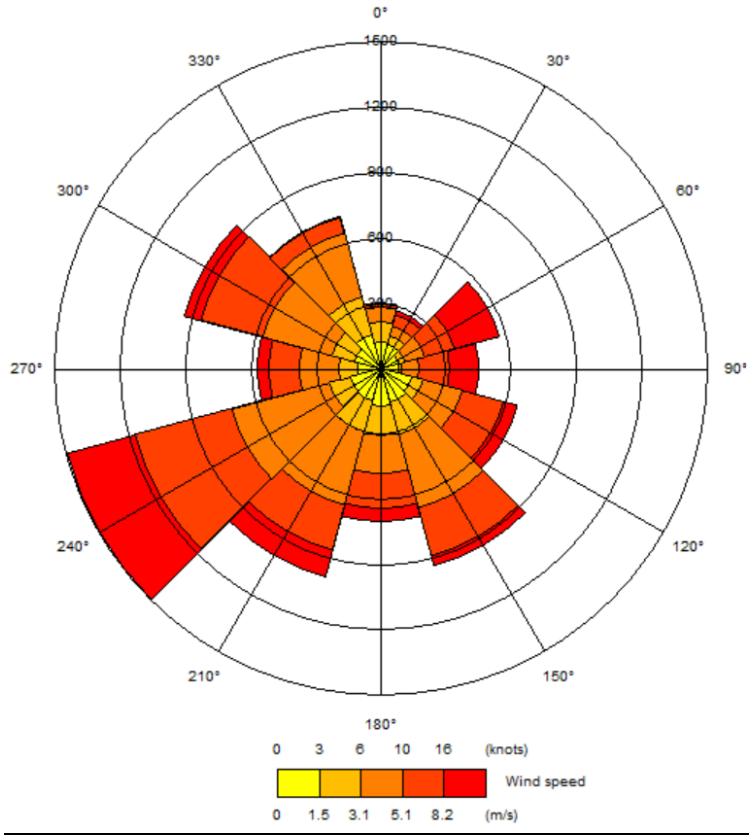
0 3 6 10 16 (knots)
Wind speed
0 1.5 3.1 5.1 8.2 (m/s)

2020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