Haweswater Aqueduct Resilience Programme - Proposed Bowland Section

Environmental Statement

Volume 4

Appendix 18.1: Dispersion Model Input Parameters

June 2021

Water for the North West

Haweswater Aqueduct Resilience Programme - Proposed Bowland Section

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1. Diesel Generator Emissions Modelling

1.1 Emission Parameters

1) The emission data used to represent the two construction compounds are set out in Table 1. The Proposed Bowland Section would require two sizes of diesel generators (250 kVa and 1250 kVa) and these are located at the following compounds:

2) Lower Houses Compound: Emission points: A5 and A6

3) Newton-In-Bowland Compound: Emission points A1, A2, A3 and A4

Table 1: Dispersion modelling parameters

Parameters	Unit	250 kVa	1250 kVa
Fuel	-	Diesel	Diesel
Emission point	-	A1, A5, A6	A2, A3, A4
Stack location	m	A1 – E 368945 N 450010 A5 – E 363600 N 465519 A6 – E 363603 N 465518	A2 – E 368945 N 450003 A3 – E 368945 N 449999 A4 – E 368945 N 450006
Stack height	m	2.66	2.80
Stack diameter (actual)	m	0.2	0.4
Flue gas temperature	°C	406	406
Efflux velocity (actual)	m/s	34.1	37.7
Moisture content of exhaust gas	%	12.0	12.0
Oxygen content of exhaust gas (dry)	%	11.8	11.8
Volumetric flow rate (actual)	m^3/s	1.073	4.737
Volumetric flow rate (normal)[1]	Nm^3/s	0.59	2.58
NOx emission concentration	mg/Nm^3	41.2	77.4
NOx emission rate	g/s	0.024	0.2
CO emission concentration	mg/Nm^3	361	425
CO emission rate	g/s	0.211	1.044
PM_{10} / $PM_{2.5}$ emission concentration	mg/Nm^3	1.5	4.0
PM_{10} / $PM_{2.5}$ emission rate	g/s	0.001	0.010
SO_2 emission concentration	mg/Nm^3	40.0	40.1
SO_2 emission rate	g/s	0.023	1.044
NH_3 emission concentration	mg/Nm^3	13.1	13.1
NH_3 emission rate	g/s	0.008	0.034

Note 1: Normalised flows and concentrations presented at 273 K, 101.3 kPa, dry gas and oxygen content of 15%.

1.2 Structural influences on dispersion

4) The main structures within the compounds which have been included in the model to reflect the existing compound layout are identified within Table 2

Table 2: Building parameters

Compound	Building	Modelled building shapes	Length (m)	Height (m)	Width (m)	Angle of length to north	Centre point co-ordinates	
							X	Y
Lower Houses Compound	Building 1	Rectangular	20.9	2.6	5.1	110	363584	465521
	Building 2	Rectangular	4.0	2.3	1.1	20	363600	465519
	Building 3	Rectangular	4.0	2.3	1.1	20	363603	465518
	Building 4	Rectangular	6.1	2.0	2.7	20	363606	465516
	Building 5	Rectangular	5.1	2.0	2.3	20	363610	465515
	Building 6	Rectangular	40.0	2.5	25.0	20	363646	465523
	Building 7	Rectangular	10.0	2.2	3.0	133	363581	465529
	Building 8	Rectangular	10.0	2.2	3.0	78	363592	465526
Newton-In-Bowland Compound	Building 9	Rectangular	4.7	2.0	1.6	90	368946	450013
	Building 10	Rectangular	4.0	2.3	1.1	90	368945	450010
	Building 11	Rectangular	6.1	2.4	2.4	90	368945	450007
	Building 12	Rectangular	6.1	2.4	2.4	90	368945	450003
	Building 13	Rectangular	6.1	2.4	2.4	90	368945	450000
	Building 14	Rectangular	12.2	2.0	1.8	90	368942	449996

1.3 Operational hours

5) The generators at both compounds were assumed to operate continuously at maximum load for 8,760 hours for each calendar year of meteorological data modelled.

1.4 Calculation of PECs

6) To determine, the total concentration (i.e. the Predicted Environmental Concentration (PEC)) the process contribution (PC - emissions from the modelled process alone) is added to the existing concentration). In the case of determining the total long-term mean concentrations, it is relatively straightforward to combine the modelled PC with the annual mean baseline air quality concentrations, as long-term mean concentrations due to the diesel generator emissions could be added directly to long-term mean baseline concentrations.

7) It is not possible to add short-period peak baseline and PCs directly to determine the PEC. This is because the conditions which give rise to peak ground-level concentrations of substances emitted from an elevated source at a particular location and time are likely to be different to the conditions which give rise to peak concentrations due to emissions from other sources.

8) As described in the Environment Agency guidance[1], for most substances the short-term peak PC values are added to twice the long-term mean baseline concentration to provide a reasonable estimate of peak concentrations due to emissions from all sources.

9) Where locations are also close to the road network and the contribution of the diesel generators and road traffic emissions is being calculated, the PEC was produced by addition of the road traffic and diesel

[1] Environment Agency (2016) Air emissions risk assessment for your environmental permit Published 1 February 2016, updated 7 October 2020 [Online] Available from: https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit#environmental-standards-for-air-emissions

generator PCs (where applicable) to the background concentrations of NOx, PM_{10} and $PM_{2.5}$ for human and relevant ecological locations. The total NO_2 concentrations from road traffic, including the background NO_2 concentrations, were derived from the modelled NOx concentrations at locations located within 200m of the modelled road links using the Defra NOx to NO_2 calculator (v8.1)[2].

1.5 Meteorological Data

10) Five years of hourly sequential data (from 2015 – 2019 inclusive) recorded at Manchester meteorological station were used. Manchester meteorological station is located approximately 84 km south of the Lower Houses compound and 68 km south of the Newton-In-Bowland compound and is considered the closest most representative meteorological monitoring station to the compound that provides all the required validated meteorological parameters for dispersion modelling, with low levels of missing data. The wind roses for each year of meteorological data utilised in the assessment are shown below.

Illustration 2: Wind rose for Manchester meteorological station, 2015

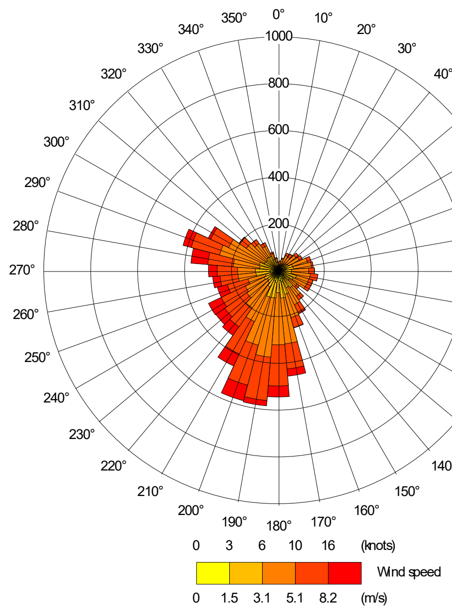
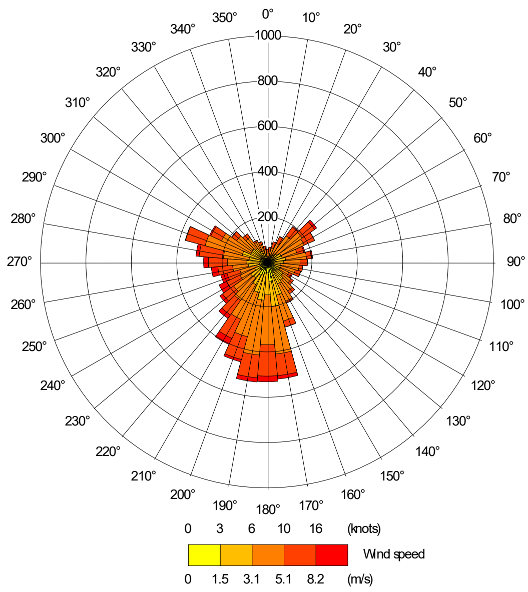


Illustration 1: Wind rose for Manchester meteorological station, 2016



[2] Department for Environment, Food and Rural Affairs (2020), NOx to ,NO_2 calculator Version 8.1, [online]. Available from: https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html#NOxNO2calc [Accessed January 2021]

Illustration 4: Wind rose for Manchester meteorological station, 2017

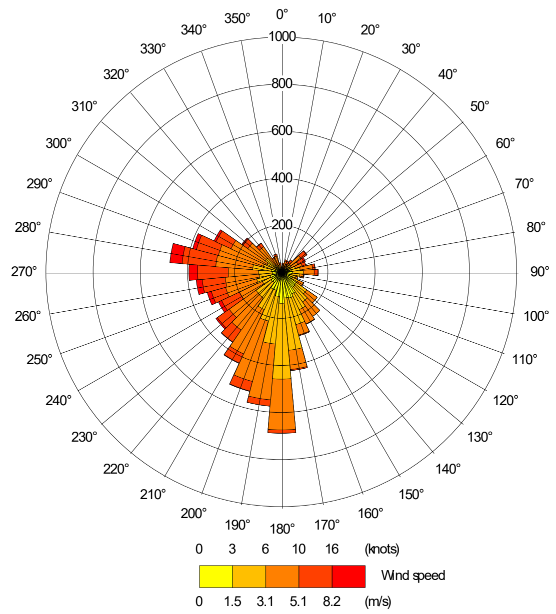


Illustration 3: Wind rose for Manchester meteorological station, 2018

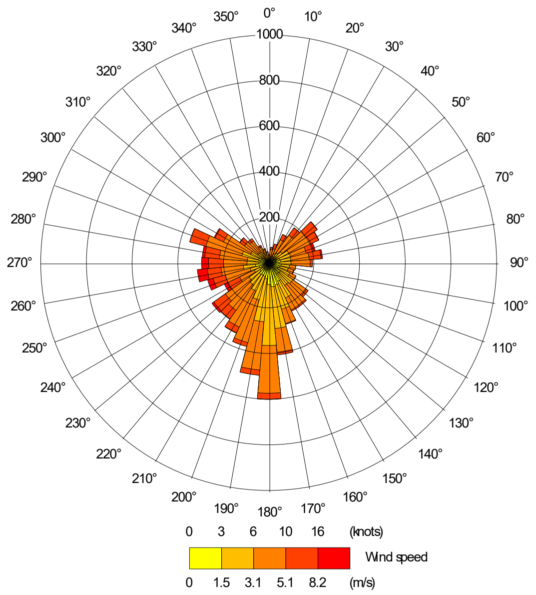
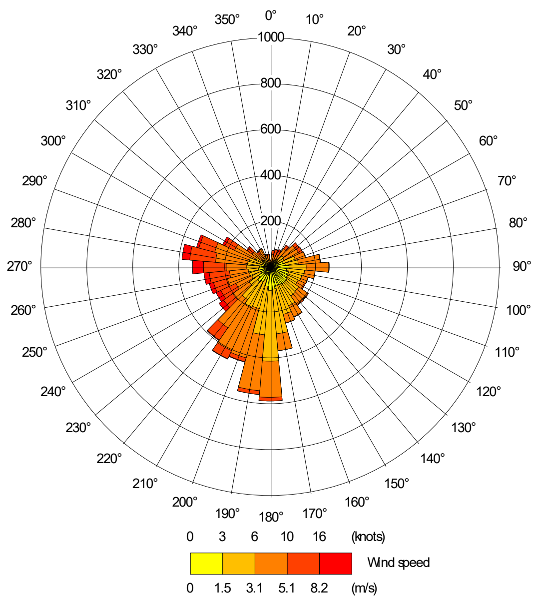


Illustration 5: Wind rose for Manchester meteorological station, 2019



1.6 Surface Roughness

11) The surface roughness is a length scale used to represent the turbulent effect of obstructions in the surrounding area. The surface roughness used in this assessment was 0.3 m which is appropriate for an area where the local land-use is categorised as mainly rural and agricultural. For the Manchester weather station, a value of 0.3 m was used to represent the surface roughness.

1.7 Minimum Monin-Obukhov Length, Surface Albedo and Priestley-Taylor Parameter

12) The model default values were used for the Minimum Monin-Obukhov Length (1 m), Surface Albedo (0.23) and Priestley-Taylor Parameter (1).

1.8 Terrain

13) Guidance for the use of the ADMS model suggests that terrain is normally incorporated within a modelling assessment when the gradient exceeds 1:10. As the gradient in the vicinity of the compounds does not exceed 1:10 over a large area, a terrain file was not included in the modelling.

1.9 Model Domain/Assessment Area

14) The ADMS model calculates the predicted concentrations based on a set of user defined points. The potential impact was predicted at 35 human locations (e.g. exposure locations such as residential properties and public footpaths) and 48 protected nature conservation areas (ecological locations) within the required assessment area were assessed. The locations are shown in Figure 18.1 and further details of the locations are provided in Table 3 and Table 4.

Table 1: Assessed human locations

Location	Description	Grid reference		Compound	Distance from the compound (km)	Direction from the compound
		X	Y			
R1	Leyland Farm	362754	465578	Lower Houses Compound	0.8	W
R2	High Park House Farm	363636	466185		0.7	N
R3	Lower House Farm	363772	465820		0.3	NNE
R4	Bottomhill Farm	363941	465169		0.5	SE
R5	Gamble Hole Farm	368644	450988	Newton-In-Bowland Compound	1.0	NNW
R6	Brownhills Farm	369065	450896		0.9	N
R7	Higher House Farm	369327	450630		0.7	NNE
R8	Residential off Back Lane	369519	450406		0.7	NE
R9	Hodder Croft	369680	450369		0.8	ENE
R10	Residential off Newton Rd	369539	450358		0.7	ENE
R11	Hill House Farm	370264	449753		1.3	E
R12	Longstripes Farm	369968	449548		1.1	ESE
R13	Slim Row Farm	370397	449217		1.7	ESE
R14	Wyndfell Farm	370540	448932		1.9	SE
R15	Storth Farm	369710	449257		1.1	SE
R16	Residential off Eastington Rd	369283	449360		0.7	SSE
R17	Ashnott Farm	369279	448193		1.8	S
R18	Residential off Eastington Rd	368942	448512		1.5	S
R19	Forber Farm	368742	450133		0.2	WNW
R20	Residential off Dunlop Rd	368563	450459		0.6	NW
R21	Residential off Slaidburn Rd	370347	449588		1.5	ESE
R22	Gibbs Farm	369328	449160	Lower Houses Compound	0.9	SSE
R23	New Laithe Farm	369938	448755		1.6	SE
R24	Footpath	363909	465285		0.4	SE

Location	Description	Grid reference X	Grid reference Y	Compound	Distance from the compound (km)	Direction from the compound
R25	Footpath	363860	465407		0.3	ESE
R26	Footpath	363825	465546		0.2	E
R27	Footpath	363810	465725		0.3	NE
R28	Footpath	363554	465769		0.3	N
R29	Footpath	363409	465809		0.3	NNW
R30	Footpath	363255	465777	Newton-In-Bowland Compound	0.4	NW
R31	Footpath	363177	465723		0.5	WNW
R32	Footpath	368681	449700		0.4	SW
R33	Footpath	368756	449836		0.3	SW
R34	Footpath	368853	449912		0.1	SW
R35	Footpath	368927	450059		0.1	NNW

Table 2: Assessed ecological locations

Location	Description	Grid reference X	Grid reference Y	Compound	Distance from the compound (km)	Direction from the compound
H1	Scales Wood Ancient Woodland (ID 1102544)	362396	465549	Lower Houses Compound	1.2	W
H2	Ancient Woodland (ID 1413140)	362500	467116		1.9	NW
H3	Cragg/Holme/Birks Woods Ancient Woodland (ID 1102542)	364071	466077		0.7	NE
H4	Ancient Woodland (ID 1413137)	364069	466832		1.4	NNE
H5	Ancient Woodland (ID 1413135)	364480	466071		1.0	ENE
H6	Ancient Woodland (ID 1413132)	364135	465556		0.5	E
H7	Ancient Woodland (ID 1413134)	364230	465553		0.6	E
H8	Far Holme Meadow SSSI	364537	465549		0.9	E
H9	Ancient Woodland (ID 1102554)	364727	465708		1.1	E
H10	Ancient Woodland (ID 1413131)	364731	465409		1.1	E

Location	Description	Grid reference		Compound	Distance from the compound (km)	Direction from the compound
		X	Y			
H11	Ancient Woodland (ID 1413130)	365479	465272		1.9	E
H12	Ancient Woodland (ID 1413128)	364854	465057		1.3	ESE
H13	Ancient Woodland (ID 1413126) and Helks Wood BHS	364417	464980		1.0	ESE
H14	Ancient Woodland (ID 1413125)	364870	464878		1.4	ESE
H15	Ancient Woodland (ID 1413123)	365018	464618		1.7	ESE
H16	Ancient Woodland (ID 1413120)	364819	464181		1.8	SE
H17a	North Pennine Dales Meadows SAC	370376	452978	Newton-In-Bowland Compound	3.3	NNE
H17b		371500	452310		3.4	NE
H17c		372410	451755		3.9	ENE
H18	Ancient Woodland (ID 1413096)	368645	450496		0.6	NNW
H19	Great Dunnow Wood Ancient Woodland (ID 1102670)	370123	450753		1.4	ENE
H20a	Ashnott Wood Ancient Woodland (ID 1102518)	369500	448346		1.7	SSE
H20b		369328	448388		1.7	SSE
H20c	Ashnott Wood Ancient Woodland (ID 1102518)	369136	448434		1.6	S
H21a	Over Houses Great Wood BHS	364098	465538	Lower Houses Compound	0.5	E
H21b	Over Houses Great Wood BHS and Ancient Woodland (ID 1413134)	364466	465400		0.9	E
H22a	Goodber Common (incl Summersgill Fell and White Moss) BHS	363359	465078		0.5	SSW
H22b		363662	464924		0.6	S
H23	Lower Helks Pastures BHS	364512	465025		1.0	ESE
H24	Calf Hill and Cragg Woods SAC	355017	461577		9.4	WSW
H25	Crag House Roadside Verges BHS	368903	448550	Newton-In-Bowland Compound	1.5	S
H26	Ashnott Meadow BHS	369163	448110		1.9	S
H27	Bonstone Brook Pastures BHS	369799	448616		1.6	SSE

Location	Description	Grid reference		Compound	Distance from the compound (km)	Direction from the compound
		X	Y			
H28a	Waddington Fell Road, Roadside Verges BHS	370247	449758		1.3	E
H28b		370161	449913		1.2	E
H29a	Birkett Fell, Hodder Bank Fell and Mosswaite Fell	367823	449217		1.4	SW
H29b		367926	448895		1.5	SW
H30a	Gibb's Wood and Bonestone Wood BHS	369582	448761		1.4	SSE
H30b		369213	449100		0.9	SSE
H31	Gamble Hole Farm Pasture BHS	368851	450242	Lower Houses Compounds	0.3	NNW
H32	Sugar Loaf BHS	367123	450697		1.9	WNW
H33	Clerk Laithe BHS	369805	450956		1.3	NE
H34	Great Dunnow Hill BHS	370101	450906		1.5	NE
H35	Newton North Roadside Verges BHS	369859	450682		1.1	NE
H36	Newton West Roadside Verges BHS	369057	450107		0.2	NE
H37	Wray Wood Moor BHS	362033	465494		1.6	W
H38	Pike Gill Wood (Including Willock Close Wood and High Grasses Wood) BHS	362006	466294		1.8	WNW
H39	Cowkins Coppice BHS and Cragg/Holme/Birks Wood (ID 1102542)	363548	466951		1.4	N
H40a	Hole House and Lower House Grasslands BHS	364128	466321		1.0	NNE
H40b		364234	466056		0.8	NE
H40c		364397	465855		0.9	ENE
H41a	Meadows Adjoining Far Holme Meadow SSSI BHS	364476	465676		0.9	E
H41b		364603	465415		1.0	E
H41c		364636	465219		1.1	ESE
H42a	Well Beck Wood (Including Helks Home Wood and Middlefield Wood) BHS	364907	464051		2.0	SE
H42b		364534	463751		2.0	SSE
H42c		364181	463627		2.0	SSE
H43	New Barn Meadow, Low Gill BHS	365092	465416		1.5	E
H44	Foss Bank Wood, High Lot Wood, Over Wood and Mosit Shoe Wood BHS	365216	475372		1.6	E

Location	Description	Grid reference X	Grid reference Y	Compound	Distance from the compound (km)	Direction from the compound
H45	Bank Wood, High Lot Wood, Over Wood and Mosit Shoe Wood BHS	364606	465806		1.0	ENE
H46	Cragg Wood, Holme Wood, Birks Wood and Park House Wood BHS and Cragg/Holme/Birks Wood (ID 1102542)	363357	466624		1.1	NNW
H47a	Bowland Fells SPA and Bowland Fells SSSI	359372	461704	Lower Houses Compounds	5.7	SW
H47b		361219	461502		4.7	SSW
H47c		364412	461259		4.3	S
H47d		366744	462500		4.4	SE
H47e		361402	445606	Newton-In-Bowland Compound	8.7	S
H47f		363293	447008		6.4	S
H47g		364002	449324		5.0	S
H47h		365317	450846		3.7	S
H47i		366869	452287		3.1	SSE
H47j		367642	453864		4.1	SSE
H47k		368668	455098		5.1	SSE

1.10 Treatment of Oxides of Nitrogen Emissions

15) It was assumed that 70 % of NOx emitted from the assessed combustion plant would be converted to NO_2 at ground level in the vicinity of the compound, for determination of the annual mean NO_2 concentrations, and 35 % of emitted NOx would be converted to NO_2 for determination of the hourly mean NO_2 concentrations, in line with guidance provided by the Environment Agency [3]. This approach is likely to overestimate the annual mean NO_2 concentrations considerably at the most relevant assessment locations close to the compound.

1.11 Modelling Uncertainty

16) There are always uncertainties in dispersion models, in common with any environmental modelling assessment, because a dispersion model is an approximation of the complex processes which take place in the atmosphere. Some of the key factors which lead to uncertainty in atmospheric dispersion modelling are as follows.

- The quality of the model output depends on the accuracy of the input data enter the model. Where model input data are a less reliable representation of the true situation, the results are likely to be less accurate

[3] Environment Agency (2014) Environmental permitting: air dispersion modelling reports. Published 1 November 2014, updated 19 January 2021, [Online] Available from: [online] Available at: https://www.gov.uk/guidance/environmental-permitting-air-dispersion-modelling-reports [Accessed January 2021]

- The meteorological data sets used in the model are not likely to be completely representative of the meteorological conditions at the compound. However, the most suitable available meteorological data was chosen for the assessment
- Models are generally designed on the basis of data obtained for large scale point sources and may be less well validated for modelling emissions from smaller scale sources
- The dispersion of pollutants around buildings is a complex scenario to replicate. Dispersion models can take account of the effects of buildings on dispersion; however, there will be greater uncertainty in the model results when buildings are included in the model
- Modelling does not specifically take into account individual small-scale features such as vegetation, local terrain variations and off-site buildings. The roughness length (zo) selected is suitable to take general account of the typical size of these local features within the model domain
- To take account of these uncertainties and to ensure the predictions are more likely to be over-estimates than under-estimates, the conservative assumptions described below have been used for this assessment.

1.12 Conservative Assumptions

17) The conservative assumptions adopted in this assessment are summarised below.

- All of the diesel generators at each compound were assumed to operate at maximum load for 8,760 hours each calendar year. In practice, the generators would have periods of shut-down and maintenance and may not always operate at maximum load, particularly at reception compounds where electricity demand peaks only when the tunnel boring machine is removed from the shaft
- The assessment is based on emissions being continuously at the emission limits (i.e. the EU Stage V Non-Road Mobile Machinery emission limits) and calculated emissions specified. The diesel generator emissions may be below the maximum allowable emission limits
- The maximum predicted concentrations at any residential areas as well as off-site locations were considered for the assessment of short-term concentrations and the maximum predicted concentrations at any residential areas were considered for assessment of annual mean concentrations within the air quality assessment area. Concentrations at other locations would be less than the maximum values presented
- The highest predicted concentrations obtained using any of the five different years of meteorological data have been used in this assessment. During a typical year the ground level concentrations are likely to be lower
- It was assumed that 100 % of the particulate matter emitted from the plant is in the PM_{10} size fraction. The actual proportion would be less than 100 %
- It was assumed that 100 % of the particulate matter emitted from the plant is in the $PM_{2.5}$ size fraction. The actual proportion would be less than 100 %
- It was assumed that NH_3 would be emitted by the diesel generators due to 'ammonia slip' from the Selective Catalytic Reduction (SCR) system used to reduce NOx emissions to the emission limit values and that an ammonia slip catalyst is not installed (i.e. a worse case assumption).

2. Calculating Acid and Nitrogen Deposition

18) Nitrogen and acid deposition have been predicted using the methodologies presented in the Air Quality Technical Advisory Group (AQTAG) guidance note: AQTAG 06 "Technical Guidance on Detailed Modelling Approach for an Appropriate Assessment for Emissions to Air"[4].

19) When assessing the deposition of nitrogen, it is important to consider the different deposition properties of nitric oxide and nitrogen dioxide. It is generally accepted that there is no wet or dry deposition arising from nitric oxide in the atmosphere. Thus, it is normally necessary to distinguish between nitric oxide (NO) and nitrogen dioxide in a deposition assessment. In this case, the conservative assumption that 70% of the oxides of nitrogen are in the form of nitrogen dioxide was adopted.

20) Information on the existing nitrogen and acid deposition was obtained from the APIS database[5]. Information on the deposition critical loads for each habitat site was also obtained from the APIS database using the Site Relevant Critical Load function.

21) The annual dry deposition flux can be obtained from the modelled annual average ground level concentration via use of the formula:

Dry deposition flux (µg/m^2/s) = ground level concentration (µg/m^3) x deposition velocity (m/s)

(where µg refers to µg of the chemical species under consideration).

22) The deposition velocities for various chemical species recommended for use in the AQTAG guidance[6] are shown in Table 5

Table 3: Recommended dry deposition velocities

Chemical species	Recommended deposition velocity (m/s)	
NO_2	Grassland (short)	0.0015
	Forest (tall)	0.003
SO_2	Grassland (short)	0.012
	Forest (tall)	0.024
NH_3	Grassland (short)	0.020
	Forest (tall)	0.030

23) To convert the dry deposition flux from units of µg/m^2/s (where µg refers to µg of the chemical species) to units of kg N/ha/yr (where kg refers to kg of nitrogen) multiply the dry deposition flux by the conversion factors shown in Table 6. To convert dry deposition flux to acid deposition multiply by factors shown in Table 7.

Table 4: Dry deposition flux conversion factors for nutrient nitrogen deposition

µg/m^2/s of species	Conversion factor to kg N/ha/yr
NO_2	95.9
NH_3	260

[4] Air Quality Technical Advisory Group (AQTAG) (2014). AQTAG 06 Technical Guidance on Detailed Modelling Approach for an Appropriate Assessment for Emissions to Air, updated version approved March 2014.
[5] Centre for Ecology and Hydrology (2020). Air Pollution Information System [online] Available at: http://www.apis.ac.uk [Accessed February 2021].
[6] Air Quality Technical Advisory Group (AQTAG) (2014) *op cit*.

Table 5: Dry deposition flux conversion factors for acidification

µg/m^2/s of species	Conversion factor to keq/ha/yr
NO_2	6.84
SO_2	9.84
NH_3	18.5