Haweswater Aqueduct Resilience Programme - Proposed Marl Hill Section

Environmental Statement

Volume 4

Appendix 18.1: Dispersion Model Input Parameters

June 2021

Water for the North West

Haweswater Aqueduct Resilience Programme - Proposed Marl Hill Section

Project No:	B27070CT
Document Title:	Proposed Marl Hill Section Environmental Statement Volume 4 Appendix 18.1: Dispersion Model Input Parameters
Document Ref:	RVBC-MH-TA-018-001
Revision:	0
Date:	June 2021
Client Name:	United Utilities Water Ltd

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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 Marl Hill Section will require two sizes of diesel generators (250 kVa and 1250 kVa) and these are located at the following compounds:

- Bonstone Compound: Emission points A4 and A5
- Braddup Compound: Emission points A1, A2 and A3.

Table 1: Dispersion modelling parameters

Parameters	Unit	250 kVa	1250 kVa
Fuel	-	Diesel	Diesel
Emission point	-	A1, A4, A5	A2, A3
Stack location	m	A1 – E 371008 N 445064 A4 – E 369684 N 448934 A5 – E 369680 N 448934	A2 – E 371006 N 445067 A3 – E 371005 N 445070
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	0.585	2.582
NOx emission concentration	mg/Nm^3	41.2	77.4
NOx emission rate	g/s	0.024	0.2
CO emission concentration1	mg/Nm^3	361	404
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	0.104
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

2) The main structures within the compounds which have been included in the model to reflect the existing compound layouts 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
Bonstone Compound	Building 1	Rectangular	5.0	2.0	2.0	0	369673	448934
	Building 2	Rectangular	6.0	2.0	2.0	0	369677	448933
	Building 3	Rectangular	4.0	2.3	1.1	0	369681	448934
	Building 4	Rectangular	4.0	2.3	1.1	0	369684	448934
	Building 5	Rectangular	23.4	2.6	5.2	90	369699	448935
	Building 6	Rectangular	10.0	2.2	3.0	67	369695	448929
	Building 7	Rectangular	10.0	2.2	3.0	108	369706	448930
Braddup Compound	Building 8	Rectangular	27.0	2.0	5.2	248	371001	445073
	Building 9	Rectangular	6.1	2.4	2.4	248	371005	445070
	Building 10	Rectangular	6.1	2.4	2.4	248	371007	445067
	Building 11	Rectangular	4.0	2.3	1.1	248	371008	445064
	Building 12	Rectangular	6.0	2.0	2	248	371010	445061
	Building 13	Rectangular	4.5	2.6	1.6	160	371016	445044

1.3 Operational hours

3) The diesel 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

4) 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.

5) 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.

6) 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.

7) 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 generator PCs (where applicable) to the background concentrations of NOx, PM_{10} and $PM_{2.5}$ for human

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[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

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 200 m of the modelled road links using the Defra NOx to NO_2 calculator (v8.1)[2].

1.5 Meteorological Data

8) Five years of hourly sequential data (from 2015 – 2019 inclusive) recorded at Manchester meteorological station were used. Manchester meteorological station is located approximately 66 km south of the Bonstone Compound and 62 km south of the Braddup Compound. It is considered the closest most representative meteorological monitoring station to the compounds 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 1: Wind rose for Manchester meteorological station, 2015

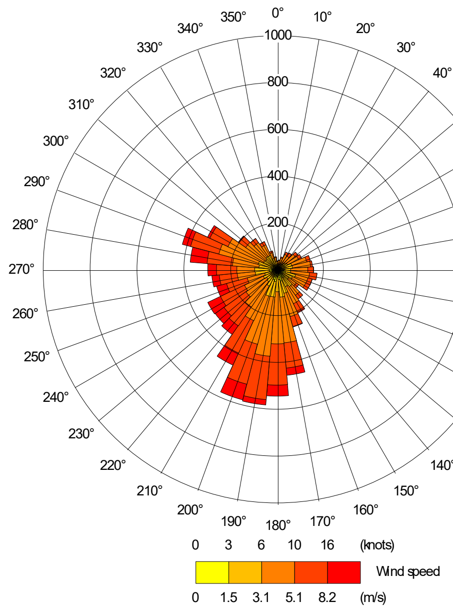
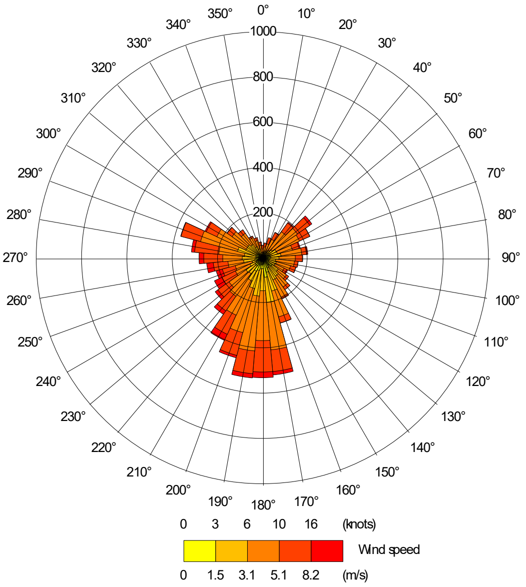


Illustration 2: Wind rose for Manchester meteorological station, 2016



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[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

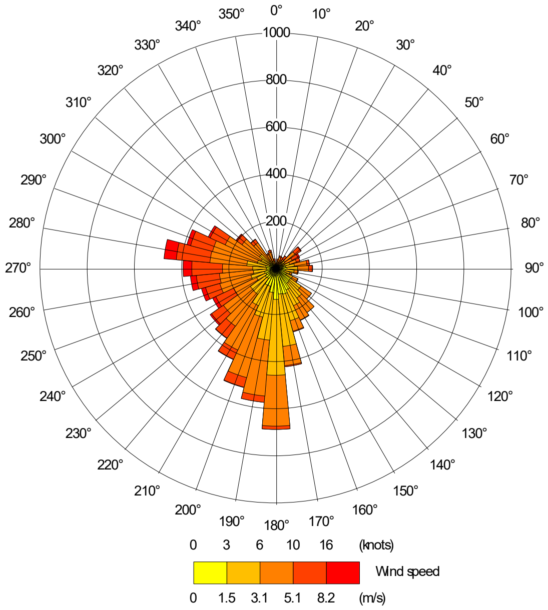


Illustration 3: Wind rose for Manchester meteorological station, 2018

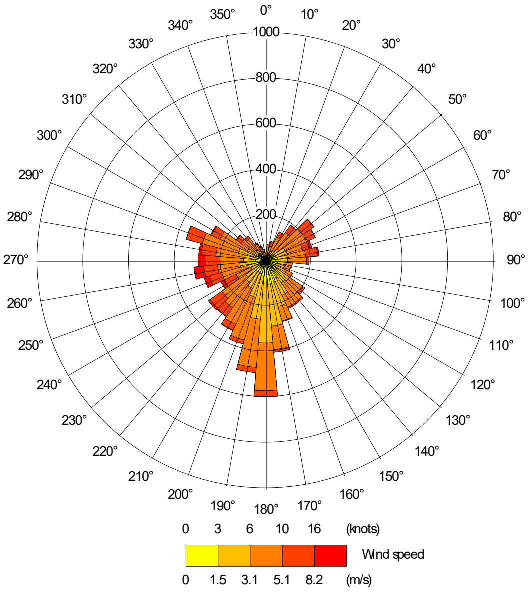
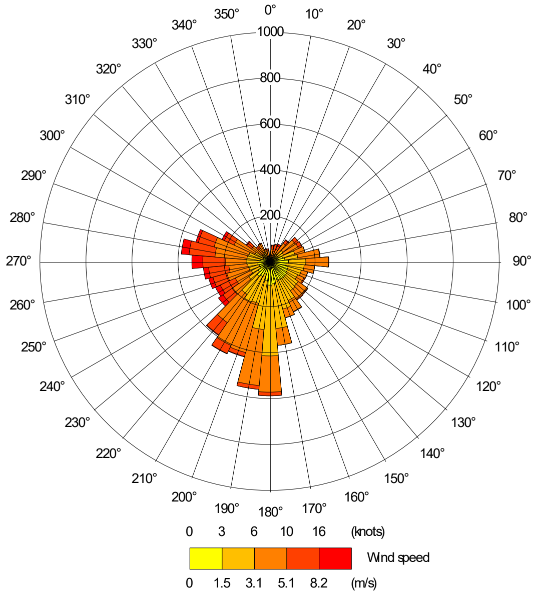


Illustration 5: Wind rose for Manchester meteorological station, 2019



1.6 Surface Roughness

9) 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

10) 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

11) 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

12) The ADMS model calculates the predicted concentrations based on a set of user defined points. The potential impact was predicted at 44 human locations (e.g. exposure locations such as residential properties and public footpaths) and 24 protected nature conservation areas (ecological locations) within the required assessment area. The locations are shown in Figure 18.1 and further details of the locations are provided in Table 3 and Table 4.

Table 3: Assessed human locations

Location	Description	Grid reference		Compound	Distance from the compound (km)	Direction from the compound	Council area
		X	Y				
R1	Storth Farm	369710	449257	Bonstone Compound	0.3	N	Lancaster
R2	Residential off Eastington Rd	369283	449360		0.6	NW	
R3	Gibbs Farm	369328	449160		0.4	WNW	
R4	Residential off Eastington Rd	368942	448512		0.9	WSW	
R5	Ashnott Rd	369279	448193		0.8	SSW	
R6	New Laithe Farm	369938	448755		0.3	SE	
R7	Wyndfell Farm	370540	448932		0.9	E	
R8	Slim Row Farm	370397	449217		0.8	ENE	
R9	Hill House Farm	370264	449753		1.0	NE	
R10	Longstripes Farm	369968	449548		0.7	NNE	
R11	Residential off Slaidburn Rd	370347	449588		0.9	NE	
R12	Residential off Slaidburn Rd	370822	445791	Braddup Compound	0.7	SSE	Ribble Valley
R13	Hareclough Farm	370011	445491		1.1	S	
R14	Braddup Farm	370181	444544		1.0	S	
R15	Peter Barn	371251	444284		0.8	SSE	
R16	Residential off Cross Lane	371751	444536		0.9	SSE	
R17	Bookers Farm	372285	445045		1.3	SE	
R18	Residential off Slaidburn Rd	372209	445285		1.2	SE	
R19	Teewood Farm	372231	445465		1.3	SE	

Location	Description	Grid reference		Compound	Distance from the compound (km)	Direction from the compound	Council area
		X	Y				
R20	Residential off Slaidburn Rd	371310	445541		0.6	SSE	
R21	Residential off Cross Lane	371171	444243		0.8	SSE	
R22	Residential off Cross Lane	371478	444333		0.9	SSE	
R23	Residential off Cross Lane	371545	444342		0.9	SSE	
R24	Forber Farm	368742	450133		5.6	NW	
R25	Footpath	369890	448769	Bonstone Compound	0.3	SE	Lancaster
R26	Footpath	369681	448828		0.1	S	
R27	Footpath	369475	448935		4.2	W	
R28	Footpath	369361	449112		4.4	WNW	
R29	Footpath	369509	449197		4.4	NNW	
R30	Footpath	369708	449159		4.3	N	
R31	Footpath	369870	449040		4.1	ENE	
R32	Footpath	370001	448922	Braddup Compound	4.0	E	Ribble Valley
R33	Footpath	370456	444742		0.6	S	
R34	Footpath	370526	444856		0.5	SSE	
R35	Footpath	370579	444970		0.4	SSE	
R36	Footpath	370647	445142		0.4	SSE	
R37	Footpath	370780	445321		0.3	SSE	
R38	Footpath	371002	445461		0.4	SSE	
R39	Footpath	371328	445359		0.4	SSE	
R40	Footpath	371285	445218		0.3	SSE	
R41	Footpath	371305	445089		0.3	SSE	
R42	Footpath	371308	444875		0.4	SSE	
R43	Footpath	371225	444731		0.4	SSE	
R44	Footpath	371217	444536		0.6	SSE	

Table 4: Assessed ecological locations

Location	Description	Grid reference		Compound	Distance from the compound (km)	Direction from the compound
		X	Y			
H1	Ancient Woodland (ID 1413096)	368645	450496	Bonstone Compound	1.9	NNW
H2	Great Dunnow Wood BHS and Great Dunnow Wood Ancient Woodland (ID 1102670)	370123	450753		1.9	NNE
H3a	North Pennine Dales Meadows SAC	370376	452978		4.1	N
H3b	North Pennine Dales Meadows SAC	371500	452310		3.8	NNE
H3c	North Pennine Dales Meadows SAC	372410	451755		3.9	NE
H4a	Waddington Fell Road, Roadside Verges BHS	370247	449758		1.0	NE
H4b	Waddington Fell Road, Roadside Verges BHS	370161	449913		1.1	NNE
H5	Bradford Fell, Easington Fell and Harrop Fell BHS	370853	448402		1.3	ESE
H6	Waddington Fell and Browsholme Moor BHS	370529	448113		1.2	SE
H7	Waddington Fell and Browsholme Moor BHS	371100	446570		1.5	N
H8	Waddington Fell and Browsholme Moor BHS	370086	447757		1.2	SSE
H9	Bonstone Brook Pastures BHS	369799	448616		0.3	SSE
H10a	Gibb's Wood and Bonestone Wood BHS	369582	448761		0.2	SSW
H10b	Gibb's Wood and Bonestone Wood BHS	369213	449100		0.5	WNW
H11a	Ashnott Wood BHS and Ashnott Wood Ancient Woodland (ID 1102518)	369500	448346		0.6	SSW
H11b	Ashnott Wood BHS and Ashnott Wood Ancient Woodland (ID 1102518)	369328	448388		0.7	SSW
H11c	Ashnott Wood BHS and Ashnott Wood Ancient Woodland (ID 1102518)	369136	448434		0.7	SW
H12	Crag House Roadside Verges BHS	368903	448550		0.9	WSW

Location	Description	Grid reference		Compound	Distance from the compound (km)	Direction from the compound
		X	Y			
H13	Ashnott Meadow BHS	369163	448110		1.0	SSW
H14a	Birkett Fell, Hodder Bank Fell and Mosswaite Fell	367823	449217		1.9	W
H14b	Birkett Fell, Hodder Bank Fell and Mosswaite Fell	367926	448895		1.8	W
H15a	Feazer Wood BHS and Ancient Woodland (ID 1413082)	372527	445275	Braddup Compound	1.5	E
H15b	Feazer Wood BHS and Ancient Woodland (ID 1413082)	372409	445659		1.5	ENE
H16a	Hospital Wood BHS and Hospital Wood Ancient Woodland ID 1102662)	372657	445002		1.7	E
H16b	Hospital Wood BHS and Hospital Wood Ancient Woodland ID 1102662)	372689	444505		1.8	ESE
H17	Cross Lane Roadside VergesBHS	370414	444235		1.0	SW
H18a	Marsdens Wood Ancient Woodland (ID 1102521) and Braddup Wood South BHS	370192	444193		1.2	SW
H18b	Marsdens Wood Ancient Woodland (ID 1102521) and Braddup Wood South BHS	370056	444207		1.3	SW
H19a	Braddup Wood North BHS/Braddup Wood Ancient Woodland (ID 11102520)	369995	444634		1.1	WSW
H19b	Braddup Wood North BHS/Braddup Wood Ancient Woodland (ID 11102520)	369943	444978		1.1	W
H19c	Braddup Wood North BHS/Braddup Wood Ancient Woodland (ID 11102520)	370364	445337		0.7	WNW
H20	Moor Piece BHS	369769	444733		1.3	WSW
H21	Ancient Woodland (ID 1413085)	369443	445615		1.7	WNW
H22	Newton North Roadside Verges	369859	450682	Bonstone Compound	1.8	N
H23	Newton West Roadside Verges	369057	450107		1.3	NNW
H24	Gamble Hole Farm Pasture	368851	450242		1.6	NNW
H25a	Bowland Fells SPA and Bowland Fells SSSI	361402	445606		8.9	WSW
H25b		363293	447008		6.7	WSW

Location	Description	Grid reference		Compound	Distance from the compound (km)	Direction from the compound
		X	Y			
H25c		364002	449324		5.7	W
H25d		365317	450846		4.8	WNW
H25e		366869	452287		4.4	NW
H25f		367642	453864		5.3	NNW
H25g		368668	455098		6.2	N

1.10 Treatment of Oxides of Nitrogen Emissions

13) It was assumed that 70 % of NOx emitted from the assessed combustion plant will 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 will 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

14) 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
- 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

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

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[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]

- 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 will 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 will 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 will 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 will 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

16) 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].

17) 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.

18) Information on the existing nitrogen and acid deposition was obtained from the Air Pollution Information System (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.

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

20) 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).

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

Table 5: 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

22) 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 1: 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

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[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 2: 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