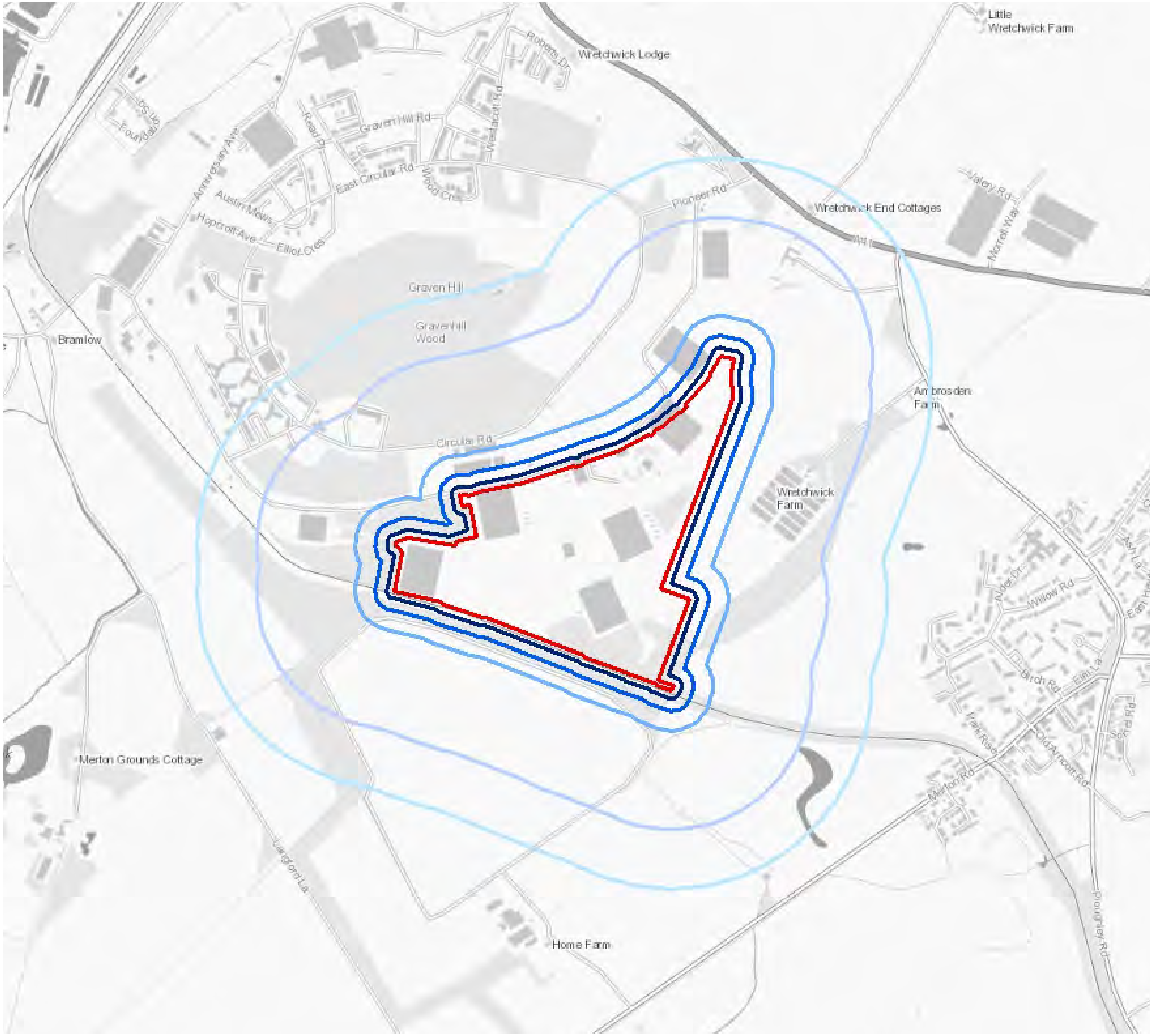
Appendix 16 Air Quality

16.1 Figure 16.1 to 16.2: Construction Phase Assessment Bands and Construction Phase Assessment Bands

16.2 Air Quality Modelling



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- Site Boundary
- 20m from Site Boundary
- 50m from Site Boundary
- 100m from Site Boundary
- 350m from Site Boundary
- 500m from Site Boundary

Project Details	WIE11386-177: Graven Hill, D1 Site, Bicester
Figure Title	Figure 16.1: Construction Phase Assessment Bands
Figure Ref	WIE11386-177_GR_ES_16.1A
Date	May 2022
File Location	\\s-lncs\wiel\projects\wie11386\177\graphics\es\issued figures

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Site Boundary

Existing Receptor Locations

Proposed Receptor Locations

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Project Details	WIE11386-177: Graven Hill, D1 Site, Bicester
Figure Title	Figure 16.2: Site Plan and Receptor Locations
Figure Ref	WIE11386-177_GR_ES_16.2A
Date	May 2022
File Location	\\s-lncs\wiel\projects\wie11386\177\graphics\es\issued figures

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Appendix 16.2: Air Quality Modelling Study

Introduction

Appendix 16.2 presents the technical information and data upon which the operational phase of the air quality assessment is based.

Model

In urban areas, pollutant concentrations are primarily determined by the balance between pollutant emissions that increase concentrations, and the ability of the atmosphere to reduce and remove pollutants by dispersion, advection, reaction and deposition. An atmospheric dispersion model is used as a practical way to simulate these complex processes; which requires a range of input data, which can include pollutant emissions rates, meteorological data and local topographical information.

The effect of the Proposed Development on local air quality was assessed using the advanced atmospheric dispersion model ADMS-Roads taking into account the contribution of emissions from forecast road-traffic on the local road network by the completion year respectively.

ADMS-Roads

The ADMS-Roads model is a comprehensive tool for investigating air pollution in relation to road networks. On review of the Site, and its surroundings, ADMS-Roads was considered appropriate for the assessment of the long and short term effects from road traffic emissions associated with the proposals on air quality. The model uses advanced algorithms for the height-dependence of wind speed, turbulence and stability to produce improved predictions of air pollutant concentrations. It can predict long-term and short-term concentrations, including percentile concentrations.

ADMS-Roads model is a formally validated model, developed in the United Kingdom (UK) by CERC (Cambridge Environmental Research Consultants). This includes comparisons with data from the UK's air quality Automatic Urban and Rural Network (AURN) and specific verification exercises using standard field, laboratory and numerical data sets. CERC is also involved in European programmes on model harmonisation, and their models were compared favourably against other EU and U.S. EPA systems. Further information in relation to this is available from the CERC website at www.cerc.co.uk.

Model Scenarios

Due to the COVID-19 pandemic, 2020 monitoring data was not considered representative of baseline air quality conditions at and surrounding the Site and was not considered further.

The year 2019 was modelled to establish the existing baseline situation, because it is the year for which available monitoring data surrounding the Site is available against which the air quality model is verified (discussed further below). Base year traffic data for 2019 and meteorological data for 2019 were also used to be consistent with the verification year.

To assess the effect of the Proposed Development on local air quality, future 'without Development' and 'with Development' scenarios were assessed. The Proposed Development is anticipated to be completed in 2024 and therefore this is the year in which these future scenarios were modelled.

Traffic Data

Traffic flow data comprising Annual Average Daily Traffic (AADT) flows, traffic composition (% HDVs – Heavy-Duty Vehicles) and speeds (in kph) were used in the model as provided by Waterman for the surrounding road network.

The methodology for calculating the expected change in vehicle trips because of the Proposed Development is set out in detail within Chapter 13 Traffic and Transport and the Transport Assessment. The assessment covers all traffic generated by the Site, including servicing and delivery trips.

Table A16.1 presents the traffic data used within the air quality assessment.

Table A16.1: 24 hour AADT Data Used within the Assessment

Link Reference	Link Name	Speed (kph)	Base 2019		Without Development 2024		With Extant Permission 2024		With Development 2024	
			AADT	%HDV	AADT	%HDV	AADT	%HDV	AADT	%HDV
L1	A41	96	28,228	10.0	30,005	9.8	30,967	9.9	30,585	10.5
L2	A41	84	28,855	9.7	30,807	9.6	31,769	9.7	31,387	10.3
L3	A41	58	28,005	9.1	29,984	8.7	30,945	8.8	30,564	9.4
L4	A41	78	21,652	8.8	24,860	7.7	26,302	8.0	25,730	9.0
L5	A41	78	18,735	7.6	17,776	7.8	20,183	8.3	19,228	10.7
L6	A41	87	21,138	6.7	23,413	6.2	23,723	6.3	23,600	6.5
L7	A4421	72	12,012	5.3	12,103	5.0	12,698	5.3	12,462	6.2
L8	A4421	72	9,321	6.8	9,553	6.3	10,148	6.7	9,912	7.8
L9	A4421	72	13,813	4.6	17,363	3.5	17,958	3.8	17,722	4.4
L10	A4421	72	18,880	4.4	22,561	3.6	23,156	3.8	22,920	4.2
L11	A4421	72	17,831	5.9	20,378	5.2	20,973	5.4	20,737	5.9
L12	EAR	50	-	-	-	-	2,717	12.0	1,639	46.2

Vehicle Speeds

To consider the presence of slow-moving traffic near junctions and at roundabouts with the model, the speed at each junction was reduced to 20 kph. This follows the criteria recommended within LAQM.TG(16)[1], which considers that in most instances the two-way average speed for all vehicles at a junction would be in the range of 20-40 kph based on the estimate that:

- Traffic pulling away from the lights, 40-50 kph;
- Traffic approach the lights when green, 20-50 kph; and
- Traffic on the carriageway approaching the lights when red, 5-20 kph, depending on the time of day and how congested the junction is.

Diurnal Profile

The ADMS-Roads model uses an hourly traffic flow based on the daily (AADT) flows. Traffic flows follow a diurnal variation throughout the day and week. Therefore, a diurnal profile was used in the model to replicate how the average hourly traffic flow would vary throughout the day and the week. This was based on data collated by Waterman from the Department for Transport (DfT) statistics Table TRA0307: 'Traffic Distribution by Time of Day on all roads in Great Britain', 2019[2]. **Figure A16.1** presents the diurnal variation in traffic flows which has been used within the model.

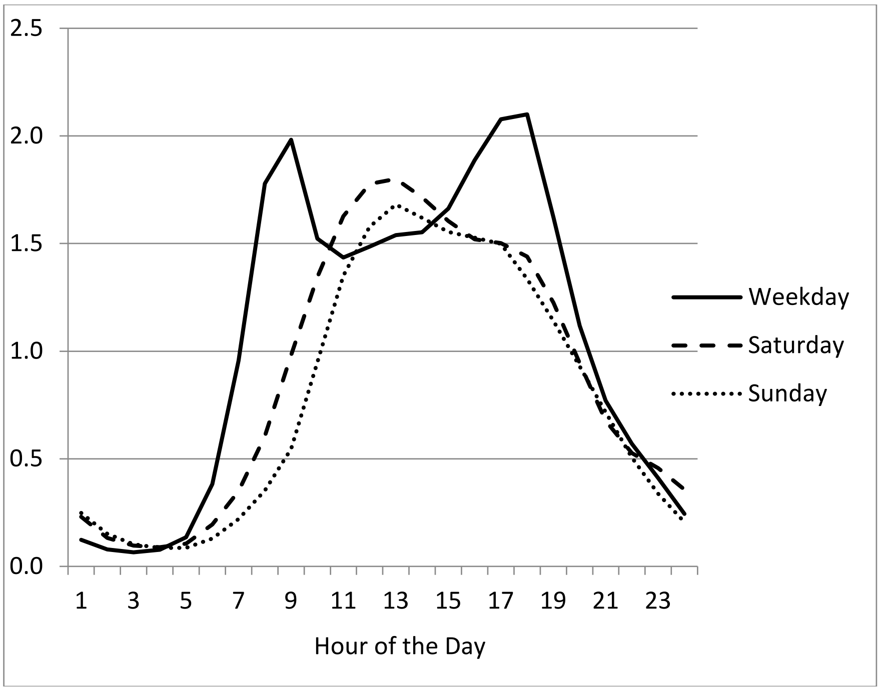

Figure A16.1: Department for Transport 2019 Diurnal Traffic Variation

Road Traffic Emission Factors

The latest version of the ADMS-Roads model (version 5.0.1.3) was used for the assessment. The model was input with the latest vehicle emission factors published by Defra in the

Emission Factors Toolkit (v11.0 published in November 2021) and is based on the latest COPERT database published by the European Environment Agency.

The model uses several parameters (traffic flow, percentage of HDV, speed and road type) to calculate road traffic emissions for the selected pollutants.

Street Canyon Effect

Narrow streets with tall buildings on either side have the potential to create a confined space, which can interfere with the dispersion of traffic pollutants and may result in pollutant emissions accumulating in these streets. In an air quality model these narrow streets are described as street canyons.

ADMS-Roads includes a street canyon model to take account of the additional turbulent flow patterns occurring inside such a narrow street with relatively tall buildings on both sides. LAQM.TG(16) identifies a street canyon *"as narrow streets where the height of buildings on both sides of the road is greater than the road width."*

Following a review of the road network to be included within the model, it was considered that modelled roads are relatively wide and the existing buildings along these roads are not considered to be tall.

The proposed buildings within the Site would not cause any street canyons to be created where there is sensitive public exposure. Therefore, no street canyons were included within the model for any of the scenarios considered.

Background Pollutant Concentrations

Background pollutant concentrations are pollution sources not directly considered in the dispersion modelling. Background pollutant concentrations have therefore been added to contributions from the modelled pollution sources, for each year of assessment.

CDC conduct urban background monitoring at five urban background diffusion tubes across the borough. The nearest urban background diffusion tube to the Site is the Villiers Road diffusion tube located approximately 3.1km north-west of the Site.

The 2019 concentration for the five urban background diffusion tubes are presented in **Table A16.2.**

Table A16.2: NO_2 Concentrations at the CDC urban background diffusion tubes

Site ID	Distance to Site (km)	2019 Annual Mean NO_2 Concentration (µg/m^3)
Villiers Road	3.1	17.0
Tamarisk Gardens	4.7	15.0
Benmead Road	11.4	13.8
Cranleigh Close	24.7	11.0
Sinclair Avenue	26.1	14.4

The monitoring results in **Table A16.2** shows the annual mean NO_2 objective was met at all the urban background diffusion tubes in 2019.

In addition to the monitoring data, forecast UK background concentrations of NOx, NO_2, PM_{10} and $PM_{2.5}$ are available from the Defra LAQM Support website3 for 1x1km grid squares for assessment years between 2018 and 2030 (published in August 2020). **Table A16.3** presents the Defra background concentrations for the years 2019 and 2024, for the grid squares the Site is located within.

Table A16.3: Defra Background Maps in 2019 and 2024 for the Grid Squares at the Site

Grid Square	Year	Annual Mean Concentration (µg/m^3)		
		NO_2	PM_{10}	$PM_{2.5}$
458500, 219599	2019	9.0	14.6	9.2
	2024	7.4	13.7	8.5
459500, 219500	2019	8.7	14.1	9.1
	2024	7.2	13.2	8.3
459500, 220500	2019	9.5	14.8	9.3
	2024	7.7	13.9	8.6

As shown in **Tables A16.2** and **A16.3**, the monitored NO_2 background concentration at the Villiers Road diffusion tube (17.0µg/m^3) is higher than the Defra background map concentrations across the Site. The Villiers Road diffusion tube has therefore been used for a conservative assessment of NO_2 for receptors at every grid square.

CDC do not undertake monitoring of PM_{10} and $PM_{2.5}$, Defra background maps have therefore been used to assess of PM_{10} and $PM_{2.5}$ concentrations. Background concentrations used in the assessment are presented in **Table A16.4**.

Table A16.4: Background Concentrations used within the Assessment

Grid Square and Receptors	Year	Annual Mean Concentration (µg/m^3)		
		NO_2	PM_{10}	$PM_{2.5}$
457500, 221500: Receptor 5	2019	17.0	16.7	10.2
	2024	13.4	15.7	9.5
459500, 221500: Verification Aylesbury Road, Receptors 3 and 4	2019	17.0	15.0	9.9
	2024	13.8	14.0	9.2
457500, 220500: Receptor 6	2019	17.0	15.5	9.4
	2024	13.7	14.6	8.7
459500, 220500: Receptors 2, 8 and 9	2019	17.0	14.8	9.3
	2024	13.8	13.9	8.6
455500, 219500: Receptor 7	2019	17.0	17.2	10.6
	2024	12.6	16.2	9.8
457500, 224500: Verification Howes Lane	2019	17.0	15.4	9.8
	2024	13.9	14.5	9.0
459500, 224500: Receptor 1	2019	17.0	14.1	9.5
	2024	14.0	13.1	8.8

Note: The following adjustment factors were obtained from Defra Maps to calculate 2024 NO_2 concentrations:
Grid square 457500, 221500 - 0.7898, Grid square 459500, 221500 - 0.8136, Grid square 457500, 220500 - 0.8073, Grid square 459500, 220500 - 0.8126, Grid square 455500, 219500 - 0.7433, Grid square 457500, 224500 - 0.8192, Grid square 459500, 224500 - 0.8230

Meteorological Data

Local meteorological conditions strongly influence the dispersal of pollutants. Key meteorological data for dispersion modelling include hourly sequential data for wind direction, wind speed, temperature, precipitation and the extent of cloud cover for each hour of a given year. As a minimum ADMS-Roads and ADMS 5 requires wind speed, wind direction, and cloud cover.

Meteorological data to input into the model were obtained from the Brize Norton Meteorological Station, which is the closest to the Site and considered to be the most representative. The 2019 data were used to be consistent with the base traffic year and model verification year. It was also used for the 2024 scenario for the air quality assessment. **Figure A16.2** presents the wind-rose for the meteorological data.

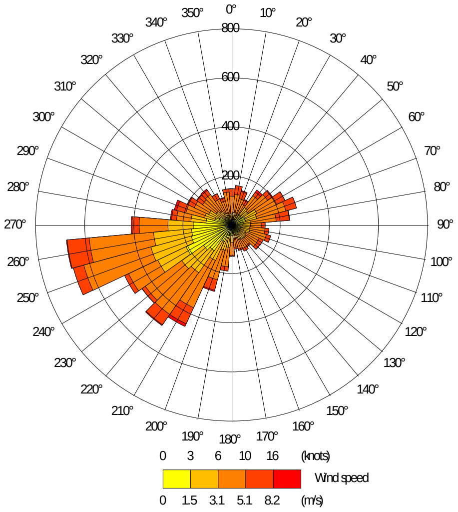

Figure A16.2: 2019 Wind Rose for the Brize Norton Meteorological Site

Most dispersion models do not use meteorological data if they relate to calm winds conditions, as dispersion of air pollutants is more difficult to calculate in these circumstances. ADMS-Roads treats calm wind conditions by setting the minimum wind speed to 0.75 m/s. It is recommended in LAQM.TG(16) that the meteorological data file be tested within a dispersion model and the relevant output log file checked, to confirm the number of missing hours and calm hours that cannot be used by the dispersion model. This is important when considering predictions of high percentiles and the number of exceedances. LAQM.TG(16) recommends that meteorological data should only be used if the percentage of usable hours is greater than 85%. 2019 meteorological data from Brize Norton includes 8,610 lines of usable hourly data out of the total 8,760 for the year, 98.3% of usable data. This is above the 85% threshold and, therefore, is adequate for the dispersion modelling.

Within the air quality models, the surface roughness of 0.5 has been used for the meteorological site, which is representative of parkland and open suburbia and is considered appropriate given the immediate open surrounding area at the meteorological site.

Model Data Processing

The modelling results were processed to calculate the averaging periods required for comparison with the AQS objectives.

NOx emissions from combustion sources (including vehicle exhausts) comprise principally nitric oxide (NO) and nitrogen dioxide (NO_2). The emitted nitric oxide reacts with oxidants in the air (mainly ozone (O_3)) to form more NO_2. Since only NO_2 is associated with effects on human health, the air quality standards for the protection of human health are based on NO_2 and not total NOx or NO.

ADMS-Roads was run without the Chemistry Reaction option to allow verification (see below). Therefore, a suitable NO_X:NO_2 conversion needed to be applied to the modelled NO_X concentrations. There are a variety of different approaches to dealing with NO_X:NO_2 relationships, a number of which are widely recognised as being acceptable. However, the current approach was developed for roadside sites, and is detailed within Technical Guidance LAQM.TG(16).

The LAQM Support website provides a spreadsheet calculator[4] to allow the calculation of NO_2 from NOx concentrations, accounting for the difference between primary emissions of NOx and background NOx, the concentration of O_3, and the different proportions of primary NO_2 emissions, in different years. This approach is only applicable to annual mean concentrations.

Research[5] undertaken in support of LAQM.TG(16) has indicated that the 1-hour mean AQS objective for NO_2 is unlikely to be exceeded at a roadside location where the annual-mean NO concentration is less than 60µg/m^3. The 1-hour mean objective is, therefore, not considered further within this assessment where the annual mean NO_2 concentration is predicted to be less than 60µg/m^3.

In order to calculate the number of PM_{10} 24-hour means exceeding 50µg/m^3 the relationship between the number of 24-hour mean exceedances and the annual mean PM_{10} concentration from LAQM.TG (09)1 was applied as follows:

$$\textbf{Number of Exceedances} = -18.5 + 0.00145 \times (\text{annual mean}^3) + \frac{206}{\text{annual mean.}}$$

Other Model Parameters

There are a number of other parameters that are used within the ADMS-Roads which are described here for completeness and transparency:

- the model requires a surface roughness value to be inputted. A value of 0.5 was used at the Site (which is representative of parkland and open suburbia) and a value of 0.5 was used at the location of the Northolt Meteorological Station, which is representative of parkland and open suburbia;
- the model requires the Monin-Obukhov length (a measure of the stability of the atmosphere) to be inputted. A value of 30m (representative of mixed urban/industrial) was used for the modelling; and
- the ADMS-Roads model requires the Road Type to be inputted. *'England [Urban]'* was selected and used for the modelling.

Model Verification

Model verification is the process of comparing monitored and modelled pollutant concentrations for the same year, at the same locations, and adjusting modelled concentrations, if necessary, to be consistent with monitoring data. This increases the robustness of modelling results.

Discrepancies between modelled and measured concentrations can arise for a number of reasons, for example:

- traffic data uncertainties;
- background concentration estimates;
- meteorological data uncertainties;
- sources not explicitly included within the model (e.g. car parks and bus stops);
- overall model limitations (e.g. treatment of roughness and meteorological data, treatment of speeds); and
- uncertainty in monitoring data, particularly diffusion tubes.

Verification is the process by which uncertainties such as those described above are investigated and minimised. Disparities between modelling and monitoring results are likely to arise as result of a combination of all of these aspects.

Nitrogen Dioxide

The dispersion model was run to predict annual mean NOx concentrations at the project specific CDC kerbside and roadside diffusion tube monitoring locations, as there were considered most suitable for model verification.

The following roadside diffusion tubes, were modelled:

- Aylesbury Road; and
- Howes Lane.

Table A16.5 compares the modelled and equivalent measured roadside NO_2 concentrations at the diffusion tube sites.

Table A16.5: Annual Mean NO_2 Modelled and Monitored Concentrations

Site ID	Monitored Annual Mean NO_2 (µg/m^3)	Modelled Total Annual Mean NO_2 (µg/m^3)	% Difference
Aylesbury Road	26.7	23.9	-10.5
Howes Lane	20.7	21.5	3.8

Table A16.5 indicates the model under predicts at the Aylesbury Road diffusion tube by more than 10%. Technical Guidance LAQM.TG(16) suggests that where there is a disparity of more than 10% between modelled and monitored results, adjustment of the modelling results is necessary. The steps involved in the adjustment process are presented in **Table A16.6** and **Table A16.7**.

Box 7.15 in LAQM.TG(16) indicates a method based on comparison of the road NOx contributions and calculating an adjustment factor. This requires the roadside NOx contribution to be calculated. In addition, monitored NOx concentrations are required, which were calculated from the annual mean NO_2 concentration at the diffusion tube site using the NOx to

NO_2 spreadsheet calculator as described above. The steps involved in the adjustment process are presented in **Table A16.6**.

Table A16.6: Model Verification Result for Adjustment NO_x Emissions

Site ID	Monitored NO_2 ($\mu g/m^3$)	Monitored Road NO_x ($\mu g/m^3$)	Modelled Road NO_x ($\mu g/m^3$)	Ratio of Monitored Road Contribution NO_x/Modelled Road Contribution NO_x
Aylesbury Road	26.7	18.6	13.1	1.4
Howes Lane	20.7	6.9	8.4	0.8

Figure A16.3 shows the mathematical relationship between modelled and monitored roadside NOx (i.e. total NOx minus background NOx) in a scatter graph (data taken from **Table A16.6**), with a trendline passing through zero and its derived equation.

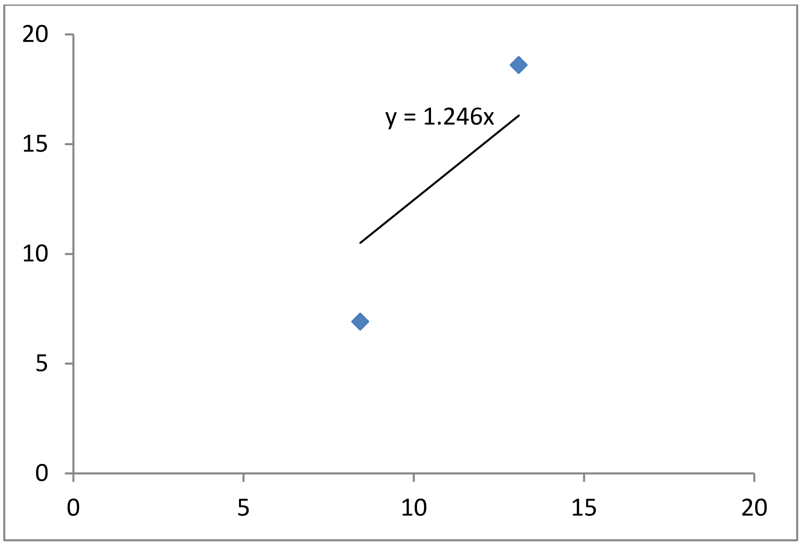

Figure A16.3: Unadjusted Modelled versus Monitored Annual Mean Roadside NO_x at the Monitoring Sites

Consequently, in **Table A16.7** the adjustment factor (1.246) obtained from **Figure A16.3** is applied to the modelled NOx Roadside concentrations to obtain improved agreement between monitored and modelled annual mean NOx. This has been converted to annual mean NO_2 using the NOx:NO_2 spreadsheet calculator.

Table A16.7: Adjusted Annual Average NO_2 Concentrations Compared to Monitored Annual Mean NO_2 Concentrations

Site ID	Adjusted Modelled Road NO_x ($\mu g/m^3$)	Modelled Total NO_2 ($\mu g/m^3$)	Monitored Total NO_2 ($\mu g/m^3$)	% Difference
Aylesbury Road	16.3	25.5	26.7	-4.3
Howes Lane	10.5	22.6	20.7	9.0

The data in **Table A16.7** indicates a much closer agreement between monitored and modelled annual mean NO_2 results compared to the unadjusted model in **Table A16.5**. The NO_x adjustment process was therefore applied to the roadside NOx modelling for 2019 and 2024.

Statistical Analysis

To determine if the model is performing well further statistical analysis of the performance of the modelled results has been undertaken using the methodology detailed in LAQM.TG(16) Box 7.17: Methods and Formulae for Description of Model Uncertainty. This statistical analysis checks the performance of the model used and the accuracy of the results (observed vs predicted).

The methodology for the calculations is presented in LAQM.TG(16) for the following:

- Correlation Coefficient: This is used to measure the linear relationship between the predicted and observed data. A value of zero means no relationship and a value of 1 means an absolute relationship. This statistic can be particularly useful when comparing a large number of model and observed data points.
- Fractional Bias: this is used to identify if the model shows a systematic tendency to over or under predict. Values very between +2 and -2 and has an ideal value of zero. Negative values suggest a model over-prediction and positive values suggest a model under-prediction.
- Root Mean Square Error: This is used to define the average error or uncertainty of the model. The units of the Root Mean Square Error are the same as the quantities compared.

The results of the statistical calculation are presented in **Table A16.8**.

Table A16.8: Statistical Calculations of Error for the Modelled Results

Statistical Calculation	Perfect Value	Acceptable Variable Tolerance	Unadjusted Model Score	Unadjusted Model Score
Correlation Coefficient	1	N/A	1.0	1.0
Fractional Bias	0	+2 to -2	0.09	-0.03
Root Mean Square Error	0	±10	0.8	0.6

Based on the results presented in **Table A16.8** it is considered that the model is performing well, there is no systematic over or under prediction of results and the root mean square error is within the acceptable tolerance levels, further adjustment is not necessary.

Particulate Matter (PM_{10} and $PM_{2.5}$)

PM_{10} and $PM_{2.5}$ monitoring data is not available for the Site area. Therefore, the roadside modelled NOx factor of 1.246 factor has been applied to the roadside PM_{10} and $PM_{2.5}$ modelling results.

Verification Summary

Any atmospheric dispersion model study will always have a degree of inaccuracy due to a variety of factors. These include uncertainties in traffic emissions data, the differences between available meteorological data and the specific microclimate at each receptor location, and simplifications made in the model algorithms that describe the atmospheric dispersion and chemical processes. There will also be uncertainty in the comparison of predicted concentrations with monitored data, given the potential for errors and uncertainty in sampling methodology (technique, location, handling, and analysis) as well as processing of any monitoring data.

Whilst systematic under or over prediction can be taken into account through the model verification / adjustment process, random errors will inevitably occur and a level of uncertainty will still exist in corrected / adjusted data.

Model uncertainties arise because of limited scientific knowledge, limited ability to assess the uncertainty of model inputs, for example, emissions from vehicles, poor understanding of the interaction between model and / or emissions inventory parameters, sampling and measurement error associated with monitoring sites and whether the model itself completely describes all the necessary atmospheric processes.

Overall, it is concluded that with the adjustment factors applied to the ADMS-Roads model, it is performing well and modelled results are considered to be suitable to determine the potential effects of the Proposed Development on local air quality.

Assessor Experience

Name: Eleri Paterson Hughes

Years of Experience: 1

Qualifications:

- BSc (Hons)
- Msc (Hons)
- Associate Member of IAQM
- Associate Member of IES

Eleri is a graduate air quality consultant with experience in preparing the technical delivery of a wide range of air quality projects for a variety of clients in both the public and private sector.

Name: Andy Fowler

Years of Experience: 11

Qualifications:

- CEnv
- BSc (Hons)
- Member of the IAQM
- Full Member of the Institution of Environmental Sciences (IES)

Andy has been responsible for the technical delivery of a wide range of air quality projects for a variety of clients in both the public and private sector. These projects include consideration of emissions from both transportation and industrial sources, through both monitoring and modelling, and therefore he has an in depth understanding of the regulatory requirements for these sources and the published technical guidance for their assessment.

References

1 Defra, 2016, Local Air Quality Management Technical Guidance LAQM.TG(16)

2 Department for Transport (DfT) Statistics, www.dft.gov.uk/statistics/series/traffic

3 http://laqm.defra.gov.uk/

4 AEA (2021); NOX to NO2 Calculator, http://laqm1.defra.gov.uk/review/tools/monitoring/calculator.php Version 8.1, August 2020

5 AEA (2008); 'Analysis of the relationship between annual-mean nitrogen dioxide concentration and exceedences of the 1-hour mean AQS Objective', 2008.