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Appendix 10.1: Air Quality Modelling Study

Introduction

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

Model

10.1.2 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.

10.1.3 The effect of the Development on local air quality was assessed using the advanced atmospheric dispersion model ADMS-Roads and ADMS 5, taking into account the contribution of emissions from forecast road-traffic on the local road network and from the heating plant by the completion year respectively.

ADMS-Roads

10.1.4 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.

10.1.5 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.

ADMS 5

10.1.6 ADMS 5 is a Gaussian atmospheric dispersion model widely used for investigating air pollution from controlled or fugitive emissions. The model is used for a wide range of air quality assessments, from small energy centres in urban areas to large industrial facilities. It is also used to model the dispersion of odours to determine the potential for nuisance at sensitive receptors around installations. The model uses advanced algorithms for the height-dependence of wind speed, turbulence and atmospheric stability which improve calculations of air pollutant concentrations. It can predict long-term and short-term concentrations, as well as concentration percentiles.

10.1.7 ADMS 5 is developed in the UK by CERC, and has been extensively validated against field data sets in order to assess various configurations of the model such as flat or complex terrain, line/area/volume sources, buildings, dry deposition, fluctuations and visible plumes. Further information in relation to the model validation is available from the CERC website at www.cerc.co.uk.

Model Scenarios

10.1.8 To assess the effect of the Development on local air quality, future 'without Development' and 'with Development' scenarios were assessed. The Development is anticipated to be complete in 2027 and therefore this is the year in which these future scenarios were modelled. The year 2018 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 2018 and meteorological data for 2018 were also used to be consistent with the verification year.

Traffic Data

10.1.9 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 Stantec for the surrounding road network. **Table A1** presents the traffic data used within the air quality assessment. **Table A7** presents the trips associated with the development for the air quality neutral assessment.

10.1.10 The methodology for calculating the expected change in vehicle trips because of the development proposals is set out in detail within the Transport Assessment and covers all of the proposed land uses. The assessment covers all traffic generated by the Site, including servicing and delivery trips.

Table A1: 24 hour AADT Data Used within the Assessment

Receptor Name	Speed (kph)	Direction	Base 2018		Without 2027		With 2027	
			AADT	%HDV	AADT	%HDV	AADT	%HDV
A316 Clifford Ave	65	NB	16237	10.99	17786	10.99	17952	10.94
A316 Lower Richmond Road	64	SB	14213	9.51	15569	9.51	15885	9.43
A316 Lower Richmond Road	48	WB	17903	5.22	19611	5.22	19906	5.23
South Circular (north of A316)	48	EB	19651	5.68	21526	5.68	21802	5.68
South Circular (north of A316)	48	NB	7950	6.10	8708	6.10	8801	6.09
South Circular (south of A316)	48	SB	7243	5.60	7933	5.60	8072	5.60
South Circular (south of A316)	48	NB	11320	3.91	12400	3.91	12400	3.91
A3003 Lower Richmond Road (Watney's Sports Ground)	48	SB	10313	3.60	11297	3.60	11390	3.61
A3003 Lower Richmond Road (Watney's Sports Ground)	44	WB	8341	8.57	9053	8.57	9700	8.40

A3003 Lower Richmond Road (Mortlake Green)	48	EB	8943	8.89	9706	8.89	10437	8.67
A3003 Lower Richmond Road (Mortlake Green)	39	WB	8334	8.34	9045	8.34	9737	8.16
Williams Lane	45	EB	9111	11.19	9889	11.19	10614	10.84
Williams Lane	41	NB	279	6.71	302	6.71	665	6.19
Mortlake High Street	42	SB	343	7.43	372	7.43	694	6.76
Mortlake High Street	51	WB	8722	13.39	9466	13.39	9941	13.03
The Terrace (west of Barnes Bridge Station)	33	EB	9697	8.48	10524	8.48	11026	8.37
The Terrace (west of Barnes Bridge Station)	46	WB	8461	8.66	9184	8.66	9559	8.55
White Hart Lane (south of Mortlake High Street)	47	EB	9111	8.69	9888	8.69	10355	8.57
White Hart Lane (south of Mortlake High Street)	39	NB	2212	8.27	2401	8.27	2500	8.17
Sheen Lane (north of Level Crossing)	41	SB	2711	7.53	2942	7.53	2978	7.51
Sheen Lane (north of Level Crossing)	48	NB	3169	4.38	3440	4.38	3657	4.46
Sheen Lane (south of Level Crossing)	48	SB	2784	2.54	3022	2.54	3245	2.77
Sheen Lane (south of Level Crossing)	48	NB	3055	1.99	3343	1.99	3560	2.22
Sheen Lane (south of South Circular)	48	SB	2627	2.98	2875	2.98	3097	3.19
Sheen Lane (south of South Circular)	33	NB	2358	3.32	2580	3.32	2718	3.44
South Circular Road (west of Sheen Lane)	34	SB	2566	5.07	2808	5.07	2937	5.11
South Circular Road (west of Sheen Lane)	43	WB	9387	8.74	10272	8.74	10272	8.74
16 Lower Richmond Road	44	EB	9066	8.09	9920	8.09	9920	8.09

Table A2: 24-hour AADT Data Used within the Air Quality Neutral Assessment

Land Use	Annual Trips
Residential (Use Class C3)	1,174
Office (Use Class B1)	463
Flexible Uses - Restaurant / bar / retail / community / leisure (Use Classes A1 / A2 / A3 / A4 / B1 / D1 / Boathouse)	285
School (Use Class D1)	455
Cinema (Use Class D2)	164

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Vehicle Speeds

10.1.11 To consider the presence of slow moving traffic near junctions, at roundabouts, the high level of congestion at the Chalkers Corner Junction; and vehicles idling at railway level crossings the following speeds have been used:

- 10kph at road links approaching junctions, Chalkers Corner Junction and the railway level crossings on Sheen Lane and White Hart Lane;
- 5kph at the Chalkers Corner Junction and the railway level crossings on Sheen Lane and White Hart Lane; and
- at all other junction's a reduction of 10kph from the free-flowing speed.

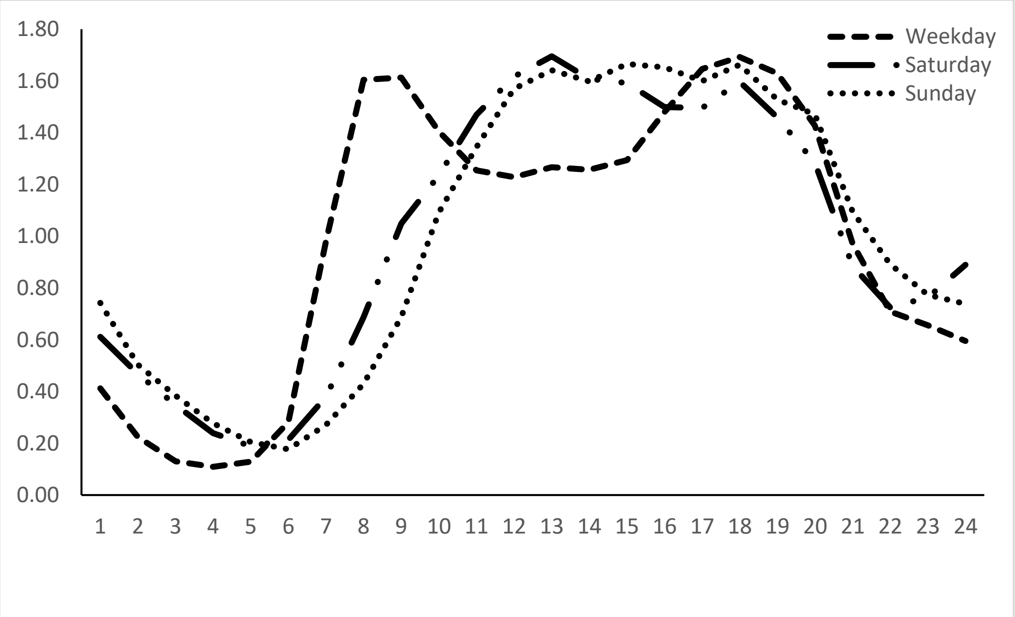
10.1.12 Queue lengths at Chalkers Corner have been provided by Stantec to replicate the existing levels of congestion on the road network and to determine when to apply the above speeds.

10.1.13 The approach to the speeds was agreed with LBRuT during a meeting on the 14th November 2017.

Diurnal Profile

10.1.14 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 traffic counts undertaken by Stantec on A316 Clifford Avenue; A3003 (at the Sports Ground and Mortlake Green); Williams Lane; Mortlake High Street; The Terrace; White Hart Lane; Sheen Lane; and the South Circular. Figure A1 presents the diurnal variation in traffic flows which has been used within the model.

Figure A1: Local Road Network Diurnal Traffic Variation



Street Canyon Effect

10.1.15 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.

10.1.16 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.”*

10.1.17 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.

10.1.18 With the Development, it is considered that a street canyon, with residential exposure (contained within Buildings 13 and 17) would be created along Ship Lane. This street canyon would be created from the construction of Buildings 17, 13, 2 and 1 within the Development. A height of 27m was used in the ‘with Development’ scenarios to represent the proposed nine floors in Building 2. This is worst case as the opposite buildings are lower.

10.1.19 Where receptors are located along these roads within the model domain, they have been positioned so as to be located within the street canyon (i.e. the distance from the receptor to the road centreline is less than half the canyon width).

Road Traffic Emission Factors

10.1.20 The ADMS-Roads model (version 4.1.1.0) was used for the assessment. At the time of the assessment this includes the latest vehicle emission factors published by Defra in the Emission Factors Toolkit (EFT) (version 9.0, published in May 2019).

10.1.21 As stated previously for the future year assessments revised NOx emissions data using the Air Quality Consultants Ltd Calculator Using Realistic Emissions for Diesels (CURED) spreadsheet[1] have been inputted into the model. This spreadsheet has been designed to provide a reasonable worst-case assumption for future vehicle emissions.

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

Chalkers Corner Junction

10.1.23 Following the resolution to refuse Application C by LBRuT in January 2020 (planning ref: 18/0549/FUL), alternative highway design mitigation has been investigated by the project team. It is proposed that highways mitigation for the traffic impacts will now be undertaken via S278 works, with the final details to be agreed with the GLA/LBRuT in consultation with TfL.

10.1.24 The highways works may be carried out on adopted highways land and therefore will not require separate planning permission. If it is agreed that all necessary highways works are within the adopted highway, then Application C may be withdrawn. Therefore, the following four highways options have been assessed within this ES Addendum to ensure that the likely significant effects of the final design is considered in the decision making process:

- Option 1: ‘Do Nothing’ – no change from the existing junction (refer to drawing 38262-5514-020);
- Option 2: ‘Chalkers Corner ‘Light’ Scheme’ (new left-hand lane westbound on Lower Richmond Road) (refer to drawing 38262-5514-021);

1 Air Quality Consultants Ltd (2017) Calculator Using Realistic Emissions for Diesels (CURED) Spreadsheet. CURED V3A December 2017.

- Option 3: 'Lower Richmond Road Bus Lane' Option 1 but with a dedicated bus lane westbound on Lower Richmond Road (refer to drawing 38262-5514-022); and
- Option 4: 'Chalkers Corner 'Light' & Bus Lane' Option 2 but with a dedicated bus lane westbound on Lower Richmond Road (refer to drawing 38262-5514-023).

10.1.25 As discussed in **Chapter 5: The Proposed Development**, the Chalkers Corner Junction forms part of the Development and as such the amendments have been considered within the 'with Development' scenario of this air quality assessment. However, during consultation LBRuT requested additional information on the potential air quality impacts associated with the junction amendments in isolation. As such **Appendix 10.4** considers the junction in more detail. **Appendix 10.4: Chalkers Corner Junction Interim Design Assessment** of the February 2018 ES considers the impact to air quality from the changes made to the junction in isolation from the Development within the Stag Brewery component of the Site.

Car Park Extraction Strategy

10.1.26 The Development includes basement car parking with an extraction system located on Site and away from existing air quality sensitive receptors. The technical specification of the ventilation strategy is indicative at this stage and does not reflect the final system to be used. As such the basement extraction system has not been considered in the air quality assessment and the final extraction system would be designed in accordance with best practice design and appropriate regulations. This would be secured by a suitably worded planning condition. As such, it is anticipated that the car park extraction system uses within the Development would not give rise to significant environmental effects and has not been considered further at this stage.

Heating and Energy Strategy

10.1.27 The Development heating and energy strategy would provide two energy centres to serve the eastern and western parts of the Development (Application A), either side of Ship Lane. In addition, a separate energy centre would be provided for the school (Application B). These are collectively referred to as the Energy Centres.

10.1.28 Technical details of indicative plant have been provided by Hoare Lea and the stack parameters used within the ADMS 5 model are presented in **Table A9**. These details do not represent the final plant to be used, however, the air quality assessment has considered the potential impacts to determine the likely significant effect from their operation. It is considered that a suitably wording planning condition requesting an air quality assessment of the final plant would be provided by LBRuT with the granting of any planning permission.

10.1.29 To take account of the multiple point sources from the boilers and Combined Heat and Power (CHP) at each Energy Centre, ADMS 5 contains the ability to combine multiple point sources into a single stack. The stack parameters for each Energy Centre, as presented in **Table A9,** have been combined using the additional input file option within ADMS 5.

Table A9: Plant Stack Parameters

Energy Centre	Unit	No.	Grid Ref.	Flue Diameter (m)	Release Rate (m/s)	Release Height (m)[(a)]	Release Temp (deg ºC)	Total NO_x Emissions (g/s)[(b)(c)]
Building 02	Boiler (2400kW)	5	520401, 176011	0.70	15	34.1	70	0.1300
	CHP (560kW)	2	520401, 176011	0.15	10	34.1	150	0.0204
	CHP (610kW)	1	520401, 176011	0.18	10	34.1	150	0.0111
Building 16*	Boiler (2500kW)	4	520309, 176032	0.70	15	33.0	70	0.1027
	CHP (560kW)	2	520309, 176032	0.15	10	33.0	150	0.0204
	CHP (610kW)	1	520309, 176032	0.18	10	33.0	150	0.0111
School	Boiler (750kW)	2	520246, 175979	0.35	15	20.20	70	0.0154
	CHP (226kW)	1	520246, 175979	0.10	10	20.20	150	0.0041

Note: Information has been provided by Hoare Lea. The location of the energy centre in Building 16 is not known and is indicative.
Hoare Lea have provided an estimated seasonal profile for the energy centre, which show the boilers are used during the winter months when heating demand is high. To account of this seasonal profile, the emissions from the boilers presented in Table A1.3 have been halved following modelling as a full year. For the purposes of this assessment this approach is a reasonable assumption.

10.1.30 As shown in **Table A9** above, the Development introduces three separate heating plants, located in Building 2, Building 16 and the School. Due to the limitations on the number of sources to be modelled within ADMS 5 within each model run, the heating plant assessment has modelled each Energy Centre separately. Following the model run, the predicted emissions of each heating plant have been added together to determine the total contribution.

10.1.31 The indicative plant stack parameters presented in **Table A9** have been modelled in ADMS 5 across a 1km by 1km grid centred on the Development.

Building Parameters

10.1.32 Buildings can have a significant effect on the dispersion of pollutants from sources, and as a result, can increase the maximum predicted ground level concentrations. ADMS 5 allows buildings to be included in the model domain as a rectangle or as a circle.

10.1.33 The buildings module is based on experiments in which there was one dominant site building and several smaller surrounding buildings less important for dispersion.

10.1.34 For each of the Energy Centre, the building the flue is located on has been considered to be the main building. These main buildings have been considered as a rectangular building. The parameters are presented in **Table A10**.

Table A10: Main Building Parameters

Energy Centre	Main building	X	Y	Height (m)	Length (m)	Width (m)	Angle (deg)
Building 02	Plot 02	520430	176035	31.1	76	40	20
Building 16	Plot 16	520308	176041	30	48	19	0
School	School	520246	175979	17.2	100	38	0

Background Pollutant Concentrations

10.1.35 Background pollutant concentration data (concentrations due to the contribution of pollution sources not directly considered in the dispersion modelling) have been added to contributions from the modelled pollution sources, for each year of assessment.

10.1.36 The EHO at LBRuT requested background pollutant concentrations monitored at the Wetlands Centre, Barnes are used within the February 2018 ES air quality assessment. The Wetlands Centre automatic monitor is located approximately 2.5km to the north east from Site and is classified as a suburban monitor.

10.1.37 **Table A11** presents the most recent monitored concentrations measured at the Wetlands Centre automatic monitor.

Table A11: Measured Concentrations at the Wetlands Centre Suburban Background Automatic Monitor

Pollutant	Air Quality Strategy Objective	2014	2015	2016	2017	2018
NO_2	Annual Mean (40µg/m^3)	25	21	25	21	20
	200ug/m^3 as a 1 hour mean, not to be exceeded more than 18 times a year	0	0	0	0	0
PM_{10}	Annual Mean (40µg/m^3)	18	17	16	15	15
	50ug/m^3 as a 24 hour mean, not to be exceeded more than 35 times a year	3	1	3	3	0

Source: London Air Quality Network. Available at www.londonair.org.uk

10.1.38 **Table A11** shows all monitored pollutants at the Wetland Centre Suburban monitor were below their respective objectives in all years.

10.1.39 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 website1 for 1x1km grid squares for assessment years between 2017 and 2030 (published in May 2019). **Table A12** presents the Defra background concentrations for the years 2018 and 2027, for the grid squares the Site and local receptors considered in the air quality assessment are located within.

Table A12: Defra Background Maps in 2018 for the Grid Square at the Site and the Local Area

Pollutant	Annual Mean Concentration (µg/m^3)		
	520500, 176500[(a)]	519500, 175500[(b)]	520500, 175500[(c)]
NO_x		36.3	35.9
NO_2	22.2	23.5	23.3
PM_{10}	16.3	17.2	16.9
$PM_{2.5}$	11.3	12.0	11.8

Note: (a) Representative of Receptors: 1, 4, 5, 7 and Proposed Buildings 2-4, 7-9, 11, 12, 17-19, 21, 22
(b) Representative of Receptors located at Chalker's Corner and Diffusion Tube 52

(c) Representative of Receptors: Receptors 2, 3, 5-16 and Proposed Buildings 1, 5, 6. 10, 13- 16, 20 and Diffusion Tubes 21, 51, 49 and 36.

10.1.40 As shown in **Table A11** and **Table A12**, the monitored background concentrations at the Wetlands Centre Suburban monitor in 2018 (as 20µg/m^3 for annual mean NO_2 and 15µg/m^3 for annual mean PM_{10}) are lower than the Defra background maps.

10.1.41 The Defra background maps have therefore been used for a conservative assessment.

10.1.42 Background concentrations used in the assessment are presented in **Table A13**.

Table A13: Background Concentrations (µg/m^3) Used within the Assessment

Pollutant	Source	2018			2027		
		(a)	(b)	(c)	(a)	(b)	(c)
NO_x	Defra Background Map	33.9	36.3	35.9	22.6	23.9	23.9
NO_2		22.2	23.5	23.3	15.7	16.5	16.5
PM_{10}		16.3	17.2	16.9	15.0	15.9	15.6
$PM_{2.5}$		11.3	12.0	11.8	10.3	11.0	10.8

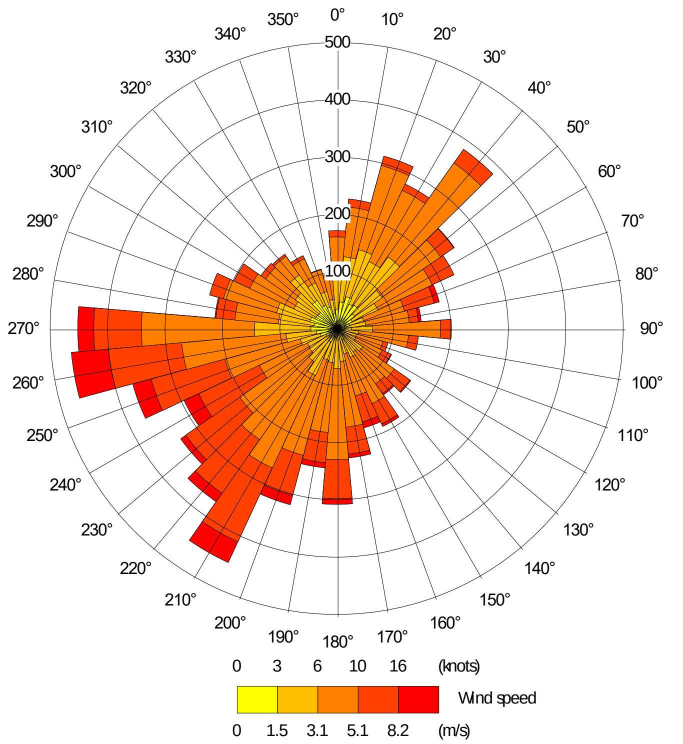
Note: (a) Representative of Receptors: 1, 4, 5, 7 and Proposed Buildings 2-4, 7-9, 11, 12, 17-19, 21, 22
(b) Representative of Receptors located at Chalker's Corner and Diffusion Tube 52
(c) Representative of Receptors: Receptors 2, 3, 5-16 and Proposed Buildings 1, 5, 6. 10, 13- 16, 20 and Diffusion Tubes 21, 51, 49 and 36.

Meteorological Data

10.1.43 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.

10.1.44 Meteorological data to input into the model were obtained from the London Heathrow Airport Meteorological Station, which is the closest to the Site and considered to be the most representative. The 2018 data were used to be consistent with the base traffic year and model verification year. It was also used for the 2027 scenarios for the air quality assessment. **Figure A2** presents the wind-rose for the meteorological data.

Figure A2: 2018 Wind Rose for the London Heathrow Airport Meteorological Site



10.1.45 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%. 2018 meteorological data from London Heathrow includes 8,551 lines of usable hourly data out of the total 8,760 for the year, i.e. 100% of usable data. This is above the 97.6% threshold and, therefore, is adequate for the dispersion modelling.

10.1.46 Within the air quality models, the surface roughness of 0.2 has been used for the meteorological site, which is representative of large open areas and is considered appropriate given the immediate open surrounding area at the meteorological site.

Model Data Processing

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

10.1.48 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.

10.1.49 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).

10.1.50 The LAQM Support website provides a spreadsheet calculator[2] 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.

10.1.51 Research[3] 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/m3. The 1-hour mean objective is, therefore, not considered further within this assessment where the annual mean NO2 concentration is predicted to be less than 60µg/m^3.

10.1.52 In order to calculate the number of PM_{10} 24-hour means exceeding 50µg/m3 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:

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

10.1.53 With regards to the conversion factor for the Energy Centres, the screening approach suggested by the Environment Agency[4] for continuously operating plant is to assume that for the annual mean, 70% of the NOx is converted to NO_2 at ground level. This approach has been used for the NOx emissions prior to adding to the predicted annual mean NO_2 concentrations.

Other Model Parameters

10.1.54 There are a number of other parameters that are used within the ADMS-Roads and ADMS 5 model which are described here for completeness and transparency:

- the model requires a surface roughness value to be inputted. A value of 1 was used at the Site (which is representative of cities and woodland) and a value of 0.2 was used at the location of the London Heathrow Airport Meteorological Station, which is representative of large open areas;
- the model requires the Monin-Obukhov length (a measure of the stability of the atmosphere) to be inputted. A value of 100m (representative of large conurbations >1,000,000) was used for the modelling; and
- the ADMS-Roads model requires the Road Type to be inputted. *'London [Outer]'* was selected and used for the modelling.

Model Verification

10.1.55 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.

10.1.56 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.

10.1.57 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

10.1.58 The dispersion model was run to predict annual mean NOx concentrations at the project specific kerbside and roadside diffusion tube monitoring locations (as originally presented in Table 7 of the May 2019 ES Addendum) to determine the accuracy of the updated 2018 baseline.

10.1.59 The methodology used for the model verification is the same as that presented in Appendix 10.2 of Chapter 10: Air Quality of the 2018 ES.

10.1.60 The following roadside and kerbside diffusion tubes were modelled:

- Diffusion Tube 1: Lower Richmond Road;
- Diffusion Tube 2: Chertsey Court metal railings;
- Diffusion Tube 2: Chertsey Court, Lower Richmond Road
- Diffusion Tube 4: Chalkers Corner Junction;
- Diffusion Tube 6: Clifford Avenue;
- Diffusion Tube 6: Clifford Avenue;
- Diffusion Tube 7: Clifford Avenue metal railings;
- Diffusion Tube 8: Chertsey Court Clifford Avenue;
- School 1: Stag Brewery Sports Club; and
- School 2: Stag Brewery Sports Club.

10.1.61 **Table A14** compares the modelled and equivalent measured roadside NO_2 concentrations at the diffusion tube sites.

Table A14: 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
DT21	50.0	45.8	-8.5
DT51	33.0	23.4	-29.1
DT52	59.0	40.4	-31.6
Diffusion Tube 1	45.5	44.9	4.5
Diffusion Tube 2	40.1	38.2	3.6
Diffusion Tube 4	54.4	50.5	18.1
Diffusion Tube 6	45.1	42.5	-13.4
Diffusion Tube 7	41.5	38.9	-7.7
School 1	27.5	25.2	-16.6
School 2	27.0	24.6	-18.2

10.1.62 LAQM.TG(16) suggests that where there is no systematic over or under prediction at the diffusion tube results and where the majority of modelled results are within 10% of the monitored concentrations that the model verification is appropriate and no further adjustment factor is required. Given the results in **Table A14** model adjustment was undertaken.

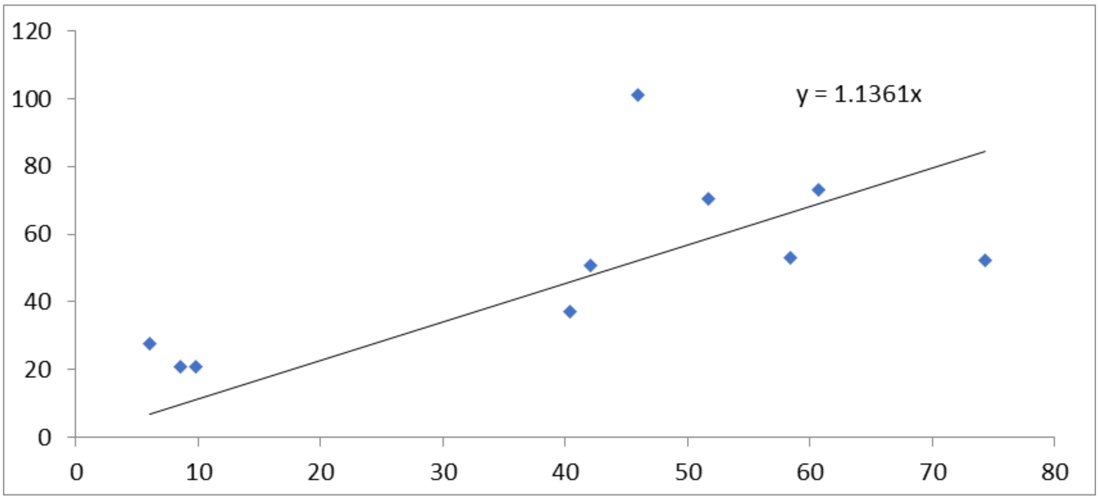
10.1.63 Box 7.15 in LAQM.TG(16) indicates a method based on comparison of the road NOx contributions and calculating an adjustment factor. This requires the roadside NO_x contribution to be calculated. In addition, monitored NO_x concentrations are required, which were calculated from the annual mean NO_2 concentration at the diffusion tube site using the NO_x to NO_2 spreadsheet calculator as described above. The steps involved in the adjustment process are presented in **Table A15**.

Table A15: Model Verification Result for Adjustment NO_x Emissions (µg/m³)

Site ID	Monitored NO_2	Monitored Road NO_x	Modelled Road NO_x	Ratio of Monitored Road Contribution NO_x/Modelled Road Contribution NO_x
DT21	50.0	73.0	60.7	1.2
DT51	33.0	27.5	6.0	4.6
DT52	59.0	101.3	46.0	2.2
Tube 1	43.0	53.0	58.4	0.9
Tube 2	36.9	37.1	40.4	0.9
Tube 4	42.7	52.2	74.3	0.7
Tube 6	49.1	70.3	51.7	1.4
Tube 7	42.1	50.7	42.1	1.2
School 1	30.2	21.0	9.8	2.1
School 2	30.1	20.7	8.5	2.4

10.1.64 Figure A3 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 A15**), with a trendline passing through zero and its derived equation.

Figure A3: Unadjusted Modelled versus Monitored Annual Mean Roadside NO_x at the Monitoring Sites (µg/m³)



10.1.65 Consequently, in **Table A16** the adjustment factor (1.1361) obtained from Figure A3 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: Adjusted Annual Average NO_2 Concentrations Compared to Monitored Annual Mean NO_2 Concentrations (µg/m^3)

Site ID	Adjusted Modelled Road NO_x	Adjusted Modelled Total NO_x	Modelled Total NO_2	Monitored Total NO_2	% Difference
DT21	68.9	111.9	48.6	50.0	-2.7
DT51	6.8	49.8	23.8	33.0	-27.9
DT52	52.2	95.2	42.7	59.0	-27.6
Tube 1	66.3	109.3	47.7	43.0	11.0
Tube 2	45.9	88.9	40.4	36.9	9.3
Tube 4	84.5	127.5	53.8	42.7	25.9
Tube 6	58.7	101.7	45.1	49.1	-8.2
Tube 7	47.8	90.8	41.1	42.1	-2.5
School 1	11.2	54.2	25.8	30.2	-14.6
School 2	9.7	52.7	25.1	30.1	-16.4

Statistical Analysis

10.1.66 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).

10.1.67 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.

10.1.68 The results of the statistical calculation are presented in **Table A17**.

Table A17: 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	0.7	0.7
Fractional Bias	0	+2 to -2	0.11	0.11
Root Mean Square Error	0	±10	7.9	7.5

10.1.69 Based on the results presented in **Table A17** 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 $PM_{2.5}$)

10.1.70 PM_{10} and $PM_{2.5}$ monitoring data is not available for the Site area. Therefore, the roadside modelled NOx factor of 1.1361 factor has been applied to the roadside PM_{10} and $PM_{2.5}$ modelling results.

Verification Summary

10.1.71 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.

10.1.72 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.

10.1.73 While every effort has been made to reduce the uncertainties within the model and thus reduce the verification factor as much as possible, the model verification has been unable to be reduced further and maybe a result of:

- local microclimate experienced at the monitoring locations which the model cannot replicate;
- limited ability to assess the uncertainty of model inputs, for example, the actual emission rates of vehicles on the local road network (particularly in proximity to the monitors used for the verification) compared to the emission rates used within the model;
- the inability to model all contributions in the local area (e.g. all heating plants) due to a lack of available information (including emissions and locations of flues);
- sampling and measurement error associated with the monitoring sites used for the verification. Such as the duration of monitoring (over saturated samples), accuracy of written monitoring duration, collection and transportation errors (if the sample cap has been replaced properly) and errors in analysis; and

- whether the model itself completely describes all the necessary atmospheric and built form processes, such as the local microclimate experienced at the monitoring locations and the real world impact of the street canyon.

10.1.74 Having consideration of the above uncertainty, overall, it is concluded that without the adjustment factor applied to the ADMS-Roads, the model is performing well and modelled results are considered to be suitable to determine the effects of the Development on local air quality.

Assessor Experience

Name: Chris Brownlie

Years of Experience: 13

Qualifications:

- BSc (Hons)
- MSc
- AIEMA (Associate Member of the Institute of Environmental Management and Assessment)
- MIAQM (Member of the Institute of Air Quality Management)

Chris has over thirteen years of experience in the assessment of air quality and odour for a variety of environmental impact assessment projects. Chris has knowledge and extensive experience of designing and undertaking ambient air quality monitoring programmes using real time equipment and passive diffusion tubes. This includes devising monitoring programs for dust deposition, typically to monitor levels of dust generated during construction activities in populated areas where there is the potential for nuisance to be caused.

Chris 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.

waterman

References

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2 AEA (2017); NO_X to NO_2 Calculator, http://laqm1.defra.gov.uk/review/tools/monitoring/calculator.php Version 7.1, April 2019

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