Woking Borough Council

2016 LAQM Detailed Assessment for Woking Borough Council

Air Quality Assessment

November 2016

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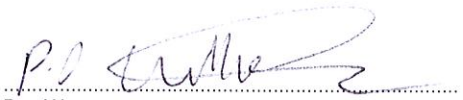

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1	Draft Report	13/10/16
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Executive summary

As part of the Local Air Quality Management (LAQM) process, Amec Foster Wheeler Environment & Infrastructure UK Ltd (Amec Foster Wheeler) has carried out a Detailed Assessment into air quality at the junction between Guildford Road, Constitution Hill and Mount Hermon Road on behalf of Woking Borough Council (WBC).

Exceedances of the annual mean Air Quality Objectives (AQOs) for NO_2 have been recorded in 2012, 2013, 2014 and 2015 at diffusion tubes located at Guildford Road. Diffusion tubes recorded concentrations above 40 μgm^{-3} at four locations in this area in 2015. A Detailed Assessment is required to provide an accurate assessment of the likelihood of an Air Quality Objective (AQO) being exceeded at locations with relevant exposure in this area.

ADMS-Roads (version 4.0) modelling has been used to model dispersion from traffic to determine likely NO_2 concentrations at residential receptors. Predicted concentrations at receptors were then compared to the Air Quality Objectives (AQOs).

Dispersion modelling indicates that concentrations at some receptor locations with relevant exposure are exceeding the AQO of 40 μgm^{-3} for NO_2 as a result of road traffic emissions around Guildford Road.

The following recommendations are made based on the results of the Detailed Assessment:

- It is recommended that an AQMA is declared along Guildford Road, with the extent of the boundary determined in this assessment; and
- Further monitoring is required around the junctions where Guildford Road meets York Road and Station Approach to confirm if the NO_2 annual mean AQO is exceeded where there is relevant exposure.

Contents

1. Introduction

1.1 Purpose of this report

Part IV of the Environment Act 1995[1] places a statutory duty on local authorities to review and assess the air quality within their area through the Local Air Quality Management (LAQM) process. Where it has been identified that there is a risk of the Air Quality Objectives (AQOs) not being achieved, the authority will need to carry out further assessment to determine if an Air Quality Management Area (AQMA) needs to be declared[2] and the extent of any AQMA required.

Woking Borough Council (WBC) has recorded exceedances of the NO_2 annual mean AQO around Guildford Road area. Monitoring at this location began in 2012, when a concentration of 41.1 μgm^{-3} was recorded. An annual mean concentration of 48.8 μgm^{-3} was recorded at this location in 2015. As a result, it was concluded that it is necessary to proceed to a Detailed Assessment for annual mean NO_2 concentrations at the junction between Guildford Road, Constitution Hill and Mount Hermon Road. The Detailed Assessment is required to provide an assessment of the likelihood of the AQO being exceeded at locations with relevant exposure and the population exposed to the exceedance. This will determine the extent of the AQMA required.

1.2 Legislative background

The legislative framework for air quality consists of legally enforceable EU Limit Values that are transposed into UK legislation as Air Quality Standards (AQS) that must be at least as challenging as the EU Limit Values. Action in the UK is then driven by the UK's Air Quality Strategy[3] that sets the AQOs.

The EU Limit Values are set by the European directive on air quality and cleaner air for Europe (2008/50/EC)[4] and the European directive relating to arsenic, cadmium, mercury, nickel, and polycyclic aromatic hydrocarbons in ambient air (2004/107/EC)[5] as the principal instruments governing outdoor ambient air quality policy in the EU. The Limit Values are legally binding levels for concentrations of pollutants for outdoor air quality.

The two European directives, as well as the Council's decision on exchange of information were transposed into UK Law via the Air Quality Standards Regulations 2010[6], which came into force in the UK on 11 June 2010, replacing the Air Quality Standards Regulations 2007[7]. Air Quality Standards are concentrations recorded over a given time period, which are considered to be acceptable in terms of what is scientifically known about the effects of each pollutant on health and on the environment. The Air Quality Strategy sets the AQOs, which give target dates and some interim target dates to help the UK move towards achievement of the EU Limit Values. The AQOs are a statement of policy intentions or policy targets and as such, there is no legal requirement to meet these objectives except in as far as they mirror any equivalent legally binding Limit Values in EU legislation. The most recent UK Air Quality Strategy for England, Scotland, Wales and Northern Ireland was published in July 2007.

Since Part IV of the Environment Act 1995[8] came into force, local authorities have been required to regularly review concentrations of the UK Air Quality Strategy pollutants within their areas and to identify areas where

[1] HMSO (1995) Environment Act 1995.
[2] Defra (2016) Local Air Quality Management Technical Guidance LAQM.TG (16).
[3] Defra in partnership with the Scottish Executive, Welsh Assembly Government and Department of the Environment Northern Ireland (2007) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland.
[4] Official Journal of the European Union, (2008) Directive 2008/50/EC of the European Parliament and of The Council of 21 May 2008 on ambient air quality and cleaner air in Europe.
[5] Official Journal of the European Union, (2004) Directive 2004/107/EC of the European Parliament and of The Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air.
[6] The Stationery Office Limited (2010) Statutory Instrument 2010 No. 1001 Environmental Protection – The Air Quality Standards Regulation 2010.
[7] The Stationery Office Limited (2007) Statutory Instrument 2010 No. 64 Environmental Protection – The Air Quality Standards Regulation 2007.
[8] HMSO (1995) Environment Act 1995.

the AQOs may not be achieved by their relevant target dates. This LAQM process is an integral part of delivering the Government's AQOs detailed in the Strategy. When areas are identified where some or all of the AQOs might potentially be exceeded and where there is relevant public exposure, i.e. where members of the public would regularly be exposed over the appropriate averaging period, the local authority has a duty to declare an AQMA and to implement an Air Quality Action Plan (AQAP) to reduce air pollution levels towards the AQOs.

As part of recent changes to the LAQM system, England and Scotland have adopted a new streamlined approach which places greater emphasis on action planning to bring forward improvements in air quality and to include local measures as part of EU reporting requirements. The Annual Status Report (ASR) will replace the cycle of Updating and Screening Assessments and Progress Reports. This Detailed Assessment refers to both the latest guidance on the LAQM process given in Defra's 2016 Local Air Quality Management Technical Guidance (LAQM TG (16))[2].

NO_2 as this is the pollutant of greatest health concern associated with road traffic in the area. The nitrogen oxides (NO_X - NO and NO_2) emitted from vehicle exhausts and other combustion sources undergoes photochemical oxidation in the atmosphere, with NO_2 being formed by oxidation of NO to NO_2 and, conversely, NO_2 undergoing photolysis (in the presence of sunlight) to create NO and ozone.

For NO_2, it is the annual mean objective that is the more stringent AQO; it is generally considered that the 1-hour mean NO_2 AQO will not be exceeded if the annual mean objective is not exceeded.

Table 1.1 sets out the AQOs that are relevant to this assessment, and the dates by which they are to be achieved.

Table 1.1 Summary of relevant air quality standards and objectives

Pollutant	Objective (UK)	Averaging Period	Date to be Achieved by and Maintained thereafter (UK)
Nitrogen dioxide - NO_2	200 μgm^{-3} not to be exceeded more than 18 times a year	1-hour mean	31 Dec 2005
	40 μgm^{-3}	Annual mean	31 Dec 2005

The likelihood of exceedance of the NO_2 short-term AQO can be assessed with reference to the predicted annual means and the relationships recommended by LAQM.TG(16)[2]. The 1-hour mean NO_2 objective is unlikely to be exceeded if the annual mean is less than 60 μgm^{-3};

2. Scope of the assessment

Exceedances of the annual mean AQO for NO_2 have been recorded in 2012, 2013, 2014 and 2015 at diffusion tubes CH, CH2, CH3 and CH, located on Guildford Road. The highest concentrations of 51.6 μgm^{-3} was recorded in 2015 at diffusion tube CH2.

This assessment considers the air quality likely to be experienced by residents of properties around the Guildford Road and Constitution Hill junction. The assessment will determine the exposure through quantitative assessment of NO_2 concentrations at residential receptor locations using the ADMS-Roads atmospheric dispersion modelling software.

2.1 Public exposure

Guidance from the UK Government and Devolved Administrations makes clear that exceedances of the health based objectives should be assessed at outdoor locations where members of the general public are regularly present over the averaging time of the objective. Workplaces are excluded, as explained in Table 2.1 which provides an indication of those locations that may or may not be relevant for each averaging period.

Table 2.1 Examples of where the air quality objectives should apply

Averaging Period	Objectives should apply at:	Objectives should generally not apply at:
Annual mean	All locations where members of the public might be regularly exposed	Building facades of offices or other places of work where members of the public do not have regular access.
	Building facades of residential properties, schools, hospitals, care homes etc.	Hotels, unless people live there as their permanent residence.
		Gardens of residential properties.
		Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.
24-hour mean and 8-hour mean	All locations where the annual mean objectives would apply, together with hotels	Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.
	Gardens or residential properties[1]	
1-hour mean	All locations where the annual mean and 24 and 8-hour mean objectives would apply.	Kerbside sites where the public would not be expected to have regular access.
	Kerbside sites (e.g. pavements of busy shopping streets).	
	Those parts of car parks, bus stations and railway stations etc. which are not fully enclosed, where the public might reasonably be expected to spend one hour or more.	
	Any outdoor locations at which the public may be expected to spend one hour or longer.	
15-minute mean	All locations where members of the public might reasonably be expected to spend a period of 15 minutes or longer.	

Note: [1] For gardens and playgrounds, such locations should represent parts of the garden where relevant public exposure is likely, for example where there is seating or play areas. It is unlikely that relevant public exposure would occur at the extremities of the garden boundary, or in front gardens, although local judgement should always be applied.

2.2 Receptor locations

This assessment has predicted pollutant concentrations at existing residential receptor locations, that is, the façade of residential properties. Receptors were plotted at the front of the residential unit, to represent the locations of receptors which would likely experience the highest exposure. A height of 1.5 m was used for the residential receptors on ground floor to represent an average human inhalation height. Receptors were also plotted at 4.5m heights at Park Heights on the junction between Guildford road and Constitution Hill.

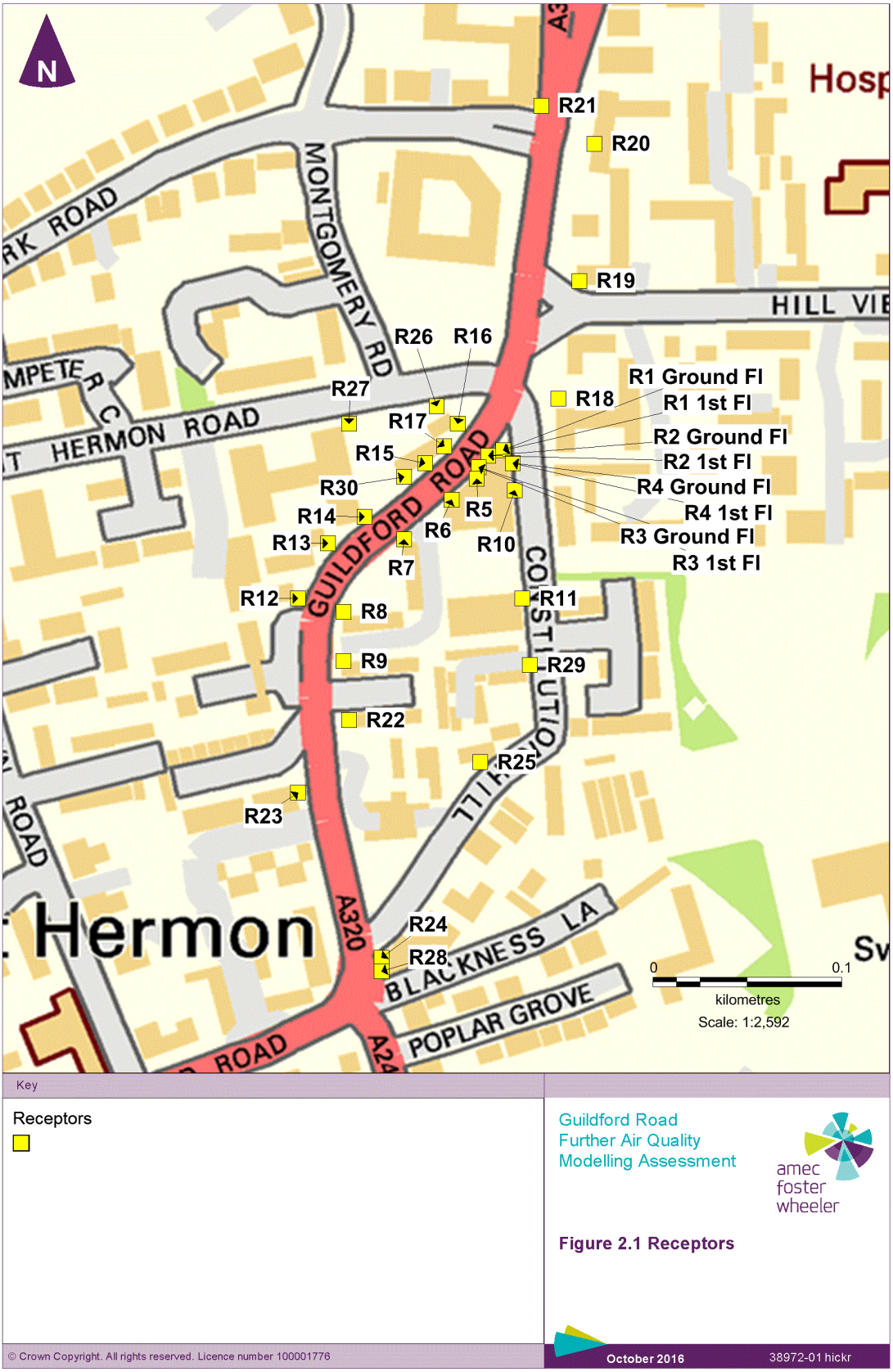
Figure 2.1 shows the receptor locations and Table 2.2 provides the Ordnance Survey grid coordinates and receptor heights for each of the receptor locations included within the air quality assessment.

Table 2.2 Human receptor locations

Receptor	X (m)	Y(m)	Location	Height (m)
R1 Ground Fl	500435	158111	Park Heights, Constitution Hill, Woking	1.5
R1 1st Fl	500435	158111	Park Heights, Constitution Hill, Woking	4.5
R2 Ground Fl	500427	158108	Park Heights, Constitution Hill, Woking	1.5
R2 1st Fl	500427	158108	Park Heights, Constitution Hill, Woking	4.5
R3 Ground Fl	500422	158102	Park Heights, Constitution Hill, Woking	1.5
R3 1st Fl	500422	158102	Park Heights, Constitution Hill, Woking	4.5
R4 Ground Fl	500440	158104	Constitution Hill, Woking	1.5
R4 1st Fl	500440	158104	Constitution Hill, Woking	4.5
R5	500421	158096	Park Heights, Constitution Hill, Woking	1.5
R6	500408	158085	Park Heights, Constitution Hill, Woking	1.5
R7	500383	158064	Guildford Rd, Woking	1.5
R8	500351	158026	Guildford Rd, Woking	1.5
R9	500351	158000	Thorsden Close, Woking	1.5
R10	500441	158090	Constitution Hill, Woking	1.5
R11	500445	158033	Constitution Hill, Woking	1.5
R12	500327	158033	Guildford Rd, Woking	1.5
R13	500343	158062	Guildford Rd, Woking	1.5
R14	500362	158076	Guildford Rd, Woking	1.5
R15	500394	158104	Guildford Rd, Woking	1.5
R16	500411	158125	Guildford Rd, Woking	1.5
R17	500404	158113	Guildford Rd, Woking	1.5
R18	500464	158138	Constitution Hill, Woking	1.5

Receptor	X (m)	Y(m)	Location	Height (m)
R19	500475	158200	Hill View Rd, Woking	1.5
R20	500483	158272	Hillview Court, Woking	1.5
R21	500455	158292	Guildford Rd, Woking	1.5
R22	500354	157969	Thorsden Close, Woking	1.5
R23	500327	157931	Guildford Rd, Woking	1.5
R24	500371	157844	Guildford Rd, Woking	1.5
R25	500423	157947	Constitution Hill, Woking	1.5
R26	500400	158134	Mount Hermon Road, Woking	1.5
R27	500354	158125	Mount Hermon Road, Woking	1.5
R28	500371	157837	Guildford Rd, Woking	1.5
R29	500449	157998	Constitution Hill, Woking	1.5
R30	500383	158097	Guildford Rd, Woking	1.5

Figure 2.1 Receptor locations



3. Assessment methodology

3.1 Modelling methodology

Annual average concentrations in air of NO_2 have been determined using the ADMS-Roads version 4.0.1 atmospheric dispersion model[9]. Further information on the ADMS-Roads model is provided in Appendix A.

Annual mean concentrations of NO_2 were derived from the model-predicted NO_x concentrations, through application of the NO_x to NO_2 conversion tool version 5.1 developed for LAQM purposes, which takes into account the interaction between NO_x and background ozone[10].

The modelling assessment requires source, emissions, meteorological and other site specific data. For modelling traffic impacts, one year of data is used and model verification is carried out following Defra's guidance.

The results of the assessment have been compared with the AQOs (Table 1.1) to assess whether the AQOs may be exceeded in the area.

As information regarding queuing traffic at the roundabout has been provided, the methodology published by Cambridge Environmental Research (CERC)[11] in 2004 is used to model emissions from queuing traffic at the roundabout under assessment. Detailed information on the queues included in the model is provided in Appendix F.

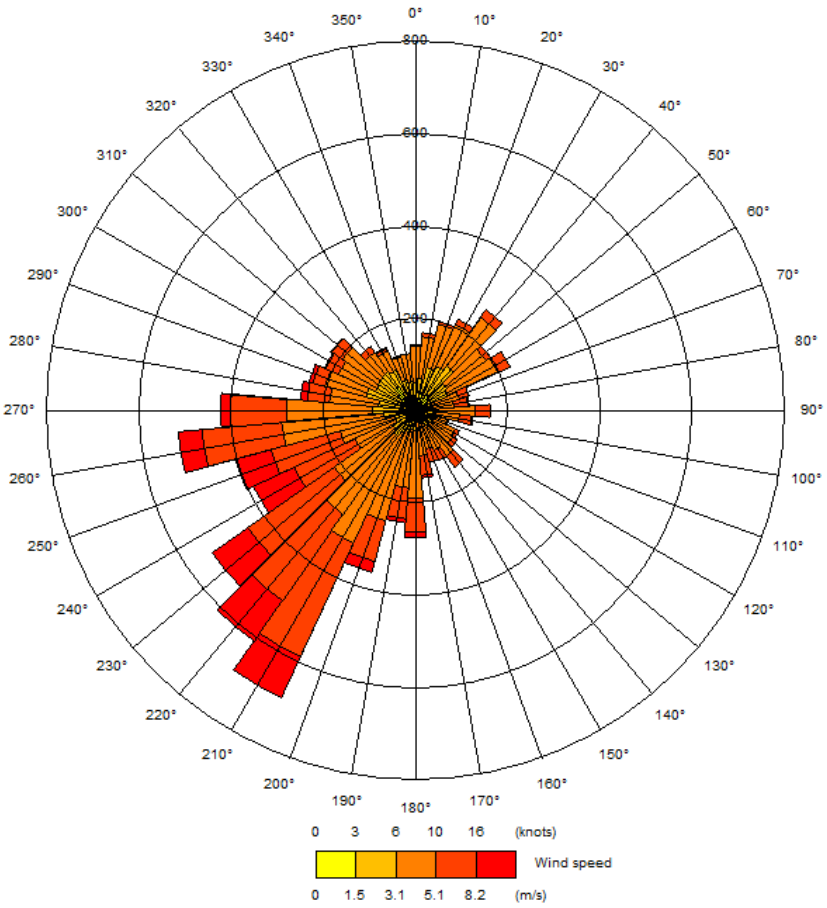
Meteorological data

Detailed dispersion modelling requires hourly sequential meteorological data from a representative synoptic observing station. Hourly sequential meteorological data was obtained for the year 2015 for Heathrow Airport, which is considered to provide representative data for the roads of interest. The meteorological data for 2015 has been used with monitoring data from 2015 in the traffic assessment and model verification.

Figure 3.1 summarises the hourly wind speed and wind direction for the meteorological data as a wind rose. The wind rose shows a predominance of winds from the south and south-west which the usual pattern is observed in and around the south-east of England.

[9] www.cerc.co.uk/environmental-software/ADMS-Roads-model.html
[10] AEA Technology (2013). *NO_x to NO_2 Calculator version 4.1.* http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html#NOxNO2calc
[11] CERC (2004) *Note 60 – Modelling queuing traffic*

Figure 3.1 Heathrow Airport Wind rose for 2015



The road network

Traffic data comprising Annual Average Daily Traffic (AADT) flows and numbers of different vehicle types were obtained for the roads around the Guildford Road and Constitution Hill junction. Traffic data for Guildford Road, Constitution Hill and Mount Hermon road were obtained from surveys carried out on by MHC Traffic Ltd in 2016.

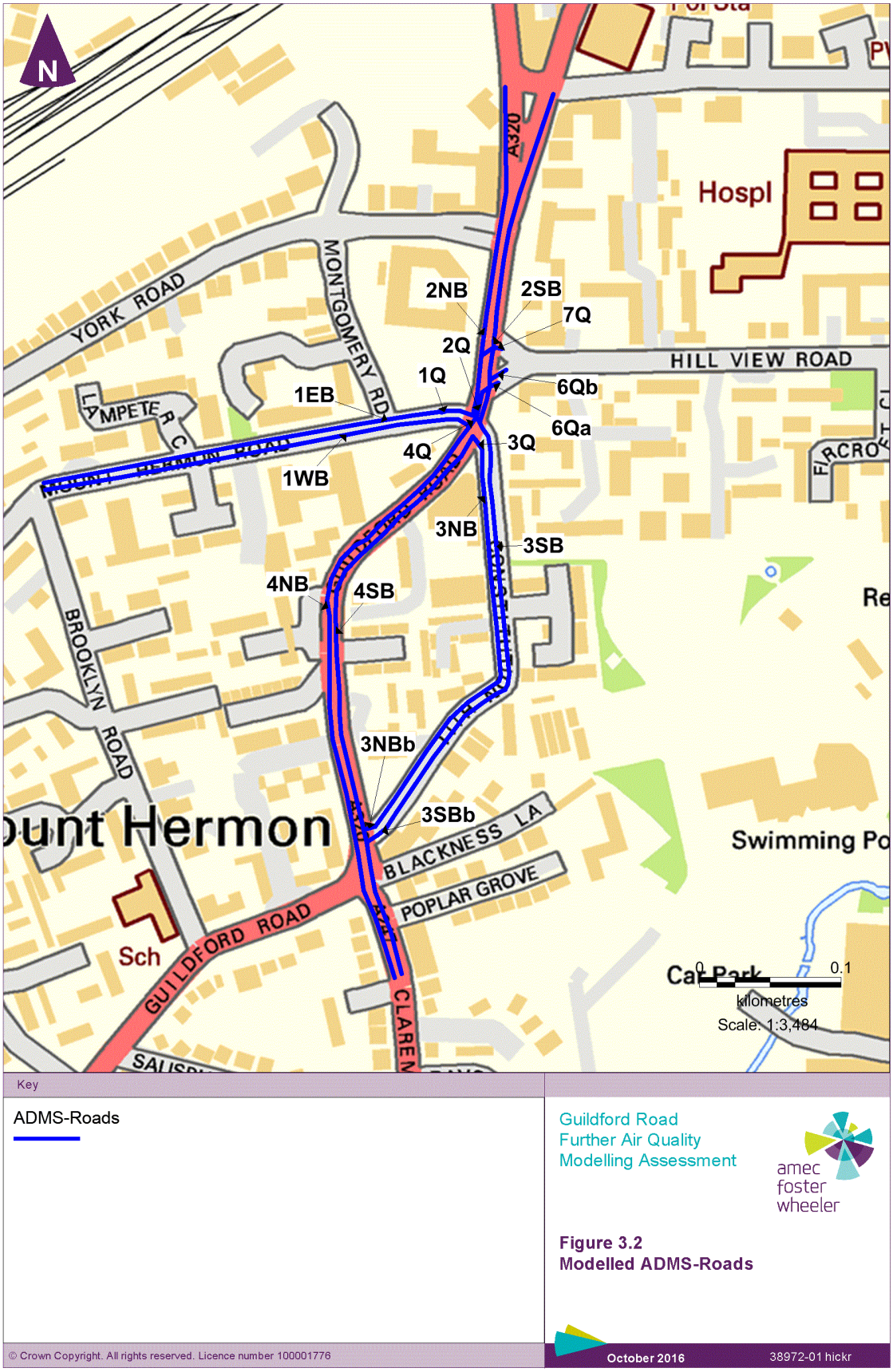
The traffic data were used to estimate emissions for the 2015 baseline, based on 2015 emission factors and background concentrations.

Emissions were calculated using the latest emissions factors from Defra, the Emission Factor Toolkit v7.0[12], which is used to predict emissions which are imported into ADMS-Roads. Particulate generated due to brake and tyre wear are also included in the Toolkit.

Figure 3.2 shows the road links that have been modelled in this assessment. The traffic data used are given in Appendix B.

12 http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html#eft

Figure 3.2 Roads modelled



Model verification

Model verification enables an estimation of uncertainty and systematic errors associated with the dispersion modelling components of the air quality assessment to be considered. There are many explanations for these errors, which may stem from uncertainty in the modelled number of vehicles, speeds and vehicle fleet composition. Defra has provided guidance in terms of preferred methods for undertaking dispersion model verification[9]. Model verification involves the comparison of modelled concentrations and local monitoring data.

Full details of the model verification procedure are provided in Appendix C. The diffusion tubes used in the verification process are shown in Figure 4.1. NO_2 concentrations have been amended using the adjustment factor of 3.22.

4. Baseline Air Quality

4.1 Summary of review and assessment by Woking Borough Council

The WBC area covers 6,359 hectares (22 square miles). It comprises a continuous urban area centred on Woking town centre but stretching from Byfleet and West Byfleet in the east to Knaphill in the west surrounded by open Green Belt countryside. Within the countryside there are small settlements the largest of which are the villages of Brookwood and Mayford. The area protected by Green Belt comprises about 60% of the borough.

The main source of air pollution in the borough is road traffic emissions from road traffic. Other pollution sources, including commercial, industrial and domestic sources, also make a contribution to background pollution concentrations.

WBC has one AQMA declared at Anchor Hill in Knaphill[13]. The Anchor Hill AQMA covers a small area around a four-way junction at the top of a steep hill and is declared for NO_2.

WBC's 2016 Annual Status Report determined that the monitoring programme should remain unchanged for the upcoming assessment year, with all diffusion tubes introduced in 2014 continued. Due to concentrations being recorded that were above the NO_2 annual mean AQO at Anchor Hill, the existing AQMA should remain. It was recommended that dispersion modelling is undertaken at Guildford Road to determine the extent of the proposed AQMA boundary, based on modelled concentrations at residential receptor locations.

4.2 Air Quality monitoring

Automatic monitoring sites

There are no continuous monitoring sites located within Woking Borough.

Non-automatic monitoring sites

WBC undertook monitoring of NO_2 using passive diffusion tubes at 28 sites during 2015. Table 4.1 shows the details of the sites.

Maps showing the location of the monitoring sites are provided in Figures 4.1.

Table 4.1 Permanent diffusion tube sites

Site ID	X	Y	Classification	Distance from road to relevant exposure (m)	Distance to kerb (m)	In AQMA?
CH	500417	158102	Roadside	4*	1.5	N
CH2	500367	158073	Roadside	12	1.0	N
CH3	500330	158012	Roadside	14*	1.5	N
CH4	500332	157983	Roadside	17*	1.0	N
Cott1	500437	158120	Roadside	3	1.0	N

[13] http://uk-air.defra.gov.uk/aqma/local-authorities?la_id=317.

Site ID	X	Y	Classification	Distance from road to relevant exposure (m)	Distance to kerb (m)	In AQMA?
Cott2	500453	158100	Roadside	4*	1.0	N

Notes
*Distances from monitoring locations to nearest receptor locations estimated from online mapping sources.
**Tube CH3 was reported as 500336, 158017 in the Woking ASR but when viewed on Google Earth it appears that the tube is located on the lamp post at 500330, 158012. Tube CH4 was reported as 500337, 157987 but the tube appears to be located on a lamp post at 500332, 157983.

Table 4.2 Results of 2011 - 2015 NO_2 diffusion tubes

Site ID	Data capture for 2015 (%)	2011	2012	2013	2014	2015
CH	100	-	41.1	43.9	34.2	**48.8**
CH2	100	-	-	-	**40.6***	**51.6**
CH3	100	-	-	-	37.9*	**51.5**
CH4	92	-	-	-	34.5*	**42.4**
Cott1	100	29.7	34.8	36.0	31.0	**40.7**
Cott2	92	23.6	24.9	27.4	17.8	24.9

Notes:
(-) Data not available
* Annualised because data capture was below 75%.
Exceedances of the AQO are shown in **bold**.
Bias adjustment factors for 2011, 2012, 2013, 2014 and 2015 respectively are 1.06, 0.91, 0.87, 0.8 and 1.07.

Table 4.2 shows that there were exceedances of the AQO for NO_2 recorded along Guildford Road in 2015. The highest annual mean NO_2 concentration of 51.6 μgm^{-3} was recorded at tube CH2. This follows previous exceedances of the AQO in 2014.

Figure 4.1 Diffusion tube locations in Woking

4.3 Estimated background concentrations

Defra has made estimates of background pollution concentrations on a 1 km^2 grid for the UK for seven of the main pollutants, including NO_2, using data for a base year of 2013, making projections for years from 2013 to 2030 inclusive[14]. Table 4.3 shows the estimated values of the pollutants for 2015 for the cells that will be used in the modelling.

Table 4.3 Defra mapped background annual mean pollutant concentrations (µg m^{-3})

Pollutant	2015
Grid Square Centre: 500500, 157500	
Nitrogen Dioxide, NO_2	15.2
Nitrogen Oxides, NO_x	21.5
Grid Square Centre: 500500, 158500	
Nitrogen Dioxide, NO_2	19.3
Nitrogen Oxides, NO_x	28.3

The last full calendar year for which meteorological and monitoring data are available is 2015. On this basis, this year was used to test the performance of the dispersion model and undertake verification of the model outputs, by comparing predicted concentrations against the actual nearby monitoring data collected close by and in a similar location that is representative of the site. The Defra gridded values have been used in the modelling.

[14] http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html

5. Dispersion modelling results

5.1 Predicted concentrations

This section presents a summary of the modelling assessment in relation to the concentrations of NO_2. Detailed results are provided in Appendix D.

Table D1 presents the annual mean NO_2 concentrations for receptors around Guildford Road. Exceedances of the AQO of 40 μgm^{-3} are predicted at two receptor locations.

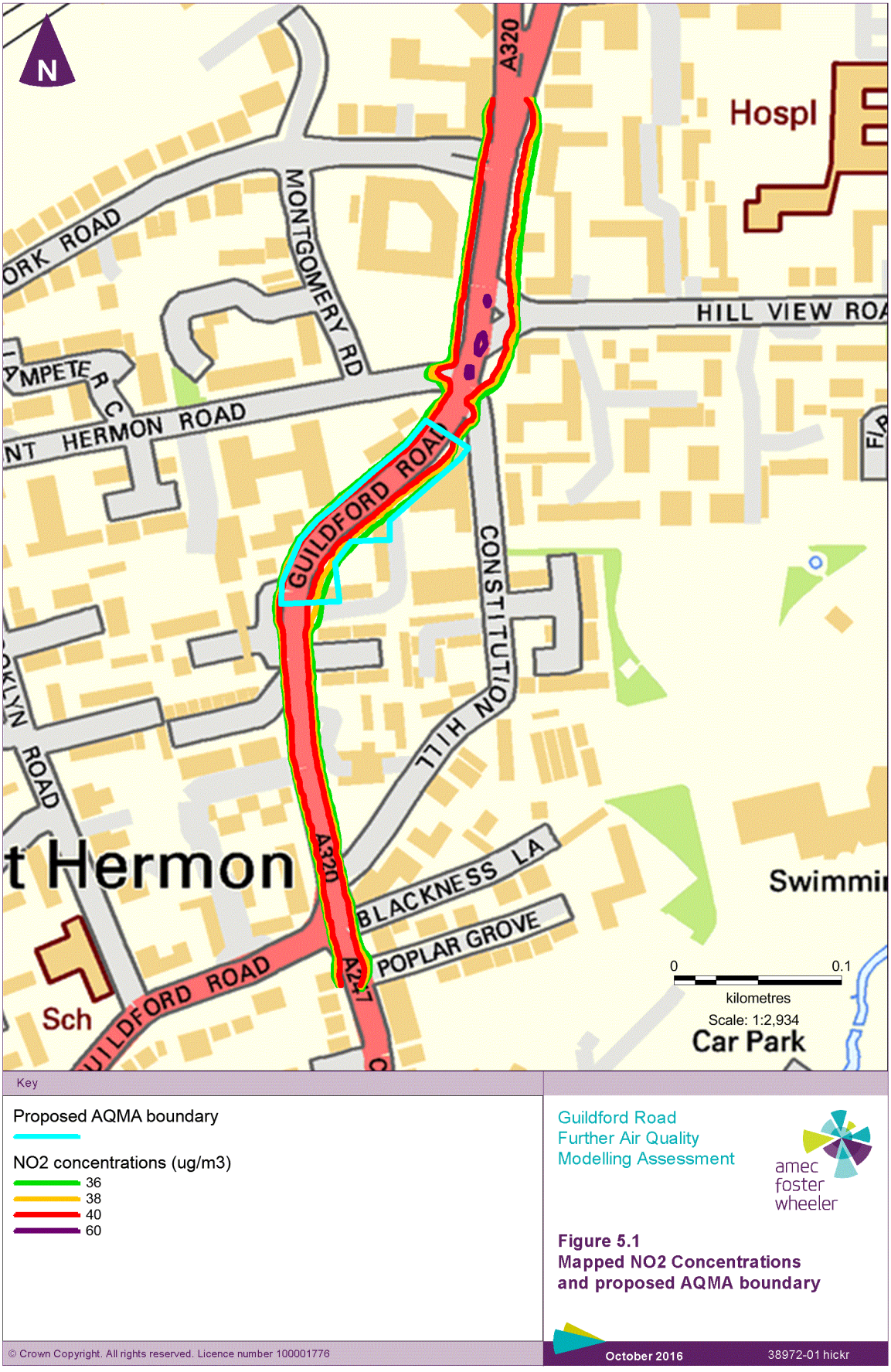
The highest concentration at a relevant receptor location is predicted at receptor R2 on Guildford Road, where a concentration of 40.3 μgm^{-3} is predicted which exceeds the AQO of 40 μgm^{-3}. This location is a relevant residential receptor location. Diffusion tube CH is located near this location, and recorded a concentration exceeding the AQO in 2015.

Exceedances of the AQO are predicted at receptors R2 and R21. Receptor R3 has a predicted concentration within 5% of the AQO, indicating that there is potential for the AQO to be exceeded at this location.

Figure 5.1 shows the mapped NO_2 concentration contours which give an indication of residential locations where NO_2 concentrations may be exceeding the AQO. Due to exceedances of the AQO for NO_2 being predicted at residential receptor locations around the junction between Constitution Hill and Guildford Road, it is proposed that an AQMA is declared in this area, as a result of road traffic emissions. The proposed boundary includes properties at Thorsden Close facing Guildford Road, where the predicted concentrations are within 5% of the AQO. The proposed boundary of the AQMA is shown in Figure 5.1.

The dispersion modelling also indicates that NO_2 concentrations may be elevated around the junctions of Guildford Road with York Road and Station approach. An NO_2 concentration of 42.2 μgm^{-3} is predicted at receptor R21, albeit there is no residential exposure at ground floor level. As there are residential properties close to the road in this area, it is recommended that monitoring is carried out to determine if the NO_2 annual mean AQO is exceeded. Figure F1 is Appendix F provides further clarification of the proposed AQMA and shows the proposed Guildford Road/ York Road/Station Road monitoring locations.

Figure 5.1 Mapped NO_2 concentrations and proposed AQMA boundary



5.2 Further analysis

Estimate of the population exposed to exceedance of the annual mean NO_2 AQO

The average number of people per household in 2015 in the UK was 2.4 (Office for National statistics, 2015)[15]. It has been estimated using online mapping systems available (e.g. Google Earth) that there are 7 residential units included with the proposed AQMA boundary. It is therefore estimated that there are approximately 17 people living within the proposed Guildford Road AQMA boundary that may be exposed to concentrations of NO_2 exceeding the AQO.

Additional monitoring recommended

It is recommended that additional monitoring locations are added at the junction of Guildford Road with York Road and Station Approach, to determine is the annual mean AQO for NO_2 is exceeded at locations of relevant exposure in this area.

15 http://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/bulletins/familiesandhouseholds/2015-11-05#household-size

6. Conclusions

An air quality assessment has been prepared to determine the extent of exceedances of the AQOs at relevant receptor locations around Guildford Road in Woking. ADMS-Roads (version 4.0) modelling has been used to model dispersion from traffic to determine likely NO_2 concentrations at residential receptors. Predicted concentrations at receptors were then compared to the Air Quality Objectives.

The highest NO_2 concentration is predicted at receptor R2 where a concentration of 40.3 μgm^{-3} is predicted on Guildford Road, which exceeds the AQO of 40 μgm^{-3}, and is a relevant residential receptor location. Exceedances of the NO_2 AQO of 40 μgm^{-3} are predicted at two receptor locations altogether.

Dispersion modelling therefore indicates that concentrations at receptor locations with relevant exposure are exceeding the AQO of 40 μgm^{-3} for NO_2 as a result of road traffic emissions around Guildford Road.

6.1 Recommendations

- It is recommended that an AQMA is declared along Guildford Road, with the extent of the boundary determined in this assessment; and
- Further monitoring is required around the junctions where Guildford Road meets York Road and Station Approach to confirm if the NO_2 annual mean AQO is exceeded where there is relevant exposure.

Appendix A
ADMS model

Introduction

The ADMS-Roads dispersion model, developed by CERC[6], is a tool for investigating air pollution problems due to small networks of roads that may be in combination with industrial sites, for instance small towns or rural road networks. It calculates pollutant concentrations over specified domains at high spatial resolution (street scale) and in a format suitable for direct comparison with a wide variety of air quality standards for the UK and other countries. The latest version of the model, version 3.1.4, was used in this study.

ADMS-Roads is referred to as an advanced Gaussian or, new generation, dispersion model as it incorporates the latest understanding of the boundary layer structure. It differs from old generation models such as ISC, R91 and CALINE in two main respects:

- it characterises the boundary layer structure and stability using the boundary layer depth and Monin-Obukhov length to calculate height-dependent wind speed and turbulence, rather than using the simpler Pasquill-Gifford stability category approach; and
- it uses a skewed-Gaussian vertical concentration profile in convective meteorological conditions to represent the effect of thermally generated turbulence.

Model features

A description of the science used in ADMS-Roads and the supporting technical references can be found in the model's User Guide[16]. The main features of ADMS-Roads are:

- it is an advanced Gaussian, "new generation" dispersion model;
- includes a meteorological pre-processor which calculates boundary layer parameters from a variety of input data e.g. wind speed, day, time, cloud cover and air temperature;
- models the full range of source types encountered in urban areas including industrial sources (up to 3 point sources, up to 3 lines sources, up to 4 area sources, up to 25 volume sources) and road sources (up to 150 roads, each with 50 vertices);
- generates output in terms of average concentrations for averaging times from 15minutes to 1 year, percentile values and exceedances of threshold values. Averages can be specified as rolling (running) averages or maximum daily values;
- the option to calculate emissions from traffic count data, speed and fleet split (light duty/ heavy duty vehicles) using UK emission factors. Alternatively, road emissions may be entered directly as user specified values;
- models plume rise by solving the integral conservation equations for mass, momentum and heat;
- models the effect of street canyons on concentrations within the canyon and vehicle–induced turbulence using a formulation based on the Danish OSPM model. It is usually only important to model street canyons when the aspect ratio (ratio of the height of buildings along the road to the width of the road) is greater than 0.5;
- models the effects of noise barriers on concentrations outside the road;
- models NO_X chemistry using the 8 reaction Generic Reaction Set plus transformation of SO_2 to sulphate particles, which are added to the PM_{10} concentration;
- models the effect of a small number of buildings on dispersion from point sources;

16 CERC (2011) ADMS-Roads, an Air Quality Management System, Version 3.1 User Guide, http://www.cerc.co.uk/environmental-software/assets/data/doc_userguides/CERC_ADMS-Roads3.1_User_Guide.pdf Date of access: 19th October 2012.

- models the effect of complex terrain (hills) and spatially varying surface roughness. Terrain effects only become noticeable for gradients greater than 1:10, but for ground level sources in a built up area, such as urban roads, low gradients will have a negligible effect;
- models concentrations in units of $ou_E m^{-3}$ for odour studies;
- link to MapInfo and ArcGIS for input of source geometry, display of sources, aggregation of emissions and plotting of contours; and
- link to an emissions inventory in Microsoft Access for input and export of source and emissions data.

In this study, street canyons, noise barriers, buildings and complex terrain were not modelled. The link to MapInfo was used to enter source geometry.

Validation

ADMS-Roads has been validated using UK and US data and has been compared with the DMRB spreadsheet model and the US model, CALINE. Validation of the ADMS and ADMS-Urban models are also applicable to the performance of ADMS-Roads as they test common features: basic dispersion, modelling of roads and street canyons, the effect of buildings and the effect of complex terrain. These validation studies are all reported on the CERC web site[17]. In addition, ADMS-Urban has been validated during its use in modelling many urban areas in the UK for local authorities as part of LAQM, Heathrow Airport for the Department for Transport[18] and all of Greater London for a Defra model inter-comparison exercise[19].

[17] http://www.cerc.co.uk/environmental-software/model-documentation.html#validation Date of access: 19 October 2012
[18] CERC (2007) Air Quality Studies for Heathrow: Base Case, Segregated Mode, Mixed Mode and Third Runway Scenarios Modelled Using ADMS-Airport, prepared for the Department for Transport, *HMSO* Product code 78APD02904CERC
[19] Carslaw, D. (2011), Defra urban model evaluation analysis – Phase 1, a report to Defra and the Devolved Authorities. http://uk-air.defra.gov.uk/library/reports?report_id=654 Date of access: 19 October 2012

Appendix B
ADMS-roads input

Table B1 shows the traffic data obtained from the Woking traffic counts.

Table B1 ADMS-roads input data

Road ID	Traffic Flow (AADT)	% Car	% LGV	% Rigid HGV	% Artic HGV	% Motorcycle	Speed (kmh^{-1})	Number of Hours	Road Width (m)
1EB	1668	94.0	0.18	4.08	1.00	0.72	32.2	24	3
1WB	1128	94.1	0.09	4.79	0.09	0.89	32.2	24	3
2NB	11556	92.1	1.06	5.27	0.55	0.99	33.8	24	4
2SB	13207	88.7	4.52	5.74	0.21	0.83	35.4	24	4
3NB	291	95.2	0.00	4.47	0.00	0.34	22.5	24	9
3SB	374	91.4	0.00	7.49	0.27	0.80	24.1	24	9
4NB	10038	91.7	0.77	6.28	0.31	0.99	40.2	24	3
4SB	12187	93.0	0.37	5.42	0.25	0.97	41.8	24	3
3NBb	291	95.2	0.00	4.47	0.00	0.34	5.0	24	3
3SBb	374	91.4	0.00	7.49	0.27	0.80	5.0	24	3
1Q	30000	100.0	0.00	0.00	0.00	0.00	5.0	24	4
2Q	30000	100.0	0.00	0.00	0.00	0.00	5.0	24	3
3Q	30000	100.0	0.00	0.00	0.00	0.00	5.0	24	5
4Q	30000	100.0	0.00	0.00	0.00	0.00	5.0	24	3
5Qa	30000	100.0	0.00	0.00	0.00	0.00	5.0	24	3
5Qb	30000	100.0	0.00	0.00	0.00	0.00	5.0	24	3
6Q	30000	100.0	0.00	0.00	0.00	0.00	5.0	24	4

Appendix C
ADMS-roads model verification

The ADMS-Roads dispersion model has been widely validated for this type of assessment and was specifically listed in the Defra's LAQM.TG (09) guidance as an accepted dispersion model.

Model validation undertaken by the software developer (CERC) will not have included validation in the vicinity of the proposed Development Site. It is therefore necessary to perform a comparison of modelled results with local monitoring data at relevant locations. This process of verification attempts to minimise modelling uncertainty and systematic error by correcting modelled results by an adjustment factor to gain greater confidence in the final results.

The predicted results from a dispersion model may differ from measured concentrations for a large number of reasons, including uncertainties associated with:

- background concentration estimates;
- meteorological data;
- source activity data such as traffic flows and emissions factors;
- model input parameters such as surface roughness length, minimum Monin-Obukhov length;
- monitoring data, including locations; and
- overall model limitations.

Model verification is the process by which these and other uncertainties are investigated and where possible minimised. In reality, the differences between modelled and monitored results are likely to be a combination of all of these aspects.

Model setup parameters and input data were checked prior to running the models in order to reduce these uncertainties. The following were checked to the extent possible to ensure accuracy:

- traffic data;
- road widths;
- distance between sources and monitoring as represented in the model;
- speed estimates on roads;
- source types, such as elevated roads and street canyons;
- selection of representative meteorological data;
- background monitoring and background estimates; and
- monitoring data.

NO_2 Verification

Suitable local monitoring data for the purpose of verification of NO_2 was available at six diffusion tube locations.

Annual mean NO_x/NO_2 concentrations as shown in Table C1 below.

Table C1 Local monitoring data suitable for ADMS-roads model verification

Location	2015 Monitored NO_2 (μgm^{-3})	X (m)	Y (m)
CH	**48.8**	500417	158102
CH2	**51.6**	500367	158073
CH3	**51.5**	500330	158012
CH4	**42.4**	500332	157983
Cott1	**40.7**	500437	158120
Cott2	**24.9**	500453	158100

Verification calculations

The verification of the modelling output was performed in accordance with the methodology provided in Chapter 7 of LAQM.TG(16). Table C2 shows that there was systematic under prediction of monitored concentrations at all six tubes; therefore, it was considered necessary to adjust modelled concentrations.

Table C2 Verification, modelled versus monitored

Site	2015 Modelled Annual Mean NO_2 (μgm^{-3})	2015 Monitored Annual Mean NO_2 (μgm^{-3})	% (Modelled-Monitored)/ Monitored
CH	31.52	48.8	-35.41%
CH2	29.58	51.6	-42.67%
CH3	28.53	51.5	-44.60%
CH4	25.09	42.4	-40.83%
Cott1	25.91	40.7	-36.34%
Cott2	21.74	24.9	-12.69%

Table C3 shows the comparison of modelled road-NO_X, a direct output from the ADMS-Roads modelling, with the monitored road-NO_X, determined from the LAQM NO_X to NO_2 conversion tool. An adjustment factor of 3.22 was used to adjust modelled results.

Table C3 Comparison of modelled and monitored road NO_x to determine verification factor

Site	2015 Modelled Annual Mean Road NO_X (μgm^{-3})	2015 Monitored Annual Mean Road NO_X (μgm^{-3})	Ratio	Average Adjustment Factor
CH	24.9252	66.23	2.66	3.22
CH2	20.7546	73.66	3.55	
CH3	18.5264	73.4	3.96	
CH4	19.5598	59.04	3.02	
Cott1	13.0839	45.91	3.51	
Cott2	4.70306	11.03	2.35	

Table C4 shows the comparison of the modelled NO_2 concentration calculated by multiplying the modelled road NO_X by the adjustment factors and using the LAQM's NO_X to NO_2 conversion tool to calculate the total adjusted modelled NO_2.

Table C4 Comparison of adjusted modelled NO_2 and modelled NO_2

Location	2015 Background NO_X Concentration	2015 Background NO_2 Concentration	2015 Adjusted Modelled Annual Mean NO_2 (μgm^{-3})	2015 Monitored Annual Mean NO_2 (μgm^{-3})	% (Modelled-Monitored)/ Monitored
CH	28.27	19.32	54.02	48.8	10.70%
CH2	28.27	19.32	49.03	51.6	-4.98%
CH3	28.27	19.32	46.25	51.5	-10.19%
CH4	21.48	15.21	43.96	42.4	3.68%
Cott1	28.27	19.32	39.11	40.7	-3.91%
Cott2	28.27	19.32	26.91	24.9	8.07%

All modelled NO_x concentrations have been amended using the adjustment factor of 3.22.

Appendix D
ADMS-roads results

Table D1 Annual mean predicted concentrations (μgm^{-3})

Receptor	Height (m)	Location	NO_2
R1 Ground Floor	1.5	Park Heights, Constitution Hill, Woking	34.52
R1 1st Floor	4.5	Park Heights, Constitution Hill, Woking	29.09
R2 Ground Floor	1.5	Park Heights, Constitution Hill, Woking	**40.34**
R2 1st Floor	4.5	Park Heights, Constitution Hill, Woking	30.31
R3 Ground Floor	1.5	Park Heights, Constitution Hill, Woking	39.97
R3 1st Floor	4.5	Park Heights, Constitution Hill, Woking	30.18
R4 Ground Floor	1.5	Constitution Hill, Woking	29.71
R4 1st Floor	4.5	Constitution Hill, Woking	27.07
R5	1.5	Park Heights, Constitution Hill, Woking	34.87
R6	1.5	Park Heights, Constitution Hill, Woking	34.59
R7	1.5	Guildford Rd, Woking	33.90
R8	1.5	Guildford Rd, Woking	33.66
R9	1.5	Thorsden Close, Woking	31.52
R10	1.5	Constitution Hill, Woking	26.83
R11	1.5	Constitution Hill, Woking	23.06
R12	1.5	Guildford Rd, Woking	29.53
R13	1.5	Guildford Rd, Woking	29.49
R14	1.5	Guildford Rd, Woking	32.69
R15	1.5	Guildford Rd, Woking	32.04
R16	1.5	Guildford Rd, Woking	30.99
R17	1.5	Guildford Rd, Woking	32.25
R18	1.5	Constitution Hill, Woking	28.32
R19	1.5	Hill View Rd, Woking	29.60
R20	1.5	Hillview Court, Woking	29.39
R21	1.5	Guildford Rd, Woking	**42.23**
R22	1.5	Thorsden Close, Woking	26.89
R23	1.5	Guildford Rd, Woking	24.78

Receptor	Height (m)	Location	NO_2
R24	1.5	Guildford Rd, Woking	30.11
R25	1.5	Constitution Hill, Woking	18.64
R26	1.5	Mount Hermon Road, Woking	27.38
R27	1.5	Mount Hermon Road, Woking	23.91
R28	1.5	Guildford Rd, Woking	30.90
R29	1.5	Constitution Hill, Woking	18.44
R30	1.5	Guildford Rd, Woking	30.72

Exceedances of the AQOs are shown in **bold.**
Concentrations within 5% of the AQO are underlined

Appendix E
Queuing traffic

As information regarding queuing traffic at the junction has been provided, the methodology published by Cambridge Environmental Research (CERC) in 2004 is used to model emissions from queuing traffic at the roundabout under assessment. Actual queue lengths are estimated using the known number of vehicles in the queues and an assumption of vehicle length (4m for a car). Queuing vehicles are modelled at the lowest possible speed in ADMS-Roads, 5 km/hour. A representative AADT has been calculated using the following equation:

$$AADT = [\text{Speed (m/hr)} / \text{Vehicle length (m)}] \times 24$$

Multiple queues were set up based on different queue lengths during the day. Analysis of the queuing data determined that there were longer queues during typical "rush hour" periods i.e. 07:00 to 9:00 and 17:00 to 19:00.

To account for the variation in queuing traffic throughout the day, a time-varying (fac) file was applied to the model. The traffic data was analysed and it was determined that queues were generally present between 0700 to 0900 and 1700 to 1900. A time-varying file was included that modelled queuing traffic between 0700 and 1900. Queue lengths were based on the average number of queuing cars during these hour periods.

The queuing traffic data indicated that there is not a major issue with regards to queuing in the area, as queue lengths and durations are relatively short. The queue at Thorsden Close was not included as it was less than one car per hour on average.

Table F1 presents the queue lengths at Mount Hermon Road, Guildford road, Constitution Hill and Hill View Road.

Table E1 Junction queue lengths

Queue ID	Queue Name	Description	Average Queuing Number of Cars	Queue Length (m)
1Q	Mount Hermon Road	Eastbound turning left	3.0	10.1
2Q	Guildford Road	Southbound turning right	1.4	5.5
3Q	Constitution Hill	Northbound	1.3	5.1
4Q	Guildford Road	Northbound turning right to Constitution Hill	2.8	11.1
5Qa	Hill View Road	Turning left	3.9	15.6
5Qb	Hill View Road	Turning right	1.4	5.4
6Q	Guildford Rd	Turning right into Hill View Road	3.0	12.1

Appendix F
Recommendations

Table F2 Proposed AQMA boundary and monitoring location

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