



Modelling Assessment of Air Quality along the M40 for Wycombe District Council

December 2010



Experts in air quality
management & assessment

Document Control

Client	Wycombe District Council	Principal Contact	Claire Spendley
---------------	--------------------------	--------------------------	-----------------

Job Number	J1151
-------------------	-------

Report Prepared By:	Dr Clare Beattie and Kiri Brown
----------------------------	---------------------------------

Document Status and Review Schedule

Report No.	Date	Status	Reviewed by
1151/1/D1	26 th October 2010	Draft Report	Prof Duncan Laxen
1151/1/F1	3 rd December 2010	Final Report	Prof Duncan Laxen

This report has been prepared by Air Quality Consultants Ltd on behalf of the Client, taking into account the agreed scope of works. Unless otherwise agreed, this document and all other Intellectual Property Rights remain the property of Air Quality Consultants Ltd.

In preparing this report, Air Quality Consultants Ltd has exercised all reasonable skill and care, taking into account the objectives and the agreed scope of works. Air Quality Consultants Ltd does not accept any liability in negligence for any matters arising outside of the agreed scope of works. The Company operates a formal Quality Management System, which is certified to ISO 9001:2008.

When issued in electronic format, Air Quality Consultants Ltd does not accept any responsibility for any unauthorised changes made by others.

When printed by Air Quality Consultants Ltd, this report will be on Evolve Office, 100% Recycled paper.

Air Quality Consultants Ltd
23 Coldharbour Road, Bristol BS6 7JT Tel: 0117 974 1086
12 Airedale Road, London SW12 8SF Tel: 0208 673 4313
aqc@aqconsultants.co.uk

Registered Office: 12 St Oswalds Road, Bristol, BS6 7HT
 Companies House Registration No: 2814570

Contents

1	Introduction	2
2	Assessment Methodology	5
3	Results.....	7
4	Conclusions and Recommendations.....	14
5	References.....	15
6	Glossary.....	16
A1	Appendix 1 – Summary of Health Effects of Nitrogen Dioxide	17
A2	Appendix 2 – Traffic Data.....	17
A3	Appendix 3 – Model Verification	18
A4	Appendix 4 – Adjustment of Short-Term Data to Annual Mean.....	20

1 Introduction

- 1.1 Air Quality Consultants Ltd has been commissioned by Wycombe District Council (WDC) to undertake a modelling study of air quality along the M40. In 2010, Wycombe District Council completed a Detailed Assessment, which concluded that an Air Quality Management Area (AQMA) is required as a result of measured and modelled exceedences of the annual and 1-hour mean nitrogen dioxide objective at locations of relevant exposure across High Wycombe. Wycombe District Council already has an AQMA declared along the length of the M40, but this declaration was made in 2001, based on the $40 \mu\text{g}/\text{m}^3$ modelled contour. Originally extending 12 metres either side of the motorway carriageway, it was subsequently extended to its current size of 30 metres either side of the carriageway. This study will remodel the M40 in order to base the entire AQMA declaration, including that in High Wycombe, on the same data and assumptions.
- 1.2 The aim of this modelling study is to determine whether the annual mean nitrogen dioxide objective continues to be exceeded at relevant locations and, if so, the extent of exceedences and thus the boundary of the Air Quality Management Area (AQMA) required.

Background

- 1.3 The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Defra, 2007) sets out a framework for air quality management, which includes a number of air quality objectives. National and international measures are expected to achieve these objectives in most locations, but where areas of poor air quality remain, air quality management at a local scale has a particularly important role to play. Part IV of the Environment Act 1995 requires local authorities to periodically review and assess air quality in their areas. The role of this process is to identify areas where it is unlikely that the air quality objectives will be achieved. These locations must be designated as AQMAs and a subsequent Air Quality Action Plan (AQAP) developed in order to reduce pollutant emissions in pursuit of the objectives.
- 1.4 Review and Assessment is a long-term, ongoing process, structured as a series of 'rounds'. Local Authorities in England, Scotland and Wales have now completed the first, second and third rounds of Review and Assessment, with the fourth round underway.
- 1.5 Technical Guidance for Local Air Quality Management (LAQM.TG(09)) (Defra, 2009) sets out a phased approach to the Review and Assessment process. This prescribes an initial Updating and Screening Assessment (USA), which all local authorities must undertake. It is based on a checklist to identify any matters that have changed since the previous round. If the USA identifies any areas where there is a risk that the objectives may be exceeded, which were not identified in the previous round, then the Local Authority should progress to a Detailed Assessment.

- 1.6 The purpose of the Detailed Assessment is to determine whether an exceedence of an air quality objective is likely and the geographical extent of that exceedence. If the outcome of the Detailed Assessment is that one or more of the air quality objectives are likely to be exceeded, then an Air Quality Management Area (AQMA) must be declared. Subsequent to the declaration of an AQMA, a Further Assessment should be carried out to confirm that the AQMA declaration is justified; and that the appropriate area has been declared; to ascertain the sources contributing to the exceedence; and to calculate the magnitude of reduction in emissions required to achieve the objective. This information can be used to inform an Air Quality Action Plan, which will identify measures to improve local air quality.
- 1.7 Following the findings of Wycombe District Council's USA published in 2009, which concluded that there were measured exceedences of the annual mean nitrogen dioxide objective at locations of relevant exposure (WDC, 2009), a Detailed Assessment was carried out (WDC, 2010). The Detailed Assessment concluded that an AQMA was required as a result of measured exceedences of the annual and 1-hour mean nitrogen dioxide objective at locations of relevant exposure across the town of High Wycombe.

The Air Quality Objectives

- 1.8 The Government's Air Quality Strategy (Defra, 2007) provides air quality standards and objectives for key air pollutants, which are designed to protect human health and the environment. The 'standards' are set as concentrations below which health effects are unlikely even in sensitive population groups, or below which risks to public health would be exceedingly small. They are based purely upon the scientific and medical evidence of the effects of a particular pollutant. The 'objectives' set out the extent to which the Government expects the standards to be achieved by a certain date. They take account of the costs, benefits, feasibility and practicality of achieving the standards. It also sets out how the different sectors: industry, transport and local government, can contribute to achieving the air quality objectives. The objectives are prescribed within The Air Quality (England) Regulations 2000 (Stationery Office, 2000) and The Air Quality (England) (Amendment) Regulations 2002 (Stationery Office, 2002). Table 1 summarises the objectives which are relevant to this report. Appendix 1 provides a brief summary of the health effects of nitrogen dioxide.
- 1.9 The air quality objectives only apply where members of the public are likely to be regularly present for the averaging time of the objective (i.e. where people will be exposed to pollutants). For annual mean objectives, relevant exposure is limited to residential properties, schools and hospitals. The 1-hour objective applies at these locations as well as at any outdoor location where a member of the public might reasonably be expected to stay for 1 hour or more, such as shopping streets, parks and sports grounds, as well as bus stations and railway stations that are not fully enclosed.
- 1.10 Measurements across the UK have shown that the 1-hour nitrogen dioxide objective is unlikely to be exceeded unless the annual mean nitrogen dioxide concentration is greater than $60 \mu\text{g}/\text{m}^3$

(Defra, 2009). Thus exceedences of $60 \mu\text{g}/\text{m}^3$ as an annual mean nitrogen dioxide concentration are used as an indicator of potential exceedences of the 1-hour nitrogen dioxide objective.

Table 1: Air Quality Objectives for Nitrogen Dioxide

Pollutant	Time Period	Objective
Nitrogen Dioxide	1-hour mean	$200 \mu\text{g}/\text{m}^3$ not to be exceeded more than 18 times a year
	Annual mean	$40 \mu\text{g}/\text{m}^3$

2 Assessment Methodology

Monitoring

- 2.1 Monitoring for nitrogen dioxide was carried out by Wycombe District Council using passive diffusion tubes at three locations alongside the M40 in 2009. The Council also operates an automatic monitor in Stokenchurch, alongside the M40. The monitoring sites and study area are shown in Figure 1. Diffusion tubes were prepared and analysed by Bureau Veritas Labs using the 20% TEA in water method. It is necessary to adjust diffusion tube data to account for laboratory bias. A bias adjustment factor for 2009 of 0.81 has been taken from the database of national factors provided on the Review and Assessment Helpdesk website (spreadsheet version 03/10).



Figure 1 Study Area and Monitoring Locations. M40 shown in blue, Diffusion Tubes shown in Red and the Automatic Monitor shown in Green

© Crown copyright 2010. All rights reserved, Wycombe DC. License number: 100023306

Modelling

- 2.2 Annual mean nitrogen dioxide concentrations have been predicted using detailed dispersion modelling (ADMS-Roads v2.3). The model outputs have been verified against the automatic and diffusion tube measurements described in paragraph 2.1. Concentrations have been predicted for a grid of receptors across the study area to allow concentration isopleths to be plotted.

Uncertainty

- 2.3 There is an element of uncertainty in all measured and modelled data. All values presented in this report are the best possible estimates, but uncertainties in the results might cause over-predictions or under-predictions. All of the measurements presented have an intrinsic margin of error. Defra (2010a) suggest that this is of the order of plus or minus 20% for diffusion tube data and plus or minus 10% for automatic measurements, provided that appropriate QA/QC procedures are applied. The model results rely on measured and modelled traffic data which has its own inherent uncertainty. There will be additional uncertainties introduced because the modelling has simplified real-world processes into a series of algorithms. For example: it has been assumed the emissions per vehicle conform to the factors published in Defra's Emission Factor Toolkit (EFT V4.2); it has been assumed that wind conditions measured at Heathrow Airport during 2009 occurred within the High Wycombe study area, and it has been assumed that the subsequent dispersion of emitted pollutants will conform to a Gaussian distribution over flat terrain. An important step in the assessment is verifying the dispersion model against the measured data. By comparing the model results with measurements, data have been corrected for any under- or over-prediction (see Appendix 3 for details of the model verification).
- 2.4 Recently however, a disparity between the road transport emission projections and measured annual mean concentrations of NO_x and NO₂ has been identified. This applies across the UK, although the effect appears to be greatest in inner London; there is also considerable inter-site variation. Whilst the emission projections suggest that both annual mean NO_x and NO₂ concentrations should have fallen over the past 6 to 8 years, at many monitoring sites levels have remained relatively stable, or have even shown a slight increase.
- 2.5 The precise reason for this disparity is not known, but is thought to be related to the actual on-road performance of diesel vehicles when compared to the calculations based on the Euro standards. It may therefore be expected that NO_x and NO₂ concentrations will not fall as quickly in future years as the current projections indicate. However, at this stage, there is no robust evidence upon which to carry out any revised predictions.
- 2.6 These limitations to the assessment should be borne in mind when considering the results set out in the following sections. While the model should give an overall accurate picture, i.e. one without bias, there will be uncertainties for individual locations.

3 Results

Monitoring

- 3.1 Monitoring data for the sites within the study area (Figure 1) are summarised in Table 2. The annual mean objective was exceeded at four of the monitoring locations in 2009.

Table 2: Annual Mean Nitrogen Dioxide Concentrations Measured within High Wycombe in 2009 ($\mu\text{g}/\text{m}^3$)

Site	Site Type	Site Description	2009 ^a
Automatic Monitor			
Stokenchurch	Suburban	Marcourt Road	42
Diffusion Tubes ^a			
D	Roadside	Wheeler End	64.0
A	Suburban	Loudwater, Knaves Hollow	34.6
H5	Roadside	Gilfield Close	35.9 ^b
Objective			40

^a Data adjusted using the national bias adjustment factor of 0.81.

^b Data have been annualised. See Appendix 4 for further details.

Modelling

- 3.2 Isopleth maps of the modelled annual mean nitrogen dioxide concentrations at ground-floor level are presented in Figure 2 to 6. These show that the annual mean objective is likely to be exceeded alongside the M40 to a distance of about 55m. The gap in predicted exceedences at ground level to the east of High Wycombe is where the motorway is elevated, and therefore where pollutants disperse prior to reaching ground level. It is, however, likely that any properties at a similar height to the motorway at this location, within approximately 55m of the carriageway would also be experiencing exceedences.
- 3.3 The isopleths show the $40 \mu\text{g}/\text{m}^3$ contour in red, the $36 \mu\text{g}/\text{m}^3$ contour in blue, as well as the $60 \mu\text{g}/\text{m}^3$ contour in green. There is some uncertainty surrounding both the measured and modelled concentrations. It is therefore recommended that an AQMA is declared to include, as a minimum, those residential properties which lie within the $36 \mu\text{g}/\text{m}^3$ contour, in order to be precautionary. This advice is also consistent with the AQMA declaration for High Wycombe.
- 3.4 In addition, there are predicted exceedences of $60 \mu\text{g}/\text{m}^3$ as an annual mean nitrogen dioxide concentration close to the carriageway. There are, potentially 2 properties immediately to the east

of the elevated section of the M40 which are within the $60 \mu\text{g}/\text{m}^3$ contour. The AQMA declaration will need to include the hourly objective, as a minimum, for these properties

- 3.5 The current M40 AQMA joins both Marlow Hill and London Road within the recommended High Wycombe AQMA area, southeast and southwest.



Figure 2 Modelled Annual Mean Nitrogen Dioxide Concentration Contours in 2009 within the west end of the study area (red line shows western boundary of Wycombe District Council). The red contour line represents $40 \mu\text{g}/\text{m}^3$, the blue contour line represents $36 \mu\text{g}/\text{m}^3$, and the green contour line represents $60 \mu\text{g}/\text{m}^3$. © Crown copyright 2010. All rights reserved, Wycombe DC. License number: 100023306



Figure 3 Modelled Annual Mean Nitrogen Dioxide Concentration Contours in 2009 along the M40 between Stokenchurch and High Wycombe (red dot is diffusion tube D). The red contour line represents $40 \mu\text{g}/\text{m}^3$, the blue contour line represents $36 \mu\text{g}/\text{m}^3$, and the green contour line represents $60 \mu\text{g}/\text{m}^3$. © Crown copyright 2010. All rights reserved, Wycombe DC. License number: 100023306



Figure 4 Modelled Annual Mean Nitrogen Dioxide Concentration Contours in 2009 along the M40 south of High Wycombe (red dot is diffusion tube H5). The red contour line represents $40 \mu\text{g}/\text{m}^3$, the blue contour line represents $36 \mu\text{g}/\text{m}^3$, and the green contour line represents $60 \mu\text{g}/\text{m}^3$. © Crown copyright 2010. All rights reserved, Wycombe DC. License number: 100023306

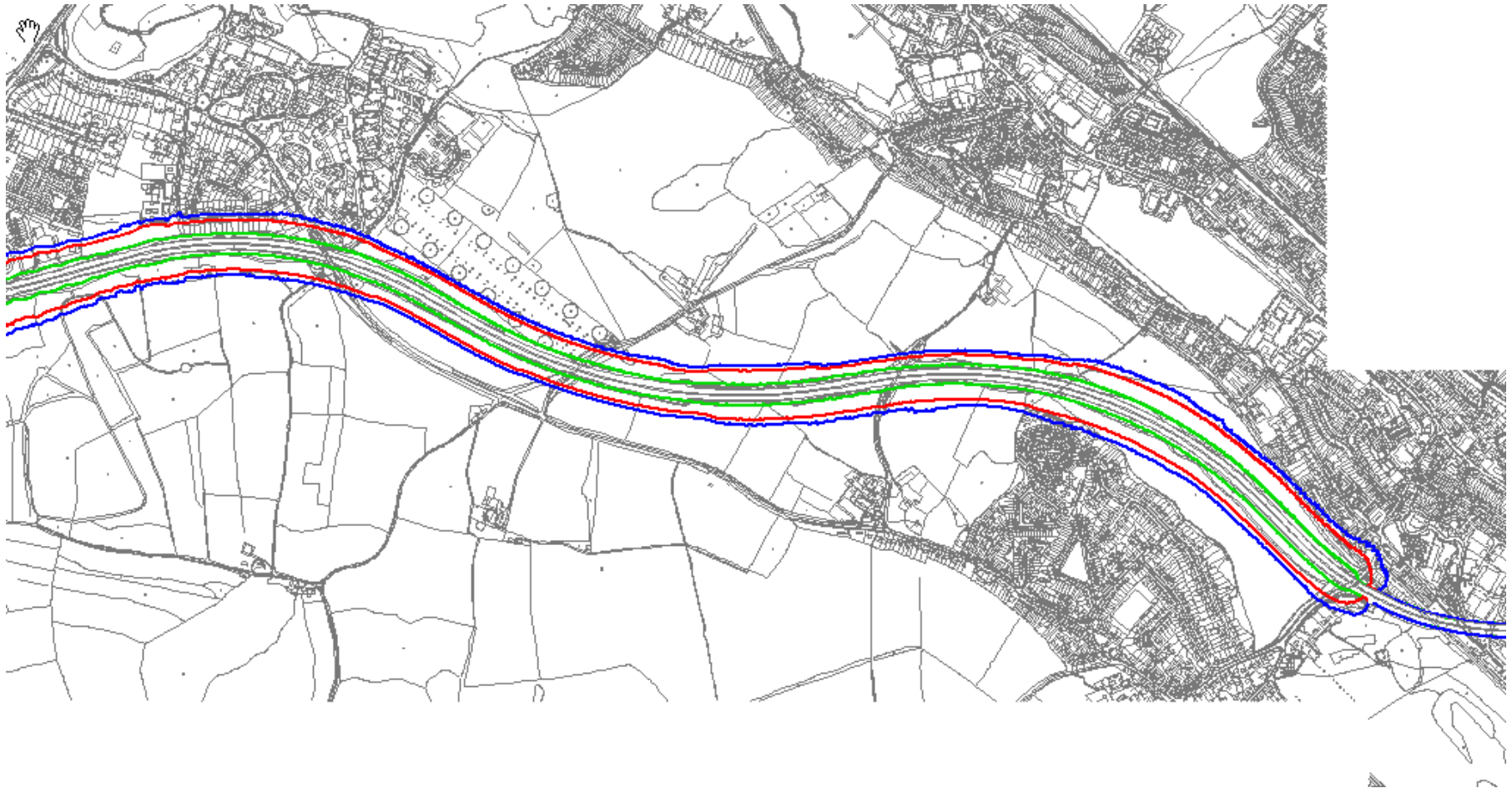


Figure 5 Modelled Annual Mean Nitrogen Dioxide Concentration Contours in 2009 along the M40 east of High Wycombe (red dot is diffusion tube A). The red contour line represents $40 \mu\text{g}/\text{m}^3$, the blue contour line represents $36 \mu\text{g}/\text{m}^3$, and the green contour line represents $60 \mu\text{g}/\text{m}^3$. Contours stop at the elevated section of motorway. © Crown copyright 2010. All rights reserved, Wycombe DC. License number: 100023306



Figure 6 Modelled Annual Mean Nitrogen Dioxide Concentration Contours in 2009 along the M40 at the east end of the District (red dot is diffusion tube A). The red contour line represents $40 \mu\text{g}/\text{m}^3$, the blue contour line represents $36 \mu\text{g}/\text{m}^3$, and the green contour line represents $60 \mu\text{g}/\text{m}^3$. Contours stop at the elevated section of motorway. © Crown copyright 2010. All rights reserved, Wycombe DC. License number: 100023306

4 Conclusions and Recommendations

- 4.1 A modelling study has been carried out for nitrogen dioxide along the M40 within Wycombe District Council. This area is currently an AQMA, but has been remodelled using up to date data and methodology in order to provide predictions of concentrations which are consistent with work undertaken within a Detailed Assessment of High Wycombe.
- 4.2 This study has been carried out using a combination of monitoring data and modelled concentrations. Concentrations of nitrogen dioxide have been modelled for 2009 using the ADMS-Roads dispersion model. The model has been verified against measurements made at three nitrogen dioxide diffusion tube monitoring locations and one real time site which lie adjacent to the M40.
- 4.3 The assessment has identified that the annual mean nitrogen dioxide objective is being exceeded along the length of the M40 included in the study. There are also two properties immediately to the east of the elevated section where potentially the hourly nitrogen dioxide objective is being exceeded.
- 4.4 There is some uncertainty surrounding both the measured and modelled concentrations. It is therefore recommended that an AQMA is declared to include, as a minimum, those residential properties that lie within the $36 \mu\text{g}/\text{m}^3$ contour, to be precautionary. This represents a distance of roughly 55-60m from the carriageway. Properties which are also predicted to exceed the $60 \mu\text{g}/\text{m}^3$ annual mean should also be declared for the hourly objective.
- 4.5 It is also recommended that Wycombe District Council continues monitoring nitrogen dioxide at the existing monitoring locations, and expand the network where possible.
- 4.6 It is further recommended that some locations adjacent to the M40 are included in the Further Assessment of the High Wycombe AQMA, particularly with regards to source apportionment and defining the reductions in emissions required to achieve the objective.

5 References

Defra, 2007. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, July 2007.

Defra, 2009. Review & Assessment: Technical Guidance LAQM.TG(09).

Defra, 2010a. National Atmospheric Emissions Inventory. www.naei.org.uk

Defra, 2010b. LAQM Support website. Available at:
www.defra.gov.uk/environment/quality/air/airquality/local/support/index.htm

Stationery Office, 2000. Air Quality Regulations, 2000, Statutory Instrument 928.

Stationery Office, 2002. Air Quality (England) (Amendment) Regulations, 2002, Statutory Instrument 3043.

WDC, 2009. 2009 Updating and Screening Assessment for Wycombe District Council. Available at:
<http://www.wycombe.gov.uk/council-services/environment/pollution/air-pollution/air-quality-monitoring.aspx>

WDC, 2010. 2010 Detailed Assessment.

6 Glossary

Standards	A nationally defined set of concentrations for nine pollutants below which health effects do not occur or are minimal.
Objectives	A nationally defined set of health-based concentrations for nine pollutants, seven of which are incorporated in Regulations, setting out the extent to which the standards should be achieved by a defined date, taking into account costs, benefits, feasibility and practicality. There are also vegetation-based objectives for sulphur dioxide and nitrogen oxides.
Exceedence	A period of time where the concentration of a pollutant is greater than the appropriate air quality objective.
AQMA	Air Quality Management Area
ADMS Roads	Atmospheric Dispersion Modelling System for Roads.
NO_x	Nitrogen oxides (taken as NO + NO ₂)
NO	Nitric Oxide
NO₂	Nitrogen dioxide.
mg/m³	Microgrammes per cubic metre.
Roadside	A site sampling between 1 m of the kerbside of a busy road and the back of the pavement. Typically this will be within 5 m of the road, but could be up to 15 m (Defra, 2009).
HDV	Heavy Duty Vehicle
LDV	Light Duty Vehicle
AADT	Annual Average Daily Traffic flows

A1 Appendix 1 – Summary of Health Effects of Nitrogen Dioxide

Table A1.1: Summary of Health Effects of Nitrogen Dioxide

Pollutant	Main Health Effects
Nitrogen Dioxide	Short-term exposure to high concentrations may cause inflammation of respiratory airways. Long term exposure may affect lung function and enhance responses to allergens in sensitised individuals. Asthmatics will be particularly at risk (Defra, 2007).

A2 Appendix 2 – Traffic Data

A2.1 The ADMS Roads model requires the user to provide various input data, including emissions from each section of road, and the road characteristics; e.g. whether there is a street canyon. Vehicle emissions have been calculated based on vehicle flow, composition and speed using the Emission Factor Toolkit (Version 4.2) published by Defra (Defra, 2010b).

A2.2 2009 AADT flows, and the proportions of HDVs have been provided by the local authority. Traffic speeds have been estimated from local speed restrictions, and take account of the proximity to junctions and pedestrian crossings. The traffic data used in this study are presented in Table A2.1, below.

Table A2.1: Summary of Traffic Data 2009

Road	AADT Flows	%HDV
M40 (J2 - J3 Wooburn)	121,176	14.5
M40 (J3 - J4 High Wycombe)	103,670	15.5
M40 (J4 - J5 Stokenchurch)	94,593	16.5
M40 (J5 - J6 Lewknor)	94,393	16.5

A3 Appendix 3 – Model Verification

- A3.1 Most nitrogen dioxide (NO₂) is produced in the atmosphere by reaction of nitric oxide (NO) with ozone. It is therefore most appropriate to verify the model in terms of primary pollutant emissions of nitrogen oxides (NO_x = NO + NO₂). The model has been run to predict the annual mean road-NO_x concentration during 2009 at the three diffusion tube monitoring sites and the automatic monitoring location described in Table 2, which lie alongside the roads included in the model.
- A3.2 The model output of road-NO_x (i.e. the component of total NO_x coming from road traffic) has been compared with the 'measured' road-NO_x. Measured road-NO_x for the diffusion tube sites was calculated from the measured NO₂ concentration and the predicted background NO₂ concentration using the recently updated NO_x from NO₂ calculator available on the LAQM Support website (Defra, 2010b).
- A3.3 A primary adjustment factor was determined as the slope of the best fit line between the 'measured' road contribution and the model derived road contribution, forced through zero (Figure A3.1). This factor was then applied to the modelled road-NO_x concentration for each receptor to provide adjusted modelled road-NO_x concentrations. The total nitrogen dioxide concentrations were then determined by combining the adjusted modelled road-NO_x concentrations with the predicted background NO₂ concentration within the recently updated NO_x from NO₂ calculator available on the LAQM Support website (Defra, 2010b). A secondary adjustment factor was finally calculated as the slope of the best fit line applied to the adjusted data and forced through zero (Figure A3.2).
- A3.4 The following primary and secondary adjustment factors have been applied to all modelled nitrogen dioxide data:
- Primary adjustment factor : 1.629
 - Secondary adjustment factor: 0.992
- A3.5 The results imply that the model was under-predicting the road-NO_x contribution. This is a common experience with this and most other models. The final NO₂ adjustment is minor.
- A3.6 Figure A3.3 compares final adjusted modelled total NO₂ at each of the monitoring sites, to measured total NO₂, and shows a 1:1 relationship.

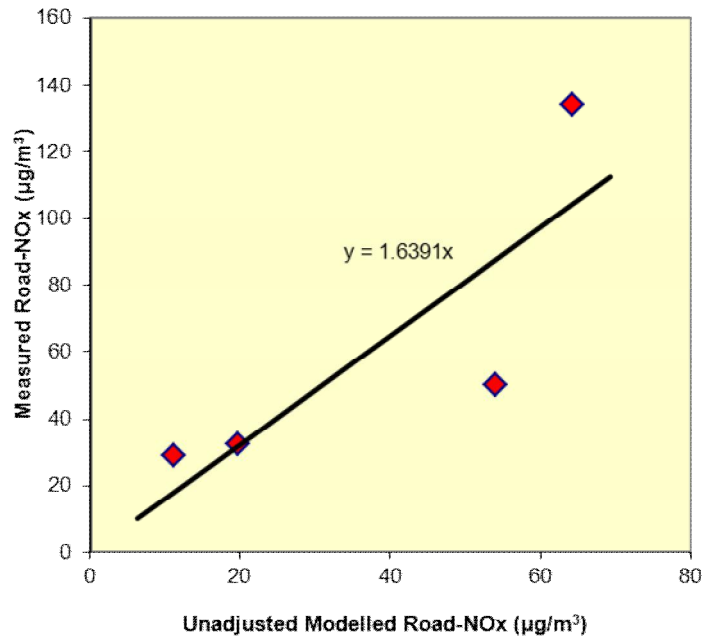


Figure A3.1: Comparison of Measured Road-NO_x to Unadjusted Modelled Road NO_x Concentrations

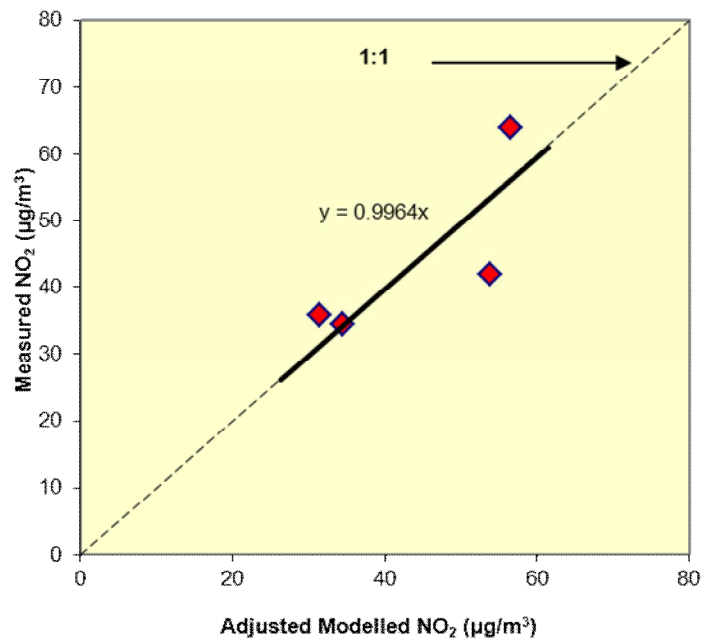


Figure A3.2: Comparison of Measured Total NO₂ to Primary Adjusted Modelled Total NO₂ Concentrations

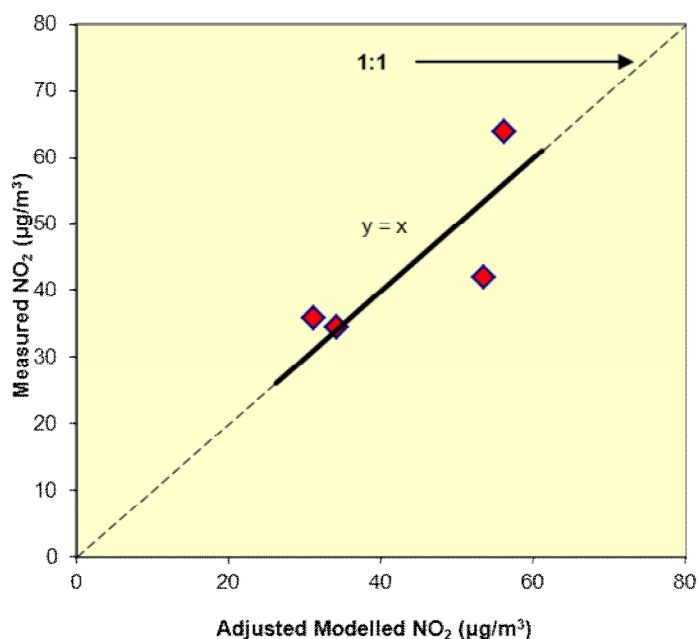


Figure A3.3: Comparison of Measured Total NO₂ to Final Adjusted Modelled Total NO₂ Concentrations

A4 Appendix 4 – Adjustment of Short-Term Data to Annual Mean

- A4.1 Diffusion tube H5 only had eight months data capture (January – March, August – December). As a result, data for these sites do not represent a full calendar year. Therefore, in accordance with the guidance in LAQM.TG(09) (Defra, 2009), the data have been adjusted to an annual mean, based on the ratio of concentrations during the short-term monitoring period to those over a full calendar year at four sites where long-term data are available.
- A4.2 The annual mean nitrogen dioxide concentrations and the period means for each of the four Herts and Beds network automatic monitoring sites from which adjustment factors have been calculated are presented in Table A4.1, along with the Overall Factors.

Table A4.1: Data used to Adjust Short-term Monitoring Data for the Period January – March, August - December (Tube H5) to a 2009 Annual Mean Equivalent

Monitoring Sites	St Albans	Dunstable	Hertsmere Borehamwood	Welwyn Hatfield	Average Ratio
Annual Mean ($\mu\text{g}/\text{m}^3$)	25.0	27.2	26.6	29.0	-
Period Mean ($\mu\text{g}/\text{m}^3$)	28.7	29.6	30.4	33.2	-
Ratio	0.87	0.92	0.88	0.87	0.89