Suffolk Coastal District Council

Air Quality Review and Assessment

Further Assessment for Woodbridge Junction, Woodbridge

Revised October 2007

Prepared by AEA Technology plc under contract to Suffolk Coastal District Council

Executive summary

The UK Government published its strategic policy framework for air quality management in 1995 establishing national strategies and policies on air quality, which culminated in the Environment Act, 1995. The Air Quality Strategy provides a framework for air quality control through air quality management and air quality standards. These and other air quality standards[1] and their objectives[2] have been enacted through the Air Quality Regulations in 1997 and 2000 and the Air Quality (Amendment) Regulations 2002. The Environment Act 1995 requires Local Authorities to undertake an air quality review. In areas where the air quality objective is not anticipated to be met, Local Authorities are required to establish Air Quality Management Areas to improve air quality.

The intention is that local authorities should only undertake a level of assessment that is proportionate to the risk of air quality objectives being exceeded. The first step in the second round of review and assessment is an Updating and Screening Assessment (USA), which is to be undertaken by all authorities. Where the USA has identified a risk that an air quality objective will be exceeded, the authority is required to undertake a detailed assessment.

Following the previous round of Detailed Air Quality Assessment, Suffolk Coastal District Council has declared an air quality management area (AQMA) for nitrogen dioxide in the Woodbridge junction area as:

- Woodbridge Junction, Woodbridge (junction of Lime Kiln Quay Rd, Thoroughfare and St John's St)

Following the declaration, Suffolk Coastal District Council has commissioned **AEA Energy & Environment** to undertake a Further Assessment for nitrogen dioxide (NO_2) in this declared Air Quality Management Area.

This report therefore constitutes a Further Assessment for Suffolk Coastal District Council. Only the impact of nitrogen dioxide emissions is considered in this report. This report investigates the nitrogen dioxide levels in 2006 (the base year) and 2010 through modelling exercises and by reference to the latest monitored air quality data.

Summary of the modelling predictions

For 2006, both monitoring and modelling indicate continued exceedences of the objective for annual mean NO2 concentrations at the Woodbridge junction, and the hourly mean objective is unlikely to have been exceeded.

No exceedences of the objectives for NO_2 concentrations are predicted at the junction in 2010.

The source apportionment analysis shows that local traffic contributes about 90% of the total local NOx and vehicles waiting in queues produce about 60% of the traffic NOx at the junction.

Recommendations

- Suffolk Coastal District Council should retain the AQMA declared at the junction.
- Suffolk Coastal District Council should continue monitoring at all sites to confirm the predicted trend between now and 2010 with a few alterations.

[1] Refers to standards recommended by the Expert Panel on Air Quality Standards. Recommended standards are set purely with regard to scientific and medical evidence on the effects of the particular pollutants on health, at levels at which risks to public health, including vulnerable groups, are very small or regarded as negligible.
[2] Refers to objectives in the Strategy for each of the eight pollutants. The objectives provide policy targets by outlining what should be achieved in the light of the air quality standards and other relevant factors and are expressed as a given ambient concentration to be achieved within a given timescale.

- Suffolk Coastal District Council should consider revoking diffusion tube WBG 19 in St John Street.
- A reduction of vehicle emitted NOx by 16.4% would have eliminated the exceedences to the objective for annual mean NO_2 concentration in 2006. Queuing and HDV reductions will be the keys to improve air quality at the junction.

Maps reproduced within this document

Table of contents

Appendices

Acronyms and definitions used in this report

AADTF	Annual Average Daily Traffic Flow
ADMS	an atmospheric dispersion model
AQDD	an EU directive (part of EU law) - Common Position on Air Quality Daughter Directives, commonly referred to as the Air Quality Daughter Directive
AQMA	Air Quality Management Area
AQS	Air Quality Strategy
AURN	Automatic Urban and Rural Network (Defra funded network)
base case	In the context of this report, the emissions or concentrations predicted at the date of the relevant air quality objective (2005 for nitrogen dioxide)
CO	Carbon monoxide
d.f.	degrees of freedom (in statistical analysis of data)
DETR	Department of the Environment Transport and the Regions (now Defra)
Defra	Department of the Environment, Food and Rural Affairs
DMRB	Design Manual for Roads and Bridges
EA	Environment Agency
EPA	Environmental Protection Act
EPAQS	Expert Panel on Air Quality Standards (UK panel)
EU	European Union
GIS	Geographical Information System
HDV	All commercial vehicles, including HGV , buses and coaches
HGV	Vehicles > 7.5T
kerbside	0 to 1 m from the kerb
LGV	Vehicles 3.5 –7.5 T
Limit Value	An EU definition for an air quality standard of a pollutant listed in the air quality directives
NAEI	National Atmospheric Emission Inventory
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NRTF	National Road Traffic Forecast
ppb	parts per billion (1 ppb is 1 volume of pollutant in 10^9 volumes of air
PSG	All buses and coaches
r	the correlation coefficient (between two variables)
receptor	In the context of this study, the relevant location where air quality is assessed or predicted (for example, houses, hospitals and schools)
roadside	1 to 5 m from the kerb
SD	standard deviation (of a range of data)
SEPA	Scottish Environment Protection Agency
SO_2	Sulphur dioxide
TEA	Triethanolamine
TEMPRO	A piece of software produced by the Defra used to forecast traffic flow increases
TEOM	Tapered Element Oscillating Microbalance
TEOM (Grav.)	TEOM Measurements expressed as the equivalent value from a gravimetric monitor
V/V	Volume ratio

1 Introduction

1.1 Purpose of the study

Suffolk Coastal District Council have completed a 'Detailed' assessment which concluded that they needed to declare an air quality management area (AQMA) for NO_2 at the following location in the district:

- Woodbridge Junction, Woodbridge (junction of Lime Kiln Quay Rd, Thoroughfare and St John's St)

Following the declaration of this AQMA Suffolk Coastal District Council is required to complete a 'Further' assessment for NO_2 at this location in order to confirm the conclusions of the 'Detailed' assessment, to conduct source apportionment analysis and to assess potential measures which could be considered in the Council's Action Plan. The Council will then be required to proceed to completion of an Action Plan aimed at bringing about the required improvements in air quality.

1.2 General Approach taken

The approach taken in this study was to:

- Collect and interpret additional data to that already used in previous assessments, in order to support the Further Assessment, including more detailed traffic flow data around the areas outlined above;
- Utilise the monitoring data from the Council's monitoring campaign to assess the ambient concentrations resulting from road traffic emissions, and to validate the output of the modelling studies;
- Model the concentrations of NO_2 around the AQMA in 2006 and in 2010 concentrating on the locations (receptors) where people might be exposed over the relevant averaging times of the air quality objectives;
- Present the concentrations as contour plots and assess the uncertainty in the predicted concentrations;
- Undertake source apportionment analysis, where exceedences are predicted.

1.3 Version of the Pollutant Specific Guidance used in this assessment

This report has used the latest guidance in LAQM.TG(03), published in February 2003.

1.4 Numbering of figures and tables

The numbering scheme is not sequential, and the figures and tables are numbered according to the chapter and section that they relate to.

1.5 Units of concentration

The units throughout this report are presented in $\mu g\ m^{-3}$ (which is consistent with the presentation of the new AQS objectives), unless otherwise noted.

1.6 Structure of the report

This document is a further air quality review and assessment for Suffolk Coastal District Council for nitrogen dioxide at the Woodbridge Junction.

Chapter 1 has summarised the need for the work and the approach to complete the study.

Chapter 2 of the report describes developments in the UK's Air Quality Strategy (AQS). In addition, it discusses when implementation of an AQMA is required.

Chapter 3 contains details of the information used to conduct this Further Assessment for Suffolk Coastal District Council.

Chapter 4 introduces the latest standards and objectives for nitrogen dioxide, summarises the monitoring of NO_2 that has taken place in the area of concern and model validation against these monitoring data.

Chapter 5 describes the results of the modelling assessment and discusses whether the nitrogen dioxide objectives will be exceeded in 2006 (the base case) and in 2010. The results of the analysis are displayed as contour plots. Source apportionment is presented to illustrate the contributions from different sources of pollutants to the predicted exceedences.

Chapter 6 summarises the recommendations from this study.

1.7 GIS data used

Suffolk Coastal District Council provided the Ordnance Survey landline data for use in this project.

1.8 Explanation of the modelling output

The contour maps generated in the modelling for this report are an indication of the predicted pollutant concentrations around the area modelled. They are not lines of absolute values and should not be considered as such. Care should also be taken, in cases where contours join up as enclosed loops. This is common, for example along a section of road. The contours may appear to circle a section of the road, rather than extend all the way along it. This is due to the input area over which the model was run being only a section of the road in question. No assumptions of pollutant concentrations can be made on locations outside of the area being modelled.

2 The updated Air Quality Strategy

2.1 The need for an Air Quality Strategy

The Government published its proposals for review of the National Air Quality Strategy in early 1999 (DETR, 1999). These proposals included revised objectives for many of the regulated pollutants. A key factor in the proposals to revise the objectives was the agreement in June 1998 at the European Union Environment Council of a Common Position on Air Quality Daughter Directives (AQDD).

Following consultation on the Review of the National Air Quality Strategy, the Government prepared the Air Quality Strategy for England, Scotland, Wales and Northern Ireland for consultation in August 1999. It was published in January 2000 (DETR, 2000).

The Environment Act (1995) provides the legal framework for requiring LA's to review air quality and for implementation of an AQMA. The main constituents of this Act are summarised in Table 2.1 below.

Table 2.1 Major elements of the Environment Act 1995

Part IV Air Quality	Commentary
Section 80	Obliges the Secretary of State (SoS) to publish a National Air Quality Strategy as soon as possible.
Section 81	Obliges the Environment Agency to take account of the strategy.
Section 82	Requires local authorities, any unitary or Borough, to review air quality and to assess whether the air quality standards and objectives are being achieved. Areas where standards fall short must be identified.
Section 83	Requires a local authority, for any area where air quality standards are not being met, to issue an order designating it an air quality management area (AQMA).
Section 84	Imposes duties on a local authority with respect to AQMAs. The local authority must carry out further assessments and draw up an action plan specifying the measures to be carried out and the timescale to bring air quality in the area back within limits.
Section 85	Gives reserve powers to cause assessments to be made in any area and to give instructions to a local authority to take specified actions. Authorities have a duty to comply with these instructions.
Section 86	Provides for the role of County Councils to make recommendations to a district on the carrying out of an air quality assessment and the preparation of an action plan.
Section 87	Provides the SoS with wide ranging powers to make regulations concerning air quality. These include standards and objectives, the conferring of powers and duties, the prohibition and restriction of certain activities or vehicles, the obtaining of information, the levying of fines and penalties, the hearing of appeals and other criteria. The regulations must be approved by affirmative resolution of both Houses of Parliament.
Section 88	Provides powers to make guidance which local authorities must have regard to.

2.2 Overview of the principles and main elements of the National Air Quality Strategy

The main elements of the AQS can be summarised as follows:

- The use of a health effects based approach using national air quality standards and objectives.
- The use of policies by which the objectives can be achieved and which include the input of important factors such as industry, transportation bodies and local authorities.
- The predetermination of timescales with target dates of 2003, 2004, 2005, 2008 and 2010 for the achievement of objectives and a commitment to review the Strategy every three years.

It is intended that the AQS will provide a framework for the improvement of air quality that is both clear and workable. In order to achieve this, the Strategy is based on several principles which include:

- the provision of a statement of the Government’s general aims regarding air quality;
- clear and measurable targets;
- a balance between local and national action and
- a transparent and flexible framework.

Co-operation and participation by different economic and governmental sectors is also encouraged within the context of existing and potential future international policy commitments.

National Air Quality Standards

At the centre of the AQS is the use of national air quality standards to enable air quality to be measured and assessed. These also provide the means by which objectives and timescales for the achievement of objectives can be set. Most of the proposed standards have been based on the available information concerning the health effects resulting from different ambient concentrations of selected pollutants and are the consensus view of medical experts on the Expert Panel on Air Quality Standards (EPAQS). These standards and associated specific objectives to be achieved between 2003 and 2010 are shown in Table 2.2. The table shows the standards in ppb and $\mu g\ m^{-3}$ with the number of exceedences that are permitted (where applicable) and the equivalent percentile.

Specific objectives relate either to achieving the full standard or, where use has been made of a short averaging period, objectives are sometimes expressed in terms of percentile compliance. The use of percentiles means that a limited number of exceedences of the air quality standard over a particular timescale, usually a year, are permitted. This is to account for unusual meteorological conditions or particular events such as November 5th. For example, if an objective is to be complied with at the 99.9th percentile, then 99.9% of measurements at each location must be at or below the level specified.

Table 2.2 Air Quality Objectives in the Air Quality Regulations (2000) and (Amendment) Regulations 2002 for the purpose of Local Air Quality Management.

Pollutant	Concentration limits		**Averaging period**	**Objective** [number of permitted exceedences a year and equivalent percentile]	
	(μg m^{-3})	(ppb)		(**μg m^{-3}**)	date for objective
Benzene	16.25	5	**running annual** mean	**16.25**	by 31.12.2003
	5	1.5	**Annual mean**	**5**	by 31.12.2010
1,3-butadiene	2.25	1	**running annual** mean	**2.25**	by 31.12.2003
CO	10,000	8,600	**running 8-hour** mean	**10,000**	by 31.12.2003
Pb	0.5	-	**annual** mean	**0.5**	by 31.12.2004
	0.25	-	**annual** mean	**0.25**	by 31.12.2008
NO_2 (see note)	200	105	**1 hour** mean	**200** [maximum of 18 exceedences a year or equivalent to the 99.8th percentile]	by 31.12.2005
	40	21	**annual** mean	**40**	by 31.12.2005
PM_{10} gravimetric (see note)	50	-	**24-hour** mean	**50** [maximum of 35 exceedences a year or ~ equivalent to the 90th percentile]	by 31.12.2004
	40	-	**annual** mean	**40**	by 31.12.2004
SO_2	266	100	**15 minute** mean	**266** [maximum of 35 exceedences a year or equivalent to the 99.9th percentile]	by 31.12.2005
	350	132	**1 hour** mean	**350** [maximum of 24 exceedences a year or equivalent to the 99.7th percentile]	by 31.12.2004
	125	47	**24 hour** mean	**125** [maximum of 3 exceedences a year or equivalent to the 99th percentile]	by 31.12.2004

Notes

1. Conversions of ppb and ppm to (μg m^{-3}) correct at 20°C and 1013 mb.
2. The objectives for nitrogen dioxide are provisional.

PM_{10} measured using the European gravimetric transfer standard or equivalent.

Relationship between the UK National Air Quality Standards and EU air quality Limit Values

As a member state of the EU, the UK must comply with EU Directives.

There are three EU ambient air quality directives that the UK has transposed in to UK law. These are:

- **96/62/EC** Council Directive of 27 September 1996 on ambient air quality assessment and management (the Ambient Air Framework Directive).

- **1999/30/EC** Council Directive of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide, oxides of nitrogen, particulate matter and lead in ambient air (the First Daughter Directive).

- **2000/69/EC** Directive of the European Parliament and the Council of 16 Nov 2000 relating to limit values for benzene and carbon monoxide in ambient air (the Second Daughter Directive).

The first and second daughter directives contain air quality Limit Values for the pollutants that are listed in the directives. The United Kingdom (i.e. Great Britain and Northern Ireland) must comply with these Limit Values. The UK air quality strategy should allow the UK to comply with the EU Air Quality Daughter Directives, but the UK air quality strategy also includes some stricter national objectives for some pollutants, for example, the 15-minute sulphur dioxide objective.

The Government is ultimately responsibility for achieving the EU limit values. However, it is important that Local Air Quality Management is used as a tool to ensure that the necessary action is taken at local level to work towards achieving the EU limit values by the dates specified in those EU Directives.

New particle objectives (not included in Regulations[3])

For particulates (as PM10) new objectives are proposed.

- For all parts of the UK, except London and Scotland, a 24 hour mean of 50 $\mu g/m^3$ not to be exceeded more than 7 times a year and an annual mean of 20 $\mu g/m^3$, both to be achieved by the end of 2010;
- For London, a 24 hour mean of 50 $\mu g/m^3$ not to be exceeded more than 10 times a year and an annual mean of 23 $\mu g/m^3$, both to be achieved by the end of 2010;
- For Scotland, a 24 hour mean of 50 $\mu g/m^3$ not to be exceeded more than 7 times a year and an annual mean of 18 $\mu g/m^3$, both to be achieved by the end of 2010.

Policies in place to allow the objectives for the pollutants in AQS to be achieved

The policy framework to allow these objectives to be achieved is one that that takes a local air quality management approach. This is superimposed upon existing national and international regulations in order to effectively tackle local air quality issues as well as issues relating to wider spatial scales. National and EC policies that already exist provide a good basis for progress towards the air quality objectives set for 2003 to 2008. For example, the Environmental Protection Act 1990 allows for the monitoring and control of emissions from industrial processes and various EC Directives have ensured that road transport emission and fuel standards are in place. These policies are being developed to include more stringent controls. Developments in the UK include the announcement by the Environment Agency in January 2000 of controls on emissions of SO_2 from coal and oil fired power stations. This system of controls means that by the end of 2005 coal and oil fired power stations were expected to meet the air quality standards set out in the AQS.

Local air quality management provides a strategic role for local authorities in response to particular air quality problems experienced at a local level. This builds upon current air quality control responsibilities and places an emphasis on bringing together issues relating to transport, waste, energy and planning in an integrated way. This integrated approach involves a number of different aspects. It includes the development of an appropriate local framework that allows air quality issues to be considered alongside other issues relating to polluting activity. It should also enable co-operation with and participation by the general public in addition to other transport, industrial and governmental authorities.

[3] The exception is the Scottish Executive which has incorporated the new PM10 objectives in their Regulations.

An important part of the Strategy is the requirement for local authorities to carry out air quality reviews and assessments of their area against which current and future compliance with air quality standards can be measured. Over the longer term, these will also enable the effects of policies to be studied and therefore help in the development of future policy. The Government has prepared guidance to help local authorities to use the most appropriate tools and methods for conducting a review and assessment of air quality in their District. This is part of a package of guidance being prepared to assist with the practicalities of implementing the AQS. Other guidance covers air quality and land use planning, air quality and traffic management and the development of local air quality action plans and strategies.

Timescales to achieve the objectives

In most local authorities in the UK, objectives will be met for most of the pollutants within the timescale of the objectives shown in Table 2.2. It is important to note that the objectives for NO_2 remain provisional. The Government has recognised the problems associated with achieving the standard for ozone and this will not therefore be a statutory requirement. Ozone is a secondary pollutant and transboundary in nature and it is recognised that local authorities themselves can exert little influence on concentrations when they are the result of regional primary emission patterns.

2.3 Air Quality Reviews

A range of Technical Guidance has been issued to enable air quality to be monitored, modelled, reviewed and assessed in an appropriate and consistent fashion. This includes LAQM.TG(03), on 'Local Air Quality Management: Technical Guidance, February 2003. This review and assessment has considered the procedures set out in the guidance.

The primary objective of undertaking a review of air quality is to identify any areas that are unlikely to meet national air quality objectives and ensure that air quality is considered in local authority decision-making processes. The complexity and detail required in a review depends on the risk of failing to achieve air quality objectives and it has been proposed in the second round that reviews should be carried out in two stages. Every authority is expected to undertake at least a first stage Updating and screening Assessment (USA) of air quality in their authority area. Where the USA has identified a risk that an air quality objective will be exceeded at a location with relevant public exposure, the authority will be required to undertake a Further assessment. The Stages are briefly described in the following table, Table 2.3.

Table 2.3: The phased approach to review and assessment.

Level of assessment	Objective	Approach
Updating and screening assessment (USA)	To identify those matters that have changed since the last review and assessment, which might lead to a risk of the air quality objective being exceeded.	Use a checklist to identify significant changes that require further consideration. Where such changes are identified, apply simple screening tools to decide whether there is sufficient risk of an exceedence of an objective to justify a Further assessment
Detailed assessment	To provide an accurate assessment of the likelihood of an air quality objective being exceeded at locations with relevant exposure. To recommend designation or amendment of AQMAs when needed.	Use quality-assured monitoring and validated modelling methods to determine current and future pollutant concentrations in areas where there is a significant risk of exceeding an air quality objective.
Further assessment	To confirm boundaries of identified areas of exceedence using the latest and most detailed input information available. To provide source apportionment information to identify primary emissions sources contributing to exceedences so that action planning measures can be targeted. To test out the likely impact of potential action planning scenarios if possible.	Use quality-assured monitoring and validated modelling methods to determine current and future pollutant concentrations in areas where there is a significant risk of exceeding an air quality objective.

2.4 Locations that the review and assessment must concentrate on

For the purpose of review and assessment, the authority should focus their work on locations where members of the public are likely to be exposed over the averaging period of the objective. Table 2.4 summarises the locations where the objectives should and should not apply.

Table 2.4 Typical locations where the objectives should and should not apply (England only)

Averaging Period	Pollutants	Objectives *should* apply at …	Objectives should *not* generally apply at …
Annual mean	• 1,3 Butadiene • Benzene • Lead • Nitrogen dioxide • Particulate Matter (PM_{10})	• All background locations where members of the public might be regularly exposed.	• Building façades of offices or other places of work where members of the public do not have regular access.
		• Building façades of residential properties, schools, hospitals, libraries etc.	• 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	• Carbon monoxide • Particulate Matter (PM_{10}) • Sulphur dioxide	• All locations where the annual mean objective would apply.	• Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.
		• Gardens of residential properties.	

Table 2.4 (contd.) Typical locations where the objectives should and should not apply (England only)

Averaging Period	Pollutants	Objectives should apply at …	Objectives should generally not apply at …
1 hour mean	• Nitrogen dioxide • Sulphur dioxide	• All locations where the annual mean and 24 and 8-hour mean objectives 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 and railway stations etc. which are not fully enclosed.	
		• Any outdoor locations to which the public might reasonably expected to have access.	
15 minute mean	• Sulphur dioxide	• All locations where members of the public might reasonably be exposed for a period of 15 minutes or longer.	

It is unnecessary to consider exceedences of the objectives at any location where public exposure over the relevant averaging period would be unrealistic, and the locations should represent non-occupational exposure.

Key Points

- The Environment Act 1995 has required the development of a National Air Quality Strategy for the control of air quality.
- A central element in the Strategy is the use of air quality standards and associated objectives based on human health effects that have been included in the Air Quality Regulations.
- The Strategy uses a local air quality management approach in addition to existing national and international legislation. It promotes an integrated approach to air quality control by the various factors and agencies involved.
- Air quality objectives, with the exception of ozone, are to be achieved by specified dates up to the end of 2010.

3 Information used to support this assessment

This chapter summarises the information used to support this review and assessment.

3.1 Maps

Suffolk Costal District Council provided OS Landline data for the area, which needed to be modelled. This enabled accurate road widths and the distance of the housing to the kerb to be determined.

3.2 Road traffic data

AADT flow, hourly fluctuations in flow, speed and fraction of HDVs.

As suggested by the previous detailed assessment, Suffolk Costal District Council carried out an 11-hour and a 14-day traffic survey in the Woodbridge junction area in November/December 2005. The survey results are summarised in Tables A1.1 - A1.3 in Appendix 1. The 11-hour manual survey data was scaled up to predict AADTs using a factor of 1.207 provided by the council. Where discrepancies occurred between the estimated AADTs based on these two traffic surveys, the higher values were used in this assessment as the conservative estimations.

Table A1.4 in Appendix 1 summaries the additional traffic flows at the Woodbridge junction due to committed developments which will be completed before 2010, but are not included in the traffic surveys. The committed developments include:

- Annington Development, Sutton
- RAF Woodbridge Airfield Barracks
- Rendlesham Enterprise Park and New Rendlesham development
- Deben Mill development, Woodbridge
- Oak Lane Car Park development, Woodbridge
- Redevelopment of Woodbridge Primary School, New Street, Woodbridge
- Redevelopment of Woodbridge Library Site, New Street, Woodbridge
- Notcutts Garden Centre, Ipswich Road, Woodbridge
- Former Gas works site, Station Road, Woodbridge
- Former Goods Shed – W R Refrigeration Ltd building, Station Road, Woodbridge
- Snape Maltings expansion, Snape

The TEMPRO growth factors for the Woodbridge area are given in Table A1.5 in Appendix 1.

Suffolk County Council carried out detailed hourly traffic counts at Woodbridge junction between 24th November 2005 and 27th November 2005, as summarised in Table A1.6 in Appendix 1, and the results were used to determine the hourly fluctuations of traffic flow in the model.

3.3 Meteorological data used in the dispersion modelling

Hourly sequential meteorological data for the nearest suitable meteorological station with adequate data capture was obtained in Mildenhall for 2006 and was used for this assessment. The meteorological data provided information on wind speed and direction and the extent of cloud cover for each hour of the year.

3.4 Ambient monitoring

Nitrogen dioxide concentrations are monitored:

- By a continuous automatic monitor outside 93 Thoroughfare at the junction. The monitor has been managed by AEA Energy & Environment since 2004 and has been at its current location since 04/01/2006. The air quality report of this monitor in 2006 is given in table A2.1 of Appendix 2.

- By 17 diffusion tubes at 13 sites in the area. Diffusion tube results are available at 12 roadside locations (two of them are triplicate sites) and one rural background site in 2006. The tubes were supplied and analysed by Harwell Scientific Services. The unadjusted monthly diffusion tube data and their average concentrations in 2006 are given in table A2.2 of Appendix 2.

- A collocation study was undertaken at the site of the automatic monitor, i.e. outside 93 Thoroughfare with diffusion tubes WBG 1a,b,c.

- The regional background NO_2 concentrations were taken from the nearest rural AURN site at St Osyth (OS co-ordinates 610200 213200).

3.5 Computer modelling

The modelling programmes used in this assessment make a number of assumptions during the calculations. These include no consideration of terrain relief, or direct consideration of buildings over the surface being modelled. Modelling of pollutant concentrations on roads can sometimes provide misleading information on produced contour maps. For example, polygons and circles on certain areas of the contour maps, e.g. roundabouts or the centres of roads, can be generated. This is not a deficiency in the model – it is an artefact of the data. As such, these additional features should be ignored and the wider context and implications of the contour maps be considered.

4 Nitrogen Dioxide Monitoring and Model Bias

4.1 Introduction

Nitrogen oxides are formed during high temperature combustion processes from the oxidation of nitrogen in the air or fuel. The principal source of nitrogen oxides, nitric oxide (NO) and nitrogen dioxide (NO_2), collectively known as $NO_{x,}$ is road traffic, which is responsible for approximately half the emissions in Europe. NO and NO_2 concentrations are therefore greatest in urban areas where traffic is heaviest. Other important sources are power stations, heating plant and industrial processes.

Nitrogen oxides are released into the atmosphere mainly in the form of NO, which is then readily oxidised to NO_2 by reaction with ozone. Elevated levels of NO_x occur in urban environments under stable meteorological conditions, when the air mass is unable to disperse.

Nitrogen dioxide has a variety of environmental and health impacts. It is a respiratory irritant, may exacerbate asthma and possibly increase susceptibility to infections. In the presence of sunlight, it reacts with hydrocarbons to produce photochemical pollutants such as ozone. In addition, nitrogen oxides have a lifetime of approximately 1-day with respect to conversion to nitric acid. This nitric acid is in turn removed from the atmosphere by direct deposition to the ground, or transfer to aqueous droplets (e.g. cloud or rainwater), thereby contributing to acid deposition.

4.2 Latest standards and objectives for nitrogen dioxide

The National Air Quality Regulations (1997) set two provisional objectives to have been achieved by 2005 for nitrogen dioxide:

- An annual average concentration of 40 $\mu g\ m^{-3}$ (21 ppb);
- A maximum hourly concentration of 286 $\mu g\ m^{-3}$ (150 ppb).

In June 1998, the Common Position on Air Quality Daughter Directives (AQDD) agreed at Environment Council included the following objectives to be achieved by 31 December 2005 for nitrogen dioxide:

- An annual average concentration of 40 $\mu g\ m^{-3}$ (21 ppb);
- 200 $\mu g\ m^{-3}$ (100 ppb) as an hourly average with a maximum of 18 exceedences in a year.

The National Air Quality Strategy was reviewed in 1999. The Government proposed that the annual objective of 40 $\mu g\ m^{-3}$ be retained as a provisional objective and that the original hourly average be replaced with the AQDD objective. The revised Air Quality Strategy for England, Scotland, Wales and Northern Ireland (DETR, 1999; 2000) included the proposed changes. Modelling studies suggest that in general achieving the annual mean of 40 $\mu g\ m^{-3}$ is more demanding than achieving the hourly objective. If the annual mean is achieved, the modelling suggests the hourly objectives will also be achieved.

4.3 The National Perspective

The main source of NO_x in the United Kingdom is road transport, which, in 2003 accounted for approximately 40% of emissions. Power generation contributed approximately 29% and domestic sources 5%. In urban areas, the proportion of local emissions due to road transport sources is larger (NAEI, 2005).

National measures are expected to produce reductions in NO_x emissions and achieve the objectives for NO_2 in many parts of the country. However, the results of the analysis set out in the National Air Quality Strategy suggested that for NO_2 a reduction in NO_x emissions over and above that achievable by national measures would be required to ensure that air quality objectives were achieved everywhere by the end of 2005. Local authorities with major roads, or highly congested roads, which have the potential to result in elevated levels of NO_2 in relevant locations, are expected to identify a need to progress to a Further Assessment for this pollutant.

4.4 Summary of the 2005 detailed assessment

Diffusion tube results for 2004 showed exceedences at sites WBG 1, WBG 6 and WBG 8 (as shown in Figure 4.1a). It was predicted that WBG1 and WBG 6 were also likely to exceed the objective in 2005 (Beth Conlan, 2005).

The modelling results of the 2005 detailed assessment showed that it was at most ***probable*** (with probability between 50% and 80%) that an exceedence of the annual objective would occur in 2005 at:

- Woodbridge Junction, Woodbridge

At all receptor locations it was assessed that the risk of the UK objective for hourly NO_2 in 2005 being exceeded was at most ***unlikely*** (with probability between 5% and 20%).

The modelling results also indicated that there was a marginal exceedence for two properties at Melton Hill, Woodbridge. Owing to the high concentrations measured along the western pavement of Melton Hill, it was recommended that the Council should undertake traffic surveys at this location to further characterise traffic flows along this road. In particularly, detailed observation with regards to traffic congestion, queuing, location of delivery points and frequency should be taken adjacent to monitoring locations.

Following the 2005 Detailed Assessment, Suffolk Coastal District Council has declared an AQMA at Woodbridge Junction as shown in Figure 4.1a. Relevant receptors included in the AQMA are No 85, 87, 89-91, 93 (excluding ground-floor shop front), 95 and 97 of Thoroughfare, Woodbridge. No 2 Sun Lane (adjoining 95 Thoroughfare inside the AQMA) is not a receptor as it is part of Jewson Builder Merchants.

As suggested by the 2005 Detailed Assessment, Suffolk County Council had carried out road traffic survey in 2006 at three locations in roads leading to the roundabout, i.e. St John's Street, Quay Street (linked to Lime Kiln Quay Road) and Melton Hill as illustrated in Figure 4.1a. The survey results (including daily traffic flows, vehicle queues and hourly traffic flows) are summarised in Appendix 1 and briefly described in Section 3.2, and were used for this assessment

Figure 4.1a Monitoring sites around the Woodbridge Junction area in 2006

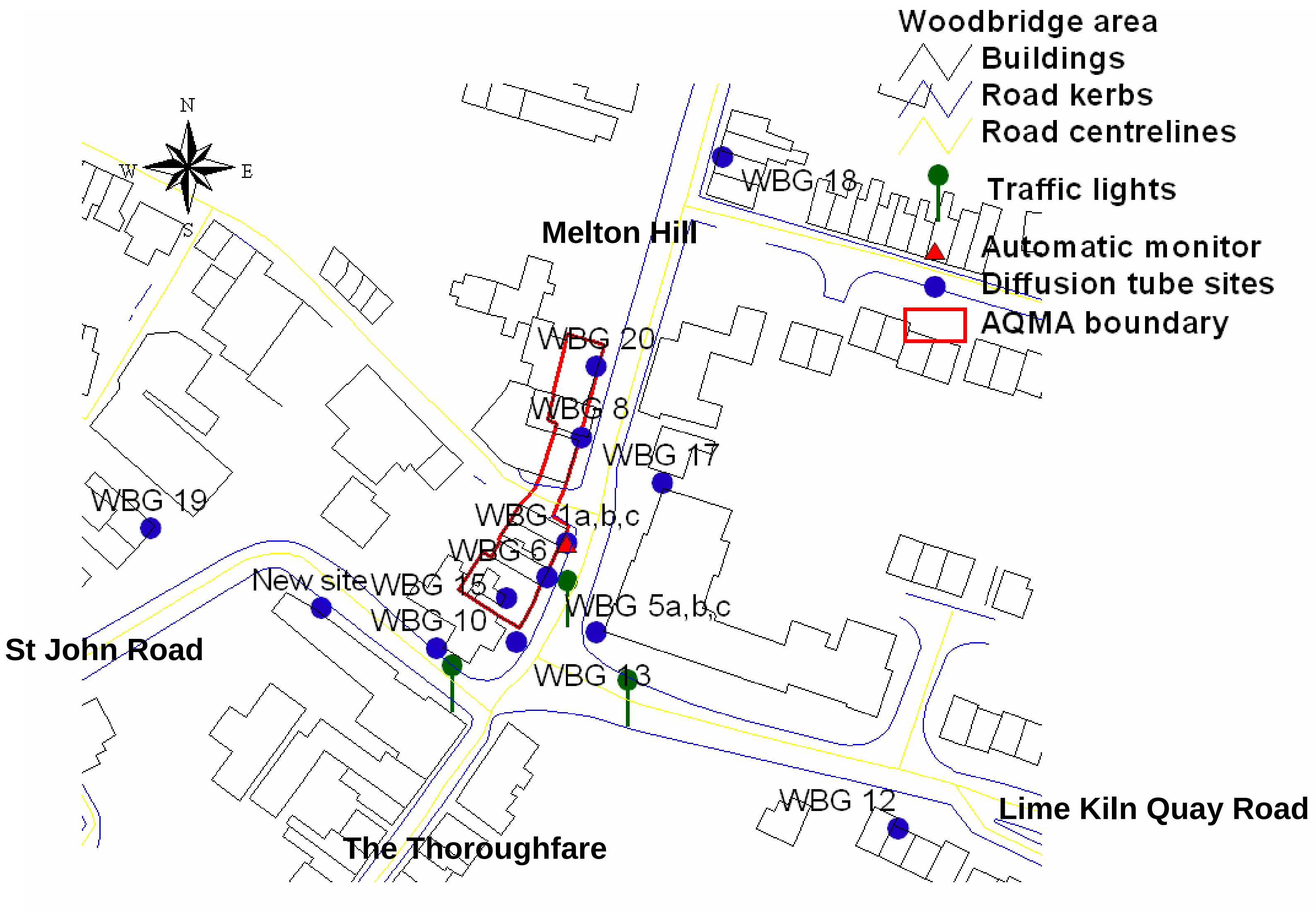
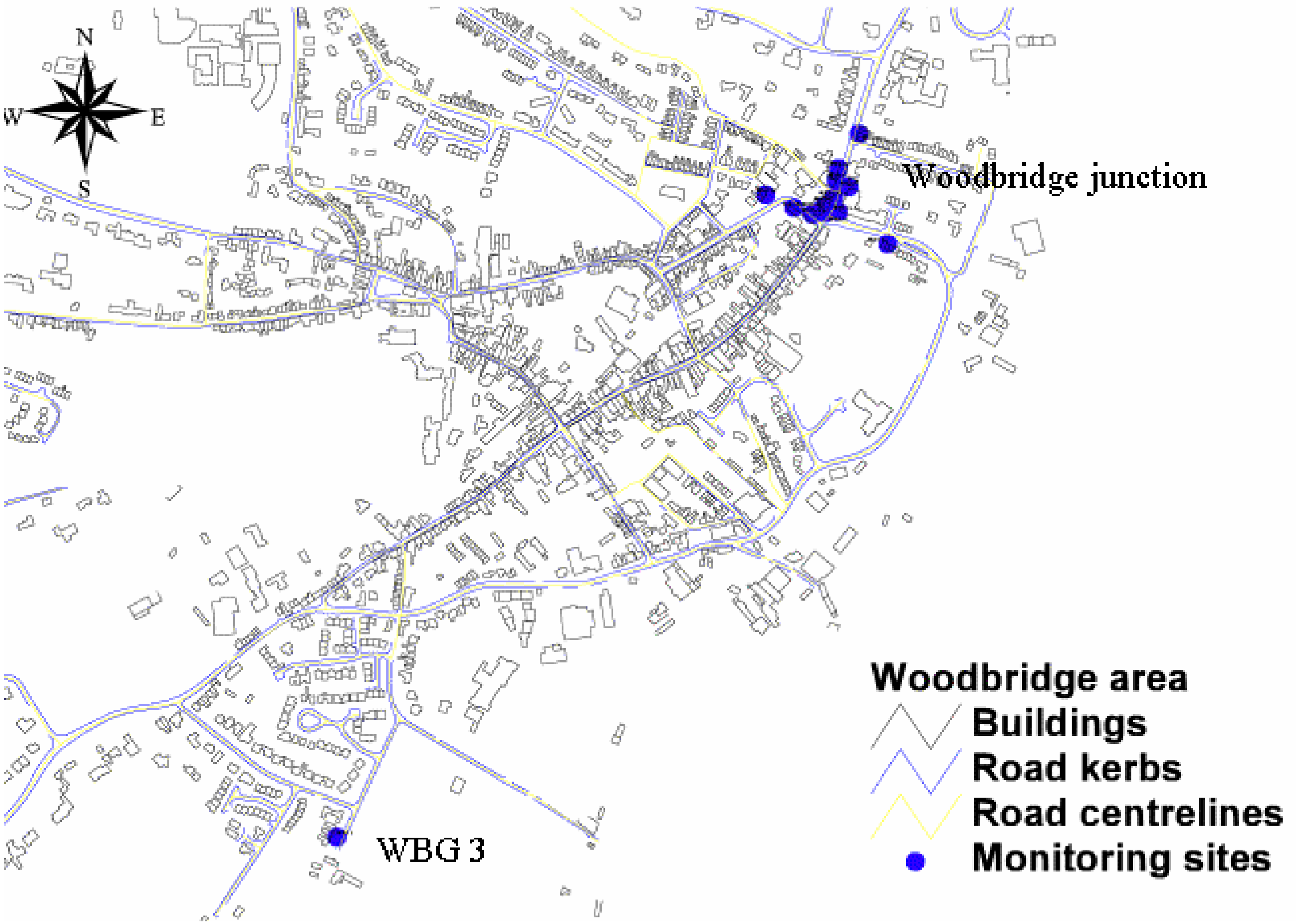


Figure 4.1b The background Monitoring site near to the Woodbridge Junction area in 2006



4.5 Monitoring data

In 2006, nitrogen dioxide concentrations were monitored at one site at the Woodbridge junction by continuous monitoring and by 17 diffusion tubes at 12 roadside sites and one rural background site as shown in Figures 4.1a and 4.1b.

Continuous automatic monitoring

The automatic monitor is collocated with diffusion tubes WBG 1a,b,c and its OS coordinates are (627597, 249261)

Measurement technique and QA/QC of the automatic monitor

For the measurement of NO2 the recommended method for Detailed Assessments, under the LAQM regime, is Ozone chemiluminescence. This is also the reference method specified by CEN for NO2 monitoring under the first Daughter Directive.

To help ensure that the data is of acceptably high quality routine calibrations of the instrument were undertaken on a fortnightly basis by Suffolk Coastal District Council. The procedures adopted for the calibrations were modelled on those developed by AEA Energy & Environment for use in the national monitoring networks. The calibrations were undertaken using certified calibration gas provided by Air Liquide with traceability to National Metrology Standards obtained via regular UKAS Quality Control Audits. The audits provide a range of information that is utilised within the data management process for the data sets. Audit tests undertaken include accredited audit zero and span calibrations, linearity, NOx converter efficiency, flow and leak checks as well as checks of the instruments sampling system.

The data sets were screened, scaled and validated using all available routine site calibrations, audit results and service engineer records. This was an ongoing process with checks made daily to ensure high data capture is achieved. A final process of data ratification ensures that the data provide the most accurate record of the pollution concentrations across the measurement period. The data management process adopted is that evolved and implemented by AEA Energy & Environment within the data management programme of the AURN UK national monitoring network. This process is expected to deliver data sets that meet the EU Data Quality Objective of a measurement uncertainty of better than 15%.

Measurements of the automatic monitor in 2006

Table 4.1 shows the measured NO_2 concentrations by the automatic monitor in 2006. The measured annual mean concentration was 44 $\mu g/m^3$, so the annual mean objective for nitrogen dioxide was not met at the Woodbridge junction in 2006. Based on this measurement, the predicted annual mean concentration of NO_2 in 2010 is 37.5 $\mu g/m^3$, so no exceedence is predicted for 2010.

Table 4.1 Summary of the ratified NO_2 data recorded by the automatic monitor between 01 Jan 2006 to 31 Dec 2006

	Values
Annual mean	**44** $\mu g/m^3$
Maximum hourly mean	199 $\mu g/m^3$
Data capture	96.3%

Diffusion tubes

Diffusion tube results are available at 12 roadside locations and one rural background location in the Woodbridge junction area as shown in Figures 4.1a & 4.1b. WBG 1 and WBG 5 are triplicate sites and WBG 3 is a rural background site. The automatic monitor is collocated with diffusion tubes WBG 1a,b,c. The unadjusted monthly diffusion tube data for 2006 are given in tables A2.1 of Appendix 2. The diffusion tubes were supplied and analysed by Harwell Scientific Services using 50% TEA in Acetone.

Diffusion tubes can under or over-read and if possible should be bias adjusted to the results of continuous monitoring. The Review & Assessment Helpdesk in UWE has collated bias adjustment factors determined from collocation studies throughout the UK and these data are available as a spreadsheet from their website. There are only two collocation studies for this preparation method in 2006 in the database by the time of this assessment, without including the site at Woodbridge junction, and both of them are single tube sites. The results of these three studies indicate bias adjustment factors in the range of 0.93- 0.96, as shown in Table 4.2, and an overall adjustment factor of 0.94. There are 15 collocation studies for this preparation method in 2005 in the database and the averaged adjustment factor is 0.88.

The local bias adjustment factor at Woodbridge junction is at the low end of the narrow range indicated by the three collocation studies available for 2006, but it is higher than the mean adjustment factor of 15 studies in 2005. Because of limited data for 2006 and the availability of local collocation result at a triplicate site, it was decided to use the local bias adjustment factor to adjust the diffusion tube data in this study. The measurements and the adjusted diffusion tube data using the local adjustment factor of 0.93 in 2006 are summarised in Table 4.3 below.

It should be taken into account that diffusion tubes are spot measurements and may be very sensitive to distance from the road as concentrations change rapidly with distance from the kerbside when comparing them with modelled results.

Table 4.2 Collation studies for the preparation method used at Woodbridge junction in 2006 and the estimated local bias adjustment factor for diffusion tubes at the junction

Analysed By	Method	Year	Site Type	Local Authority	Length of Study (months)	Diffusion Tube Mean Conc. (Dm) (μg/m3)	Automatic Monitor Mean Conc. (Cm) (μg/m3)	Bias (B)	Tube Precision	Bias Adjustment Factor (A) (Cm/Dm)
Harwell Scientific Services	50% TEA in Acetone	2006	Industrial	Watford BC	9	39	37	6.9%	Single	**0.94**
Harwell Scientific Services	50% TEA in Acetone	2006	Roadside	Cambridge CC	11	47	45	4.1%	Single	**0.96**
Harwell Scientific Services	50% TEA in Acetone	2006	Roadside	Suffolk Coastal DC Woodbridge	11	47	44	7.00%	Triple	**0.93**
					Overall adjustment factor					**0.94**
					Adjustment factor of the Woodbridge collocation study					**0.93**

Table 4.3 Nitrogen dioxide diffusion tube data for 2006

Site	Annual mean (mg/m^3)	Data Capture %	Bias adjusted annual mean (mg/m^3)	Projected 2010 annual mean (mg/m^3)
WBG 1 mean	**47.3**	100.0	**44.0**	37.4
WBG 3	19.7	100.0	18.3	15.6
WBG 5 mean	32.5	100.0	30.2	25.7
WBG 6	**45.6**	100.0	**42.4**	36.0
WBG 8	**47.8**	83.3	**44.4**	37.8
WBG 10	**41.3**	100.0	38.4	32.6
WBG 12	33.3	100.0	31.0	26.3
WBG 13	39.5	100.0	36.7	31.2
WBG 15	**44.6**	100.0	**41.5**	35.2
WBG 17	36.5	100.0	33.9	28.8
WBG 18	41.8	100.0	38.9	33.1
WBG 19	24.4	91.7	22.7	19.3
WBG 20	**45.7**	91.7	**42.5**	36.1

Figures in bold indicate exceedences.

Comparison of monitoring data with AQ objectives

The automatic monitoring shows that nitrogen dioxide concentration at the site was above the annual mean objective for NO_2 in 2006.

Diffusion tube data shown in Table 4.3 indicates NO_2 concentrations were above the annual mean objective for NO_2 in 2006 at five locations as:

- WBG 1a,b,c. The kerbside tubes at the signpost outside 93 Thoroughfare.
- WBG 6. The roadside tube at the front drainpipe on 87 Thoroughfare.
- WBG 8. The roadside tube at drainpipe on 95 Thoroughfare.
- WBG15. The roadside tube at the back drainpipe on 87 Thoroughfare.
- WBG 20. The roadside tube at drainpipe on 97 Thoroughfare.

There is no additional predicted exceedence at the Woodbridge junction even if the slightly higher national bias adjustment factor of 0.94 is used.

No exceedence is predicted in 2010 at the junction based on the measurements in 2006.

As the measured concentrations are well below 60μg/m^3 it is considered unlikely that the hourly mean objective for NO_2 is exceeded and therefore it should not be necessary to further assess concentrations at the kerbside.

4.6 Modelling methodology

The air quality impact from road traffic emissions in this modelling was calculated using the proprietary urban model developed at AEA Energy & Environment. There are two parts to this model:

- ***The Local Area Dispersion System (LADS) model.*** This model was used to calculate background concentrations of oxides of nitrogen on a 1 km x 1 km grid. Estimates of emissions of oxides of nitrogen for each 1 km x 1 km area grid square were obtained from the 2004 National Atmospheric Emission Inventory disaggregated inventory, projected forward to 2005 and 2010 using factors in the **Defra** Technical Guidance.

- ***The LADS-URBAN model*.** This model is a tool for calculating atmospheric dispersion using a point-source kernel. Estimates of emissions from vehicles were calculated using the latest emission factors. The dispersion kernels for the LADS-URBAN model were derived from model runs using ADMS V3.3. The detailed hourly traffic counts at Woodbridge junction between 24th November 2005 and 27th November 2005 was used as the daily time varying emission factor of the site in the model.

This advanced two-component model is suitable for modelling road traffic emissions as defined in "Review and assessment: Selection and Use of Dispersion Models, LAQM.TG3 (00)", and in the Technical Guidance LAQM.TG(03).

Concentrations of NO_2 from road traffic emissions were assessed using a high-resolution approach, with air quality modelled at 10 m intervals along all of the roads assessed. This high spatial resolution is recommended in LAQM.TG3 (00) and in the Technical Guidance LAQM.TG (03).

4.7 Traffic modelling summary

In this study, the concentrations of NO_2 at receptors close to the roads and junctions of interest have been modelled using ADMS-3.3 as a dispersion kernel model.

The roads were defined as volume sources, 3m high, and were broken up in to a series of adjoining segments. The length of these segments was dictated by the way in which the OS LandLine data was digitised and varied from one or two metres in length (where the road rapidly changed direction) to hundreds of metres in length (where the road was essentially straight). The OS LandLine data was used to provide the co-ordinates of the centre line of the road, and the road widths. Therefore, the positions of the volume sources (here the roads) were accurate to approximately a metre.

Traffic queues were observed at junction before the traffic lights as shown in Figure 4.1a and the queue lengths are summarised in Table A1.3 in Appendix 1. Where queuing of vehicles was reported, emissions from stationary vehicles were estimated on the basis that the engine power output and hence emissions were the same as those at a speed of 5 kph. Queuing vehicles were assumed to be 5 m apart (including the vehicle).

4.8 Sources of background (non-traffic) emissions data

Background emissions of oxides of nitrogen (NO_x) from sources not modelled in detail have been taken from the 2004 UK National Atmospheric Emissions Inventory (www.naei.org.uk) and scaled to the year of interest where necessary following the recommended procedure in LAQM. TG(03). The contribution to emissions from the roads modelled in detail has been omitted where this would lead to double counting of the local impact of emissions.

4.9 Model bias

A comparison was undertaken between the measured and predicted annual mean NO_2 concentrations at the locations of the automatic monitor and the NO_2 diffusion tubes in Table 4.4.

The model has generally under-predicted the annual mean NO_2 concentrations at the junction, apart from at the rural background site WBG 3. The under-prediction is 33% at the automatic monitoring site and 26% for the average of all roadside diffusion tubes.

There are a number of possible explanations for the under-prediction by the model. Since the model has predicted the rural background concentration well at the diffusion tube site WBG3 as shown in Figure 4.1b (within 10% as shown in Table 4.4), the under-predictions are most likely related to local traffic emissions. Uncertainty regarding traffic speeds and queuing and congestion and parking are likely to have led to some errors in the calculation of emissions.

Table 4.4: Comparison of modelled and measured concentrations by the automatic monitor and diffusion tubes for 2006 (Base Year)

X	Y	Site Location	2006 Measured Mean (adjusted)	2006 Predicted	Difference %
627597	249261	Signpost outside 93 Thoroughfare**(co-location site)**	**44.00**	29.53	-33%
626990	248480	Lampost outside 8 Kingston Farm Road	18.33	18.63	2%
627603	249243	Drainpipe on corner of Suffolk Place, Lime Kiln Quay Road	30.23	27.49	-9%
627593	249254	Drainpipe on 87 Thoroughfare	**42.42**	30.14	-29%
627595	249282	Drainpipe on 95 Thoroughfare	**44.47**	27.55	-38%
627569	249240	Signpost in St. John's Street (opposite Surgery)	38.42	28.57	-26%
627663	249204	Drainpipe on 8 Lime Kiln Quay Road	30.98	22.36	-28%
627587	249241	Traffic lights at front of 85 Thoroughfare	36.74	27.14	-26%
627585	249250	Drainpipe on 87 Thoroughfare	**41.30**	25.49	-38%
627616	249269	Drainpipe at front Northern end of Suffolk Place	34.05	26.31	-23%
627628	249338	Drainpipe between 106 / 108 Thoroughfare	38.88	24.50	-37%
627514	249258	Front porch of 25 St. John's Street	22.70	21.28	-6%
627603	249296	Drainpipe on 97 Thoroughfare	**42.51**	25.08	-41%
		Average	**35.77**	**25.70**	**-26%**

Figures in **bold** indicate predicted exceedences of the UK objective in 2006

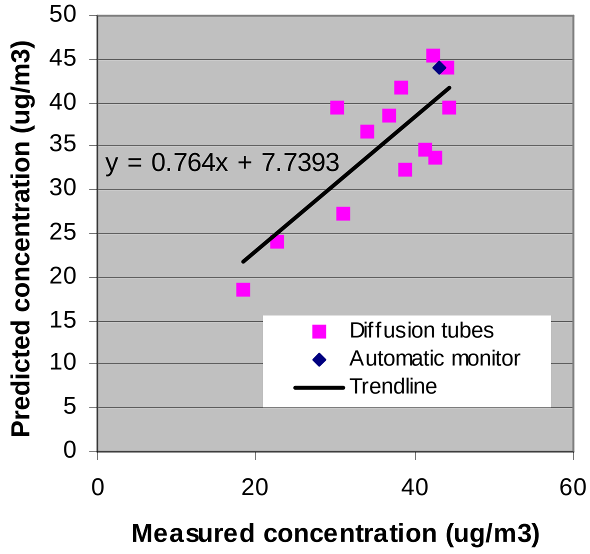
To compensate for the under-predictions at the junction, the predicted traffic NOx was adjusted until the predicted NO_2 concentration at the automatic site matched the measurement. Table 4.5 shows the comparison between the measurements and model predictions with and without the adjustment to traffic NOx. The adjustment factor derived is 2.41. The same adjustment factor was then applied to the predicted concentrations of traffic NOx at all other locations at the junction.

Figure 4.2 shows the comparison between the predictions of the adjusted model and the measurements by diffusion tubes in 2006. The prediction at the rural background site still agrees well with measurement, and the correlation between the predictions and measurements are satisfactory at all other sites. The overall under-prediction of all diffusion tube sites by the adjusted model is only 1%, reduced from 26% of the unadjusted model as shown in Table 4.4. The adjusted model was then used in this Further Assessment.

Table 4.5 Adjusting the model predictions to the measurements of the automatic monitor in 2006

	Total NOx (ug/m^3)	Traffic NOx (ug/m^3)	NO_2 (ug/m^3)	Differerce between measured and predicted NO_2
Measured by the automatic monitor	99	na	44	
Model predictions without adjustment	51.1	25.06	29.53	-33%
Model predictions with adjustment of the traffic NOx	86.3	60.4	44	0%
Adjustment factor for the predicted traffic Nox		2.41		

Figure 4.2 Regression analysis of modelled and diffusion tube measured annual mean concentrations of nitrogen dioxide



4.10 Model validation

In simple terms, model validation is where the model is tested at a range of locations and is judged suitable to use for a given application. The modelling approach used in this assessment has been validated, and used in numerous air quality review and assessments. Statistical techniques have been used to assess the likelihood that there will be an exceedence of the air quality objectives given the modelled concentration. The validation statistics are given in Appendix 3. Confidence limits for the predicted concentrations were calculated based on the validation studies by applying statistical techniques based on Student's t distribution. The confidence limits took account of uncertainties resulting from:

- Model errors at the receptor site;
- Model errors at the reference site;
- Uncertainty resulting from year to year variations in atmospheric conditions.

The confidence limits have been used to estimate the likelihood of exceeding the objectives at locations close to the roads. The following descriptions have been assigned to levels of risk of exceeding the objectives.

It would be recommended that Suffolk Coastal District Council generally consider declaring or reconfirming an AQMA where the probability of exceedence in 2005 is greater than 50% ("Probable").

Table 4.6: Uncertainties in the modelled concentrations for NO_2.

Description	Chance of exceeding objective	Modelled annual average concentrations, $\mu g/m^3$	
		Likelihood of exceeding annual average objective	Likelihood of exceeding hourly average objective
Very unlikely	Less than 5%	<28	<38
Unlikely	5-20%	28-34	38-52
Possible	20-50%	34-40	52-67
Probable	50-80%	40-46	67-82
Likely	80-95%	46-52	82-95
Very likely	More than 95%	>52	>95

The confidence limits for the ‘probable’ and ‘likely’ annual average and hourly objective concentrations have been set equal to those for ‘possible’ and ‘unlikely’, respectively. In reality, the intervals of concentration increase in size as the probability of exceeding the annual and hourly objective increases from ‘unlikely’ to ‘likely’. The advantage to setting symmetrical concentration intervals is that the concentration contours on the maps become simpler to interpret. This is a mildly conservative approach to assessing the likelihood of exceedences of the NO_2 objectives since a greater geographical area will be included using the smaller confidence intervals.

A simple linear relationship can be used to predict the 99.8^{th} hourly percentile concentration of NO_2 from the annual concentration: the 99.8^{th} percentile is three times the annual mean at kerbside/roadside locations. Therefore, plots of the modelled annual mean NO_2 concentrations can be used to show exceedences of both the annual and hourly NO_2 objectives. However, the magnitude of the concentrations used to judge exceedences of the hourly objective need to be adjusted so they may be used directly with the plots of annual concentration. This has been performed by simply dividing the concentrations of the confidence limits by three.

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations. Appendix 3 provides a comparison of modelled and measured nitrogen dioxide concentrations.

5 Modelling results for nitrogen dioxide

5.1 2006 NO_2 modelling results (Base Case)

The model developed for this Further Assessment includes all the major roads approaching the Woodbridge junction. Emissions from traffic movements on other roads in Woodbridge and outside the Council have not been explicitly modelled, but are all included in the modelled background concentrations. Figures 5.1 shows the modelled annual mean NO_2 concentrations for 2006. The adjusted model has predicted that the annual average objective of 40μg/m^3 for nitrogen dioxide has been exceeded at the junction in Lime Kiln Quay Road and in Thoroughfare/Melton Hill behind the traffic lights in 2006. The predicted distributions are very similar to that predicted for 2005 in the 2005 detailed assessment (Beth Conlan, 2005).

Within the Woodbridge Junction, the model predicts that it is ***probable*** (with a probability of 50- 80%) that the annual average objective has been exceeded in 2006 (as illustrated in Table 4.6), and it is ***unlikely*** (with a probability of 5- 20%) the hourly mean objective to have been exceeded in 2006 (Table 4.6).

When analysing the predicted results, attention was focused on the areas with predicted concentrations exceeding the objective for annual mean NO_2 concentrations and, particularly, on building facades within these areas (i.e. the relevant locations).

Table 5.1 below summaries the highest annual mean NO_2 concentrations predicted at relevant locations at the junction. As identified in the 2005 detailed assessment, there is still a marginal exceedence for two properties at Thoroughfare/Melton Hill in 2006. There may be also a marginal exceedence in Lime Kiln Quay Road in 2006 as indicated in Table 5.1 and Figure 5.1. The highest predicted NO_2 concentration is 43.5μg/m^3 at a relevant location near to the automatic monitor. The largest exceedence predicted is 8%, as shown in Table 5.1. Source apportionment has been undertaken at these relevant locations with predicted exceedences.

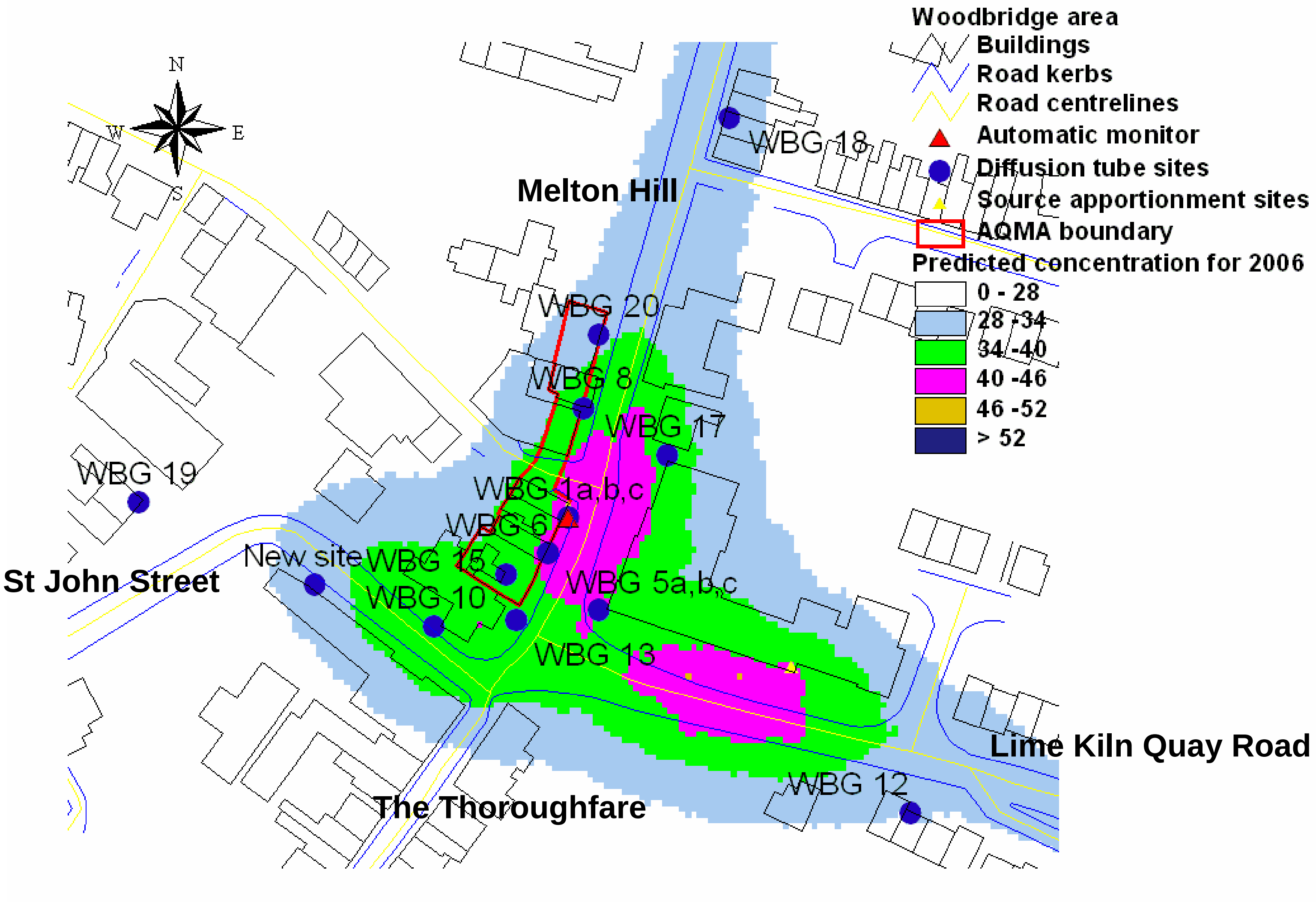
Table 5.1 The highest NO_2 concentrations predicted at relevant locations at the Woodbridge junction in 2006

Area	The relevant location with the highest predicted concentration		Total NO_2 ug/m^3	Exceedence
	X	Y		
Thoroughfare/Melton Hill	627597	249263	**43.5**	8%
Lime Kiln Quay Road	627640	249232	**41.9**	5%

Figures in **bold** indicate predicted exceedences of the UK objective in 2006
% Figures are rounded to the nearest whole number

As shown in Figure 5.1, sites 8, 15 and 20 are all within the declared AQMA and the model has not predicted exceedences at these locations. However exceedences were indicated by diffusion tubes as shown in Table 4.3, so it is recommended the AQMA to be retained as it is because of the diffusion tube data. On the other hand, the model has predicted marginal exceedences on building facades at the east side of Mellton Hill (opposite the AQMA declared), but diffusion tubes at sites 5 and 17 didn't indicate exceedence and their readings are not even near to the objective in 2006 (as shown in Table 4.3), therefore the original AQMA boundary is still retained because of the diffusion tube data.

Figure 5.1 Modelled contours of annual mean NO_2 concentration at the Woodbridge junction for 2006
(See Table A2.3 in Appendix 2 for the names and locations of the numbered monitoring sites)



5.2 2010 NO_2 modelling results

Figure 5.2 shows the modelled annual mean NO_2 concentrations for 2010 at the Woodbridge junction and Table 5.2 summaries the highest annual mean NO_2 concentrations predicted at relevant locations at the junction.

The adjusted model has predicted no exceedence of the annual average objective of 40μg/m^3 for nitrogen dioxide at the Woodbridge junction in 2010. The highest predicted NO_2 concentration is only 38.4 μg/m^3 at the relevant location near to the automatic monitor.

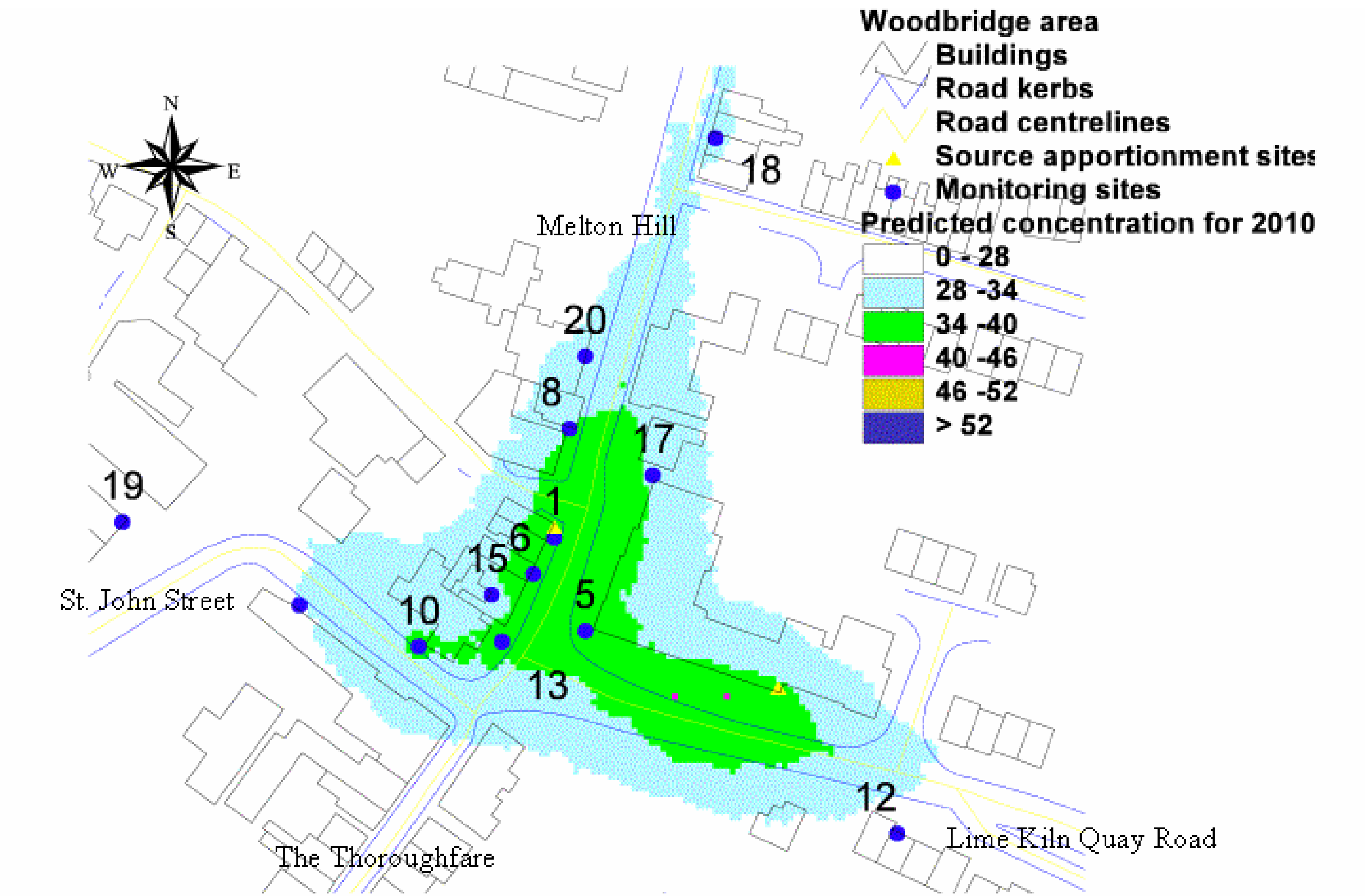
Within the Woodbridge junction area, the model predicts that it is ***possible*** (with a probability of 20-50%) that the annual average objective will be exceeded in 2010 and it is ***very unlikely*** (with a probability less than 5%) the hourly mean objective to be exceeded in 2010 (Table 4.6).

Table 5.2 The highest NO_2 concentrations predicted at relevant locations in the Woodbridge junction area in 2010

Area	The relevant location with the highest predicted concentration		Total NO_2 ug/m^3	Exceedence
	X	Y		
Thoroughfare/Melton Hill	627597	249263	38.4	No
Lime Kiln Quay Road	627640	249232	36.3	No

The above results predict a significant decline in NO_2 levels between 2006 and 2010 due to national measures to reduce NOx emissions. This decline is based on predicted future vehicle NOx emissions, and on predicted future declines in background NO_2 and NOx provided in TG(03). Current evidence suggests that these predicted declines towards 2010 are optimistic and that in fact, in urban areas at least, NO_2 levels may be declining more slowly than previously anticipated. The reasons for this are subject to current investigation. One possible reason may be that primary emissions of NO_2 from vehicles, especially those fitted with particulate traps, are higher than previously thought. For now it is recommended that decisions regarding air quality and NO_2 be made based on the results predicted for 2006, and that the results for 2010 be treated with caution and treated as indicative only.

Figure 5.2 Modelled contours of annual mean NO_2 concentration at the Woodbridge junction in 2010
(See Table A2.3 in Appendix 2 for the names and locations of the numbered monitoring sites)



5.3 Source apportionment of the predicted exceedences

Source apportionment is the process whereby the contributions from different sources of a pollutant are determined. In local air quality of Woodbridge, the relevant sources could include: road traffic; local background; industrial and domestic. Contributions from the different types of vehicles (for example, cars, lorries and buses) can also be considered to highlight which class of vehicle is contributing most to the emissions from traffic. Source apportionment allows the most important source or sources to be identified and options to reduce ambient concentrations of pollutants can then be considered and assessed.

Source apportionment analysis should:

- Confirm that exceedences of NO_2 are due to road traffic
- Determine the extent to which different vehicle types are responsible for the emission contributions to NO_2 within predicted areas of exceedence. This will allow traffic management scenarios to be modelled/tested to reduce the exceedences
- Quantify what proportion of the exceedences of NO_2 is due to background emissions, or local emissions from busy roads in the local area. This will help determine whether local traffic management measures could have a significant impact on reducing emissions in the area of exceedence, or, whether national measures would be a suitable approach to achieving the air quality objectives

Receptors considered

When analysing the predicted results, attention was focused on areas with predicted concentrations exceeding the objective for annual mean NO_2 concentrations and, particularly, on building facades within these areas. Source apportionment had been considered for NOx at the two relevant locations with predicted exceedences in 2006 (as shown in Table 5.1 and Figure 5.1).

Sources of pollution considered

We have considered the effect of the following sources in this assessment at the receptors considered:

- Background concentrations used in the assessment
- Traffic - Light Duty Vehicles on main roads in the junction area
- Traffic - Heavy Duty Vehicles on main roads in the junction area
- LDVs in queues at the junction
- HDVs in queues at the junction

It should be noted that the modelling has particularly considered traffic on the busiest roads. Reference in Tables 5.3-5.6 below to ‘vehicles’ refers to the contribution to pollutant concentrations by traffic movements on these roads. Emissions from traffic movements on other roads in Suffolk Coastal District Council and outside the Council have not been explicitly modelled. However, their contribution to pollutant concentrations in the Woodbridge area is included in the modelled background concentrations based on background emission data as described in Section 4.6 & 4.8. The background concentrations in Tables 5.3 - 5.4 therefore include contributions from traffic on roads other than those modelled in this study.

The concentration of NO_2 at a given location is determined by a number of factors, including the magnitude and proximity of NOx emission sources, dispersion of the emissions and the processes that determine which proportion of NOx is in the form of NO_2, and they are all considered in the model. The concentrations apportioned to each source category and the fractions of the total concentrations of NOx are shown in Tables 5.3 – 5.6.

Table 5.3: Source apportionment at the relevant site in Thoroughfare/Melton Hill according to source category

Thoroughfare/Melton Hill (627597, 249263) Source category	NOx	
	Concentration ug/m3	Contribution %
Light Duty Vehicles (LDV)	31.17	47%
Heavy Duty Vehicles (HDV)	28.69	44%
Local background	5.93	9%
Local total	65.80	100%

% Figures are rounded to the nearest whole number

Table 5.4: Source apportionment at the relevant site in Thoroughfare/Melton Hill according to vehicle state at the junction

Thoroughfare/Melton Hill (627597, 249263) Vehicle state	NOx	
	Concentration ug/m3	Contribution %
Moving vehicles	24.44	41%
HDVs in the queues	19.82	33%
LDVs in the queues	15.60	26%
Local traffic total	59.86	100%

% Figures are rounded to the nearest whole number

Table 5.5: Source apportionment at the relevant site in Lime Kiln Quay Road accordingt to source categoty

Lime Kiln Quay Road (627640, 249232) Source category	NOx	
	Concentration ug/m3	Contribution %
Light Duty Vehicles (LDV)	27.43	45%
Heavy Duty Vehicles (HDV)	28.14	46%
Local background	5.69	9%
Local total	61.26	100%

% Figures are rounded to the nearest whole number

Table 5.6: Source apportionment at the relevant site in Lime Kiln Quay Road accordingt to vehicle state at the junction

Lime Kiln Quay Road (627640, 249232) Vechicle state	NOx	
	Concentration ug/m3	Contribution %
Moving vehicles	20.94	38%
HDVs in the queues	20.18	36%
LDVs in the queues	14.16	26%
Local traffic total	55.58	100%

% Figures are rounded to the nearest whole number

From the above source apportionment, it can be seen that local traffic accounts for about 90% of the local NOx concentrations at the two locations analysed, HDVs and LDVs account for about half of the traffic contribution each, as shown in Tables 5.3 & 5.5. In the traffic emitted NOx at the two sites analysed (i.e. the total concentration of LDVs and HDVs), about 60% of them are produced by vehicles waiting in the queues on Lime Kiln Quay Road and on Thoroughfare/Melton Hill, as shown in Tables 5.4 & 5.6.

After knowing the contributions from different sources to the exceedences predicted, proper measures could be formulated to target the primary sources to eliminate these exceedences. At the source apportionment sites where marginal exceedences were predicted for 2006 (as shown in Table 5.1), the model shows that a reduction of vehicle emitted NOx by 16.4% would have eliminated these exceedences to the objective for annual mean NO_2 concentration in 2006 as given in Table 5.7 below. Queuing (particularly HDVs in queues) and HDV reductions will be the keys to achieve the NOx reduction.

Table 5.7 Estimated traffic NOx reduction required to eliminate all exceedences at the junction

	Total NOx (ug/m^3)	**Traffic NOx* (ug/m^3)**	**NO_2 (ug/m^3)**
Predictions at the source apportionment site for 2006	85.0	59.1	**43.5**
Estimated Traffic NOx required to eliminate the exceedence	75.3	49.4	39.9
Traffic NOx reduction required (ug/m^3)		*9.7*	
Traffic NOx reduction required (%)		*16.4*	

*The traffic NOx has been adjusted by a factor of 2.41 as decsribed in Section 4.9
Figure in **bold** indicates exceedence of the UK air quality objective

6 Recommendations

6.1 Summary of modelling predictions

For 2006, both monitoring and modelling indicate continued exceedences of the objective for annual mean NO2 concentrations at the Woodbridge junction. The model predicts that it is ***probable*** (with a probability of 50- 80%) that the annual average objective has been exceeded in 2006 and it is ***unlikely*** (with a probability of 5- 20%) the hourly mean objective to have been exceeded in 2006 (Table 4.6).

No exceedence of the objectives for NO_2 concentration is predicted at the junction in 2010.

The source apportionment analysis shows that local traffic contributes about 90% of the total local NOx and vehicles waiting the queues produce about 60% of the traffic NOx at the junction.

6.2 Recommendations

Below are our recommendations for the areas assessed in this report:

- Suffolk Coastal District Council should retain the AQMA declared at the junction.
- Suffolk Coastal District Council should continue monitoring at all sites to confirm the predicted trend between now and 2010 with a few alterations.
- Suffolk Coastal District Council should consider revoking diffusion tube WBG19. The readings by this tube were quite low in 2006 and a new site has been established nearby in St. John Street, as illustrated in Figure 4.1a.
- A reduction of vehicle emitted NOx by 16.4% would have eliminated these exceedences to the objective for annual mean NO_2 concentration in 2006. Queuing and HDV reductions will be the keys to improve the air quality at the junction.

6.3 Further actions to be taken

Should Suffolk Coastal District Council be satisfied and in agreement with the contents of this report, it should be then be forwarded to Defra for approval. Defra will then forward the report to their external assessors who will comment on the work. Defra will then return the critique of the work to Suffolk Coastal District Council.

Suffolk Coastal District Council should then forward a copy of this critique to **AEA Energy and Environment.** Suffolk Coastal District Council should also consider if they could answer any of the questions directly.

7 References

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Appendices

Appendix 1: Traffic data

Appendix 2: Monitoring data

Appendix 3: Model validations: Nitrogen dioxide roadside concentrations

Appendix 1

Traffic data

Contents

Table A1.1 – Summary of the 11-hour traffic survey on 24th November 2005 (Data source: Woodbridge/Melton traffic surveys, 2005)

		Car/ MC	LGV	HGV	BUS	AADT
Lime Kiln	Southbound	4189	409	89	74	4761
Quay Rd	Northbound	3066	348	63	53	3530
St. John St	Eastbound	2442	227	45	14	2728
	Westbound	463	40	5	0	508
Melton Hill	Southbound	3478	404	73	61	4016
	Northbound	3802	416	77	54	4349
Thoroughfare	Southbound	532	114	11	0	657

Table A1.2 – Summary of the 14-day traffic survey between 23rd November and 6th December 2005 (Data source: Woodbridge/Melton traffic surveys, 2005)

		Cars/ LGV	HGV	AADT	Average speed (mph)
Lime Kiln	Southbound	5040	141	5192	24
Quay Rd	Northbound	3819	147	3965	26
St. John St	Eastbound	2921	152	3192	15
	Westbound	1296	11	1449	8
Melton Hill	Southbound	4629	227	4975	27
	Northbound	5076	230	5455	26
Thoroughfare	Southbound	NS	NS	NS	12*

NS: Not surveyed

* No average speed was recorded for Thoroughfare and it was assumed to be the average speed observed in nearby St. John Street.

Table A1.3 – Summary of average number of vehicles queuing at the Woodbridge Junction between 8.00-18.00 hours on 23rd November 2005 (Data source: Woodbridge/Melton traffic surveys, 2005)

	St John Street	Lime Kiln Quay Rd	Melton Hill/Thoroughfare
08.00 – 09.00	11.7	8.9	8.7
09.00 – 10.00	7.3	8.1	6.9
10.00 – 11.00	5.7	7.0	4
11.00 – 12.00	7.9	12.4	7.5
12.00 – 13.00	7.5	10.3	4.6
13.00 – 14.00	7.6	10.5	5.1
14.00 – 15.00	5.8	7.7	5.5
15.00 – 16.00	8	8.0	5.5
16.00 – 17.00	11.2	8.9	7.8
17.00 – 18.00	8.5	10.3	6.8
10-hour average	8.12	9.21	6.23

Table A1.4 Additional traffic flow at the Woodbridge junction due to committed developments to be completed before 2010

Road	Additional AADT
Lime Kiln Quay Rd	489
St. John St	257
Melton Hill	2154

Table A1.5 TEMPRO growth factors for the Woodbridge area

From	To	NRTF Central	Suffolk Coastal Growth Central
2005	2006	1.017	1.013
2005	2007	1.032	1.029
2005	2008	1.048	1.045
2005	2009	1.063	1.061
2005	2010	1.079	1.076

Table A1.6 Averaged hourly traffic flows at Woodbridge junction between 24th November 2005 and 27th November 2005

Time of day	Weekday	Saturday	Sunday
00:00	9	27	26
01:00	3	10	10
02:00	2	5	4
03:00	3	8	3
04:00	7	7	5
05:00	12	13	3
06:00	45	24	8
07:00	154	53	26
08:00	329	150	68
09:00	335	264	110
10:00	322	361	216
11:00	335	409	271
12:00	344	361	289
13:00	322	311	243
14:00	354	312	237
15:00	348	306	226
16:00	358	266	175
17:00	302	210	109
18:00	206	144	101
19:00	177	154	83
20:00	106	87	54
21:00	85	67	32
22:00	70	60	42
23:00	45	53	15

Appendix 2

Monitoring data

Contents

2.1 Automatic monitoring data

Air Pollution Report

Produced by AEA Energy & Environment on behalf of Suffolk Coastal District Council

SUFFOLK COASTAL WOODBRIDGE 2
01 January to 31 December 2006

These data have been fully ratified by AEA Energy & Environment

POLLUTANT	NO	NO_2	NO_X
Number Very High	-	0	-
Number High	-	0	-
Number Moderate	-	0	-
Number Low	-	8434	-
Maximum 15-minute mean	628 $\mu g\ m^{-3}$	419 $\mu g\ m^{-3}$	1092 $\mu g\ m^{-3}$
Maximum hourly mean	483 $\mu g\ m^{-3}$	199 $\mu g\ m^{-3}$	875 $\mu g\ m^{-3}$
Maximum running 8-hour mean	364 $\mu g\ m^{-3}$	154 $\mu g\ m^{-3}$	700 $\mu g\ m^{-3}$
Maximum running 24-hour mean	218 $\mu g\ m^{-3}$	100 $\mu g\ m^{-3}$	425 $\mu g\ m^{-3}$
Maximum daily mean	217 $\mu g\ m^{-3}$	95 $\mu g\ m^{-3}$	421 $\mu g\ m^{-3}$
Average	36 $\mu g\ m^{-3}$	44 $\mu g\ m^{-3}$	99 $\mu g\ m^{-3}$
Data capture	96.3 %	96.3 %	96.3 %

All mass units are at 20'C and 1013mb
NO_X mass units are NO_X as NO_2

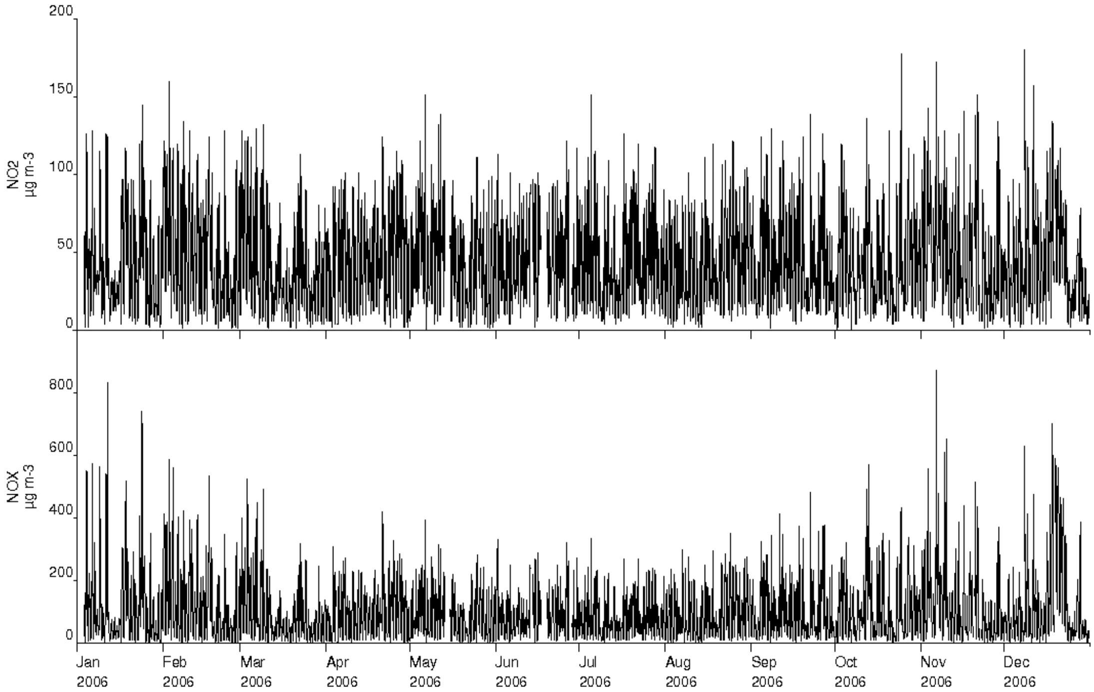
Pollutant	Air Quality (England) Regulations 2000 and (Amendment) Regulations 2002	Exceedences	Days
Nitrogen Dioxide	Annual mean > 40 $\mu g\ m^{-3}$	1	0
Nitrogen Dioxide	Hourly mean > 200 $\mu g\ m^{-3}$	0	0

AEA Energy & Environment
From the AEA group

Air Pollution Report

Produced by AEA Energy & Environment on behalf of Suffolk Coastal District Council

Suffolk Coastal Woodbridge 2 Air Monitoring
Hourly Mean Data for 01 January to 31 December 2006



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From the AEA group

Table A2.2 Unadjusted monthly diffusion tube data in the Woodbridge area in 2006 (μg/m³)

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WBG 1a	47.1	53.7	40.5	50.1	46.1	42.2	33.0	39.7	49.8	48	57.8	52.2
WBG 1b	40.1	50.5	45.1	49.1	49.6	48.6	41.6	41.5	51.3	50.3	54.7	52.7
WBG 1c	41.7	51.6	43.4	53.4	46.2	46.4	44.5	41.0	no data	46.6	56.3	44.7
WBG 1 mean	43.0	51.9	43.0	50.9	47.3	45.7	39.7	40.7	50.6	48.3	56.3	49.9
WBG 3	24.7	22.3	18.0	16.7	17.9	17.8	10.6	11.9	19.6	23.1	28.1	25.1
WBG 5a	39.9	36.1	34.3	30.5	29.7	33.2	35.4	19.6	32.6	34.9	35.7	36.6
WBG 5b	41.6	38.7	34.0	33.2	32.8	33.6	27.9	21.4	28.5	32	39.2	38.3
WBG 5c	31.9	36.9	29.5	27.5	28.3	29.8	27.7	20.8	32.7	34.3	37.2	34.6
WBG 5 mean	37.8	37.2	32.6	30.4	30.3	32.2	30.3	20.6	31.3	33.7	37.4	36.5
WBG 6	40.7	50.2	43.2	46.7	44.9	45.6	45.2	36.7	48.0	47.5	51.6	46.8
WBG 8	41.8	50.7	45.1	51.3	48.5	no data	45.8	34.7	no data	49.5	59.2	51.3
WBG 10	41.3	42.2	39.6	37.3	41.0	49.2	49.5	30.6	41.7	41.5	41.6	39.6
WBG 12	30.8	36.5	32.0	34.5	33.8	26.4	27.3	27.6	34.2	32.4	44.3	39.9
WBG 13	41.2	42.2	36.2	37.2	36.2	42.2	41.2	30.7	41.7	38.4	44.0	42.5
WBG 15	43.5	51.8	36.0	48.7	42.4	42.1	35.5	42.2	47.0	48.0	50.2	47.7
WBG 17	39.1	37.4	35.2	34.8	33.1	41.3	34.4	26.0	38.0	39.1	44.5	34.7
WBG 18	45.4	43.0	38.8	38.9	40.6	43.7	44.8	29.4	43.2	46.1	46.8	41.4
WBG 19	24.7	30.3	21.4	22.9	20.4	21.8	15.0	15.7	29.4	no data	35.3	31.5
WBG 20	~	45.6	41.3	51.2	44.1	45.9	35.7	41.9	49.4	40.7	59	47.6

N/A: Not available at the time when this assessment was done

Key:

WBG 1a,b,c	Kerbside site, signpost outside 93 Thoroughfare, Woodbridge **(co-location with continuous monitor from January 2006)**
WBG 3	Urban Background site, lampost outside 8 Kingston Farm Road, Woodbridge
WBG 5a,b,c	Roadside site, drainpipe on corner of Suffolk Place, Lime Kiln Quay Road, Woodbridge **(Triplicate site)**
WBG 6	Roadside site, drainpipe on 87 Thoroughfare, Woodbridge
WBG 8	Roadside site, drainpipe on 95 Thoroughfare, Woodbridge
WBG 10	Roadside site, signpost in St. John's Street (opposite Surgery), Woodbridge
WBG 12	Roadside site, drainpipe on 8 Lime Kiln Quay Road, Woodbridge. **Site reinstated from January 2006**
WBG 13	Roadside site, traffic lights at front of 85 Thoroughfare, Woodbridge
WBG 15	Roadside site, drainpipe on 87 Thoroughfare, Woodbridge
WBG 17	Roadside site, drainpipe at front Northern end of Suffolk Place, Lime Kiln Quay Road. **New site from January 2006**
WBG 18	Roadside site, drainpipe between 106 / 108 Thoroughfare, Woodbridge. **New site from January 2006**
WBG 19	Roadside site, front porch of 25 St. John's Street, Woodbridge. **New site from January 2006**
WBG 20	Roadside site, drainpipe on 97 Thoroughfare, Woodbridge. **New site from February 2006**

Table A2.3 Locations of the monitoring sites

Site No	X	Y	Site Name
1	627597	249261	WBG 1a,b,c
3	626990	248480	WBG 3
5	627603	249243	WBG 5a,b,c
6	627593	249254	WBG 6
8	627600	249282	WBG 8
10	627571	249240	WBG 10
12	627663	249204	WBG 12
13	627587	249241	WBG 13
15	627585	249250	WBG 15
17	627616	249273	WBG 17
18	627628	249338	WBG 18
19	627514	249264	WBG 19
20	627603	249296	WBG 20
New site	627548	249248	New site

Appendix 3

Model Validation: Nitrogen Dioxide Roadside Concentrations

Contents

INTRODUCTION

The dispersion model ADMS-3 was used to predict nitrogen dioxide concentrations at roadside locations. ADMS-3 is a PC-based model that includes an up-to-date representation of the atmospheric processes that contribute to pollutant dispersion.

The model was used to predict

- the local contribution to pollutant concentrations from roads; and
- The contribution from urban background sources.

The contribution from urban background sources was calculated from the ADMS-3 output using the NETCEN Local Area Dispersion System (LADS) model. The LADS model provides efficient algorithms for applying the results of the dispersion model over large areas.

The model was verified by comparison with monitoring data obtained at a number of roadside, kerbside or near-road monitoring sites in London.

- London Marylebone
- Camden Roadside
- Haringey Roadside
- London Bloomsbury
- London North Kensington
- London A3 Roadside

London Marylebone site is located in a purpose built cabin on Marylebone Road opposite Madame Tussauds. The sampling point is located at a height of 3 m, around 1 m from the kerbside. Traffic flows of over 80,000 vehicles per day pass the site on six lanes. The road is frequently congested. The surrounding area forms a street canyon and comprises of education buildings, tourist attractions, shops and housing

Camden Roadside site (TQ267843) is located in a purpose built cabin on the north side of the Swiss Cottage Junction. The site is at the southern end of a broad street canyon. Sampling points are approximately 1 m from the kerbside of Finchley Road at a height of 3 m. Traffic flows of 37,000 vehicles per day pass the site and the road is often congested. Pedestrian traffic is also high. The surrounding area mainly consists of shops and offices.

London North Kensington site (TQ240817) is located within the grounds of Sion Manning School. The sampling point is located on a cabin, in the school grounds next to St Charles Square, at a height of 3 m. The surrounding area is mainly residential.

London A3 monitoring station (TQ193653) is within a self-contained, air-conditioned housing immediately adjacent to the A3 Kingston Bypass (6 lane carriageway). Traffic flow along the bypass is approximately 112,000 vehicles per day and is generally fast and free flowing with little congestion. The manifold inlet is approximately 2.5 m from the kerbside at a height of approximately 3 m. The surrounding area is generally open and comprises residential dwellings and light industrial and commercial properties.

London Bloomsbury monitoring station (TQ302820) is within a self-contained, air-conditioned housing located at within the southeast corner of central London gardens. The gardens are generally laid to grass with many mature trees. All four sides of the gardens are surrounded by a busy (35,000 vehicles per day), 2/4 lane one-way road system which is subject to frequent congestion. The nearest road lies at a distance of approximately 35 metres from the station. The manifold inlet is approximately 3 metres high. The area in the vicinity of the manifold is open, but there are mature trees within about 5 metres.

London Haringey site (TQ339906) is located in a purpose built cabin within the grounds of the Council Offices. The sampling point is at a height of 3 m located 5 m from High Road Tottenham (A1010) with traffic flows of around 20,000 vehicles per day. The road is frequently congested. The surrounding area consists of shops, offices and housing.

MODEL APPLICATION

Study area

Two study areas were defined- a local study area and an urban background study area. The local study area was defined for each of the monitoring sites extending 200 m in each direction (NSEW) from the monitoring site. Roads in the study area were identified. Each road in the study are was then treated as a quadrilateral volume source with depth 3 m, with spatial co-ordinates derived from OS maps. The urban background study area extended over an 80 km x 80 km area covering the London area. The background study area was divided into 1 km x 1 km squares-each 1 km square was then treated as a square volume source with depth 10 m.

Traffic flows in the local study area

Traffic flows, by vehicle category, on each of the roads within the local study area for 1996 were obtained from the DETR traffic flow database. The traffic flows were scaled to 1998 by factors shown in Table A3.1 obtained by linear interpolation from Transport Statistics GB, 1997.

Table A3.1 Traffic growth 1998:1996

	Growth factor
Cars	1.05
Light goods vehicles	1.05
Heavy goods vehicles	1.04
Buses	1.00
Motorcycles	1.00

Traffic flows follow a diurnal variation. Table A3.2 shows the assumed diurnal variation in traffic flows.

Table A3.2 Assumed diurnal traffic variation

Hour	Normalised traffic flow
0	0.20
1	0.11
2	0.10
3	0.07
4	0.08
5	0.18
6	0.49
7	1.33
8	1.97
9	1.50
10	1.33
11	1.46
12	1.47
13	1.51
14	1.62
15	1.74
16	1.94
17	1.91
18	1.53
19	1.12
20	0.88
21	0.68
22	0.46
23	0.33

Vehicle speeds in the local study area
Vehicle speeds were estimated on the basis of TSGB, 1997 data for central area, inner area and outer area average traffic speeds in London, 1968-1995 and for non-urban and urban roads for 1996. Table A3.3 shows the traffic speeds applied to each of the sites. The low speeds in Central London reflect the generally high levels of congestion in the area.

Table A3.3 Traffic speeds used in the modelling

Site	Road class	Vehicle speed, kph
London Marylebone	Central London	17.5
Camden Roadside	Central London	17.5
London Bloomsbury	Central London	17.5
London A3 Roadside	Non-urban dual carriageway	88
London Haringey	Outer London	32
London North Kensington	Background site	Not applicable

Vehicle emissions in the local study area
Vehicle emissions of oxides of nitrogen were estimated using the Highways Agency Design Manual for Roads and Bridges, 1999 (DMRB). DMRB provides a series of monograms that allow the effect on emission rates of the proportion of heavy goods vehicles and the average vehicle speed to be taken into account. The estimated emissions are based on average speeds and take account of the variations in emissions that follow from normal patterns of acceleration and deceleration. DMRB provides estimates of the emissions of particulate material from vehicle exhausts.

Emissions in the urban background study area
Emission estimates for each 1 km square in the urban background study area were obtained from two emission inventories. The London inventory for 1995/6 (LRC, 1997) was used for most of the urban background study area: the National Atmospheric Emission Inventory, 1996 was used for areas within the urban background study area not covered by the London inventory.

The emission estimates for each square for 1996 were scaled to 1998 using factors taken from DMRB.

Meteorological data
Meteorological data for Heathrow Airport 1998 was used to represent meteorological conditions. The data set included wind speed and direction and cloud cover for each hour of the year. It was assumed that a surface roughness of 0.5 m was representative of the suburban area surrounding Heathrow Airport.

The meteorological conditions over London are affected by heat emissions from buildings and vehicles. This “urban heat island” effect reduces the frequency and severity of the stable atmospheric conditions that often lead to high pollutant concentrations. In order to take this into account the Monin-Obukhov length (a parameter used to characterise atmospheric stability in the model) has been assigned a lower limit as shown in Table A3.4.

Table A3.4: Monin-Obukhov limits applied

Site	Limit, m	Note
London Marylebone	100	Large conurbation
Camden Roadside	100	Large conurbation
London Bloomsbury	100	Large conurbation
London A3 Roadside	30	Mixed urban/industrial
London Haringey	30	Mixed urban/industrial
London North Kensington	100	Large conurbation
Small towns <50,000	10	
Urban background area	100	
Rural	1	

Surface roughness
The surface roughness is used in dispersion modelling to represent the roughness of the ground. Table A3.5 shows the surface roughness values applied.

Table A3.5 Surface roughness

Site	Surface roughness, m	Note
London Marylebone	2	Street canyon
Camden Roadside	1	City
London Bloomsbury	1	City
London A3 Roadside	0.5	Suburban
London Haringey	1	City
London North Kensington	1	Suburban
Urban background area	1	

Model output
The local model was used to estimate:

- Annual average road contribution of oxides of nitrogen ;
- road contribution to oxides of nitrogen concentrations for each hour of the year.

The urban background model was used to estimate:

- the contribution from urban background sources to annual average oxides of nitrogen concentrations;
- the contribution from roads considered in the local model to urban background concentrations;
- the contribution from urban background sources to oxides of nitrogen concentrations for each hour of the year.

Background concentrations
A rural background concentration of 20 $\mu g\ m^{-3}$ was added to the urban background oxides of nitrogen concentration.

Calculation of annual average nitrogen dioxide concentrations
Nitrogen dioxide is formed as the result of the oxidation of nitrogen oxides in air, primarily by ozone. The relationship between oxides of nitrogen concentrations and nitrogen dioxide concentrations is complex; an empirical approach has been adopted.

The contribution from locally modelled roads to urban background oxides of nitrogen concentrations was first subtracted from the calculated urban background concentration. The annual average urban background nitrogen dioxide concentration was then calculated from the corrected annual average urban background oxides of nitrogen concentration using the following empirical relationship based on monitoring data from AUN sites:

For NO_x>23.6 μg m^{-3}

$$NO_2 = 0.348.NO_x + 11.48$$ μg m^{-3}

For NO_x<23.6 μg m^{-3}

$$NO_2 = 0.833.NO_x$$ μg m^{-3}

The contribution of road sources to nitrogen dioxide concentrations was then calculated using the following empirical relationship (Stedman):

$$NO_2 = 0.162.NO_x$$

The contributions from road and background sources to annual average nitrogen dioxide concentrations were then summed.

The calculated value was then corrected so that there was agreement between modelled and measured concentrations at a reference site (London North Kensington (LNK)):

NO_2(corrected, site)= NO_2(modelled, site)+ NO_2(measured, LNK)- NO_2(modelled, LNK)

Calculation of 99.8th percentile hourly average concentrations
A simple approach has been used to estimate 99.8th percentile values. The approach relies on an empirical relationship between 99.8th percentile of hourly mean nitrogen dioxide and annual mean concentrations at kerbside/roadside sites, 1990-1998:

NO_2(99.8th percentile)=3.0 NO_2(annual mean)

99.8 th percentile values were calculated on the basis of the modelled annual mean.

The calculated value was then corrected so that there was agreement between modelled and measured concentrations at a reference site (London North Kensington (LNK)):

NO_2(corrected, site)= NO_2(modelled, site)+ NO_2(measured, LNK)- NO_2(modelled, LNK)

RESULTS

Modelled results are shown in Table A3.6. Fig. A3.1 shows modelled annual average nitrogen dioxide concentrations plotted against the measured values. Similarly Fig. A3.2 shows modelled 99.8th percentile average nitrogen dioxide concentrations plotted against measured values.

Table A3.6 Comparison of modelled and measured concentrations

Site	Nitrogen dioxide concentration, ppb			
	Annual average		99.8th percentile hourly	
	Modelled	Measured	Modelled	Measured
London A3	32	30	94	73
North Kensington	24	24	70	70
Bloomsbury	28	34	83	78
Camden	32	33	95	89
London Marylebone	45	48	134	121
Haringey	22	28	65	77

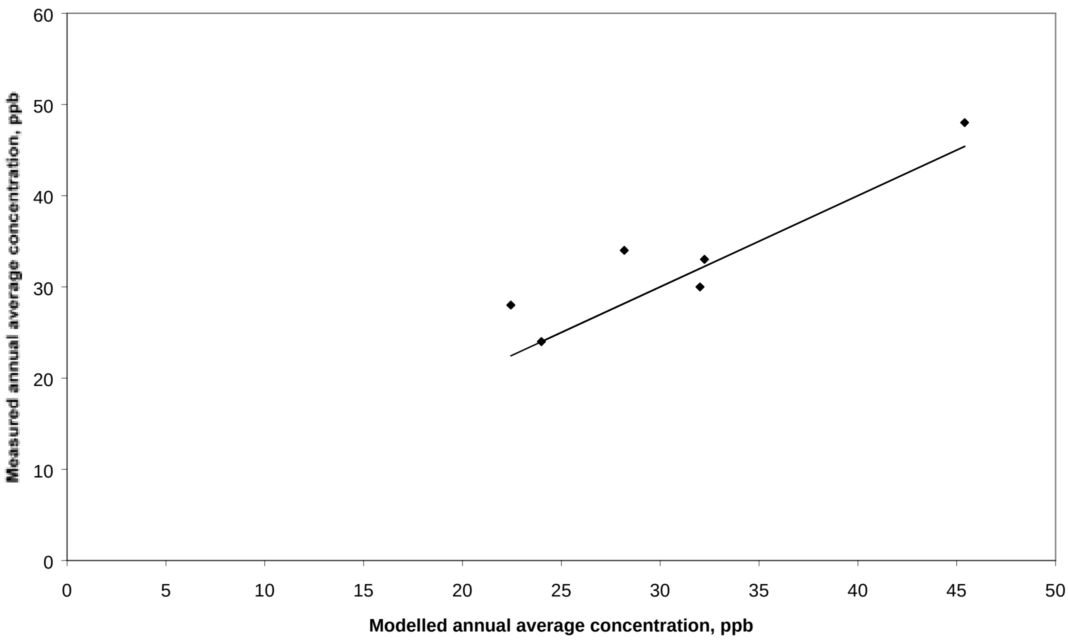

Fig. A3.1 Comparison of modelled and measured annual average nitrogen dioxide concentrations

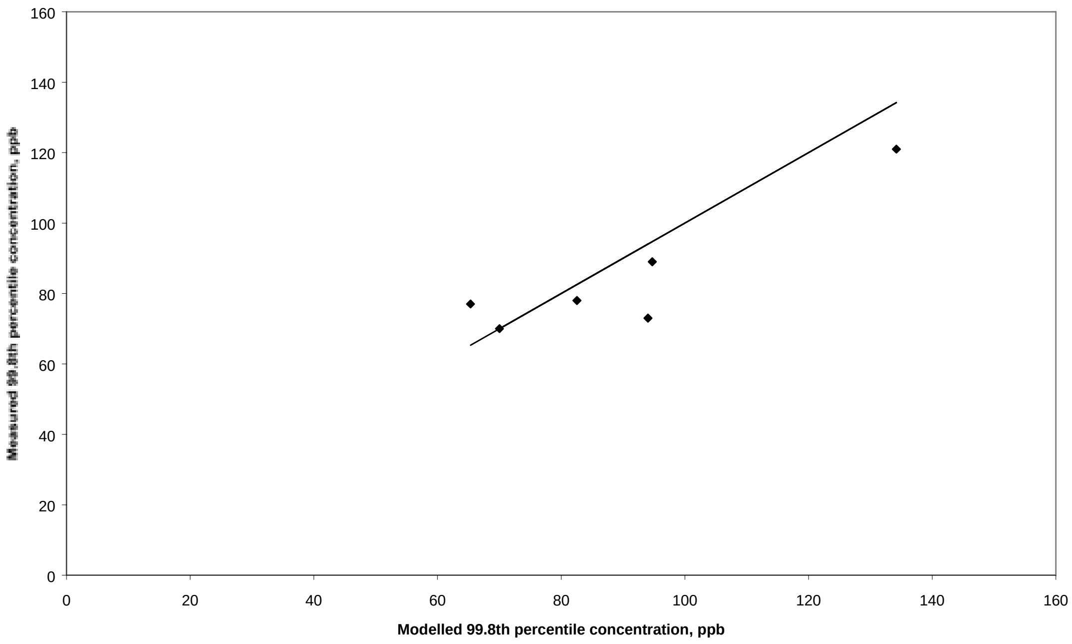

Fig. A3.2 Comparison of modelled and measured 99.8th percentile hourly average nitrogen dioxide concentrations

DISCUSSION

Model errors

The error in the modelled annual average at each site was calculated as a percentage of the modelled value. The standard deviation of the errors was then calculated: it was 12% with five degrees of freedom.

The error in the 99.8 th percentile concentration at each site was calculated as a percentage of the modelled value. The standard deviation of the errors was then calculated: it was also 12% with five degrees of freedom.

Year to year variation in background concentrations

Nitrogen dioxide concentrations at monitoring sites show some year-to-year variations. Reductions in emissions in the United Kingdom are responsible for some of the variation, but atmospheric influences and local effects also contribute to the variation.

In order to quantify the year-to-year variation monitoring data from AUN stations with more than 75% data in the each of the years 1996-1998 was analysed using the following procedure.

First, the expected concentrations in 1997 and 1996 were calculated from the 1998 data.

$$c_e = \frac{d_{1998}}{d_y}.c_{1998}$$

where c_{1996} is the concentration in 1998;

d_{1998}, d_y are correction factors to estimate nitrogen dioxide concentrations in future years (1996=1, 1997=0.95, 1998=0.91) from DETR guidance;

The difference between the measured value and the expected value was then determined for each site and normalised by dividing by the expected value. The standard deviation of normalised differences was determined for each site. A best estimate of the standard deviation from all sites was then calculated. The standard deviation of the annual mean was 0.097 with 2 degrees of freedom. The standard deviation of the 99.8th percentile hourly concentration was 0.21 with 2 degrees of freedom.

Short periods of monitoring data
Additional errors can be introduced where monitoring at the reference site (used to calibrate the modelling results against) takes place over periods less than a complete year, typically of three or six months.

In this case, a whole year of data was available at the monitoring site (1999 in Glasgow Centre), and so no correction was necessary for short periods of monitoring.

Confidence limits
Upper confidence limits for annual mean and 99.8th percentile concentrations were estimated statistically from the standard deviation of the model error and the year-to-year standard deviation:

$$u = c + \sqrt{(t_m s_m)^2.\left(1 + \frac{1}{k}\right) + (t_y s_y)^2 + \sum (t_p s_p)^2 / k}$$

where:

s_m, s_y, s_p are the model error standard deviation , the year to year standard deviation and the standard error introduced using part year data;

c is the concentration calculated for the modelled year;

t_m, t_y, t_p are the values of Student's t distribution for the appropriate number of degrees of freedom at the desired confidence level;

k is the number of reference sites used in the estimation of the modelled concentration.

In many cases, the concentration estimate is based on a single reference site (k=1). However, improved estimates can be obtained where more than one reference site is used.

Table A3.7 shows confidence levels for predictions as a percentage of modelled values

Table A3.7 Upper confidence levels (k=1) for modelled concentrations for future years

Confidence level	Annual mean	99.8^{th} percentile
80 %	+19%	+27%
90%	+31%	+47%
95%	+44%	+70%

In practical terms,

- there is less than 1:5 chance (i.e.100-80=20%) that the 40 $\mu g\ m^{-3}$ objective will be exceeded if the modelled annual average concentration in 2005 is less than 34 $\mu g\ m^{-3}$ (i.e. 40/1.19);
- there is less than 1:20 (i.e. 100-5=5%) chance that the objective will be exceeded if the modelled roadside concentration is less than 28 $\mu g\ m^{-3}$ (i.e. 40/1.44).

- Similarly, there is less than 1:5 chance that the 200 $\mu g\ m^{-3}$ 99.8^{th} percentile concentration will be exceeded if the modelled concentration for 2005 is less than 157 $\mu g\ m^{-3}$;
- there is less than 1:20 chance that the objective will be exceeded if the modelled concentration in 2005 is less than 117 $\mu g\ m^{-3}$.

In the figures shown in the report, the intervals of confidence limits for the 'probable' and 'likely' annual average and hourly objective concentrations have been set equal to those for 'possible' and 'unlikely', respectively. In reality, the intervals of concentration increase as the probability of exceeding the annual and hourly objective increases from 'unlikely' to 'likely'. The advantage to setting symmetrical concentration intervals is that the concentration contours on the maps become simpler to interpret. This is a mildly conservative approach to assessing the likelihood of exceedences of the NO_2 objectives since a greater geographical area will be included using the smaller confidence intervals.

A simple linear relationship can be used to predict the 99.8^{th} percentile concentration of NO_2 from the annual concentration: the 99.8^{th} percentile is three times the annual mean at kerbside/roadside locations. Therefore, plots of the modelled annual mean NO_2 concentrations can be used to show exceedences of both the annual and hourly NO_2 objectives. However, the magnitude of the concentrations used to judge exceedences of the hourly objective need to be adjusted so they may be used directly with the plots of annual concentration. This has been performed by simply dividing the concentrations of the confidence limits by three.

The following table shows the difference between assigning symmetrical confidence intervals and assigning intervals based directly on the statistics.

Table A3.8a Confidence levels for modelled concentrations for future years based on symmetrical concentration intervals and concentration intervals derived purely from the statistics

Description	Chance of exceeding objective	Confidence limits for the modelled annual average concentrations (μg m^{-3})			
		Annual average objective (symmetrical intervals)	Symmetrical intervals	Annual average objective (intervals based on statistics)	Interval
Very unlikely	Less than 5%	< 28		< 28	
Unlikely	5 to 20%	28 to 34	6.0	28 to 34	6.0
Possible	20 to 50%	34 to 40	6.3	34 to 40	6.3
Probable	50 to 80%	40 to 46	6.3	40 to 47	7.5
Likely	80 to 95%	46 to 52	6.0	47 to 58	10.3
Very likely	More than 95%	> 52		> 58	

Table A3.8b Confidence levels for modelled concentrations for future years based on symmetrical concentration intervals and concentration intervals derived purely from the statistics

Description	Chance of exceeding objective	Confidence limits for the modelled annual average concentrations (µg m^{-3})			
		Hourly average objective (symmetrical intervals)	Symmetrical intervals	Hourly average objective (intervals based on statistics)	Interval
Very unlikely	Less than 5%	< 39		< 39	
Unlikely	5 to 20%	39 to 52	13.2	39 to 52	13.2
Possible	20 to 50%	52 to 67	14.3	52 to 67	14.3
Probable	50 to 80%	67 to 81	14.3	67 to 85	18.1
Likely	80 to 95%	81 to 94	13.2	85 to 113	28.7
Very likely	More than 95%	> 94		> 113	