Report

Air Quality Review and Assessment - Detailed Assessment

A Report produced for
Waveney District Council

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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 outcome of their updating and screening report of May 2003, Waveney District Council commissioned **netcen** to undertake a Detailed Assessment for nitrogen dioxide and PM_{10} to predict current and likely future concentrations of these pollutants in two areas of Lowestoft: the junction of the A146 and A1117 (Flying Dutchman junction) for NO_2 and PM_{10}, and the roundabout junction of the A1117 with the B1375 (PM_{10} only), both approximately 2.5km east of central Lowestoft.

The screening report had also concluded that a detailed assessment was required for the Pier Terrace junction of the A12 and A146 in central Lowestoft. However, the latter junction is to be reconfigured during construction of the South Lowestoft Relief Road (SLRR), currently under construction. This new road will lead to much reduced traffic flows along some arms of the junction. The air quality assessment undertaken by Faber Maunsell in 2003 as part of the environmental impact assessment of the scheme, concluded that once the scheme is completed, it is not predicted that exceedances of the UK objectives for NO_2 in 2005, nor for PM_{10} in 2004 will occur at this location. It is however predicted that the UK objectives for PM_{10} in 2010 (not currently in Regulation) may be widely exceeded across Lowestoft, including at Pier Terrace. This Detailed Assessment has therefore only modelled concentrations at the first two junctions, as the results of the SLRR environmental statement indicate that no exceedances will occur at Pier Terrace. Furthermore, diffusion tube monitoring at the kerbside at this junction in 2002 did not indicate a likelihood of exceedance of the NO_2 objectives in 2005.

Pollutant concentrations are suspected to be elevated around these junctions owing to traffic congestion and queuing.

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[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.

Nitrogen Dioxide

At all receptor locations it was assessed that the risk of the UK objective for annual average NO_2 in 2005 being exceeded was at most ***possible*** (with probability between 20% and 50%).

At all receptor locations it was assessed that the risk of the EU Limit Value for annual average NO_2 in 2010 being exceeded was at most ***possible*** (with probability between 20% and 50%).

At all receptor locations it was assessed that the risk of the UK objective for hourly NO_2 in 2005, and of the EU Limit Value for hourly NO_2 in 2010, being exceeded was at most ***unlikely*** (with probability between 5% and 20%).

It is not recommended that Waveney District Council declare an air quality management area for NO_2 at the Flying Dutchman junction of the A146 and the A1117. However, given the uncertainty in the traffic data available for this assessment, and in the likely impact of the forthcoming SLRR on local traffic flows, it is recommended that Waveney District Council commission traffic surveys to look at traffic conditions at this junction, with particular attention being paid to congestion and queuing. In addition, it is recommended that the Council undertake diffusion tube monitoring at one or more of the closest properties to the junction. This work would be best undertaken following opening of the SLRR.

PM_{10}

The modelling results predicted that annual average concentrations of PM_{10} in 2004 would be well below the annual objective for PM_{10} in 2004 at all of the locations modelled.

The modelling results showed that it is at most ***unlikely*** (with probability between 5% and 20%) that an exceedance of the daily objective for PM_{10} in 2004 would occur at either junction.

The modelling results predicted exceedance of both of the 2010 indicative objectives for PM_{10} at the 2 junctions. It was predicted to be ***likely*** that the annual mean objective for PM_{10} in 2010 would be exceeded at these locations. Furthermore, the number of days in which daily mean PM_{10} exceeded 50 $\mu g/m^3$ in 2010 was predicted to exceed 7 at locations in the vicinity of both junctions.

It is not predicted that either of the UK objectives for PM_{10} in 2004 will be exceeded. Waveney District Council is not therefore required to declare an air quality management area with regard to these objectives.

It is predicted that both the UK objectives for PM_{10} in 2010 will be exceeded in that year. However, as these objectives have not yet been included in the Air Quality Regulations for the purposes of air quality management, Waveney District Council is not required to declare an air quality management area with regard to these objectives either. However, Waveney District Council may wish to bear these conclusions in mind when planning future air quality monitoring. In addition, given the uncertainties in the traffic data used in this assessment regarding traffic queuing and congestion, it is recommended that Waveney District Council commission a detailed survey of queuing and congestion throughout the day at both junctions, once the SLRR is open, in order to inform future subsequent rounds of review and assessment.

If DEFRA agree with the contents of this report, Waveney District Council will next be required to submit either a Progress Report in April 2005, or a revised Updating and Screening report in April 2006. These will provide Waveney District Council with the opportunity to report on progress made regarding the further work recommended in this Detailed Assessment.

Maps reproduced within this document

Acronyms and definitions

AADTF	annual average daily traffic flow
ADMS	an atmospheric dispersion model
AQDD	Common Position on Air Quality Daughter Directives
AQMA	Air Quality Management Area
AQS	Air Quality Strategy
AURN	Automatic Urban and Rural Network
CNS	central nervous system
d.f.	degrees of freedom
DEFRA	Department for the Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DMRB	Design Manual for Roads and Bridges
EA	Environment Agency
EPA	Environmental Protection Act
EPAQS	Expert Panel on Air Quality Standards
ERG	Environmental Research Group, Kings College, London
GIS	Geospatial Information System
HDV	Heavy Duty Vehicles
kerbside	0 to 1 m from the kerb
n	number of pairs of data
NAEI	National Atmospheric Emission Inventory
NAQS	National Air Quality Strategy (now called the Air Quality Strategy)
NETCEN	National Environmental Technology Centre
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NPL	National Physical Laboratory
NRTF	National Road Traffic Forecast
ppb	parts per billion
r	the correlation coefficient
roadside	1 to 5 m from the kerb
WDC	Waveney District Council
SD	standard deviation
TEMPRO	A piece of software produced by the DETR used to forecast traffic flow increases

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1 Introduction

1.1 PURPOSE OF THE STUDY

Following the outcome of their updating and screening report of May 2003, Waveney District Council commissioned **netcen** to undertake a Detailed Assessment for nitrogen dioxide and PM_{10} to predict current and likely future concentrations of these pollutants at two busy junctions in Lowestoft.

In the updating and screening report, diffusion tube monitoring and modelling results obtained using the DMRB screening model indicated that concentrations of NO_2 were likely to exceed the UK annual average objective for NO_2 in 2005 at roadside locations at the following two junctions:

- A12 with A146 at Pier Terrace; and
- A1117 with the A146 ('Flying Dutchman' junction).

Furthermore, screening modelling also indicated that the 24 hour objective for PM_{10} in 2004 was also likely to be breached at the above two locations and at a third junction, namely:

- A1117 with B1345 (Gorleston Rd and Bridge Rd, Oulton Broad).

Pollutant concentrations are suspected to be elevated around the above junctions owing to traffic congestion and queuing.

The Pier Terrace junction of the A12 and A146 in central Lowestoft is to be reconfigured during construction of the South Lowestoft Relief Road (SLRR), currently under construction. This new road will lead to much reduced traffic flows along some arms of this junction. The environmental impact assessment of the scheme, undertaken by Faber Maunsell in 2001 concluded that once the scheme is completed, it is not predicted that exceedances of the UK objectives for NO_2 in 2005, nor for PM_{10} in 2004 will occur at this location. This junction has not therefore been reassessed in this detailed assessment.

1.2 GENERAL APPROACH TAKEN

The approach taken in this study was to:

- Collect and interpret additional data to that already used in the screening assessment, in order to support the detailed assessment, including more detailed traffic flow data around the areas outlined above;
- Undertake 6 months monitoring for NO_2 and PM_{10} at a roadside location adjacent to the 'Flying Dutchman' junction;
- 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 and PM_{10} around the selected roads, 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 of concentrations and assess the uncertainty in the predicted concentrations.

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 constitutes a detailed Air Quality review and assessment for Waveney District Council for nitrogen dioxide and PM_{10}. This chapter, Chapter 1 has summarised the need for the work and the approach to completing 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 the Detailed Assessment for Waveney District Council.

Chapter 4 introduces the latest standards and objectives for nitrogen dioxide and summarises the monitoring of NO_2 that has taken place in Waveney in the areas of concern. It also describes the results of the assessment and discusses whether the nitrogen dioxide objectives will be exceeded in Waveney in the relevant years. The results of the analysis are displayed in tabular form and as contour plots. It also presents the recommendations from the assessment for NO_2.

Chapter 5 similarly introduces the latest standards and objectives for PM_{10} and summarises the monitoring of PM_{10} that has taken place in Waveney in the areas of concern. It also describes the results of the assessment and discusses whether the PM_{10} objectives will be exceeded in Waveney in the relevant years. The results of the analysis are displayed in tabular form and as contour plots. It also presents the recommendations from the assessment for PM_{10}.

1.7 GIS DATA USED

Waveney District 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.

2.2.1 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 µg m^{-3} with the number of exceedances 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 exceedances 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 exceedances a year and equivalent percentile]	
	($\mu g\ m^{-3}$)	(ppb)		**($\mu g\ m^{-3}$)**	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 exceedances 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 exceedances 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 exceedances a year or equivalent to the 99.9th percentile]	by 31.12.2005
	350	132	**1 hour** mean	**350** [maximum of 24 exceedances a year or equivalent to the 99.7th percentile]	by 31.12.2004
	125	47	**24 hour** mean	**125** [maximum of 3 exceedances a year or equivalent to the 99th percentile]	by 31.12.2004

Notes

1. Conversions of ppb and ppm to ($\mu g\ m^{-3}$) 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.

2.2.2 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.

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

For particulates (as PM_{10}) new provisional objectives have been introduced:

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

2.2.4 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 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. Recent developments in the UK include the announcement by the Environment Agency in January 2000 on 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 will 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-

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

operation with and participation by the general public in addition to other transport, industrial and governmental authorities.

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.

2.2.5 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 detailed 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 check list 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 exceedance of an objective to justify a detailed assessment
Detailed assessment	To provide an accurate assessment of the likelihood of an air quality objective being exceeded at locations with relevant exposure. This should be sufficiently detailed to allow the designation or amendment or any necessary AQMAs.	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 facades of offices or other places of work where members of the public do not have regular access.
		• Building facades of residential properties, schools, hospitals, libraries etc.	• Gardens of residential properties.
			• Kerbside sites (as opposed to locations at the building facade), 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 facade), 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 exceedances 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.
- A number of air quality reviews are required in order to assess compliance with air quality objectives. The number of reviews necessary depends on the likelihood of achieving the objectives.

3 Information used to support this assessment

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

3.1 MAPS

Waveney District Council provided OS Landline data of the areas in the district which needed to be modelled. This enabled accurate road widths and the distance of the housing to the kerb to be determined.

3.2 SUMMARY OF PREVIOUS AIR QUALITY REVIEW AND ASSESSMENT REPORTS

Waveney District Council undertook the first round of air quality review and assessment during 1999/2000. This work concluded that the risk of any of the UK air quality objectives being exceeded in the relevant years was negligible, and no air quality management areas were declared.

In the second round of review and assessment, Waveney District Council published their updating and screening assessment in May 2003. This concluded that a detailed assessment was required for NO_2 and PM_{10}.

Diffusion tube monitoring and modelling results obtained using the DMRB screening model indicated that concentrations of NO_2 were likely to exceed the UK annual average objective for NO_2 in 2005 at roadside locations at the following two junctions:

- A12 with A146 at Pier Terrace; and
- A1117 with the A146 ('Flying Dutchman' junction).

Furthermore, screening modelling also indicated that the 24 hour objective for PM_{10} in 2004 was also likely to be breached at the above two locations and at a third junction, namely:

- A1117 with B1345 (Gorleston Rd and Bridge Rd, Oulton Broad).

Pollutant concentrations are suspected to be elevated around the above junction owing to traffic congestion and queuing. Traffic flows at the junctions of concern are anticipated to change shortly as a result of the opening of the South Lowestoft Relief Road (SLRR), currently under construction. The new road, expected to open in 2005, will lead to reductions in traffic flows at the above junctions. As this is a confirmed project to be completed in the near future, this assessment has been undertaken using traffic flow forecasts assuming the SLRR to be operational.

In addition, the junction at Pier Terrace is to be reconfigured as part of the SLRR development. This will alter the road alignments, priorities and traffic flows. An environmental impact assessment of the SLRR scheme was undertaken by Faber Maunsell in 2001. This concluded that the UK objectives for NO_2 in 2005, and for PM_{10} in 2004 would not be exceeded at any location along the SLRR route, including at Pier Terrace. However, it did conclude that the EU Limit Values (Stage 2) for PM_{10} in 2010, now included in the air quality strategy for England and Wales, but not yet in Regulation, might be exceeded in that year. Furthermore, diffusion tube monitoring at the kerbside at this junction in 2002 does not indicate a likelihood of exceedance of the NO_2 objectives in 2005 (see Table 4.3).

3.3 ROAD TRAFFIC DATA

3.3.1 Average flow, hourly fluctuations in flow, speed and fraction of HDVs.

Forecast AADT traffic flow data, percentage of HGVs, and free-flowing traffic speeds for 2005 were provided by Faber Maunsell for most of the roads of concern. Forecasts were provided for two scenarios relating to the construction of the South Lowestoft Relief Road (SLRR): a Do Minimum scenario without the SLRR in place, and a corresponding Do Something scenario with the new road in place and in operation. Where data has not been provided for a road link, traffic data has been taken from the 2000 National Atmospheric Emissions Inventory (NAEI). To determine the hourly fluctuations in traffic flow the (then) DETR's diurnal traffic variation default figures were used (DETR 1999b). Appendix 1 summarises the traffic data used.

Detailed survey data on traffic queuing and congestion in Lowestoft were not available; it is understood that no such surveys have as yet been undertaken. It has therefore been necessary to make a number of assumptions regarding queuing at junctions. It has been assumed that on each arm of each junction, there is typically a queue of 40m-60m of traffic travelling at very low speed (5kph without SLRR in place, 10kph with SLRR in place.)

Concentrations in 2003 were predicted using traffic data reflecting current conditions, whilst for the future years they were predicted using 'Do Something' traffic flow forecasts for the South Lowestoft Relief Road provided by Faber Maunsell. These forecasts predicted flows on the roads and at the junctions in question following completion of the SLRR, currently under construction and due for completion during 2005.

3.3.2 Traffic Growth

2005 traffic flow data was used to estimate flows in 2003, 2004 and 2010 using traffic growth factors derived from the NRTF and the TEMPRO v4 model. TEMPRO provides regional traffic growth statistics. Details of the growth factors used in the assessment to predict traffic flows in Waveney in future years are given in Appendix 1.

3.4 METEOROLOGICAL DATA USED IN THE DISPERSION MODELLING

Hourly meteorological data for the coastal station at Hemsby, north of Lowestoft, for 2000 was used in this study. This was the only coastal weather station in the vicinity, and 2000 the latest year for which data was available. The meteorological data provided information on wind speed and direction and the extent of cloud cover for each hour of 2000.

3.5 AMBIENT MONITORING

Waveney District Council undertake diffusion tube monitoring for NO_2, but no automatic monitoring, nor is any kind of monitoring for PM_{10} regularly undertaken in Lowestoft. A temporary automatic monitoring survey was therefore conducted for the purposes of this detailed assessment.

3.5.1 Continuous monitoring

Location of the continuous monitor

Nitrogen dioxide and PM_{10} concentrations were measured by continuous monitoring for a period of 6 months between February and August 2004. The monitor was situated at a roadside site on the A146 Beccles Road (OS Grid Reference 651853,292106) at the 'Flying Dutchman' junction. The site was located approximately 2m from the kerbside in front of a row of retirement home dwellings. Nitrogen dioxide and PM_{10} were measured by ozone chemiluminescence and by TEOM respectively. The site is indicated in Figure 4.1 and a summary of the results are included in Appendix 2.

Measurement technique and QA/QC
Ozone chemiluminescence is the reference method specified by the EC NO_2 Directives. The analyser was calibrated using compressed gas mixtures certified to ISO17025 by **netcen**'s Gas Standards Calibration Laboratory. This provides traceability of measurement to recognised national standards held at NPL or equivalent organisations. The expected accuracy of the method for nitrogen dioxide is ±11% with a precision of ±3.5 ppb. **netcen** undertook installation of the equipment, site calibrations, checking of calibration data and validation of the real-time results using documented procedures.

The TEOM analyser is the most widely used instrument in the UK for monitoring PM_{10} particulate material. However, due to evaporation of volatile species in the heated inlet of the analyser, this monitoring method generally under-reads particle concentrations by between 15 and 30 % compared to measurements by the EU gravimetric reference method . There is a study by **defra** underway at the time of writing to investigate this effect in more detail. The UK Air Quality Objectives for PM_{10} are based on the European reference method and it is therefore necessary to apply a "correction factor" when comparing TEOM measurements with these objectives. In line with the **defra** Technical Guidance, a constant factor of 1.3 has therefore been applied to the measurements from this survey when comparing with the objectives. Measurements thus corrected in this report will therefore be referred to as $\mu g/m^3$ (gravimetric). In this study, the TEOM analyser was operated in line with procedures used in the AURN and hence the data will be of comparable quality. The estimated precision of the TEOM measurements is +/- 4ug/m-3, but, due to the loss of volatile material and the use of a correction factor, the accuracy cannot be fully assessed at present.

3.5.2 NO_2 Diffusion Tube Monitoring

Waveney District Council undertook diffusion tube monitoring for NO_2 at the junctions of interest between August 2001 and May 2003. Following this and the conclusion of the Council's updating and screening assessment, diffusion tube monitoring was discontinued. No co-location with automatic monitoring was undertaken. All tubes were supplied and analysed by Harwell Scientific using the TEA in Acetone (50:50 v/v) method.

Details of the type, locations, and concentrations recorded by the monitors (diffusion tubes and continuous monitors) are given in Chapter 4 and Appendix 2.

3.6 MODELLING METHODOLOGY

The air quality impact from road traffic emissions in this 'detailed' assessment was calculated using **netcen**'s proprietary urban model. 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 2000 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 V3.2.

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 and PM_{10} from road traffic emissions was 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).

3.7 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 Detailed Assessment for Nitrogen Dioxide

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 be achieved by 2005 for nitrogen dioxide:

- An annual average concentration of 40 µg m^{-3} (21 ppb);
- A maximum hourly concentration of 286 µg 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 µg m^{-3} (21 ppb);
- 200 µg m^{-3} (100 ppb) as an hourly average with a maximum of 18 exceedances in a year.

The National Air Quality Strategy was reviewed in 1999 (DETR, 1999). The Government proposed that the annual objective of 40 µg 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. The current UK objectives for 2005 are therefore identical to the EU Limit Values for 2010.

Modelling studies suggest that in general achieving the annual mean of 40 µg 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 2000 accounted for approximately 42% 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, 2000).

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 suggest that for NO_2 a reduction in NO_x emissions over and above that achievable by national measures will be required to ensure that air quality objectives are 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 detailed assessment for this pollutant.

4.4 MONITORING DATA

The locations of the temporary automatic monitoring station is shown in Figure 4.1.

4.4.1 Automatic Monitoring

Table 4.2 shows the measured concentrations in 2004. From the period mean (17/02/04 to 19/08/4) an estimate has been made of the likely annual average value for the whole of 2003, based on the relationship between the same 2004 period mean, and the 2003 annual mean at 2 surrounding AURN national network automatic monitoring sites: Norwich Centre site 35km to the north west, and St Osyth 30km to the south west, an urban centre and rural site respectively (Table 4.1).

Table 4.1 – Comparison of annual mean and period mean (17/02/04 – 19/08/04) at 2 AURN automatic monitoring stations surrounding Lowestoft

AURN Site	Site Location	NO_2 µg/m^3		Ratio Am/Pm (annual mean/period mean)
		Annual Mean	Period Mean	NO2
Norwich Centre	Urban Centre	25	18	1.4
St Osyth	Rural	18	15	1.2
Average				**1.3**

The results of the automatic monitoring in Lowestoft indicate that at this roadside location, it is likely that the UK objective for hourly NO_2 in 2005 is already being met by a clear margin (Table 4.2 below). However, annual mean NO_2 appear to currently exceed 40 µg/m^3 and is expected to be close to the objective value in 2005. It is expected that NO_2 concentrations will have declined by 2010 and so will meet EU Limit Values for that year by a clear margin.

It should be noted that currently measured concentrations reflect the result of traffic emissions at the Flying Dutchman junction without the South Lowestoft Relief Road being in place. This new road is expected to open shortly, and so traffic flows at this junction and at the other junction studied in this detailed assessment are expected to reduce to a greater or lesser degree. The predictions of NO_2 concentrations in 2005 and 2010 given here have been estimated by projecting forward the results for 2003/2004, and do not therefore take into account the opening of this new road. These therefore represent conservative estimates of likely future concentrations, and it is anticipated that NO_2 concentrations in future will be less than this provided that the SLRR is operational in the year in question.

Table 4.2 **Summary of continuous nitrogen dioxide ratified data 17th February 2004 to 19th August 2004.**

Statistic	Concentration (µg/m^3) Period Mean 17/02/04 – 19/08/04	Estimate of Year Mean 2003	Estimate of Year Mean 2005	Estimate of Year Mean 2010
Annual Mean NO_x	59.2	-	-	-
Annual Mean NO_2	32.5	42	40	33
Maximum Hour NO_2	126	-	-	-
Data Capture (%) NO_2	99.1	-	-	-

4.4.2 Diffusion tubes

Diffusion tubes monitoring at a number of locations in Lowestoft was undertaken until May 2003, when it was discontinued. No up-to-date diffusion tube monitoring, nor results from collocation studies are available for the study areas of interest. Diffusion tubes results for 2002, the only complete year of monitoring, are presented below for the 4 monitoring sites close to the junctions of interest (Table 4.3).

As no collocation study was undertaken during this period, the diffusion results have been bias corrected using factors derived from the study undertaken by UWE (2004). From the results of collocation studies throughout the UK compiled and published by UWE, a bias adjustment factor of 0.84 has been applied. To predict the diffusion tube concentrations in 2005 and in 2010 from measurements in years 2003, the adjustment factors given in LAQM.TG(03) have been applied.

Table 4.3 **Summary of nitrogen dioxide diffusion tube monitoring in 2002**

Location	**Type**	**X**	**Y**	**2002 unbiased**	**2002 Biased**	**2005 Estimate**	**2010 Estimate**
Golden Court	R	652272	292960	46.8	39.3	36.2	29.8
Saltwater Way	R	652137	292751	34.1	28.6	26.4	21.7
Flying Dutchman	R	651853	292106	31.5	26.5	24.4	20.0
Pier Terrace	K	654724	292658	48.2	40.5	37.3	30.7

R – Roadside
K - Kerbside

Results indicate that by 2005, the annual average objective for NO_2 will not be exceeded at any of the sites, although concentrations will be at or close to the objective value of 40 µg/m^3 at Golden Court (south of the A1117/B1375 junction) and at Pier Terrace. However, by 2010 it is predicted that concentrations at all sites will be in clear compliance with the EU Limit Value. Again, these projections to 2005 and 2010 do not take into account the opening of the SLRR.

4.5 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- v3.2 as a dispersion kernel model. Detailed modelling of current (2003) and future (2005, 2010) concentrations of annual average NO_2 in Lowestoft was undertaken to predict compliance with the UK objectives for 2005, and the identical EU Limit Value for 2010. Concentrations in 2003 were predicted using traffic data reflecting current conditions, whilst for the future years they were predicted using SLRR 'Do Something' traffic flow forecasts provided by Faber Maunsell. These forecasts predicted flows on the roads and at the junctions in question following completion of the SLRR, currently under construction and due for completion during 2005.

The roads were defined as volume sources, 3m deep, 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 position of the volume sources (here the roads) were accurate to approximately a metre.

Where queuing of vehicles was reported, emissions from stationary vehicles exhausts were estimated on the basis that the engine power output and hence emissions were the same as those at a speed of 5-10 kph.

4.6 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 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 have been omitted where this would lead to double counting of the local impact of emissions.

4.7 MODEL BIAS

Predictions of NO_2 concentrations at the temporary automatic monitoring site were used to predict the model bias, and thereby to bias adjust the model results. Table 4.5 shows the values used in the calculation. This procedure assumed that the modelling error was primarily in the calculation of the local background. Overall predictions of total NO_x and NO_2 were rather lower than those recorded at the monitoring site (Table 4.4).

Table 4.4 - Agreement between model and monitor

		2003 Estimates (µg/m^3)	
		Monitor	**Model**
Total	**NOx**	91	66
	NO_2	42	28

Agreement between the model and monitoring site for total NO_x and NO_2 is acceptable, with the model predicting within approximately 30% of the monitor. This suggests that the model is not predicting accurately the NO_x emissions from vehicles at the monitoring location. Given the uncertainty and lack of knowledge regarding traffic conditions at this location, particularly the lack of knowledge of queuing and congestion at the Flying Dutchman junction, this is not surprising, and it is recommended that traffic surveys be undertaken at this junction, once the SLRR is operational, to determine the extent of queuing and congestion here, and to inform any future assessments.

Table 4.5 Calculation of Bias Adjustment for NO_2.

Annual Average NO_2 (ug/m^3)				
Automatic Monitor at Flying Dutchman junction 2003 estimate	**Model Prediction at Automatic Monitoring Site in 2003**	**Bias Adjustment of Background for 2003**	**Bias Adjustment of Background for 2005***	**Bias Adjustment of Background for 2010***
42.3	28.3	14.0	13.4	11.5

* Predicted from bias adjustment factor for 2003 and multiplied by year conversion factors provided in TG(03).

4.8 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 **netcen** air quality review and assessments. Statistical techniques have been used to assess the likelihood that there will be an exceedance 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 Waveney District Council generally consider declaring an AQMA where the probability of exceedance 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, μg/m^3**	
		Likelihood of annual average objective being exceeded	Likelihood of hourly average objective being exceeded
Very unlikely	Less than 5%	<28	<39
Unlikely	5-20%	28-34	39-52
Possible	20-50%	34-40	52-67
Probable	50-80%	40-46	67-81
Likely	80-95%	46-52	81-94
Very likely	More than 95%	>52	>94

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 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 exceedances 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 99.8th hourly percentile concentration of NO_2 from the annual concentration: the 99.8th 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 exceedances of both the annual and hourly NO_2 objectives. However, the magnitude of the concentrations used to judge exceedances 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. Table 4.4 provides a comparison of modelled and measured nitrogen dioxide concentrations at the automatic site.

4.9 RESULTS OF MODELLING

Figures 4.1 – 4.2 show modelled nitrogen dioxide concentrations at the Flying Dutchman (A146/A1117) junction in 2005 and 2010. The model predicts that the annual average objective of 40 µg m^{-3} of nitrogen dioxide will not be exceeded at the Flying Dutchman Junction in either 2005 or 2010 at any relevant receptor. It is therefore also predicted that the hourly objectives will not be exceeded in these years.

Table 4.7 and 4.8 below shows the risk of exceeding the objectives for nitrogen dioxide at the location of highest concentrations. At most it is "possible" that the annual mean objective will be exceeded in 2005 at relevant receptors.

Table 4.7 Probability of exceeding the objectives for nitrogen dioxide in 2005.

Location	**Probability of exceedance, P**	
	Annual average objective	**99.8th %ile hourly average**
Property on SE corner of Flying Dutchman Corner, closest to junction	20% <P< 50% Possible	5% <P< 20% Unlikely

Table 4.8 Probability of exceeding the objectives for nitrogen dioxide in 2010.

Location	**Probability of exceedance, P**	
	Annual average objective	**99.8th %ile hourly average**
Property on SE corner of Flying Dutchman Corner, closest to junction	20% <P< 50% Possible	P< 5% Very unlikely

Figure 4.1 - Nitrogen Dioxide concentrations at the Flying Dutchman junction (A1117/A146) in Lowestoft in 2005

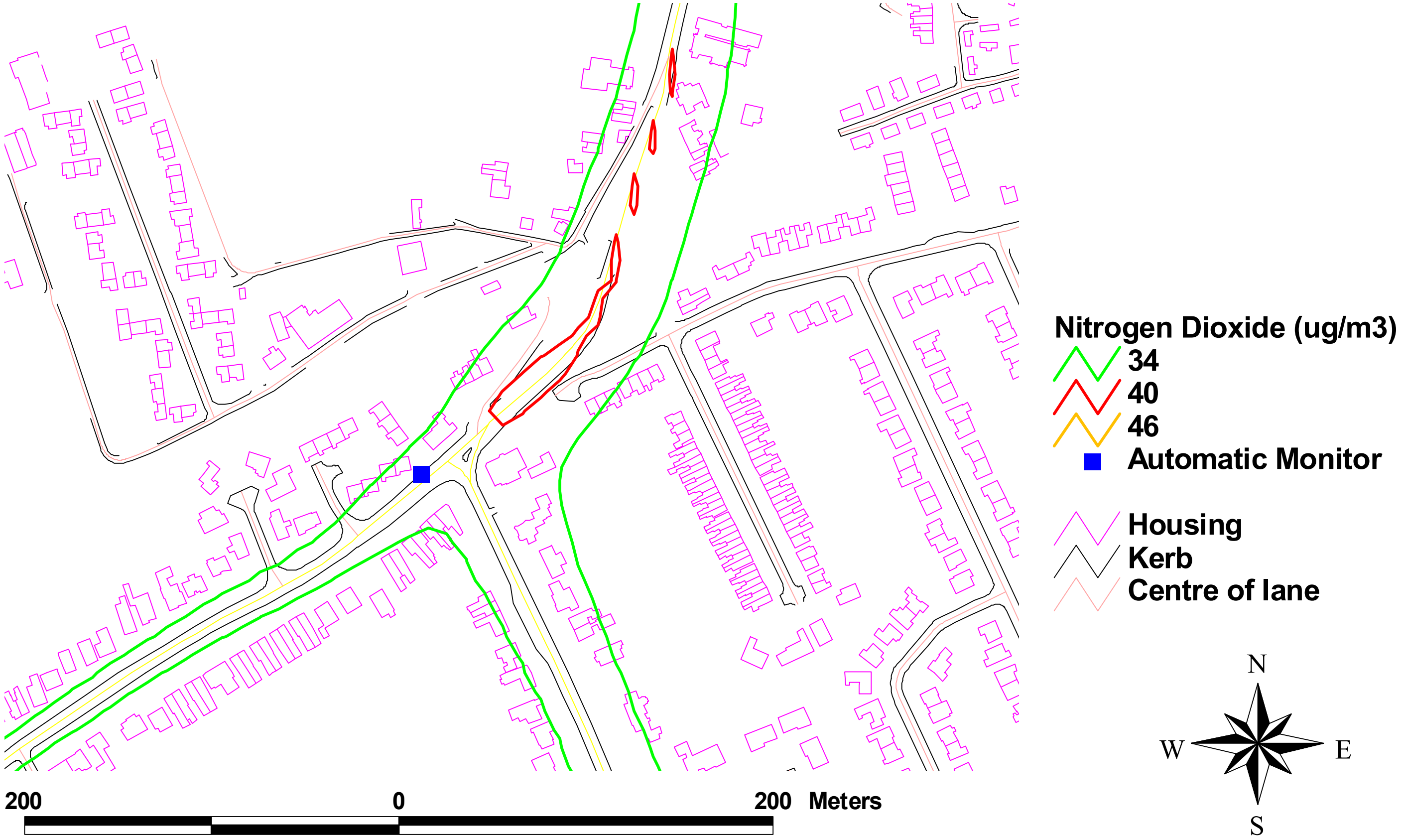
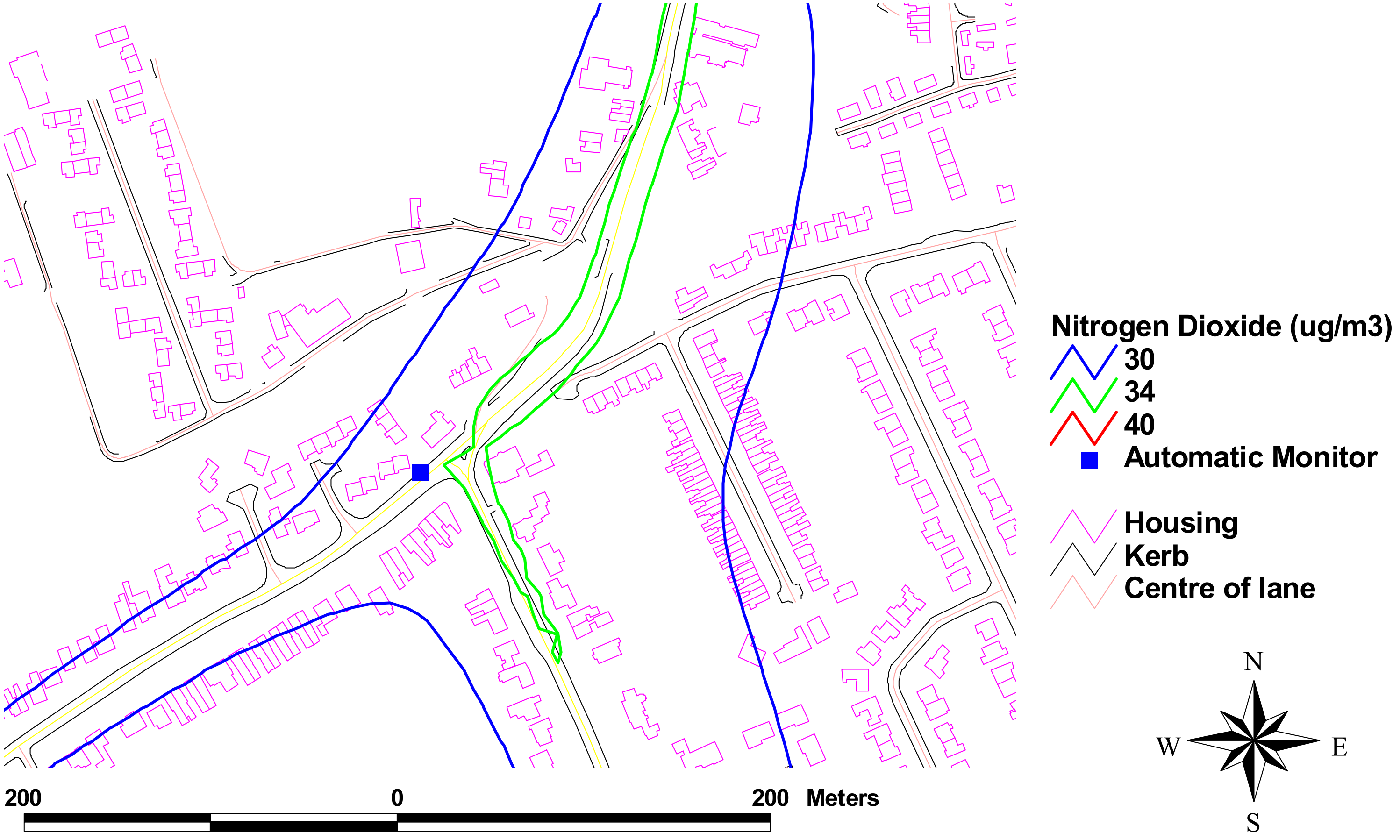


Figure 4.2 - Nitrogen Dioxide concentrations at the Flying Dutchman junction (A1117/A146) in Lowestoft in 2010



4.10 SUMMARY OF THE LIKELIHOOD OF EXCEEDING THE OBJECTIVES FOR NITROGEN DIOXIDE

At all receptor locations it was assessed that the risk of the UK objective for annual average NO_2 in 2005 being exceeded was at most ***possible*** (with probability between 20% and 50%).

At all receptor locations it was assessed that the risk of the EU Limit Value for annual average NO_2 in 2010 being exceeded was at most ***possible*** (with probability between 20% and 50%).

At all receptor locations it was assessed that the risk of the UK objective for hourly NO_2 in 2005, and of the EU Limit Value for hourly NO_2 in 2010, being exceeded was at most ***unlikely*** (with probability between 20% and 50%).

4.11 RECOMMENDATIONS

Waveney District Council is not required to declare an air quality management area for NO_2 at the Flying Dutchman junction of the A146 and the A1117. However, given the uncertainty in the traffic data available for this assessment, and in the likely impact of the forthcoming SLRR on local traffic flows, it is recommended that Waveney District Council commission traffic surveys to look at traffic conditions at this junction, with particular attention being paid to congestion and queuing. In addition, it is recommended that the Council undertake diffusion tube monitoring at one or more of the closest properties to the junction. This work would be best undertaken following opening of the SLRR.

5 Detailed Assessment for PM_{10}

5.1 INTRODUCTION

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. Particles are often classed as either primary (those emitted directly into the atmosphere) or secondary (those formed or modified in the atmosphere from condensation and growth). PM_{10} particles (the fraction of particulates in air of very small size, <10 µm aerodynamic diameter) can potentially pose significant health risks, as they are small enough to penetrate deep into the lungs. Larger particles are not readily inhaled.

A major source of fine primary particles is combustion processes, in particular diesel combustion, where transport of hot exhaust vapour into a cooler tailpipe or stack can lead to spontaneous nucleation of "carbon" particles before emission. Secondary particles are typically formed when low volatility products are generated in the atmosphere, for example the oxidation of sulphur dioxide to sulphuric acid. The atmospheric lifetime of particulate matter is strongly related to particle size, but may be as long as 10 days for particles of about 1 µm in diameter.

Concern about the potential health impacts of PM_{10} has increased very rapidly over recent years. Increasingly, attention has been turning towards monitoring the smaller particle fraction, $PM_{2.5}$, which is capable of penetrating deepest into the lungs, or to even smaller size fractions or total particle numbers.

5.2 LATEST STANDARDS AND OBJECTIVES FOR PM_{10}

The Air Quality Regulations, 1997 set the objective for PM_{10} particulate material of 50 µg m^{-3}, measured as the 99th percentile of the daily maximum running 24 hour mean (equivalent to 4 exceedences per year) to be achieved by 31 December 2005. The objective was based on measurements carried out using the TEOM analyser, or equivalent.

The Government published its proposals for review of the National Air Quality Strategy in early 1999 (DETR, 1999). The review presented proposals for revised and additional objectives for PM_{10}. Revised objectives for PM_{10} were proposed because:

- work carried out by the Airborne Particles Expert Group (APEG) indicated that the original objective was unrealistic;
- the Common Position agreed on the Air Quality Daughter Directive (AQDD) at Environment Council in June 1998 included different objectives for PM_{10}.

These included a 24 hour limit value of 50 µg m^{-3}, not to be exceeded more than 35 times per year and an annual limit of 40 µg m^{-3} to be achieved by 1 January 2005 (EU Stage 1 objectives). The AQDD specifies that the transfer reference method for determining compliance is to be a gravimetric[4] measuring method.

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[4] Comparison of UK monitoring data determined with TEOM instruments with the European Union Directive limit values is not straightforward since the EU limits are based on measurements of PM_{10} by other instrumental techniques which yield higher concentrations (APEG, 1999).

The Air Quality Strategy replaced the original objective for PM_{10} with the AQDD objectives. The current objectives to be achieved by 31st December 2004 are:

- An annual average concentration of 40 µg m^{-3} (gravimetric);
- A 24 hour mean concentration of 50 µg m^{-3} (gravimetric) not to be exceeded more than 35 times a year.

The EU has also set indicative limit values for PM_{10}, which are to be achieved by 1 January 2010. These Stage 2 limit values are considerably more stringent, and are 20 µg m^{-3} the annual mean, and 50 µg m^{-3} as the 24-hour mean to be exceeded on no more than 7 days per year. The Government, the Welsh Assembly Government and the Department of the Environment in Northern Ireland introduced provisional objectives to be achieved by the end of 2010, that are broadly in line with the Stage 2 limit values, although it is not intended that these objectives will be brought into Regulation for the purpose of Local Air Quality Management at this time. The provisional objectives are:

- For all parts of England (except London), Wales and Northern Ireland, a 24-hour mean of 50 µg m^{-3} not to be exceeded more than 7 times per year, and an annual mean of 20 µg m^{-3} to be achieved by the end of 2010;
- For London, a 24-hour mean of 50 µg m^{-3} not to be exceeded more than 10 times per year, and an annual mean of 23 µg m^{-3}, to be achieved by the end of 2010. An annual mean objective of 20 µg m^{-3} to be achieved by the end of 2015 has also been set.

5.3 THE NATIONAL PERSPECTIVE

National UK emissions of primary PM_{10} have been estimated as totalling 184,000 tonnes in 1997. Of this total, around 25% were derived from road transport sources. It should be noted that, in general, the emissions estimates for PM_{10} are less accurate than those for the other pollutants with prescribed objectives, especially for sources other than road transport.

The Government established the Airborne Particles Expert Group (APEG) to advise on sources of PM_{10} in the UK and current and future ambient concentrations. Their conclusions were published in January 1999 (APEG, 1999). APEG concluded that a significant proportion of the current annual average PM_{10} is due to the secondary formation of particulate sulphates and nitrates, resulting from the oxidation of sulphur and nitrogen oxides. These are regional scale pollutants and the annual concentrations do not vary greatly over a scale of tens of kilometres. There are also natural or semi-natural sources such as wind-blown dust and sea salt particles. The impact of local urban sources is superimposed on this regional background. Such local sources are generally responsible for winter episodes of hourly mean concentrations of PM_{10} above 100 µg m^{-3} associated with poor dispersion. However, it is clear that many of the sources of PM_{10} are outside the control of individual local authorities and the estimation of future concentrations of PM_{10} are in part dependent on predictions of the secondary particle component.

5.4 MONITORING DATA

The location of the automatic TEOM PM_{10} monitor is shown in Figure 5.1.

5.4.1 Automatic Monitoring

Table 5.2 shows the measured concentrations in 2004. From the period mean (17/02/04 to 19/08/4) an estimate has been made of the likely annual average value for the whole of 2003, based on the relationship between the same 2004 period mean, and the 2003 annual mean at a nearby AURN national network automatic monitoring sites: Norwich Centre site 35km to the north west, an urban centre site (Table 5.1). This was the only suitable site in the region available to make this comparison. In fact, the period mean 2004 and annual means 2003 were actually very similar at this site.

Table 5.1 - Comparison of annual mean and period mean (17/02/04 – 19/08/04) at 1 AURN automatic monitoring station surrounding Lowestoft

AURN Site	Site Location	PM_{10} µg/m^3 (TEOM)		Ratio Am/Pm (annual mean/period mean)
		Annual Mean	Period Mean	PM_{10}
Norwich Centre	Urban Centre	17.9	17.4	1.03
Average				**1.03**

The monitoring in Waveney indicated that the objectives for PM_{10} in 2004 are already being met at this roadside site.

Table 5.2 Summary of continuous PM_{10} ratified data 17th July 2003 to 27th January 2004.

Statistic	Concentration (µg/m^3 Gravimetric)			
	Period 17/02/04 – 19/08/04	Estimate for whole year 2003	Estimate for Year 2004	Estimate for Year 2010
Mean	27.3	28.1	27.7	25.4
Days over 50 µg/m^3	3	21*	20*	13*
Data Capture (%) PM_{10}	87.2	-	-	-

TEOM measurements corrected by factor of 1.3 to estimate µg/m^3 (Gravimetric)
* Estimated from annual average values using the methodology in LAQM.TG(03)

It can be seen from the above results that PM_{10} concentrations at this site are currently well below the UK objectives for 2004. However, by 2010 concentrations may not have declined sufficiently to meet the UK objectives for 2010 (not yet in Regulation) of an annual mean concentration of 20 µg/m^3 and no more than 7 days per year over 50 µg/m^3 (daily mean). It should be noted however that traffic flows along Beccles Road and at this junction in general are expected to decline following opening of the South Lowestoft Relief Road.

5.5 TRAFFIC MODELLING SUMMARY

In this study, the concentrations of PM_{10} at receptors close to the roads and junctions of interest have been modelled using ADMS- v3.2 as a dispersion kernel model. Detailed modelling of current (2003) and future (2004, 2010) concentrations of annual average PM_{10} in Lowestoft at the junctions of concern was undertaken to predict compliance with the UK objectives for 2004 and 2010. The number of days over 50 µg/m^3 was predicted from the annual average using the relationship given in TG(03). Concentrations in 2003 were predicted using traffic data reflecting current conditions, whilst for the future years they were predicted using SLRR 'Do Something' traffic flow forecasts provided by Faber Maunsell. These forecasts predicted flows on the roads and at the junctions in question following completion of the SLRR, currently under construction and due for completion during 2005.

The roads were defined as volume sources, 3m deep, 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 position of the volume sources (here the roads) were accurate to approximately a metre.

Where queuing of vehicles was reported, emissions from stationary vehicles exhausts were estimated on the basis that the engine power output and hence emissions were the same as those at a speed of 5-10 kph.

5.6 SOURCES OF BACKGROUND (NON-TRAFFIC) EMISSIONS DATA

Background concentrations of PM_{10} resulting from sources not modelled in this study have been taken from the background maps published by **defra** at www.airquality.co.uk, and scaled to the year of interest, where necessary, following the recommended procedure in LAQM. TG(03). The contribution to background from the roads modelled in detail have been omitted where this would lead to double counting of the local impact of emissions, following the procedures indicated in LAQM.TG(03).

5.7 MODEL BIAS

Modelled predictions of the PM_{10} concentrations at the temporary automatic monitoring site were used to predict the model bias, and thereby to bias adjust the model results. Table 5.3 shows the values used in the calculation. This procedure assumed that the modelling error was primarily in the calculation of the local background. The difference between the monitor and model was of +7.4 µg/m^3 (gravimetric) in 2003. Bias adjustment factors for subsequent years were then calculated by using the year factors in TG(03), assuming that all the error in the background was related with the secondary PM_{10} fraction.

Table 5.3 Calculation of Bias Adjustment for PM_{10}

Annual Average PM_{10} (µg/m^3 gravimetric)				
Automatic Monitor at Flying Dutchman 2003 estimate	**Model Prediction at Automatic Monitoring Site in 2003**	**Bias Adjustment of Background for 2003**	**Bias Adjustment of Background for 2004**	**Bias Adjustment of Background for 2010**
28.1	20.7	+7.4	+7.2	+6.1

The agreement between the model and monitoring site is reasonable, the model predicting within approximately 25% of the monitored concentration. The discrepancy is likely to be the result of a variety of factors such as uncertainty regarding the extent of congestion and queuing at the junction past the monitor, use of 2000 meteorological data to predict concentrations in 2003, the possible inappropriateness of the factor of 1.3 used to convert readings in µg/m^3 (TEOM) to µg/m^3 (gravimetric) at this location, and the uncertainty in estimating the 2003 annual mean from 6 months monitoring in 2004.

5.8 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 **netcen** air quality review and assessments. Statistical techniques have been used to assess the likelihood that there will be an exceedance 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. They have been calculated for 2004 in terms of the more stringent daily objective, and for 2010 in terms of the more stringent annual mean objective. The following descriptions have been assigned to levels of risk of exceeding the objectives. It would be recommended that Waveney District Council generally consider declaring an AQMA where the probability of exceedance in 2004 or in 2010 is greater than 50% ("Probable").

Table 5.4: Uncertainties in the modelled concentrations for PM_{10} in 2004

Description	Chance of exceeding daily objective for 2004	Predicted number of days PM_{10} over 50 µg/m^3 gravimetric
Very unlikely	Less than 5%	<12
Unlikely	5-20%	12-24
Possible	20-50%	24-35
Probable	50-80%	35-50
Likely	80-95%	50-73
Very likely	More than 95%	>73

Table 5.5: Uncertainties in the modelled concentrations for PM_{10} in 2010

Description	Chance of exceeding annual mean objective for 2010	Modelled annual average PM_{10} (µg/m^3 gravimetric)
Very unlikely	Less than 5%	<13
Unlikely	5-20%	13-17
Possible	20-50%	17-20
Probable	50-80%	20-23
Likely	80-95%	23-27
Very likely	More than 95%	>27

The confidence limits for the 'probable' and 'likely' daily 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 exceedances of the PM_{10} objectives since a greater geographical area will be included using the smaller confidence intervals.

5.9 RESULTS OF MODELLING

Figures 5.1-5.6 show modelled PM_{10} concentrations at the junctions of interest.

The model predicted that the annual average objective of 40 µg m^{-3} of PM_{10} will not be exceeded at either location in 2004, the highest calculated concentration being 29 µg/m^3. The maximum number of days over 50 µg/m^3 predicted was below 24, at the A1117/B1375 junction (Figure 5.4). The UK objectives for PM_{10} in 2004 are not therefore predicted to be exceeded at these locations (Figures 5.1-5.3).

It is predicted that the new UK objectives for PM_{10} in 2010 (EU Limit Values (Stage 2)), both for annual mean PM_{10} (20 µg/m^3) and for daily mean PM_{10} (not to exceed 50 µg/m^3 on more than 7 days per year) will be exceeded at these two junctions (Figure 5.4-5.6).

Table 5.6 Probability of exceeding the daily objective for PM_{10} in 2004.

Location	Probability of exceedance, P
	Daily objective
Closest house SE of Flying Dutchman Junction	5% <P< 20% Unlikely
Closest house NW of A1117/B1375 roundabout	5% <P< 20% Unlikely

Table 5.7 Probability of exceeding the annual mean objective for PM_{10} in 2010 at Butchers Corner.

Location	Probability of exceedance, P
	Annual average objective
Closest house SE of Flying Dutchman Junction	80% <P< 95% Likely
Closest house NW of A1117/B1375 roundabout	80% <P< 95% Likely

Figure 5.1 - PM10 number of days over 50 ug/m3 in 2004 at the Flying Dutchman junction in Lowestoft

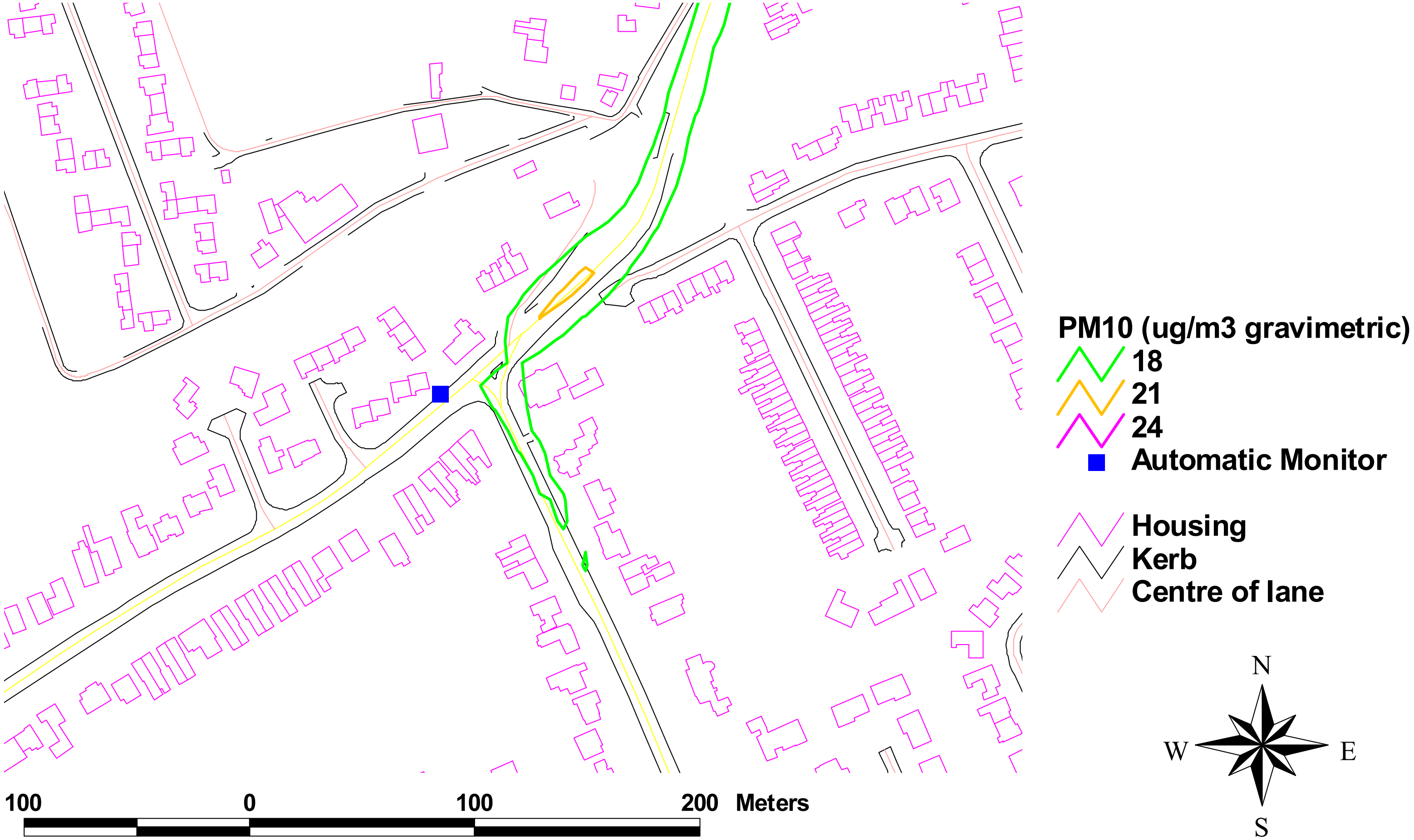


Figure 5.2 - PM10 annual average concentration at the Flying Dutchman junction (A1117/A146) in Lowestoft in 2010

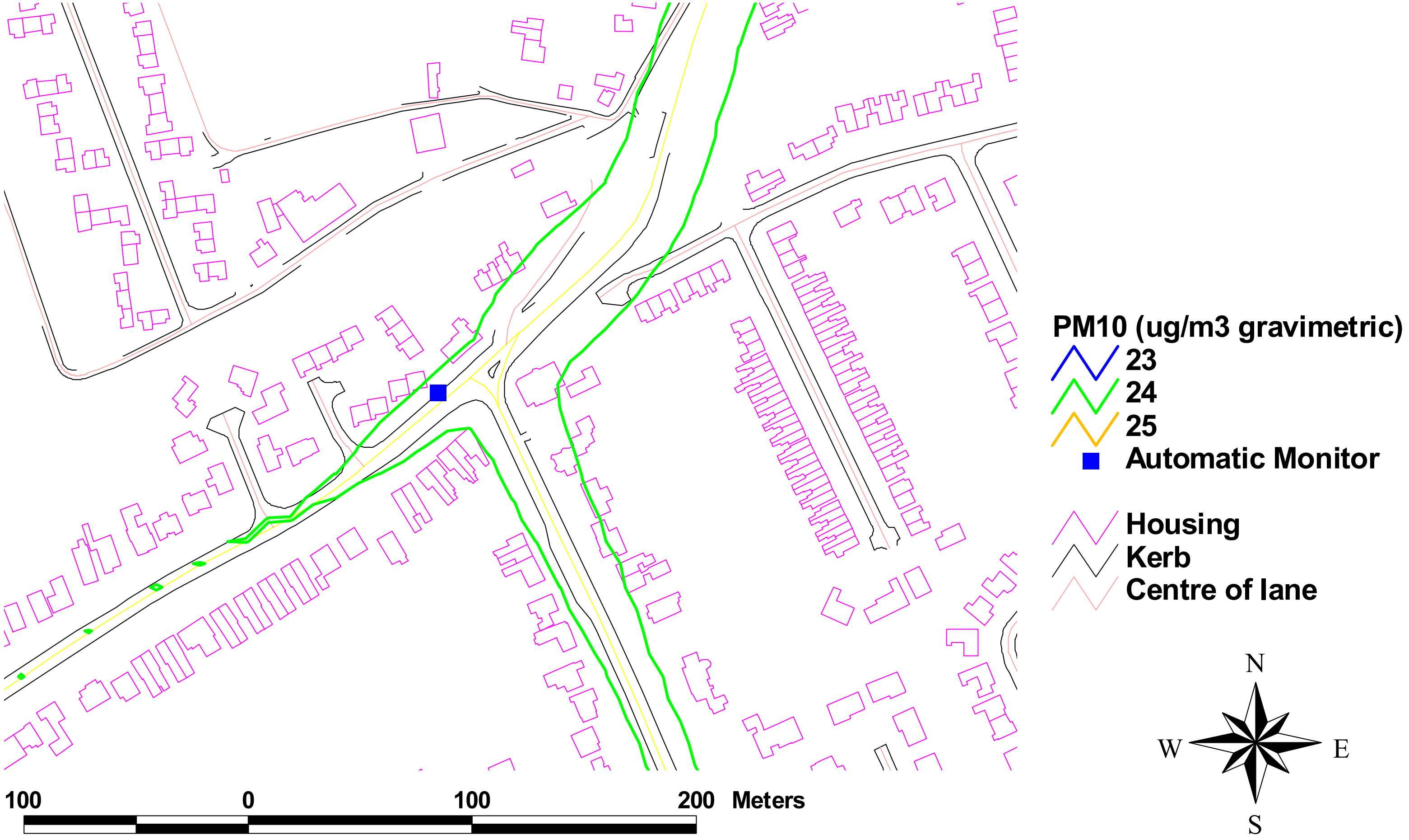


Figure 5.3 - PM10 number of days over 50 ug/m3 in 2010 at the Flying Dutchman junction in Lowestoft

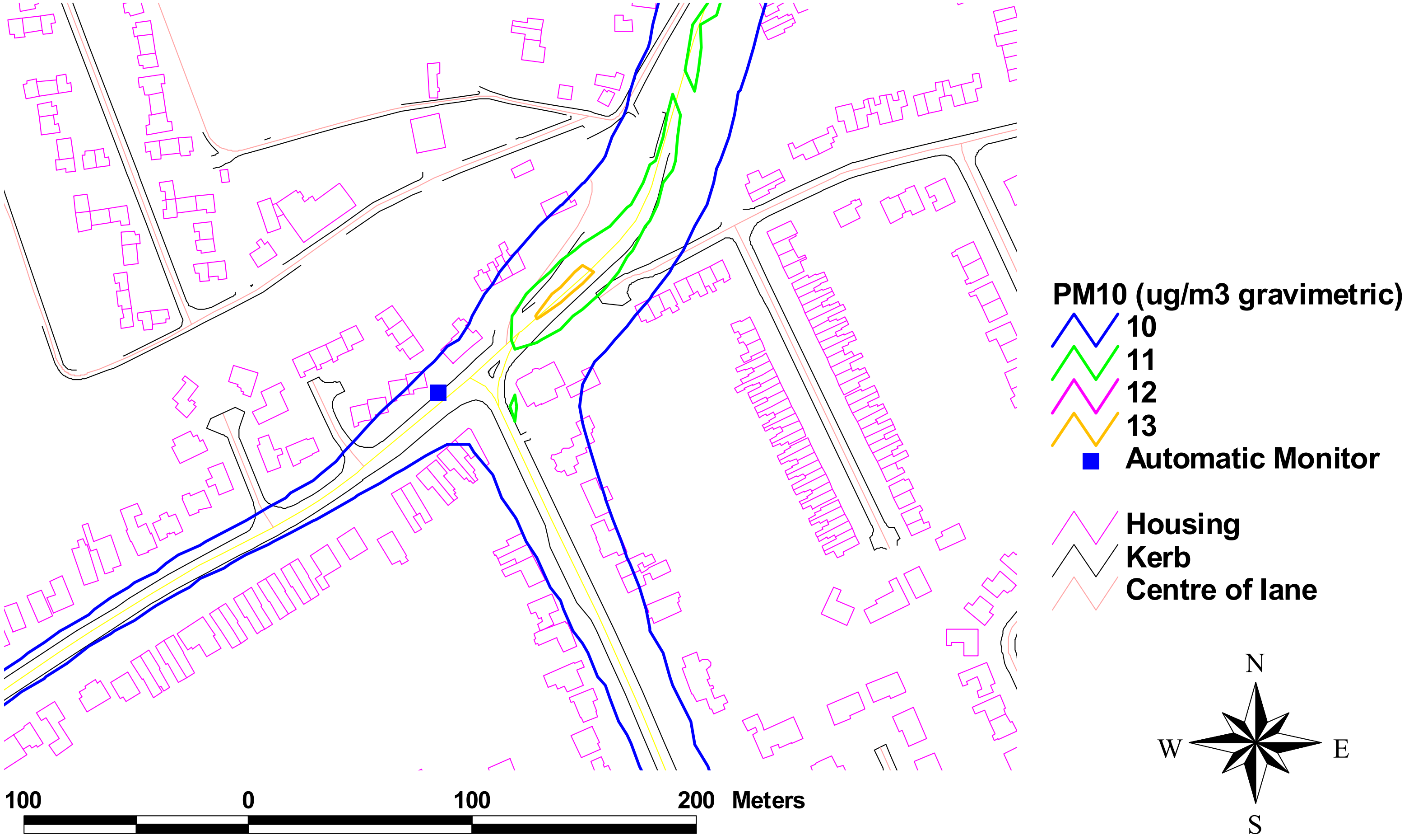


Figure 5.4 - PM10 number of days over 50 ug/m3 in 2004 at the A1117/B1375 junction in Lowestoft

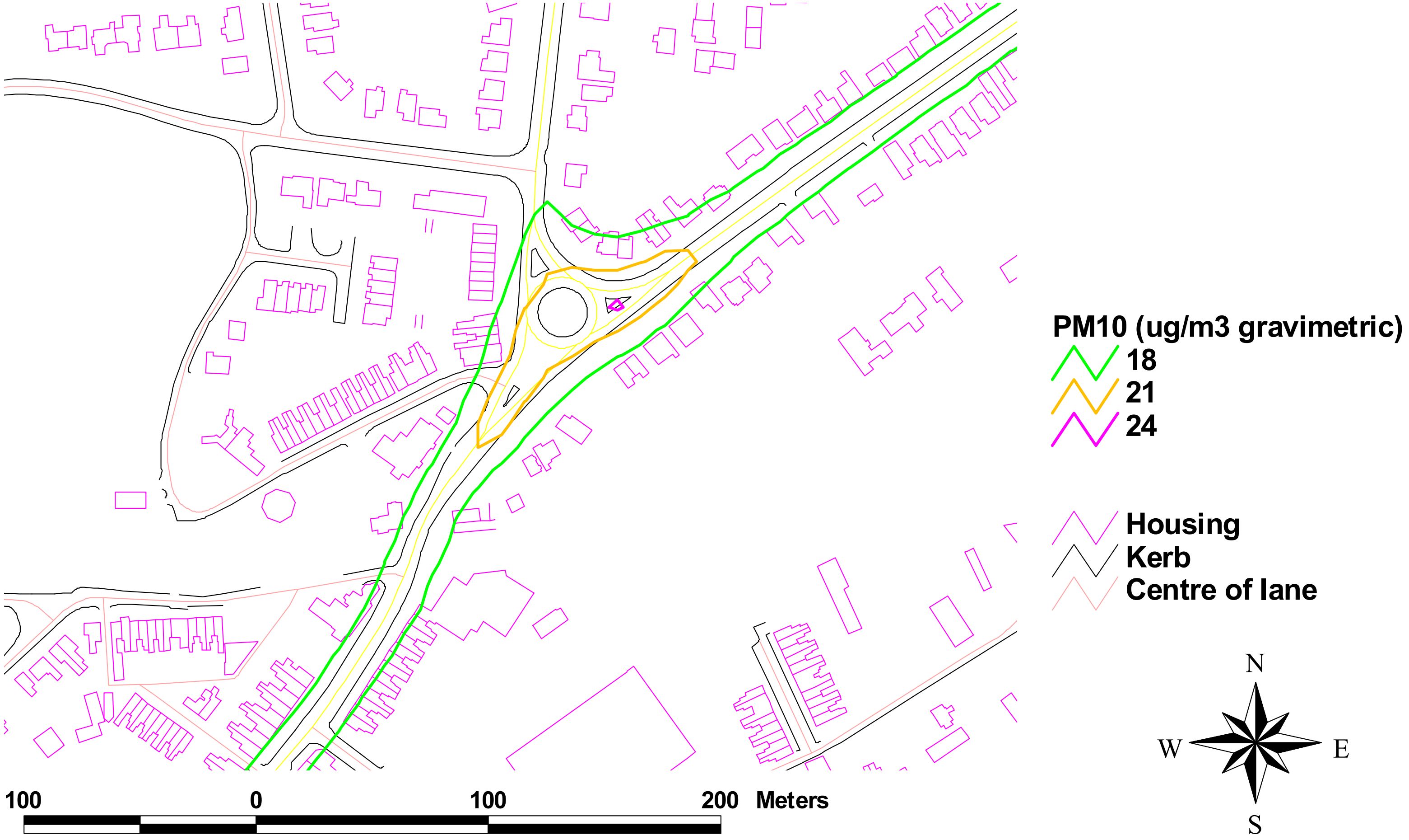


Figure 5.5 - PM10 annual average concentrations in 2010 at the A1117/B1375 junction in Lowestoft

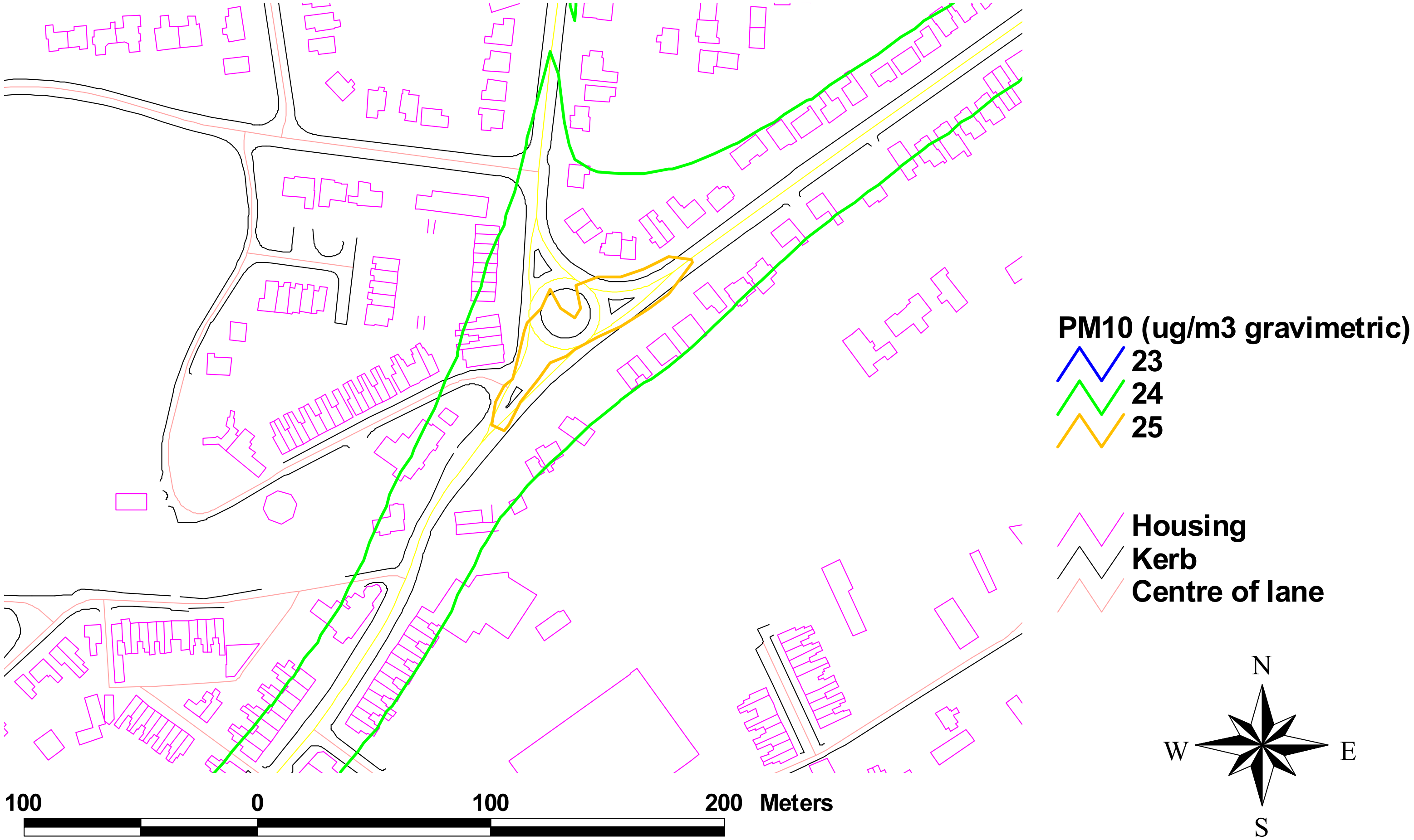
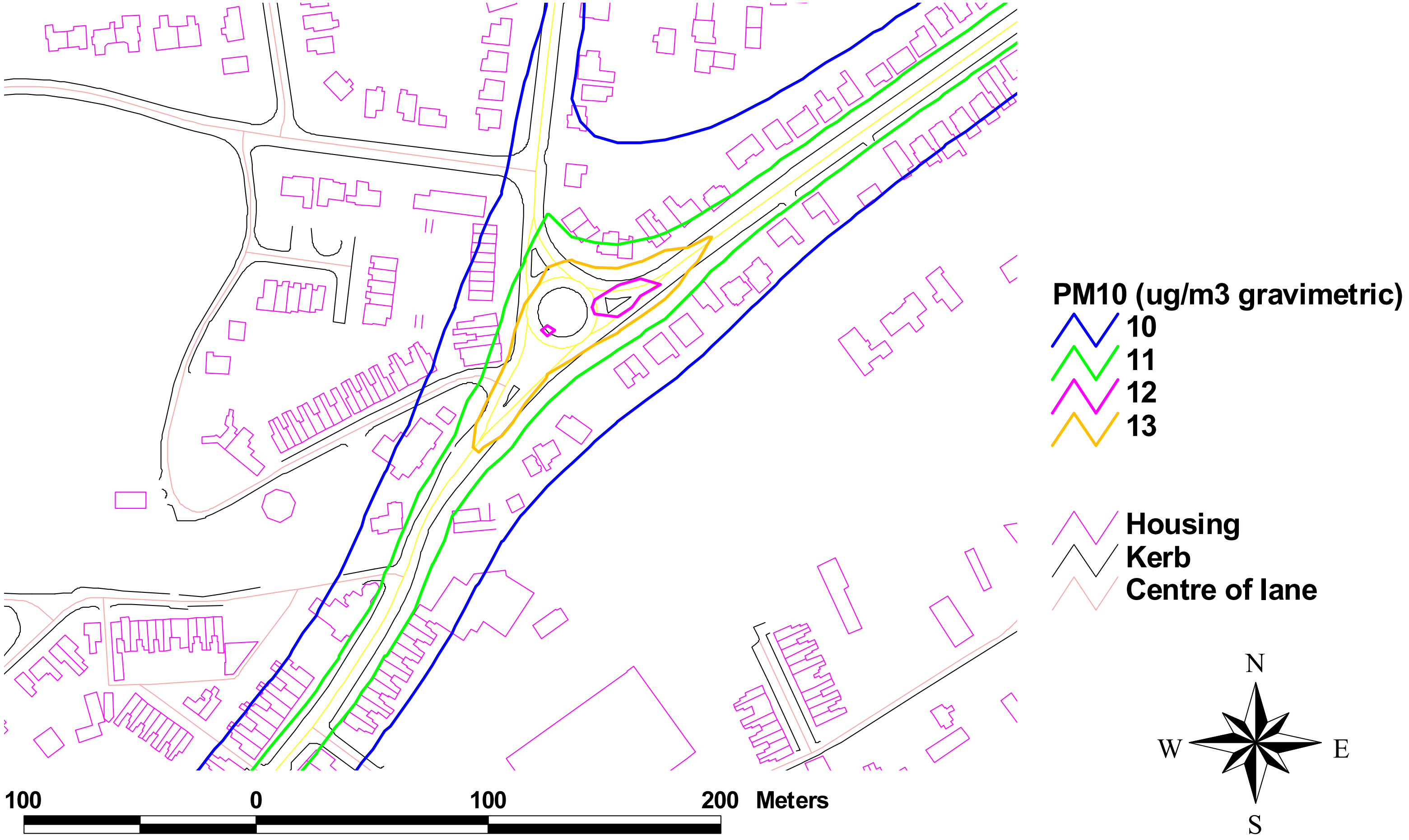


Figure 5.6 - PM10 number of days over 50 ug/m3 in 2010
at the A1117/B1375 junction in Lowestoft



5.10 SUMMARY OF THE LIKELIHOOD OF EXCEEDING THE OBJECTIVES FOR PM_{10}

The modelling results predicted that annual average concentrations of PM_{10} in 2004 would be well below the annual objective for PM_{10} in 2004 at all of the locations modelled.

The modelling results showed that it is at most ***unlikely*** (with probability between 5% and 20%) that an exceedance of the daily objective for PM_{10} in 2004 would occur at either junction.

The modelling results predicted exceedance of both of the 2010 objectives for PM_{10} at the 2 junctions. It was predicted to be ***likely*** that the annual mean objective for PM_{10} in 2010 would be exceeded at these locations. Furthermore, the number of days in which daily mean PM_{10} exceeded 50 $\mu g/m^3$ in 2010 was predicted to exceed 7 at locations in the vicinity of both junctions.

5.11 RECOMMENDATIONS

It is not predicted that either of the UK objectives for PM_{10} in 2004 will be exceeded. Waveney District Council is not therefore required to declare an air quality management area with regard to these objectives.

It is predicted that both the UK objectives for PM_{10} in 2010 will be exceeded in that year. However, as these objectives have not yet been included in the Air Quality Regulations for the purposes of air quality management, Waveney District Council is not therefore required to declare an air quality management area with regard to these objectives either. However, Waveney District Council may wish to bear these conclusions in mind when planning future air quality monitoring. In addition, given the uncertainties in the traffic data used in this assessment regarding traffic queuing and congestion, it is recommended that Waveney District Council commission a detailed survey of queuing and congestion throughout the day at both junctions, once the SLRR is open, in order to inform future subsequent rounds of review and assessment.

5.12 FURTHER ACTIONS TO BE TAKEN

Should Waveney District Council be satisfied and in agreement with the contents of this report, it should 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 Waveney District Council.

Waveney District Council should then forward a copy of this critique to **netcen**. Waveney District Council should also consider if they could answer any of the questions directly.

If DEFRA agree with the contents of this report, Waveney District Council will next be required to submit a Progress Report in April 2005, and a revised Updating and Screening report in April 2006. These will provide Waveney District Council with the opportunity to report on progress made regarding the further work recommended in this Detailed Assessment.

6 References

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Appendices

Appendix 1 - Road Traffic Data

Appendix 2 – Automatic Monitoring Location

Appendix 3 – Model Validation for NO_2

Appendix 4 – Model Validation for PM_{10}

Appendix 1

Traffic Data

CONTENTS

Traffic Data
Traffic Growth Factors

Table A1.1 - Traffic data for Lowestoft.

Location	Direction	AADT 2005 DM	AADT 2005 DS	%HDV 2005	Average Speed (kph)
Flying Dutchman Junction (A146/A1117)					
Beccles Rd south of Flying Dutchman junction	NB	6292	4111	4.5	5-50
	SB	5868	3731	6.7	5-50
Bridge Road North of Flying Dutchman junction	NB	12335	10447	6	5-50
	SB	12298	11062	6	5-50
Cotmer Road	NB	6080	6490	9	5-50
	SB	5849	5662	9	5-50
Junction A1117/B1375					
Saltwater Way	NB	-	14588	5.5	5-50
	SB	-	13682	5.8	5-50
Normanston Drive	NB	-	14588	5.5	5-50
	SB	-	13682	5.8	5-50
Gorleston Road	NB	-	5350	3.3	5-50
	SB	-	5350	3.3	5-50

DM – Do minimum scenario for South Lowestoft Relief Road
DS – Do something scenario for South Lowestoft Relief Road

Table A1.2 - Traffic Growth factors for Waveney District

Year		Growth
From	To	Central
2000	2000	1
2000	2001	1.012
2000	2002	1.03
2000	2003	1.05
2000	2004	1.07
2000	2005	1.088
2000	2010	1.173

Derived from the NRTF and from the TEMPRO v4 model

Appendix 2

Monitoring Data

CONTENTS

Automatic Monitoring Station Results

Produced by netcen on behalf of Waveney District Council

WAVENEY AUTOMATIC AIR MONITORING
February to August 2004

These data have been fully ratified by netcen

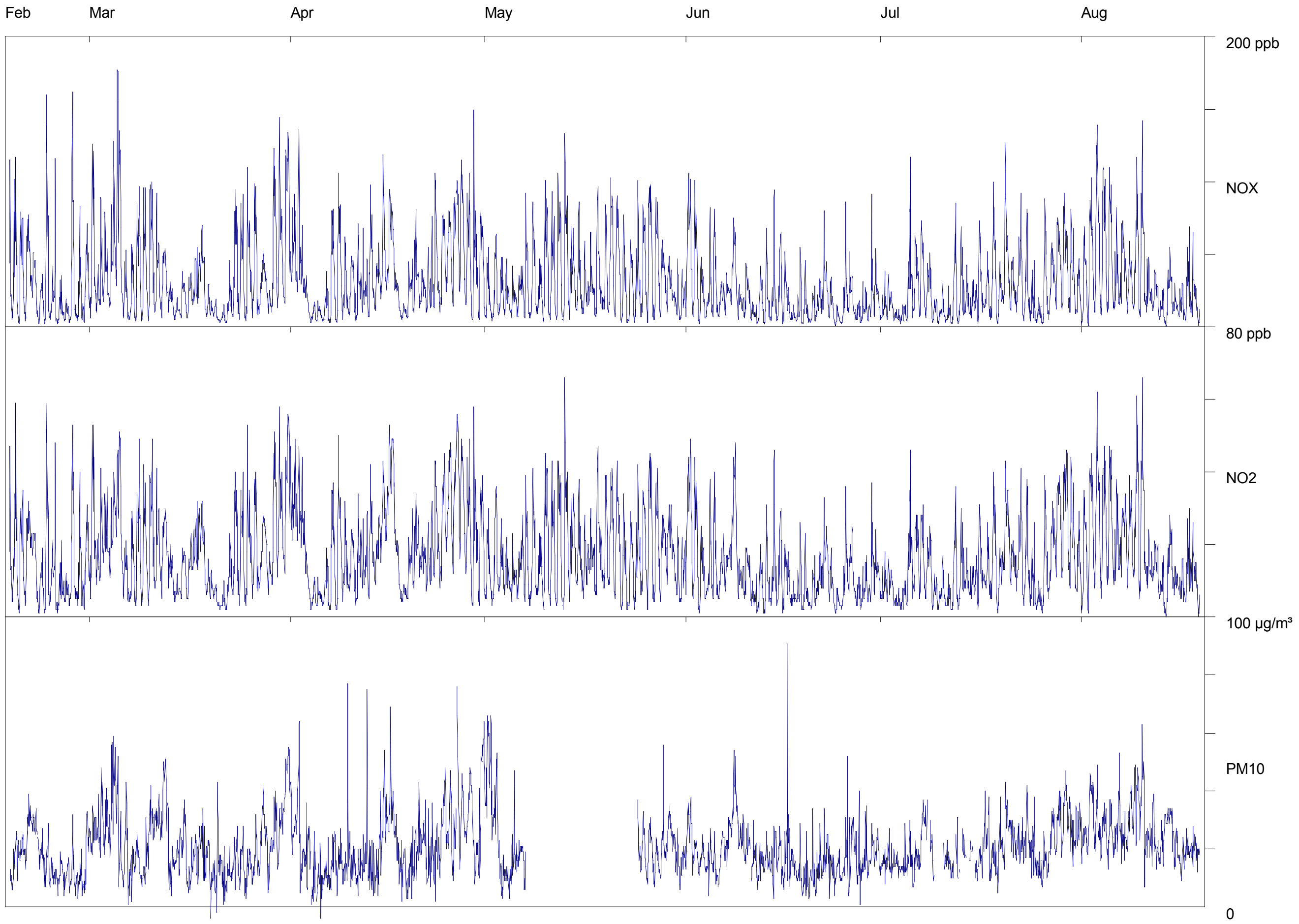
POLLUTANT	NO_X	NO_2	PM_{10}
Number Very High	-	0	0
Number High	-	0	0
Number Moderate	-	0	4
Number Low	-	4399	3796
Maximum 15-minute mean	374 ppb	112 ppb	110 µg m^{-3}
Maximum hourly mean	177 ppb	66 ppb	91 µg m^{-3}
Maximum running 8-hour mean	117 ppb	52 ppb	59 µg m^{-3}
Maximum running 24-hour mean	87 ppb	43 ppb	50 µg m^{-3}
Maximum daily mean	84 ppb	42 ppb	48 µg m^{-3}
Average	31 ppb	17 ppb	21 µg m^{-3}
Data capture	99.1 %	99.1 %	87.2 %

All mass units are at 20'C and 1013mb

Pollutant	Air Quality (England) Regulations 2000 and (Amendment) Regulations 2002	Exceedences	Days
Nitrogen Oxides	Annual mean > 16 ppb	-	-
Nitrogen Dioxide	Annual mean > 21 ppb	-	-
Nitrogen Dioxide	Hourly mean > 105 ppb	0	0
PM_{10} Particulate Matter (Gravimetric)	Daily mean > 50 µg m^{-3}	3	3
PM_{10} Particulate Matter (Gravimetric)	Annual mean > 40 µg m^{-3}	-	-

Produced by netcen on behalf of Waveney District Council

Waveney Air Monitoring
Hourly Mean Data for February to August 2004



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Appendix 3

Model validation
Nitrogen dioxide roadside concentrations

CONTENTS

Introduction
Model application
Results
Discussion

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 nomograms 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 µg 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}

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

For $NO_x < 23.6$ µg m^{-3}

$$NO_2 = 0.833.NO_x \text{ µg m}^{-3}$$

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

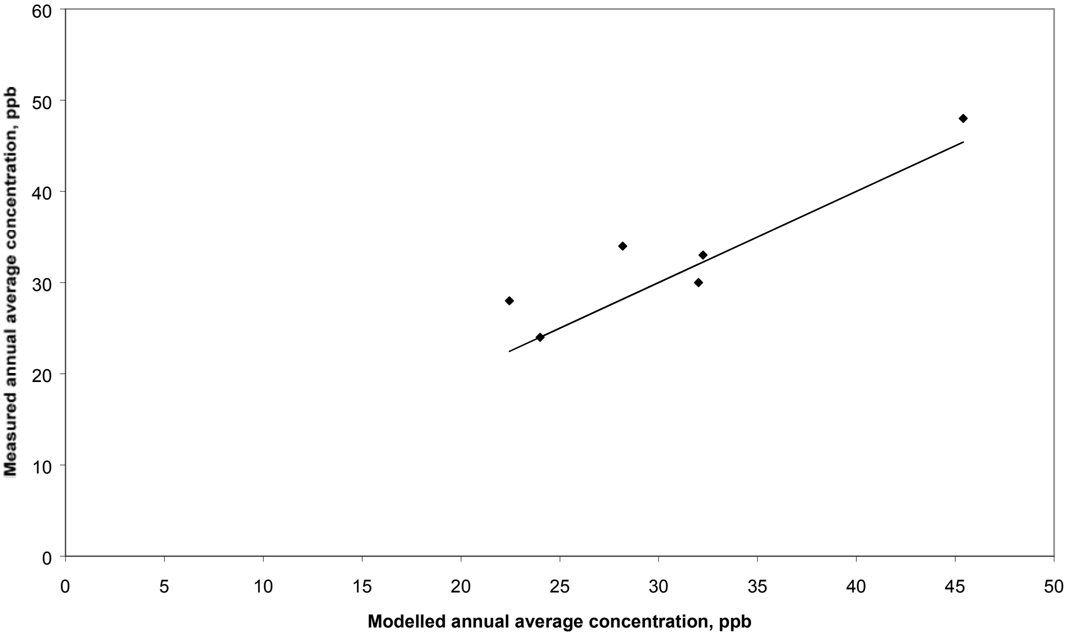

Fig. A3.1 Comparison of modelled and measured annual average nitrogen dioxide concentrations

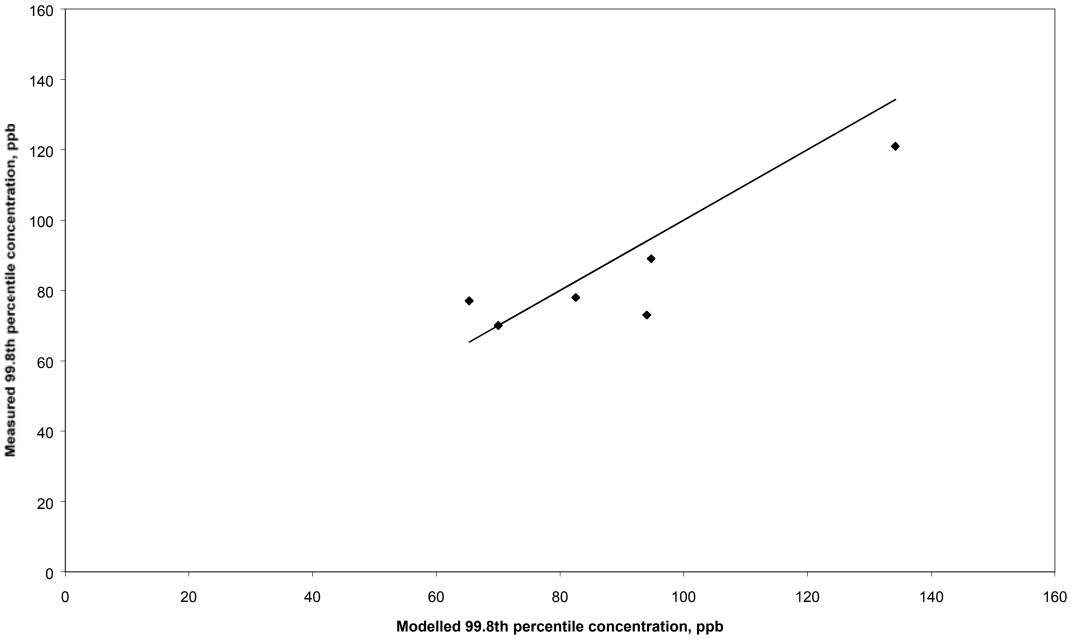

Fig. A3.2 Comparison of modelled and measured 99.8th percentile hourly average nitrogen dioxide concentrations

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 99.8^{th} 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	99.8th 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 µg m^{-3} objective will be exceeded if the modelled annual average concentration in 2005 is less than 34 µg 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 µg m^{-3} (i.e. 40/1.44).

- Similarly, there is less than 1:5 chance that the 200 µg m^{-3} 99.8th percentile concentration will be exceeded if the modelled concentration for 2005 is less than 157 µg 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 µg 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 exceedances 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 99.8th percentile concentration of NO_2 from the annual concentration: the 99.8th 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 exceedances of both the annual and hourly NO_2 objectives. However, the magnitude of the concentrations used to judge exceedances 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 ($\mu g\ m^{-3}$)			
		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	

Appendix 4

Model validation
Particulate matter

CONTENTS

	Calculation of the calibration curve for the modelled PM_{10} concentrations
Figure A4.1	Scatter plot to show the relationship between the measured (estimated) and modelled primary emissions at the Edward Benefer monitoring station
Figure A4.2	Calibration curve to derive the bias in the modelled PM_{10} concentrations

INTRODUCTION

The dispersion model ADMS-3 was used to predict PM10 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 verified by comparison with monitoring data obtained at a number of roadside, kerbside or near-road monitoring sites in London. The monitoring sites considered were:

- 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 Mme Tussauds. The sampling point is located at a height of 3m, around 1m 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 3m. 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 3m. 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 3m. 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 5m 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

A 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 area was then treated as a quadrilateral volume source with depth 3m, with spatial coordinates derived from OS maps.

Traffic flows
Traffic flows, by vehicle category, on each of the roads within the study area for 1996 were obtained from the DETR traffic flow database. The traffic flows were scaled to 1998 by factors shown in Table A4.1 obtained by linear interpolation from Transport Statistics GB, 1997.

Table A4.1: 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 A4.2 shows the assumed diurnal variation in traffic flows.

Table A4.2: 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
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 A4.3 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 A4.3: 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

Vehicle emissions were estimated using the Highways Agency Design Manual for Roads and Bridges, 1999 (DMRB). DMRB provides a series of nomograms 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. Nearly all the exhaust material is in the sub 10 µm range and so it was assumed that all the particulate material released in the exhaust was PM_{10}.

PM_{10} is also released as the result of resuspension of roadside dusts from tyre wear, brake pad wear etc.. The rate of emission is uncertain: it has been suggested that resuspended dusts may be emitted at rates approaching those from vehicle exhausts. The rate of resuspension is expected to depend to some extent on wind speed, with relatively little resuspension occurring at low wind speeds. For this assessment it has been assumed that resuspended dusts are emitted at a rate of half the exhaust emissions when calculating annual average PM_{10}concentrations but resuspension has been ignored when calculating PM_{10}concentrations for the meteorological conditions (generally low wind speeds) corresponding to the 90th percentile 24 hour average.

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 A4.4.

Table A4.4: 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	
Rural	1	

Surface roughness

The surface roughness is used in dispersion modelling to represent the roughness of the ground. Table A4.5 shows the surface roughness values applied.

Table A4.5: 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

Model output

The model was used to estimate:

- Annual average road contribution ;
- 90 th percentile 24 hour average road contribution;
- road contribution for each hour of the year.

Background concentrations
The London North Kensington site was used to provide an estimate of the background concentration of PM_{10}. The background concentration was then estimated at other sites on the basis of DETR background maps (http://www.aeat.co.uk/netcen/airqual/) for 1996. The background maps were corrected to 1998 by multiplying the concentrations by 0.82 (0.9 for 1997), based on the comparison of monitoring data at 17 monitoring sites with greater than 75% data capture in both years. Thus, background annual average concentrations at other sites were estimated using:

C_{av}(site, 1998)=C_{av}(LNK,measured,1998)+0.82*(C_{av}(site,map,1996)-C_{av}(LNK,map,1996))

The 90^{th} percentile 24 hour average concentration at other sites were estimated using:

C_{90}(site, 1998)=C_{av}(LNK,measured,1998)*1.68+0.82*1.68*(C_{av}(site,map,1996)-C_{av}(LNK,map,1996))

The background concentrations for each hour used in the calculation of 90^{th} %ile concentrations at other sites were estimated using:

C (site, 1998)=C (LNK,measured,1998)+0.82*1.68*(C_{av}(site,map,1996)-C_{av}(LNK,map,1996))

The factor 1.68 in the above equations is taken from an analysis of the relationship between the 90^{th} percentile 24 hour average PM10 and the annual average PM10 concentration at UK Automatic Network sites 1992-1997.

The background concentrations and the DETR background map were based on TEOM measurements. In order to convert to gravimetric measurements the values were multiplied by a factor 1.3, following Pollutant Specific Guidance.

Adding background concentrations
The modelled road contribution to PM_{10} were added to the background concentrations in a number of ways. For total annual average gravimetric concentrations:

C_{av}(total, site,1998)= C_{av}(background, site, 1998)*1.3+ C_{av}(roads, site, 1998)-C_{av}(roads, LNK, 1998)

90^{th} percentile 24 hour average concentrations were estimated (Method 1):

C_{90}(total, site,1998)= C_{90}(background, site, 1998)*1.3+ C_{90}(roads, site, 1998)-C_{90}(roads, LNK, 1998)

The 90th %ile 24 hour average concentration was also estimated more formally by first calculating for each hour (Method 2):

C (total, site,1998)= C (background, site, 1998)*1.3+ C (roads, site, 1998)- C (roads, LNK, 1998)

then calculating the average concentration for each day and then determining the 36th highest daily average concentration.

Results

Modelled results are shown in Table A4.6. Fig.A4.1 shows modelled annual average PM10 concentrations plotted against the measured values. Similarly Fig. A4.2 shows modelled 90 th percentile 24 hour average PM_{10} concentrations plotted against measured values (Method 1).

The two methods of calculating the 90th percentile concentration are compared in Fig. A4.3. It shows the value calculated by adding the 90th percentile road contribution to the 90th percentile background concentrated compared with the value calculated more formally by taking the 90th percentile of daily average background plus road concentrations.

Table A4.6: Model results summary

		Measured				Background, TEOM		Modelled road contribution, gravimetric		Modelled, gravimetric		
		Mean (TEOM)	Mean, gravimetric	90%ile TEOM	90 % gravimetric	DETR1996 map	Corrected to model year	Mean	90th%ile	Mean	90th%ile (1)	90th%ile (2)
1998	Haringey	22	28.6	35	45.5	27	18.36	2.28	3.08	26.15	43.18	41.34
	London Marylebone	32	41.6	45	58.5	29	20	17.60	21.55	43.60	65.23	61.33
	Camden	25	32.5	36	46.8	29	20	9.39	12.08	35.39	55.76	53.23
	Bloomsbury	23	29.9	32	41.6	29	20	1.20	1.46	27.20	45.14	43.87
	London A3	24	31.2	39	50.7	25	16.72	8.76	11.85	30.50	48.37	47.28
	North Kensington	20	26	33	42.9	29	20	0.00	0.00	26.00	43.68	42.80
1997	Camden	32	41.6	48	62.4	29	24	10.43	13.42	41.63	65.84	
	Haringey	26	33.8	43	55.9	27	22.2	2.53	3.42	31.39	51.91	
	North Kensington	24	31.2	38	49.4	29	24	0.00	0.00	31.20	52.42	

(1) 90th percentile 24 hour average value calculated by adding background and road 90th percentiles

(2) 90th percentile 24 hour average value calculated by adding daily mean background and road concentrations and then calculating the 90 th percentile value

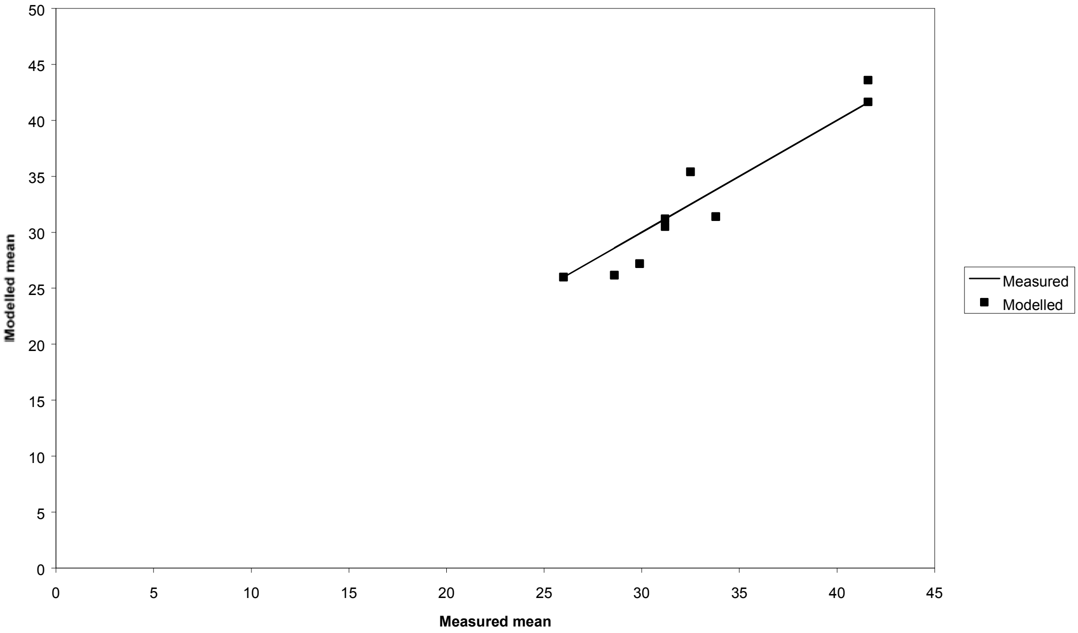

Fig. A4.1: Comparison of modelled and measured annual mean PM_{10} concentrations, µg/m^3 gravimetric

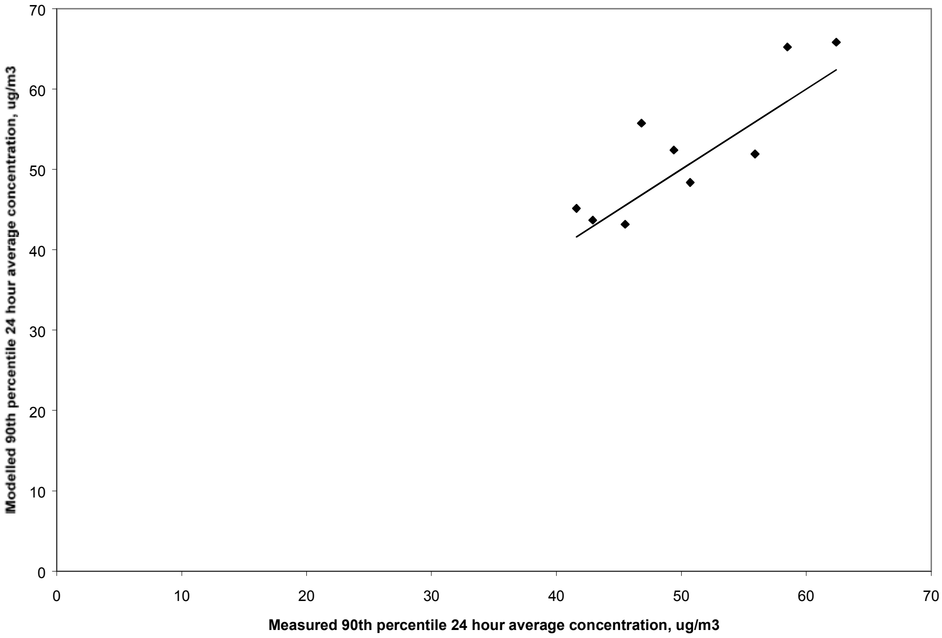

Fig. A4.2: Comparison of modelled and measured 90th percentile 24 hour average PM_{10} concentrations (Method 1), µg/m^3 gravimetric.

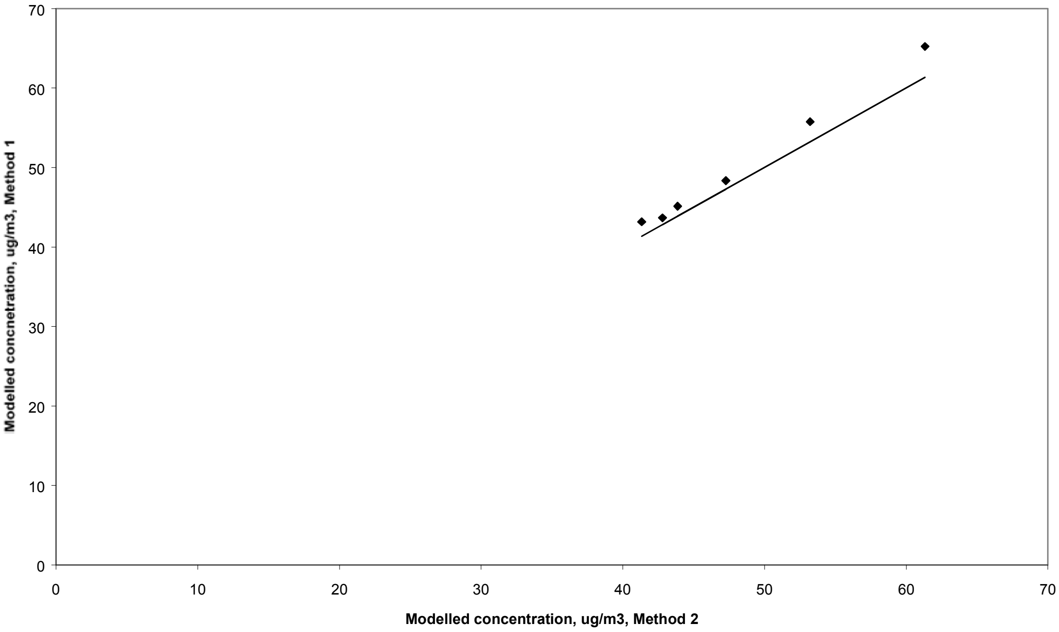

Fig. A4.3: Comparison of 90th percentile calculation methods, gravimetric units

Discussion

Model errors

The difference between the modelled and measured values were calculated. The standard deviation of the difference was then determined.

The estimated standard error was 2.0 µg m^{-3} and 4.3 µg m^{-3} (gravimetric) for the annual mean and 90th percentile concentrations respectively with 5 degrees of freedom.

Year to year variation in background concentrations

PM10 concentrations at background sites show wide year to year variations. The year 1996 showed exceptionally high PM10 concentrations while 1998 showed relatively low concentrations. Reductions in emissions in the United Kingdom are responsible for some of the variation, but atmospheric influences have a significant effect.

Measurements of PM10 concentrations in Epping Forest District were carried out for a limited period (August 1 – November 5) during 1999. Monitoring data from other measurement sites in the London area was therefore assessed to determine whether measurements made over this period were representative of concentrations in 1996.

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

First, the expected annual average concentrations in 1999 were calculated from the 199x data.

$$c_e = (c_{av,199x} - 1.3.c_m.b_{199x} - 10.5).\frac{a_{199x}}{a_{1999}} + 1.3 \times b_{1999} \times c_m + 10.5$$

where $c_{av,199x}$ is the average concentration (gravimetric) in 199x;

the factor 1.3 is used to convert TEOM measurements to gravimetric;

c_m is the annual average secondary concentration (TEOM) from DETR map for 1996;

a_{1999}, a_{199x} are correction factors to estimate primary combustion PM10 concentration in 2004 from DETR guidance;

b_{year} is a correction factor to estimate secondary PM10 in future years from 1996 mapped data;

the factor 10.5 represents the contribution of coarse dusts to annual average concentrations (gravimetric).

The expected concentrations are plotted against the average concentration over the measurement period in Fig. A4.4. The difference between the measured average concentration for the period August 1 –November 5 1999 and the expected value was then determined for each site. The average difference and the standard deviation of the differences was determined.

The average difference in annual average (the bias) was –0.06 µg m^{-3} with standard deviation 1.95 µg m^{-3} with 26 degrees of freedom (both in TEOM units).

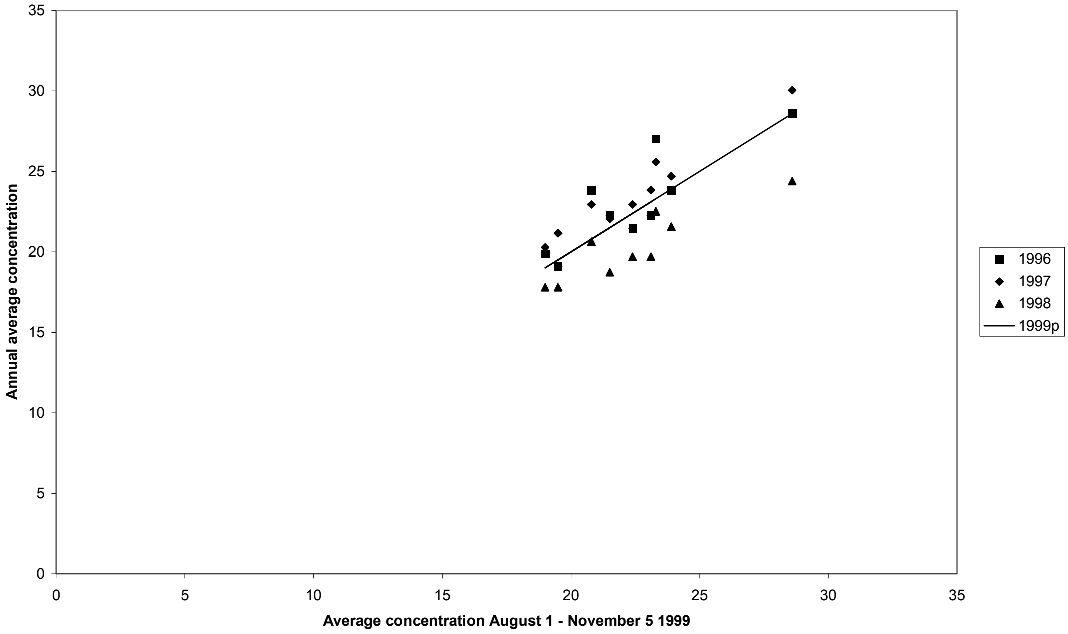

Fig. A4.4: Comparison of average concentrations (µg m^{-3} TEOM) during August 1-November 5 1999 with annual average concentrations

Confidence limits

Upper confidence limits for predicted 90th percentile 24 hour average concentrations were estimated from the standard deviation of the model error and the year to year standard deviation:

$$u = c + 1.68.b + \sqrt{2.(t_m s_m)^2 + (1.68 t_y s_y)^2}$$

where s_m, s_y are the model error standard deviation and the standard deviation in the yearly bias, b;

c is the concentration calculated for the modelled year;

b is the bias between average annual concentrations and the concentrations for the measurement period at the reference site;

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

the factor 2 allows for uncertainty in the estimates of concentrations at the reference site;

the factor 1.68 applies to 90th percentile concentrations only.

Table A4.7 shows confidence levels for predictions of concentrations in future years based on the use as reference of data from the Epping Forest District monitoring site.

Table A4.7: Confidence levels for prediction of concentrations in future years based on Epping Forest monitoring data

One sided confidence level	Upper confidence limits, µg m^{-3} gravimetric	
	Mean	90th percentile 24 hour average
80%	+3.3	+6.5
90%	+5.2	+10.4
95%	+7.0	+14

In practical terms, there is less than 1:5 chance that the 50 ug/m3 objective will be exceeded in 2004 if the modelled 90th percentile 24 hour average concentration is less than 43.5 ug/m3: there is less than 1:20 chance that the objective will be exceeded if the modelled roadside concentration is less than 36 ug/m3.

Alternative method of calculation

Figure A2.3 shows that the simple method of adding 90th percentile backgrounds and road contributions provides a good estimate of the value calculated as the 90th percentile of daily average background plus road concentrations.