Report

Air Quality Review and Assessment - Stage 4 for Luton Borough Council

Report to Luton Borough Council

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DEFRA Stage 4 requirements compliance checklist

This section has been introduced to indicate where the work expected by DEFRA in a Stage 4 air quality review and assessment can be found in this document. Only nitrogen dioxide is considered in this Stage 4.

Work area	Included or considered?	Location within the report and comments
Monitoring		
• Has further monitoring been undertaken?	No	
• Is the 'totality' of the monitoring effort sufficient?		
• Has monitoring confirmed 2005 exceedences?	No	Section 5.4.4, Inconclusive
• Has sufficient detail of QA/QC procedures been provided?	Yes	Section 5.4
• Has monitoring amended the conclusions of Stage 3?		Conclusions not amended
Modelling		
• Has further modelling been undertaken?	Yes	Sections 5.5 and 6.5
• Is the further modelling considered appropriate?		
• Has the model been appropriately validated?	Yes	Section 5.5.3 and appendices
• Has modelling confirmed 2005 exceedences?	Yes	Section 5.6
• Has modelling amended the conclusions of Stage 3?	N/A	AQMA yet to be declared
General		
• Have both the magnitude and geographical extent of any exceedences been further changed?	N/A	AQMA yet to be declared
• Has the decision to declare an AQMA been reversed at Stage 4?	N/A	AQMA yet to be declared
• Is this decision soundly based?		
• Has the authority taken account of the new vehicle emission factors	Yes	Section 4.4
• Has the authority considered source apportionment?	Yes	Section 5.8
• Has the authority considered the cost effectiveness of different abatement options?	Partly	Section 5.10
• Has the authority considered feasibility and effectiveness of different abatement options?	Partly	Section 5.10
• Has the authority considered the extent to which air quality improvement is required?	Yes	Section 5.7

Work area	Included or considered?	Location within the report and comments
Monitoring & modelling work		
• Have monitoring uncertainties been addressed fully?	Yes	Section 5.5.3
• Does the additional monitoring assessment appear sufficiently robust?		
• Have modelling uncertainties been addressed?	Yes	Section 5.5.3
• Has the model been carefully validated?	Yes	Section 5.5.3
• Does the overall modelling assessment appear sufficiently robust?		
AQO exceedences & AQMA declaration		
• Have areas of exceedence been further defined?	Yes	Section 5.6
• Is the decision to amend or revoke the AQMA(s) at Stage 4, soundly based?		
• Is the decision reached based principally on monitoring?	No	
• Is the decision reached based principally on modelling?	Yes	
General		
• Has the authority focused on areas already identified as predicted to exceed objectives?	Yes	Section 5.5.2
• Has consideration been given to the exposure of individuals in relevant locations?	Yes	Section 5.7.2
• Has the authority considered new national policy developments?	Yes	Section 7.1
• Has the authority considered new local developments?	No	
• Does the report reach the expected conclusions? (in part/full?)		
• Has the authority undertaken further liaison with other agencies (in particular HA and EA?)	No	

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. The Environment Act 1995 requires Local Authorities to undertake an air quality review. In areas where the air quality objective is not expected to be met, Local Authorities are required to establish Air Quality Management Areas to improve air quality.

The first step in this process is to undertake a review of current and potential future air quality. A minimum of two air quality reviews are recommended in order to assess compliance with air quality objectives; one to assess air quality at the outset of the Air Quality Strategy and a second to be carried out towards the end of the policy timescale (2005). The number of reviews necessary depends on the likelihood of achieving the objectives. Each of these two reviews is split into components. For the first round of air quality review and assessment, there are three components. The components are: Stages 1 to 3; Stage 4 and Action Plans. Stage 4 and Action Plans are normally completed in parallel. Not all local authorities have to complete all the components.

This report is equivalent to a Stage 4 air quality review and assessment for Luton as outlined in the Government's published guidance (LAQM.PG(03).

Luton Borough Council has completed a Stage 3 Air Quality Review and Assessment. The results of this indicated that exceedences of the annual mean objective for nitrogen dioxide (NO_2) are likely along the M1 in Luton. Work carried out for this report confirms this and we recommend that they consider declaring an Air Quality Management Area (AQMA) at the properties identified below:

Road	House numbers
Armitage Gardens	1 to 6
Bradley Road	125 to 129 odd numbers and 135
Eldon Road	79
Halfway Avenue	76 and 78
High Street	183 to 187 odd numbers
Longfield Drive	17, 19 and 20
Raleigh Grove	14 and 16
Withy Close	9, 11, 16

These properties lie within a band no more than 50 m from the M1.

[1] Refers to standards recommended by the Expert Panel on Air Quality Standards (EPAQS). 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.

The approach taken in this study was to:

- Collect and interpret data to support the assessment, including detailed traffic flow data;
- Use monitoring data from the NO_2 continuous monitor located near J11 of the M1 to assess the ambient NO_2 concentrations to calibrate the NO_2 dispersion modelling study;
- Use monitoring data from the PM_{10} continuous monitor located near J11 of the M1 to assess the ambient concentrations of PM_{10};
- Model the concentrations of NO_2 and PM_{10} near the M1, 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;
- Identify the contributions of the relevant sources to the exceedences (local traffic, background sources, and other relevant sources) and
- Consider three scenarios to improve air quality and identify the improvements in air quality that might be possible for nitrogen dioxide.

The reductions in annual mean NO_2 concentrations needed to ensure that concentrations at all relevant receptors in the AQMA did not exceed 40 μg m^{-3} were:

Receptor	Grid Easting	Grid Northing	Maximum annual mean concentration of NO_2 predicted for 2005 at the specific receptors (μg m^{-3})	Improvement required to achieve annual mean objective of 40 μg m^{-3} (μg m^{-3})
4 Armitage Gardens	505540	222320	47.6	7.6
129 Bradley Road	505610	222220	45.4	5.4
79 Eldon Road	505420	222420	40.4	0.4
78 Halfway Avenue	505600	222250	41.9	1.9
185 High Street	505260	223410	42.0	2.0
17 Longfield Drive	505490	222470	42.6	2.6
14 and 16 Raleigh Grove	505510	222430	40.7	0.7
9 and 11 Withy Close	504830	223990	40.5	0.5

The source apportionment work identified emissions of oxides of nitrogen (NO_x) from traffic on roads close to the AQMA as the important source where emissions might be reduced. Emissions of NO_x from local industrial sources were trivial and the general background of NO_x cannot be easily reduced except by national measures. Emissions of NO_x for 2005 from local traffic accounted for approximately:

Receptor	Grid Easting	Grid Northing	Background (μg m^{-3})	Traffic-LDVs (μg m^{-3})	Traffic-HDVs (μg m^{-3})	Total (μg m^{-3})
4 Armitage Gardens	505540	222320	30.4	43.3	114.5	188.2
129 Bradley Road	505610	222220	29.6	39.5	100.1	169.2
79 Eldon Road	505420	222420	31.2	27.6	74.7	133.5
78 Halfway Avenue	505600	222250	29.9	31.6	80.9	142.3
185 High Street	505260	223410	30.5	22.6	85.7	138.7
17 Longfield Drive	505490	222470	31.8	31.0	85.1	147.9
14 and 16 Raleigh Grove	505510	222430	31.4	27.9	75.2	134.5
9 and 11 Withy Close	504830	223990	28.9	21.5	82.4	132.8

The following scenarios were considered to try and reduce the emissions of NO_x and so reduce the concentrations of NO_2:

1. Reducing the average speed along the M1 to 96 kph (60 mph)
2. Reducing the average speed along the M1 to 80 kph (50 mph)
3. Reducing the number of HDVs by 20%.

In summary, the effects of these scenarios were:

Option considered	Receptor	Grid Easting	Grid Northing	Reduction in annual mean NO_2 in 2005 ($\mu g\ m^{-3}$)
Reducing speed along M1 to 96 kph				
	4 Armitage Gardens	505540	222320	2.9
	129 Bradley Road	505610	222220	2.8
	79 Eldon Road	505420	222420	2.2
	78 Halfway Avenue	505600	222250	2.5
	185 High Street	505260	223410	1.3
	17 Longfield Drive	505490	222470	2.3
	14 and 16 Raleigh Grove	505510	222430	2.2
	9 and 11 Withy Close	504830	223990	1.2
Reducing speed along M1 to 80 kph				
	4 Armitage Gardens	505540	222320	8.1
	129 Bradley Road	505610	222220	7.4
	79 Eldon Road	505420	222420	4.5
	78 Halfway Avenue	505600	222250	5.7
	185 High Street	505260	223410	4.6
	17 Longfield Drive	505490	222470	5.2
	14 and 16 Raleigh Grove	505510	222430	4.6
	9 and 11 Withy Close	504830	223990	4.7
Reducing HDV flows by 20%				
	4 Armitage Gardens	505540	222320	3.0
	129 Bradley Road	505610	222220	2.9
	79 Eldon Road	505420	222420	2.4
	78 Halfway Avenue	505600	222250	2.6
	185 High Street	505260	223410	2.9
	17 Longfield Drive	505490	222470	2.6
	14 and 16 Raleigh Grove	505510	222430	2.4
	9 and 11 Withy Close	504830	223990	2.8

Reducing speed along M1 to 96 kph is not sufficient to meet the annual mean NO_2 objective at all locations nor is reducing HDV flows by 20%. A reduction in speed to 80 kph is more likely to yield the required reduction in NO_2 concentrations. A combination of reducing the speed by a lesser amount and a reduction in HDV flows also may yield the required reduction.

Acronyms and definitions

AADTF	Annual Average Daily Traffic Flow
ADMS	an atmospheric dispersion model
AQDD	an EU directive (part of EU law) - Common Position on Air Quality Daughter Directives, commonly referred to as the Air Quality Daughter Directive
AQMA	Air Quality Management Area
AQS	Air Quality Strategy
AP	Action Plan
AUN	Automatic Urban Network (DEFRA funded network)
base case	In the context of this report, the emissions or concentrations predicted at the date of the relevant air quality objective (2005 for nitrogen dioxide)
CO	Carbon monoxide
d.f.	degrees of freedom (in statistical analysis of data)
DETR	Department of the Environment Transport and the Regions (now DEFRA)
DEFRA	Department of the Environment, Farming and Rural Affairs
DMRB	Design Manual for Roads and Bridges
EA	Environment Agency
EPA	Environmental Protection Act
EPAQS	Expert Panel on Air Quality Standards (UK panel)
EU	European Union
GIS	Geographical Information System
HDV	Heavy Duty Vehicle (includes HGVs, buses and coaches)
HGV	Heavy Goods Vehicle (vehicles over 3,500kg)
HGVa	Articulated Heavy Goods Vehicle
HGVr	Rigid Heavy Goods Vehicle
HA	Highways Agency
kerbside	0 to 1 m from the kerb
LADS	Urban background model specifically developed for Stage 3 Review and Assessment work by **netcen**. This model allowed contributions of the urban background and road traffic emissions to be calculated
LDV	Light Duty Vehicle (includes cars and LGVs)
LGV	Light Goods Vehicle (vehicles not over 3,500kg)
Limit Value	An EU definition for an air quality standard of a pollutant listed in the air quality directives
n	number of pairs of data
NAEI	National Atmospheric Emission Inventory
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NRTF	National Road Traffic Forecast
ppb	parts per billion
r	the correlation coefficient (between two variables)
receptor	In the context of this study, the relevant location where air quality is assessed or predicted (for example, houses, hospitals and schools)
roadside	1 to 5 m from the kerb
SD	standard deviation (of a range of data)
SO_2	Sulphur dioxide
TEMPRO	A piece of software produced by the DEFRA used to forecast traffic flow increases
UWE AQMRC	University of the West of England Air Quality Management Resource Centre

Contents

Appendices

1 Introduction

This section outlines the reason why Luton Borough Council commissioned a Stage 4 air quality review and assessment, and briefly explains what a Stage 4 air quality review and assessment is.

1.1 PURPOSE OF THE STUDY

Luton Borough Council has completed a Stage 3 Air Quality Review and Assessment. The results of this indicated that exceedences of objectives for nitrogen dioxide (NO_2) are likely along the M1 in Luton. As there have been a number of technical changes since the Stage 3 such as the release of new national emission factors, Luton Borough Council has proceeded with a Stage 4 review and assessment to re-examine the exceedences prior to declaring an air quality management area (AQMA).

This report for Luton Borough Council is the further review and assessment of its air quality – a Stage 4 review and assessment – as specified under Section 84 of the Environment Act (1995).

1.2 BRIEF EXPLANATION OF A STAGE 4 AIR QUALITY REVIEW AND ASSESSMENT

The 1995 Environment Act places duties on local authorities with regard to local air quality review and, where potential problems are identified, the management of local air quality. The air quality review is designed as a multi-stage process, with progressively more complex assessments at each stage.

If a local authority declares an air quality management area, Section 84(1) of the Environment Act 1995 requires the local authority to carry out a further assessment of existing and likely future air quality in the AQMA. This further assessment is called a Stage 4 air quality review and assessment, and is intended to supplement information the authority already has.

For each pollutant where there is an exceedence of the air quality, the Stage 4 should calculate:

- how great an improvement is needed and
- the extent to which different sources contribute to the problem (source apportionment).

1.3 OVERVIEW OF APPROACH TAKEN

The approach taken in this study was to:

- Collect and interpret data to support the assessment, including detailed traffic flow data;
- Use monitoring data from the NO_2 continuous monitor and the located near J11 of the M1 to assess the ambient NO_2 concentrations to calibrate the NO_2 dispersion modelling study;
- Use monitoring data from the PM_{10} continuous monitor located near J11 of the M1 to assess the ambient concentrations of PM_{10};

- Model the concentrations of NO_2 and PM_{10} near the M1, concentrating on the locations (receptors) where people might be exposed over the relevant averaging times of the air quality objectives;
- Present the concentrations as contour plots and assess the uncertainty in the predicted concentrations;
- Identify the contributions of the relevant sources to the exceedences (local traffic, background sources, and other relevant sources) and
- Consider three scenarios to improve air quality and identify the improvements in air quality that might be possible.

1.4 RELEVANT DEFRA DOCUMENTATION USED IN THIS ASSESSMENT

The latest Air Quality Strategy (AQS) for the UK has issued in 2000 (DETR, 2000) and the strategy contains some revised objectives for some pollutants (see Table 2.2). The Review and Assessment Technical Guidance (LAQM.TG(03)) has been revised and reissued to match the AQS.

1.5 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.

1.6 UNITS OF CONCENTRATION

The units throughout this assessment are normally presented in µg m^{-3}, which is consistent with the presentation of the new AQS objectives.

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1.8 STRUCTURE OF THE REPORT

The report is structured as follows:

- **Section 1** (this section) gives an overview of the work
- **Section 2** gives the background to this study and summarises the UK Air Quality Strategy and the function of a Stage 4 air quality review and assessment;
- **Section 3** contains information about Stage 4 Air Quality Review and Assessments and Action Plans. It explains the relationships between the Stage 4 and Action Plans, what each document should contain, and the timescales for producing the documents;
- **Section 4** lists the key information used in this review and assessment;

- **Section 5** presents the Stage 4 review and assessment of NO_2, which includes predictions of concentrations of NO_2 for a range of Action Plan scenarios to improve air quality;
- **Section 6** presents the review and assessment of PM_{10}
- **Section 7** highlights the implications of this Stage 4 assessment for Luton
- **Section 8** gives the references used in the work.

2 The UK 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).

2.1 UPDATED AIR QUALITY STANDARDS AND OBJECTIVES – SEE OVER

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 district, 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.

This study essentially forms part of the requirements of Section 84 of the Part IV Air Quality of the Environment Act 1995.

2.2 OVERVIEW OF THE PRINCIPLES AND MAIN ELEMENTS OF THE 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 actors such as industry, transportation bodies and local authorities.
- The predetermination of timescales with a target dates of 2003, 2004 and 2005 for the achievement of objectives and a commitment to review the Strategy every three years.

It is intended that the NAQS 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 that 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 2008 are shown in Table 2.2. The table shows the standards in ppb and µg m^{-3} with the number of exceedences that are permitted (where applicable) and the equivalent percentile.

2.2.2 The difference between 'standards' and 'objectives' in the UK AQS

Air quality *standards* (in the UK AQS) are the concentrations of pollutants in the atmosphere that can broadly be taken to achieve a certain level of environmental quality. The standards are based on assessment of the effects of each pollutant on human health including the effects on sensitive subgroups. The standards have been set at levels to avoid significant risks to health.

The *objectives* of the UK air quality policy are framed on the basis of the recommended standards. The objectives are based on the standards, but take into account feasibility, practicality, and the costs and benefits of fully complying with the standards.

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

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

Pollutant	Concentration limits		Averaging period	Objective [number of permitted exceedences 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
1,3-butadiene	2.25	1	running annual mean	2.25	by 31.12.2003
CO	11,600	10,000	running 8-hour mean	11,600	by 31.12.2003
Pb	0.5	-	annual mean	0.5	by 31.12.2004
	0.25	-	annual mean	0.25	by 31.12.2008
NO_2 (see note)	200	105	1 hour mean	200 [maximum of 18 exceedences a year or equivalent to the 99.8th percentile]	by 31.12.2005
	40	21	annual mean	40	by 31.12.2005
PM_{10} (gravimetric) (see note)	50	-	24-hour mean	50 [maximum of 35 exceedences a year or ~ equivalent to the 90th percentile]	by 31.12.2004
	40	-	annual mean	40	by 31.12.2004
SO_2	266	100	15 minute mean	266 [maximum of 35 exceedences a year or equivalent to the 99.9th percentile]	by 31.12.2005
	350	132	1 hour mean	350 [maximum of 24 exceedences a year or equivalent to the 99.7th percentile]	by 31.12.2004
	125	47	24 hour mean	125 [maximum of 3 exceedences a year or equivalent to the 99th percentile]	by 31.12.2004

Notes

1. Conversions of ppb and ppm to ($\mu g\ m^{-3}$) correct at 20°C and 1013 mb.
2. The objectives for nitrogen dioxide are provisional.
3. PM_{10} measured using the European gravimetric transfer standard or equivalent. The Government and the devolved administrations see this new 24-hour mean objective for particles as a staging post rather than a final outcome. Work has been set in hand to assess the prospects of strengthening the new objective.

2.2.3 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.

2.2.4 Recent proposed changes to the UK National Air Quality Standards

DEFRA have recently issued a consultation document with proposed changes to the UK AQS for benzene, carbon monoxide and particulate matter (DEFRA, 2001). The proposed changes are:

For **benzene**

- An objective derived from the long-term policy aim of **3.25 µg m^{-3} as a running annual mean** recommended by UK EPAQS (Expert Panel on Air Quality Standards). The objective for benzene included in the 2000 Strategy is 16.25 µg m^{-3} as a running annual mean to be achieved by 2003. This is derived from the EPAQS recommended standard. The UK adopted the second EU Air Quality Daughter Directive (which sets limit values for benzene and carbon monoxide) in 2000. This Daughter Directive sets a limit value for benzene of 5 µg m^{-3} as an annual mean to be achieved by 2010.

For **carbon monoxide**

- Replacing the existing objective derived from the recently agreed EU limit value. The objective for carbon monoxide included in the 2000 Strategy is 11.6 mg m^{-3} as a running 8-hour mean to be achieved by 2003. This is derived from the UK EPAQS recommended standard. The second EU Air Quality Daughter Directive sets a limit value for carbon monoxide of 10 mg m^{-3} as a maximum daily 8-hour mean to be achieved by 2005. DEFRA propose to set a new objective of achieving the EU limit value by the end of 2003, which is **10 mg m^{-3} as a maximum daily 8-hour mean** to be achieved by 2005.

For **particulates** (as **PM_{10}**) new provisional objectives of

- 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 per 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 10-14 times per year and an annual mean of 23-25 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 per year and an annual mean of 18 µg m^{-3}, both to be achieved by the end of 2010.

2.2.5 Policies in place to allow these objectives to be achieved

The policy framework to allow these objectives to be achieved is one that that takes a local air quality management approach. This is superimposed upon existing national and international regulations in order to effectively tackle local air quality issues as well as issues relating to wider spatial scales. National and EC policies that already exist provide a good basis for progress towards the air quality objectives set for 2003 to 2008. For example, the Environmental Protection Act 1990 allows for the monitoring and control of emissions from industrial processes and various EC Directives have ensured that road transport emission and fuel standards are in place. These policies are being developed to include more stringent controls. 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-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.

2.2.6 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 the Technical Guidance Note LAQM.TG4(98), and the latest version LAQM.TG4(00) May 2000, on 'Review and Assessment: Pollutant Specific Guidance'. This review and assessment has considered the procedures set out in the latest consultation draft.

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 therefore that reviews should be carried out in three stages. All three stages of review and assessment may be necessary and every authority is expected to undertake at least a first stage review and assessment of air quality in their authority area. The Stages are briefly described in the following table, Table 2.3.

Table 2.3 Brief details of Stages in the Air Quality Review and Assessment process

Stage	Objective	Approach	Outcome
First Stage Review and Assessment	• Identify all significant pollutant sources within or outside of the authority's area.	• Compile and collate a list of potentially significant pollution sources using the assessment criteria described in the Pollutant Specific Guidance	
	• Identify those pollutants where there is a risk of exceeding the air quality objectives, and for which further investigation is needed.	• Identify sources requiring further investigation.	• Decision about whether a Stage 2 Review and Assessment is needed for one or more pollutants. If not, no further review and assessment is necessary.
Second Stage Review and Assessment	• Further screening of significant sources to determine whether there is a significant risk of the air quality objectives being exceeded.	• Use of screening models or monitoring methods to assess whether there is a risk of exceeding the air quality objectives.	
	• Identify those pollutants where there is a risk of exceeding the objectives, and for which further investigation is needed.	• The assessment need only consider those locations where the highest likely concentrations are expected, and where public exposure is relevant.	• Decision about whether a Stage 3 Review and Assessment is needed for one or more pollutants. If, as a result of estimations of ground level concentrations at suitable receptors, a local authority judges that there is no significant risk of not achieving an air quality objective, it can be confident that an Air Quality Management Area (AQMA) will not be required. • However, if there is doubt that an air quality objective will be achieved a third stage review should be conducted.

Table 2.3 (contd.) Brief details of Stages in the Review and Assessment process

Stage	Objective	Approach	Outcome
Third Stage Review and Assessment	• Accurate and detailed assessment of both current and future air quality. Assess the likelihood of the air quality objectives being exceeded. • Identify the geographical boundary of any exceedences, and description of those areas, if any, proposed to be designated as an AQMA.	• Use of validated modelling and quality-assured monitoring methods to determine current and future pollutant concentrations. • The assessment will need to consider all locations where public exposure is relevant. For each pollutant of concern, it may be necessary to construct a detailed emissions inventory and model the extent, location and frequency of potential air quality exceedences.	• Determine the location of any necessary Air Quality Management Areas (AQMAs). Once an AQMA has been identified, there are further sets of requirements to be considered. • A further assessment of air quality in the AQMA is required within 12 months which will enable the degree to which air quality objectives will not be met and the sources of pollution that contribute to this to be determined. A local authority must also prepare a written action plan for achievement of the air quality objective. Both air quality reviews and action plans are to be made publicly available.

Local authorities are expected to have completed review and assessment of air quality by December 2000. A further review will also need to be completed for the purposes of the Act before the target date of 2003.

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

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

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 (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.	• Kerbside sites where the public would not be expected to have regular access.
15 minute mean	• Sulphur dioxide	• All locations where members of the public might reasonably be exposed for a period of 15 minutes or longer.	

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

3 Stage 4 Air Quality Review and Assessment and Action Planning

This section contains information about Stage 4 Air Quality Review and Assessments and Action Plans. It explains the relationships between the Stage 4 and Action Plans, what each document should contain, and the timescales for producing the documents.

3.1 THE RELATIONSHIPS BETWEEN A STAGE 4 AIR QUALITY REVIEW AND ASSESSMENT AND AN ACTION PLAN

If a local authority declares an air quality management area, Section 84(1) of the Environment Act 1995 requires that local authority to carry out a further assessment of existing and likely future air quality in the AQMA. This further assessment is called a Stage 4 air quality review and assessment, and is intended to supplement information the authority already has. It is a duty of the LA to complete this Stage 4 air quality review and assessment.

For each pollutant where there is an exceedence of the air quality, the Stage 4 should calculate:

- how great an improvement is needed and
- the extent to which different sources contribute to the problem (source apportionment of traffic, industrial, domestic and background – if appropriate).

This should give a clear picture of the sources which authorities can control or influence. It should ensure that Action Plans strike a balance between the contribution from local authorities and the contribution that must come from other sectors. It should allow them to target their responses more effectively and ensure that the relative contributions of industry, transport and other sectors are cost effective and proportionate. It should include, in particular, an estimate of the costs and feasibility of different abatement options to allow for the development of proportionate and effective Action Plans (although this information could be included within the Action Plan, rather than the Stage 4). Further liaison with other agencies (including, in particular, the Environment Agency and the Highways Agency) is likely to be required.

Essentially, the production of the Stage 4 air quality review and assessment and the Action Plan are activities that the LA can completed in parallel, rather than sequentially.

3.2 RECENT DEFRA GUIDANCE ON STAGE 4 AIR QUALITY REVIEW AND ASSESSMENT

DEFRA have recently issues guidance on what they expect in a Stage 4 (LAQM.PG (03). Essentially, the Stage 4 provides the technical justification for the measures an authority includes in its Action Plan. DEFRA expect that the Stage 4 will allow Local Authorities:

- To calculate more accurately how much of an improvement in air quality is needed to deliver the air quality objectives within the AQMA
- To refine their knowledge of the sources of pollution so that air quality Action Plans can be properly targeted
- To take account of national policy developments that may come to light after the AQMA declaration (the revision of the vehicle emission factors is an example of this kind of policy development)
- To take account of local policy developments, for example, new transport schemes in the vicinity of the AQMA or of any new major housing or commercial developments
- To carry out more intensive monitoring in the problem areas to confirm earlier findings
- To corroborate other assumptions on which the designation of the AQMA was based and to check that the original designation is still valid, and does not need amending
- To respond to comments made by statutory consultees (if there were any relevant comments made)

3.3 ACTION PLANS

Local authorities are required to prepare a written Action Plan for each AQMA setting out the actions they intend to take in pursuit of the air quality objectives. This has to include a timetable for implementing the plan.

The Action Plan should contain the scenarios that have been modelled in the Stage 4 review and assessment. It should contain a summary of the air quality improvements that might be possible for each of the scenarios identified. The Stage 4 provides the technical justification for the measures an authority includes in its Action Plan.

The Action Plan should also contain simple estimates of the costs and feasibilities of implementing those scenarios. The Action Plan may also consider the non-health benefits of implementing scenarios in the Action Plan, for example, reductions in road traffic accident deaths as a result of road improvements that also reduce vehicle emissions.

The LA can then identify which scenario(s) offer the most cost-effective or cost-beneficial way of improving air quality.

3.4 STAGE 4 AND ACTION PLAN TIMESCALES

The Environment Act does not set any deadline for completing Action Plans, but the Government expects authorities to begin preparing them as soon as they have designated an AQMA, and in parallel with their further assessment of air quality required under section 84(1) of the Environment Act. Authorities should not wait until they have completed their further assessment of air quality before beginning their Action Plans. They should aim to consult on their draft AQMA Action Plans within 9-12 months of designation, and should have AQMA Action Plans in place within 12-18 months of designation.

Local authorities are required under section 84(2)(a) of the Environment Act to report on the further assessment of air quality (i.e. the Stage 4 Air Quality Review and Assessment) **within 12 months of designating the Air Quality Management Area**.

4 Information used to support this assessment

This section lists the key information used in this review and assessment.

4.1 MAPS AND DISTANCES OF RECEPTORS FROM ROADS

Luton Borough Council provided electronic OS LandLine™ which was used in the Geospatial Information System (GIS) used in this assessment. Individual buildings or groups of buildings (receptors) were identified from the electronic OS Landline maps and the positions of the roads were accurately determined from the maps.

4.2 ROAD TRAFFIC DATA

Road traffic flow and speed data for 2000 obtained from the NAEI have been used in this assessment.

The vehicle fleet compositions (fraction of cars, LGVs, HGVs buses etc.) were also obtained from the NAEI.

4.2.1 Traffic Growth

The DETR's TEMPRO traffic forecast model was used to predict traffic growth from 2000 to future years (2005 for NO_2 and 2004 and 2010 for PM_{10}).

4.3 AMBIENT MONITORING

4.3.1 Nitrogen dioxide

Nitrogen dioxide concentrations are/were monitored:

- near J11 of the M1 approximately 250 m from the motorway (OS Grid Reference 505571, 222755) and
- by diffusion tubes at a number of sites within Luton.

4.3.2 PM_{10}

PM_{10} concentrations are/were monitored:

- near J11 of the M1 approximately 250 m from the motorway (OS Grid Reference 505571, 222755).

4.4 EMISSION FACTORS USED IN THIS REVIEW AND ASSESSMENT

The vehicle emission factors used for national mapping have recently been revised by DEFRA. The most recent emission factors have been used in this Stage 4 air quality assessment.

5 Stage 4 Review and Assessment for Nitrogen Dioxide (NO_2)

5.1 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 oxidised readily 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.

5.2 LATEST STANDARDS AND OBJECTIVES FOR NO_2

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 exceedences 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) includes the proposed changes.

The new hourly objective is slightly more stringent than the original hourly objective. Modelling studies suggest that in general achieving the annual mean of 40 µg m^{-3} is more demanding than achieving either the former or current hourly objective. If the annual mean is achieved, the modelling suggests the hourly objectives will also be achieved.

5.3 THE NATIONAL PERSPECTIVE

All combustion processes produce some NO_x, but only NO_2 is associated with adverse effects on human health. The main sources of NO_x in the United Kingdom are road transport, which, in 1997 accounted for about half of the emissions of per year. Power generation and domestic sources accounted for 20% and 4% respectively. In urban areas, the proportion of local emissions due to road transport sources is larger.

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 the second or third stage review and assessment for this pollutant.

5.4 MONITORING OF NO_2

5.4.1 Monitoring data used in this assessment

Data from a continuous monitor located near J11 of the M1 (OS Grid Reference 505571, 222755) as well as diffusion tubes have been used in this assessment.

Further details of the locations of the monitoring, the concentrations recorded by the diffusion tubes and the inter-comparison of the diffusion tube and continuous monitors are given in Appendix 1.

5.4.2 Measurement techniques and QA/QC

5.4.2.1 Continuous monitoring

The South East Institute for Public Health has carried out the audit for the NOx analyser.

5.4.2.2 Diffusion tubes

The diffusion tubes used were 50% TEA in water, supplied by Gradko.

5.4.3 Diffusion tube bias

The diffusion tube bias can be calculated from the diffusion tube that was collocated with the continuous monitor near J11 of the M1.

The bias in the diffusion tube results was calculated according to the procedure given in Appendix 1. In 1999 and 2000, the inter-comparison suggests the diffusion tubes were over-estimating the concentrations and for 2001, the inter-comparison suggests the diffusion tubes were under-estimating the concentrations.

Multipliers of 0.74, 0.76 and 1.11 were used to correct the diffusion tube concentrations for 1999, 2000 and 2001 respectively.

5.4.4 Comparison of the measured concentrations with NO_2 objectives

5.4.4.1 Continuous monitoring

The modelling of road traffic emissions has been calibrated against the continuous monitor located near J11 of the M1. The annual mean objective was not exceeded at the continuous monitor in either 1999, 2000 or 2001.

5.4.4.2 Diffusion tubes

The bias corrected diffusion tube data suggest no exceedences of the annual mean objective in 1999 or 2000, but the data do suggest exceedences in 2001 at Junction of A505/M1 (LN01), Round Green (LN05), Guildford Street / Bute Street (LN07) and Sundon Park Road (LN13).

5.5 DETAILED MODELLING OF NO_2

5.5.1 Overview of modelling approach

The air quality impact from roads has been assessed using our proprietary model. There are two parts to this model:

- The Local Area Dispersion System (LADS) model. This model calculates background concentrations of oxides of nitrogen on a 1 km x 1 km grid. The 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 (and projected forward to 2005 using factors in the Review and Assessment Technical Guidance LAQM.TG(02)).

- The DISP 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 available from the NAEI. The dispersion kernels for the DISP model were derived from model runs using ADMS V3.1

Both LADS and DISP were developed specially for Review and Assessment by netcen. Further detailed information about the LADS and the DISP model and the validation of these models are given in Appendix 5.

5.5.2 Definition of the receptor areas and traffic sources

In this study, the concentrations of NO_2 at receptors within 200 m of the M1 have been modelled. All the main roads within this region have been included in the modelling.

The roads were defined as volume sources, 3 m 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 within a few centimetres.

5.5.3 Validation of the model

The application of the model and its validation by comparison with monitoring results for nitrogen dioxide in London is described in Appendix 3. The basic approach was to define a local study area extending at least 200 m in each direction (NSEW) from the receptor area. The 'Urban LADS' model (LADS and DISP) was used to predict:

- the contribution to pollutant concentrations from roads within the local study area (DISP model);
- the contribution from 1 km square area sources in a 30 km square area surrounding the study area (LADS urban background model); and
- the contribution from roads within the local study area to the urban background model.

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 purpose of the validation study shown in Appendix 3 was to demonstrate that the model produced good estimates of the concentrations of nitrogen dioxide and to quantify the uncertainty in the estimates. Statistical techniques have then been used to assess the likelihood that there will be an exceedence of the air quality objectives given the modelled concentration.

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 the use of a part years monitoring data 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. A more detailed description of the approach used to derive these concentrations and their associated uncertainties is given in Appendix 3.

Table 5.1 Confidence limits for NO_2

Description	Chance of exceeding objective	Confidence limits for the modelled annual average concentrations (µg m^{-3})	
		Annual average objective	Hourly average objective (see text below)
Very unlikely	Less than 5%	< 28	< 39
Unlikely	5 to 20%	28 to 34	39 to 52
Possible	20 to 50%	34 to 40	52 to 67
Probable	50 to 80%	40 to 46	67 to 81
Likely	80 to 95%	46 to 52	81 to 94
Very likely	More than 95%	> 52	> 94

The intervals of confidence limit 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 are simpler to interpret. This is a mildly conservative approach to assessing the likelihood of exceedences of the NO_2 objectives since a greater geographical area will be included using the smaller confidence intervals. Appendix 3 provides more information.

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

The calculations have not taken account of uncertainties in traffic forecasts and uncertainties in the reduction in pollutant emissions in future years.

The best estimates of traffic growth have been used in this assessment (here taken as the mean traffic growth from the highest and lowest estimates), which is consistent with the general approach for a Stage 3 assessment that assumptions used should in general be the most likely from the range of possible options.

5.5.4 Local verification of the model

Verification is the process whereby the concentrations predicted by the model are adjusted to agree with local air quality monitoring data – the modelled concentrations are adjusted for any bias. In this case, the model has been used to predict concentrations at the site of a continuous monitor (OS Grid Reference 505571, 222755) located near J11 of the M1. The difference in the modelled and measured concentration has been used to correct for modelling bias. The bias can be viewed as the contribution to NO_x concentrations from unmodelled sources.

For the 2005 modelled predictions of concentrations, the model bias has been scaled down in line with factors in the Review and Assessment Technical Guidance LAQM.TG(03) to allow for expected future decline in concentrations of nitrogen dioxide.

The modelling bias based on continuous monitoring near J11 of the M1 was:

+ 16.9 µg m^{-3} for 2000
+ 14.1 µg m^{-3} for 2005

5.5.5 Comparison of the modelled concentrations with concentrations recorded by diffusion tubes

The NO_2 concentrations predicted by the modelling have been compared against diffusion tube data for 1999, 2000 and 2001:

Table 5.2 Comparison of modelled NO_2 concentrations with diffusion tube data – 1999 (µg m^{-3})

				Un-corrected	Bias Corrected	Modelled
LN01	Junction of A505/M1	505378	222735	53.9	40.0	65.3
LN10	Newlands Road	507898	219704	37.9	28.1	37.2
LN12	Luton Background Site (collocated with continuous analysers)	505571	222755	38.0	28.1	40.9

Table 5.3 Comparison of modelled NO_2 concentrations with diffusion tube data – 2000 (µg m^{-3})

				Un-Corrected	Bias Corrected	Modelled
LN01	Junction of A505/M1	505378	222735	50.0	37.9	62.0
LN10	Newlands Road	507898	219704	36.9	28.0	35.1
LN12	Luton Background Site (collocated with continuous analysers)	505571	222755	42.2	32.0	38.8

Table 5.4 Comparison of modelled NO_2 concentrations with diffusion tube data – 2001 (µg m^{-3})

				Un-corrected	Bias Corrected	Modelled
LN01	Junction of A505/M1	505378	222735	57.2	51.2	59.8
LN10	Newlands Road	507898	219704	32.9	39.9	33.8
LN12	Luton Background Site (collocated with continuous analysers)	505571	222755	26.5	36.8	37.4

The modelled data show reasonable agreement with the bias corrected diffusion tube data, but arguably, better agreement with the uncorrected data.

5.5.6 Modelling of NO_2 from the road links

Figure 5.1 shows predicted annual mean NO_2 concentrations for 2005. Figure 5.2 and Figure 5.3 show areas where the modelling has predicted exceedences of the annual mean NO_2 objective in 2005.

Figure 5.1 Predicted annual mean NO_2 concentrations in 2005 (µg m^{-3})

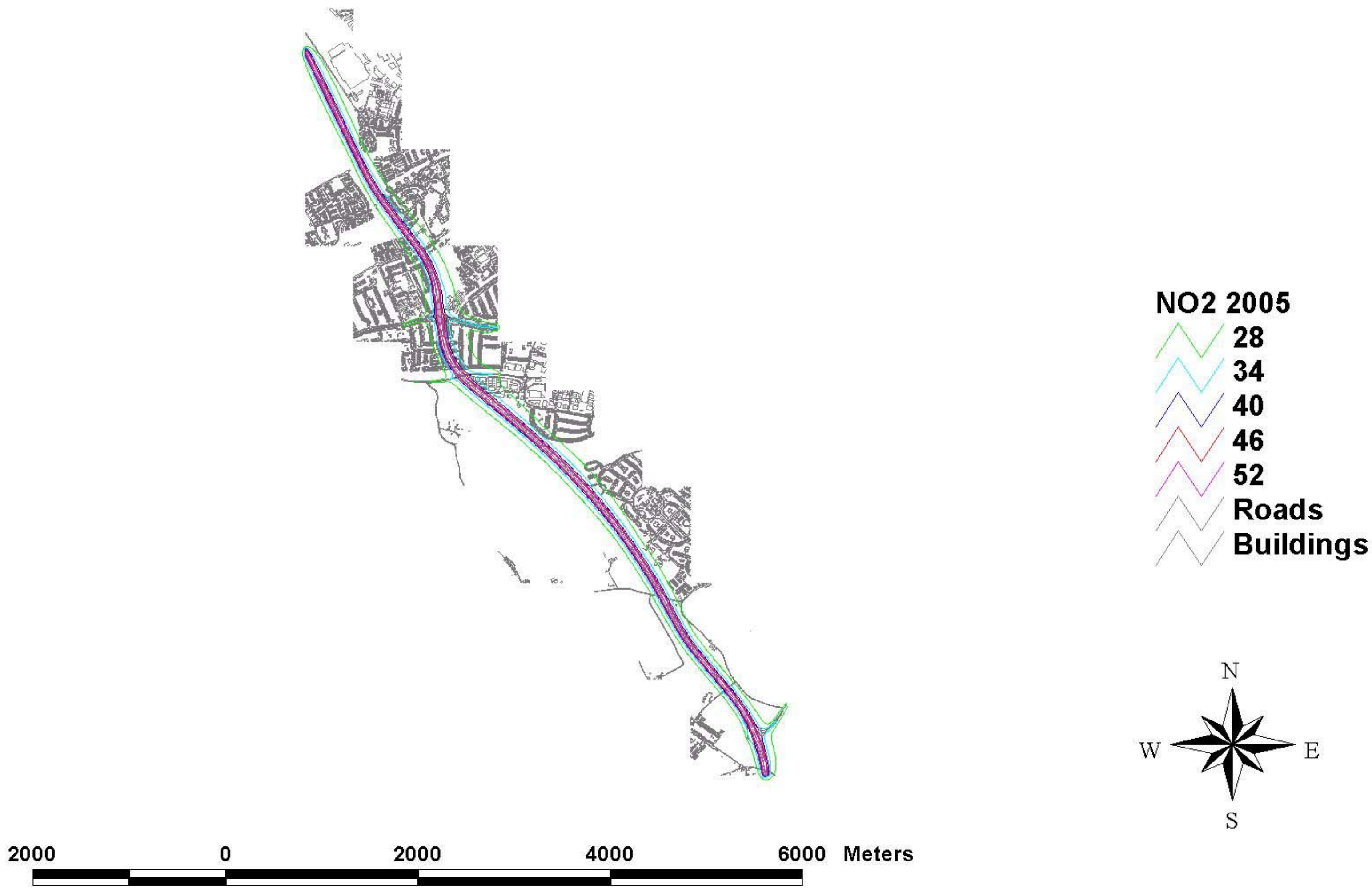


Figure 5.2 Predicted annual mean NO_2 concentrations in 2005 (µg m^{-3})

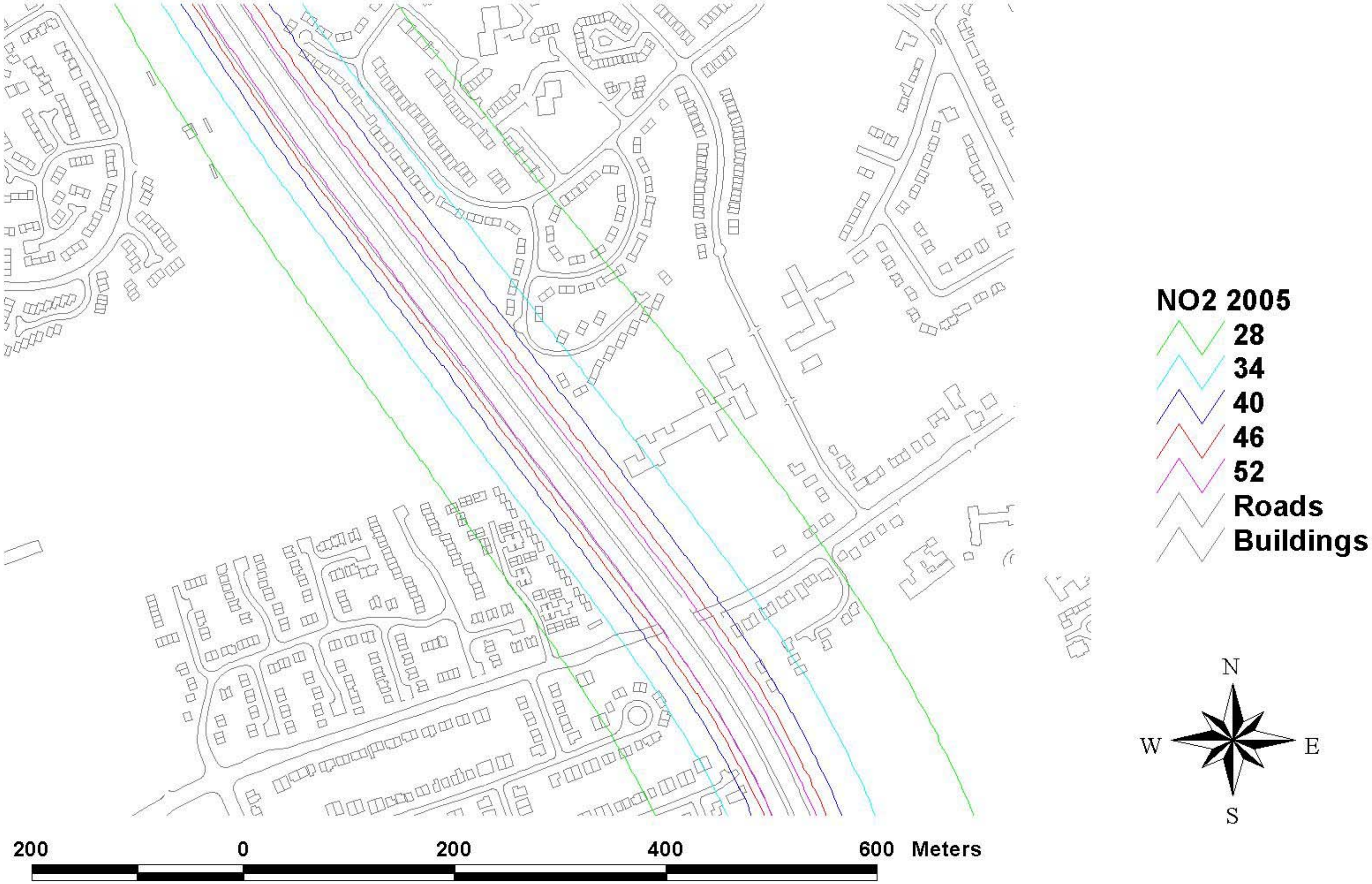
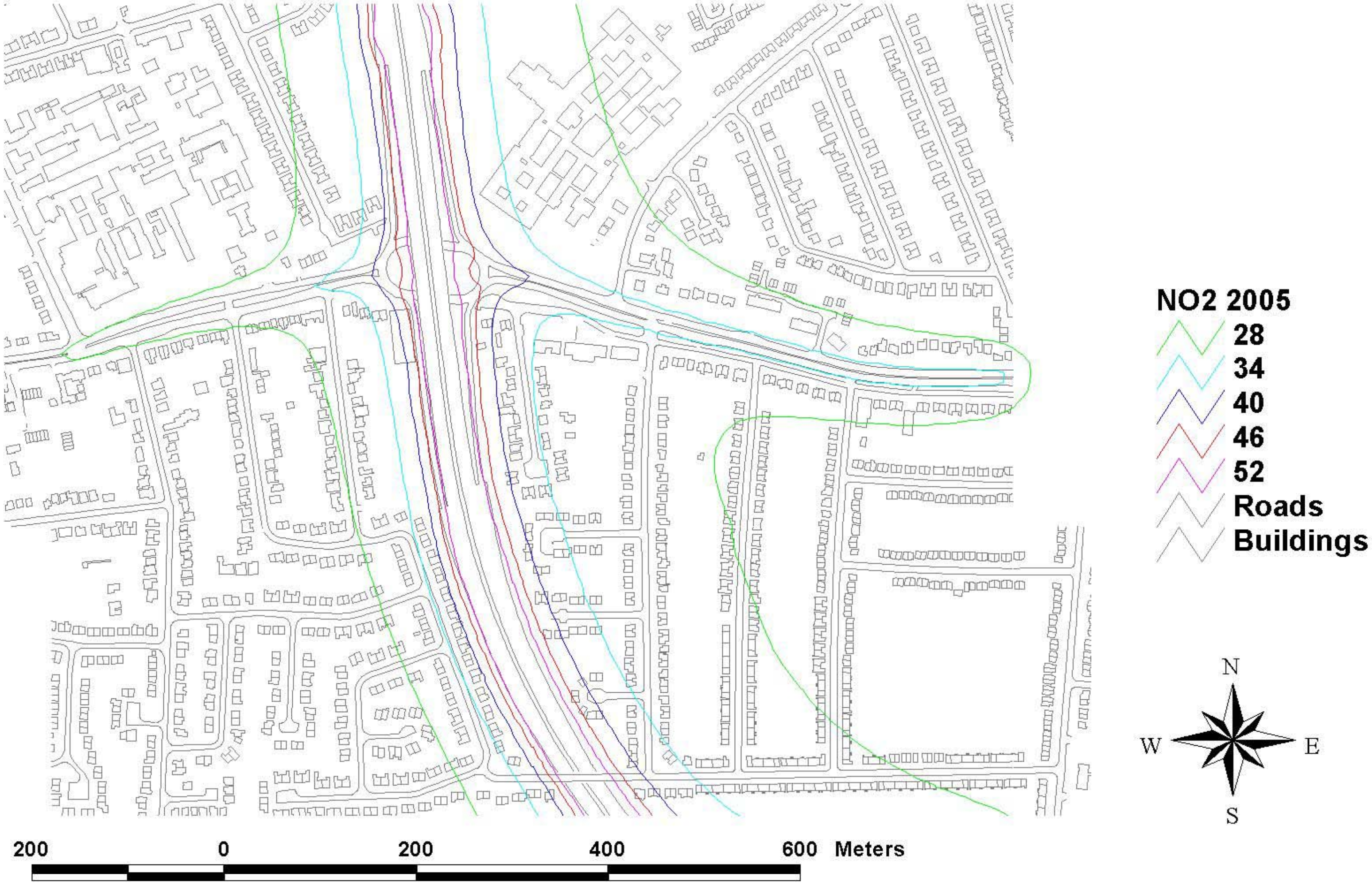


Figure 5.3 Predicted annual mean NO_2 concentrations in 2005 (µg m^{-3})



The model predicts that the annual average objective for NO_2 will be exceeded at properties close to the M1 (within approximately 50 m to the East).

5.6 ASSESSMENT OF THE LIKELIHOOD OF EXCEEDING THE OBJECTIVES FOR NO_2

Table 5.5 shows where modelling indicates it is **probable** (i.e. with probability greater than 50%) that exceedences of the annual objective could occur.

Table 5.5 Locations where the modelling indicates exceedences of the annual objective are probable

Road	House numbers
Armitage Gardens	1 to 6
Bradley Road	125 to 129 odd numbers and 135
Eldon Road	79
Halfway Avenue	76 and 78
High Street	183 to 187 odd numbers
Longfield Drive	17, 19 and 20
Raleigh Grove	14 and 16
Withy Close	9, 11, 16

Modelling predicts that it is **likely** (i.e. with probability between 80 and 95%) that there could be an exceedence of the annual objective at 4 Armitage Gardens.

Also modelling predicts that it is **possible** (i.e. with probability between 20 and 50%) that there could be exceedences at the following locations:

- Abingdon Road
- Armitage Gardens
- Bank Close
- Belper Road
- Bradley Road
- Dunstable Road
- Eldon Road
- Halfway Avenue
- High Street
- Hockwell Ring
- Lime Avenue
- Longfield Drive
- Manor Farm Close
- Mortimer Close
- Raleigh Grove
- Runley Road
- Withy Close
- Wyndham Road

Modelling indicates it is **unlikely** (i.e. with probability less tan 20%) that there could be exceedences at the following locations:

- Atherstone Road
- Bluebellwood Close
- Butely Road
- Castlecroft Road
- Copperfields

- Cradock Road
- Dallow Road
- Derby Road
- Easingwold Gardens
- Faringdon Road
- Farley Green Cottages
- Gilderdale
- Highwood Close
- Ickley Close
- Lachbury Close
- Leagrave High Street
- Lewsey Road
- Overstone Road
- Ripley Road
- Saltfield Crescent
- Seabrook
- Simpson Close
- Staveley Road
- Stonedale
- Stoneygate Road
- Strangers Way
- Warren Road
- Westerdale

At other locations modelling indicates that exceedences are very unlikely (i.e. with probability less tan 5%).

We recommend that Luton Borough Council consider declaring an Air Quality Management Area at the properties identified in Table 5.5. These properties lie within a 50 m band surrounding the M1.

5.7 IMPROVEMENTS NEEDED IN AIR QUALITY

5.7.1 The improvement that is needed – general points

A key step in the Stage 4 Review and Assessment process is to identify the improvements needed in air quality, when there are exceedences of the UK air quality objectives.

An important point to note is that the Local Authority does not need to attempt to improve air quality beyond the air quality objective that is being exceeded. This applies even if that authority has taken a precautionary approach and deliberately set the boundary of their AQMA at, for example, the 36 µg m^{-3} contour rather than the 40 µg m^{-3} contour, in the case of the annual mean NO_2 objective. For example, an AQMA may have been declared for NO_2, and for administrative reasons, the boundary of the AQMA may include houses where the concentrations of NO_2 are not predicted to exceed the annual mean objective of 40 µg m^{-3}. Let us say the maximum exceedence of the annual mean NO_2 objective at a relevant receptor in the AQMA was 43 µg m^{-3}. The maximum improvement that would be needed in this example AQMA will therefore be 3 µg m^{-3}. In this example, this will mean that some houses in the AQMA will experience concentrations of NO_2 possibly much lower than the annual mean objective.

5.7.2 Magnitude of exceedence of the air quality objectives – the improvements expected to be needed

The maximum exceedences of the annual average nitrogen dioxide air quality objective in the area of study are shown in the table below:

Table 5.6 Improvement in annual mean concentrations of nitrogen dioxide needed at receptors exposed to the highest predicted concentrations (in 2005)

Receptor	Grid Easting	Grid Northing	Maximum annual mean concentration of NO_2 predicted for 2005 at the specific receptors (µg m^{-3})	Improvement required to achieve annual mean objective of 40 µg m^{-3} (µg m^{-3})
4 Armitage Gardens	505540	222320	47.6	7.6
129 Bradley Road	505610	222220	45.4	5.4
79 Eldon Road	505420	222420	40.4	0.4
78 Halfway Avenue	505600	222250	41.9	1.9
185 High Street	505260	223410	42.0	2.0
17 Longfield Drive	505490	222470	42.6	2.6
14 and 16 Raleigh Grove	505510	222430	40.7	0.7
9 and 11 Withy Close	504830	223990	40.5	0.5

Please note that in this table and subsequent tables the concentrations of NO_2 are quoted to 0.1 µg m^{-3} purely for convenience, to avoid the risk of rounding errors, and for convenience when taking ratios. The single decimal place used should not be taken as indicative of the accuracy of the modelled estimates.

5.8 SOURCE APPORTIONMENT OF 'BASE CASE' PREDICTIONS

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

In this Stage 4 assessment, the source apportionment:
- Confirms that exceedences of NO_2 are due to road traffic;
- Determines the extent to which different vehicle types are responsible for the emissions that contribute to NO_2 within the area recommended for consideration for declaration of an AQMA.
- This will allow traffic management scenarios to be modelled and tested to reduce the exceedences and
- Quantifies what proportion of the exceedences of NO_2 are due to background emissions, or local emissions from busy roads in the local area. This will help determine whether local traffic management measures could have a significant impact on reducing emissions in the area of exceedence, or whether national measures would be a suitable approach to achieving the air quality objectives.

5.8.1 What is the 'base case'?
The base case in this assessment is defined as the annual mean concentrations of NO_2 that are predicted in the absence of any measures to improve air quality in Luton. It is these concentrations that are relevant in defining the current extent of the Air Quality Management Area. The concentrations in the base case have been calculated using the new traffic emission factors.

5.8.2 Sources of pollution considered

We have considered the effect of the following sources in this Stage 4 assessment at each of the receptors considered:

- Background – general local from the LADS model
- Traffic – Heavy Duty Vehicles (HGVs and buses)
- Traffic – Light Duty Vehicles

The absolute contribution to concentrations are shown in Table 5.7 and the percentages of the total concentrations in Table 5.8. Table 5.9 shows the reduction in traffic required to meet the annual mean NO_2 objective (in 2005).

Table 5.7 Source apportionment of oxides of nitrogen (NO_x) at receptors exposed to the highest predicted concentrations (in 2005)

Receptor	Grid Easting	Grid Northing	Background ($\mu g\ m^{-3}$)	Traffic-LDVs ($\mu g\ m^{-3}$)	Traffic-HDVs ($\mu g\ m^{-3}$)	Total ($\mu g\ m^{-3}$)
4 Armitage Gardens	505540	222320	30.4	43.3	114.5	188.2
129 Bradley Road	505610	222220	29.6	39.5	100.1	169.2
79 Eldon Road	505420	222420	31.2	27.6	74.7	133.5
78 Halfway Avenue	505600	222250	29.9	31.6	80.9	142.3
185 High Street	505260	223410	30.5	22.6	85.7	138.7
17 Longfield Drive	505490	222470	31.8	31.0	85.1	147.9
14 and 16 Raleigh Grove	505510	222430	31.4	27.9	75.2	134.5
9 and 11 Withy Close	504830	223990	28.9	21.5	82.4	132.8

Table 5.8 Source apportionment of oxides of nitrogen (NO_x as %) at receptors exposed to the highest predicted concentrations (in 2005)

Receptor	Grid Easting	Grid Northing	Background (%)	Traffic-LDVs (%)	Traffic-HDVs (%)	Total (%)
4 Armitage Gardens	505540	222320	16.2	23.0	60.8	100.0
129 Bradley Road	505610	222220	17.5	23.3	59.2	100.0
79 Eldon Road	505420	222420	23.4	20.7	55.9	100.0
78 Halfway Avenue	505600	222250	21.0	22.2	56.8	100.0
185 High Street	505260	223410	22.0	16.3	61.8	100.0
17 Longfield Drive	505490	222470	21.5	21.0	57.5	100.0
14 and 16 Raleigh Grove	505510	222430	23.4	20.7	55.9	100.0
9 and 11 Withy Close	504830	223990	21.8	16.2	62.0	100.0

Table 5.9 Reduction in AADT flows required to meet the annual mean NO_2 objective (in 2005)

Receptor	Grid Easting	Grid Northing	Reduction required (%)
4 Armitage Gardens	505540	222320	34.7
129 Bradley Road	505610	222220	26.2
79 Eldon Road	505420	222420	2.3
78 Halfway Avenue	505600	222250	10.4
185 High Street	505260	223410	11.3
17 Longfield Drive	505490	222470	14.7
14 and 16 Raleigh Grove	505510	222430	4.1
9 and 11 Withy Close	504830	223990	2.7

5.8.3 Key findings of the source apportionment

The HDVs (HGVs and buses) on roads in and near Luton are contributing disproportionately to the concentrations of NO_x – HDVs account for generally less than 20% of the AADT flows, but approximately 60% of the NO_x. So small reductions in the flow of HDVs would make a large improvement in the NO_x and hence NO_2 concentrations.

5.9 OPTIONS CONSIDERED TO IMPROVE AIR QUALITY AND THE EFFECTS OF THOSE OPTIONS

5.9.1 The options (Action Plan scenarios) considered

Of the pollutants in the UK Air Quality Strategy, exceedences are only predicted for the annual mean NO_2 objective in Luton. These exceedences are related to the levels of traffic along the M1. Therefore, the scenarios considered are designed to reduce emissions from the M1.

The three scenarios are:

4. Reducing the average speed along the M1 to 96 kph (60 mph)
5. Reducing the average speed along the M1 to 80 kph (50 mph)
6. Reducing the number of HDVs by 20%.

Other options considered include the introduction of a variable speed limit on the M1. The aim of which would be to reduced congestion and hence emissions. However, this option was not taken further as the emissions resulting from such a scheme are difficult to quantify and the effect of congestion is likely to have more impact on emissions of pollutants other than NO_x (for example carbon monoxide).

A general option that would apply to all the scenarios considered is to reduce the general background concentrations (i.e. concentrations over a scale of hundreds of metres) of NO_x. For Luton, background concentrations of NO_x are not atypically high, in comparison with other local authorities with broadly similar densities of industry and roads. This background concentration of NO_x is composed of a combination of very diluted distant sources (traffic and industry from many kilometres away) and more local sources (traffic in the region).

For Luton, attempting to reduce the general background of NO_x is not an option. This can only be achieved by national measures, for example, by introducing tighter measures on UK industrial emissions, or on vehicle emissions in general, or by limiting general traffic growth through fiscal measures.

5.9.2 Effects of those options on concentrations

Table 5.10 summarises the reductions in nitrogen dioxide that might be possible if the scenarios that have been considered are fully implemented.

Table 5.10 Improvement in annual mean concentrations of nitrogen dioxide needed at receptors exposed to the highest predicted concentrations (in 2005)

Option considered	Receptor	Grid Easting	Grid Northing	Reduction in annual mean NO_2 in2005 ($\mu g\ m^{-3}$)
Reducing speed along M1 to 96 kph	4 Armitage Gardens	505540	222320	2.9

	129 Bradley Road	505610	222220	2.8
	79 Eldon Road	505420	222420	2.2
	78 Halfway Avenue	505600	222250	2.5
	185 High Street	505260	223410	1.3
	17 Longfield Drive	505490	222470	2.3
	14 and 16 Raleigh Grove	505510	222430	2.2
	9 and 11 Withy Close	504830	223990	1.2
Reducing speed along M1 to 80 kph				
	4 Armitage Gardens	505540	222320	8.1
	129 Bradley Road	505610	222220	7.4
	79 Eldon Road	505420	222420	4.5
	78 Halfway Avenue	505600	222250	5.7
	185 High Street	505260	223410	4.6
	17 Longfield Drive	505490	222470	5.2
	14 and 16 Raleigh Grove	505510	222430	4.6
	9 and 11 Withy Close	504830	223990	4.7
Reducing HDV flows by 20%				
	4 Armitage Gardens	505540	222320	3.0
	129 Bradley Road	505610	222220	2.9
	79 Eldon Road	505420	222420	2.4
	78 Halfway Avenue	505600	222250	2.6
	185 High Street	505260	223410	2.9
	17 Longfield Drive	505490	222470	2.6
	14 and 16 Raleigh Grove	505510	222430	2.4
	9 and 11 Withy Close	504830	223990	2.8

Reducing speed along M1 to 96 kph is not sufficient to meet the annual mean NO_2 objective at all locations nor is reducing HDV flows by 20%. A reduction in speed to 80 kph is more likely to yield the required reduction in NO_2 concentrations. A combination of reducing the speed by a lesser amount and a reduction in HDV flows also may yield the required reduction.

5.10 SIMPLE ASSESSMENT OF THE FEASIBILITIES OF THE OPTIONS CONSIDERED

This section of the report provides a simple assessment of the feasibility of the options considered to try and reduce or eliminate the chances of exceedences of the air quality objectives for NO_2 in Luton. It is not intended as a full cost-benefit assessment; DEFRA do not require such as analysis in a Stage 4 assessment.

If Luton do go ahead and consider implementing one or more of the options, they will then need to rigorously consider the costs and benefits of the options. Analytical tools are available to do this, such as multi-criteria analysis. It is important that this step is taken because the decisions may be legally challenged and so need to be defensible.

The best options to improve NO_2 air quality are ones that might give the greatest improvement in concentrations for the lowest cost and are possible to implement.

It is likely that implementing speed restrictions will be easier than reducing the number of HDVs on the M1 as the latter would require regional or national measures. This is a purely subjective judgement and should not be used to base policy decisions upon.

6 Stage 4 Review and Assessment for Particulate Matter (PM_{10})

6.1 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.

6.2 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 99^{th} 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[3] measuring method.

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.

6.3 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.

[3] 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).

6.4 MONITORING OF PM_{10}

6.4.1 Monitoring data used in this assessment

Data from a TEOM analyser located near J11 of the M1 (OS Grid Reference 505571, 222755) have been used in this assessment.

Further details of the locations of the monitoring are given in Appendix 1.

All the PM_{10} concentrations presented and used in this study are in gravimetric equivalents. These concentrations have been calculated by multiplying the PM_{10} concentrations measured by the TEOM continuous monitor by a factor of 1.3, as recommended in the Review and Assessment Technical Guidance LAQM.TG(03).

6.4.2 Comparison of the measured concentrations with PM_{10} objectives

The modelling of has been calibrated against the continuous monitor located near J11 of the M1. The annual mean objective for 2004 was not exceeded in either 1999, 2000 or 2001, but the provisional annual mean objective for 2010 was exceeded in 2001.

6.5 DETAILED MODELLING OF PM_{10}

6.5.1 Overview of the modelling approach

The air quality impact from roads has been assessed using the DISP 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 available from the NAEI. The dispersion kernels for the DISP model were derived from model runs using ADMS V3.1

Background PM_{10} concentrations have been obtained from maps available via the DEFRA web site http://www.airquality.co.uk/archive/laqm/tools.php

6.5.2 Definition of the receptor areas and traffic sources

In this study, the concentrations of NO_2 at receptors within 200 m of the M1 have been modelled. All the main roads within this region have been included in the modelling.

The roads were defined as volume sources, 3 m 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 within a few centimetres.

6.5.3 Local verification of the model

Verification is the process whereby the concentrations predicted by the model are adjusted to agree with local air quality monitoring data – the modelled concentrations are adjusted for any bias. In this case, the model has been used to predict concentrations at the site of a continuous monitor (OS Grid Reference 505571, 222755) located near J11 of the M1. The difference in the modelled and measured concentration has been used to correct for modelling bias

The modelling bias based on continuous monitoring near J11 of the M1 was –6.1 $\mu g\ m^{-3}$.

6.5.4 Modelling of PM_{10} from the road links

The model predicts that the annual average objective for PM_{10} for 2004 will not be exceeded anywhere in Luton. The 24 hour mean objective for PM_{10}, which is roughly equivalent to an annual mean of 28 µg m^{-3} is also predicted not to be exceeded except on the M1 itself.

The model also predicts that the provisional annual average objective for PM_{10} for 2010 will not be exceeded except perhaps within approximately 5 m of the M1.

7 Implications of this Stage 4 air quality review and assessment for Luton

This section highlights the implications of this Stage 4 assessment for Luton Borough Council.

The section:

- comments on the effects that new national policy developments have had and may have in the future on the predicted air quality in Luton
- explains any changes that may be needed to the current extent of the current Air Quality Management Area

7.1 EFFECTS OF NEW NATIONAL POLICY DEVELOPMENTS

DEFRA have specified that the Stage 4 assessment must comment on any changes that new national policy developments may have had on the outcome of the air quality review and assessment process.

An important policy development relevant to air quality modelling for all local authorities, and for modelling on a national scale is the recent changes that have been made in the vehicle emission factors. The factors will now not be altered again until the next round of local air quality review and assessment has passed, after 31st December 2003.

The new set of emission factors can be found on the NAEI website (www.naei.org.uk/emissions/index.php) and have been approved by DEFRA and DTLR for use in emissions and air quality modelling, following consultation of the TRL Report "Exhaust Emission Factors 2001: Database and Emission Factors" by TJ Barlow, AJ Hickman and P Boulter, TRL, September 2001.

DEFRA have considered the effect that the new factors may have on predictions of pollutant concentrations made using the old factors. They suggest that forecast emissions of most pollutants (including carbon monoxide, CO, and volatile organic compounds, VOCs) will be largely unaffected by the new pollutants. However, there will be changes to forecast NOx emissions in particular, the size of which will vary according to the base year chosen for the calculations. As a rule of thumb, DEFRA suggest the following generalisations might be helpful.

Forecast emissions of NO_x in 2005 from newer petrol and diesel vehicles may increase by anything up to 36% using the new factors, with the main change being to the performance of Euro 2 vehicles. But emissions from road transport in the base year will also need to be adjusted upwards, and the modelling of these and other emissions will then need to be revalidated. This means that NO_x forecasts from road transport for 2005 are likely to be incorrect by between 10 and 20%. It also means that NO_x emissions from other sources (such as industry) may have been overestimated.

This Stage 4 assessment has used the latest vehicle emission factors. The implications of this for Luton Borough Council are given below.

7.2 CHANGES TO THE AIR QUALITY MANAGEMENT AREA AS A RESULT OF THIS STAGE 4 MODELLING

DEFRA have specified that the Stage 4 assessment must comment on any changes that might be necessary to the extent of the AQMA as a result of the Stage 4 modelling. However, Luton Borough Council have yet to declare an AQMA.

8 The next steps for Luton

This section outlines the nest steps that Luton should take when they receive and accept this Stage 4 air quality assessment.

8.1 OBTAINING DEFRA APPROVAL

DEFRA will need to approve this Stage 4 assessment. Luton should now send a copy of this report to DEFRA. DEFRA will then forward this report to their external assessors who will comment on the work. DEFRA will then forward the critique of the work to Luton.

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

8.2 LOCAL CONSULTATION ON THIS STAGE 4 ASSESSMENT

Luton can ask for feedback from stakeholders who may be interested in the outcome of this Stage 4 air quality review and assessment. Important local stakeholders may include:

External to Luton
- The Highways Agency (for the M1)
- Adjoining local authorities

Internal
- Local residents in the AQMA
- The traffic department
- The planning department

Our experience, and the experience of other Local Authorities suggests that efficient ways of disseminating the information include:

- placing the report on the local authority web site
- producing a small poster for display in the local authority offices
- producing a small poster for display in other public places (post offices, libraries etc.)

8.3 IMPLEMENTING THE OPTIONS IDENTIFIED TO IMPROVE AIR QUALITY

If Luton wish to consider implementing one or more of the options identified, they should now consider entering into discussions with the Highways Agency who are the regulatory body for the M1. This could be completed as part of the Action Plan.

9 References

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Appendices

CONTENTS

Appendix 1

Local air quality monitoring data

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Table A1.1 Continuous monitoring in Luton

Location	Type	Grid reference	Pollutants	Dates
J11 of the M1	NOx Analyser	505571, 222755	NOx	From 01/01/99
J11 of the M1	TEOM	505571, 222755	PM10	From 01/01/99

Table A1.2 Annual mean concentrations measured by continuous NO_x monitoring in Luton (µg m^{-3})

Year	Location	NO_2	NO	NO_x
1999	J11 of the M1	28.1 (14.7 ppb)	71.0 (37.1 ppb)	99.6 (52.1 ppb)
2000	J11 of the M1	32.0 (16.7 ppb)	75.1 (39.3 ppb)	107.6 (56.3 ppb)
2001	J11 of the M1	36.8 (19.3 ppb)	66.9 (35.0 ppb)	103.8 (54.3 ppb)

Table A1.3 Annual mean concentrations measured by continuous PM_{10} monitoring in Luton (µg m^{-3} (gravimetric))

Year	Location	PM_{10}
1999	J11 of the M1	13.4 (10.3 TEOM)
2000	J11 of the M1	18.3 (14.1 TEOM)
2001	J11 of the M1	20.5 (15.8 TEOM)

Table A1.4 Diffusion tube locations

	Location	Easting	Northing
LN01	Junction of A505/M1	505378	222735
LN02	Marsh Road	506099	224228
LN03	A6 / Grasmere	508304	225369
LN04	Museum - Wardown Park	508926	222958
LN05	Round Green	510094	222717
LN06	A505 / Liverpool Road	508668	221414
LN07	Guildford Street / Bute Street	509227	221455
LN08	Castle Street / Windsor Street	509047	220707
LN09	Eaton Green Road / Colwell Rise	512430	222253
LN10	Newlands Road	507898	219704
LN11	Luton Town Hall	509000	221300
LN12	Luton Background Site (collocated with continuous analysers)	505571	222755
LN13	Sundon Park Road	505130	225625
LN14	Luton Background Site (duplicate)	505571	222755

Table A1.5 NO_2 concentrations measured by diffusion tubes in Luton (µg m^{-3})

1999

				Un-corrected	Bias Corrected
LN01	Junction of A505/M1	505378	222735	53.9	40.0
LN02	Marsh Road	506099	224228	39.2	29.0
LN03	A6 / Grasmere	508304	225369	37.2	27.6
LN04	Museum - Wardown Park	508926	222958	26.2	19.4
LN05	Round Green	510094	222717	38.5	28.6
LN06	A505 / Liverpool Road	508668	221414	43.5	32.3
LN07	Guildford Street / Bute Street	509227	221455	41.9	31.0
LN08	Castle Street / Windsor Street	509047	220707	39.5	29.3
LN09	Eaton Green Road / Colwell Rise	512430	222253	31.2	23.1
LN10	Newlands Road	507898	219704	37.9	28.1
LN11	Luton Town Hall	509000	221300	38.2	28.4
LN12	Luton Background Site (collocated with continuous analysers)	505571	222755	38.0	28.1
LN13	Sundon Park Road	505130	225625	N/A	N/A
LN14	Luton Background Site (duplicate)	505571	222755	N/A	N/A

2000

				Un-corrected	Bias Corrected
LN01	Junction of A505/M1	505378	222735	50.0	37.9
LN02	Marsh Road	506099	224228	36.1	27.4
LN03	A6 / Grasmere	508304	225369	33.2	25.2
LN04	Museum - Wardown Park	508926	222958	23.1	17.5
LN05	Round Green	510094	222717	38.6	29.3
LN06	A505 / Liverpool Road	508668	221414	39.7	30.1
LN07	Guildford Street / Bute Street	509227	221455	40.7	30.9
LN08	Castle Street / Windsor Street	509047	220707	37.6	28.5
LN09	Eaton Green Road / Colwell Rise	512430	222253	30.0	22.7
LN10	Newlands Road	507898	219704	36.9	28.0
LN11	Luton Town Hall	509000	221300	N/A	N/A
LN12	Luton Background Site (collocated with continuous analysers)	505571	222755	42.2	32.0

LN13	Sundon Park Road	505130	225625	37.0	28.0
LN14	Luton Background Site (duplicate)	505571	222755	N/A	N/A

2001

				Un-corrected	Bias Corrected
LN01	Junction of A505/M1	505378	222735	57.2	51.2
LN02	Marsh Road	506099	224228	40.3	36.8
LN03	A6 / Grasmere	508304	225369	33.5	32.6
LN04	Museum - Wardown Park	508926	222958	21.8	22.2
LN05	Round Green	510094	222717	40.7	43.1
LN06	A505 / Liverpool Road	508668	221414	39.0	39.9
LN07	Guildford Street / Bute Street	509227	221455	42.1	44.1
LN08	Castle Street / Windsor Street	509047	220707	40.0	39.7
LN09	Eaton Green Road / Colwell Rise	512430	222253	26.2	32.0
LN10	Newlands Road	507898	219704	32.9	39.9
LN11	Luton Town Hall	509000	221300	N/A	N/A
LN12	Luton Background Site (collocated with continuous analysers)	505571	222755	26.5	36.8
LN13	Sundon Park Road	505130	225625	33.4	40.0
LN14	Luton Background Site (duplicate)	505571	222755	N/A	N/A

Methodology for calculating the diffusion bias relative to the continuous monitor

Bias correction factor required for the diffusion tubes assessed from:

mean of [continuous monitor]/ mean of [collocated diffusion tube]

For 1999, multiplier of 0.741 used to correct the diffusion tube concentrations
For 2000, multiplier of 0.758 used to correct the diffusion tube concentrations
For 2001, multiplier of 1.112 used to correct the diffusion tube concentrations

Appendix 2
Traffic data

CONTENTS

Table A2.1 Summary of traffic data used in the modelling

Road Name	All vehicles	CAR	BUS	LGV	HGVr	HGVa	Moto	Speed
M1 J11 to J12 Sbnd	46534.5	33800.5	408.5	3817.5	2768.5	5477	262.5	95
M1 J11 to J12 Nbnd	46534.5	33800.5	408.5	3817.5	2768.5	5477	262.5	95
M1 J10 to J11 Sbnd	55449.5	40087	248.5	5976	2561	6317	260	113
M1 J10 to J11 Nbnd	55449.5	40087	248.5	5976	2561	6317	260	113
A505(E) Wbnd	12534.5	9849	363.5	1512	434.5	318.5	57	46
A505(E) Ebnd	12534.5	9849	363.5	1512	434.5	318.5	57	46
A505(W) Ebnd	12500	10572	165.5	1262.5	260.5	102	137.5	46
A505(W) Wbnd	12500	10572	165.5	1262.5	260.5	102	137.5	46
A5065(E)	22198	18460	133	2313	744	251	297	80
A5065(W)	22198	18460	133	2313	744	251	297	80
M1 J9 to J10 Sbnd	65876.5	48293	501.5	7329.5	2978.5	6410	364	113
M1 J9 to J10 Nbnd	65876.5	48293	501.5	7329.5	2978.5	6410	364	113

Factors to convert 2000 flows to future years

2004	1.0690
2005	1.0875
2010	1.1615

Appendix 3

Model validation
Nitrogen dioxide roadside concentrations

CONTENTS

INTRODUCTION

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

The model was used to predict

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

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

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

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

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

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

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

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

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

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

MODEL APPLICATION

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

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

Table A3.1 Traffic growth 1998:1996

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

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

Table A3.2 Assumed diurnal traffic variation

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

Vehicle speeds in the local study area

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

Table A3.3 Traffic speeds used in the modelling

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

Vehicle emissions in the local study area
Vehicle emissions of oxides of nitrogen were estimated using the Highways Agency Design Manual for Roads and Bridges, 1999 (DMRB). DMRB provides a series of 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 $NO_x > 23.6\ \mu g\ m^{-3}$

$$NO_2 = 0.348\ NO_x + 11.48\ \mu g\ m^{-3}$$

For $NO_x < 23.6\ \mu g\ m^{-3}$

$$NO_2 = 0.833\ NO_x\ \mu g\ m^{-3}$$

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)

99.8th 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

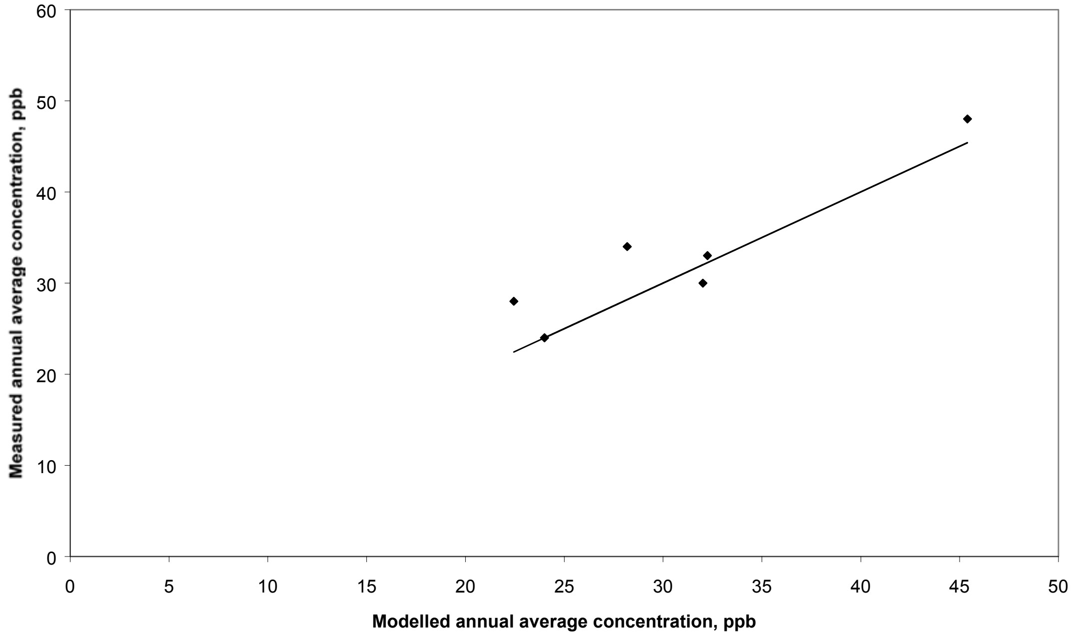


Fig. A3.1 Comparison of modelled and measured annual average nitrogen dioxide concentrations

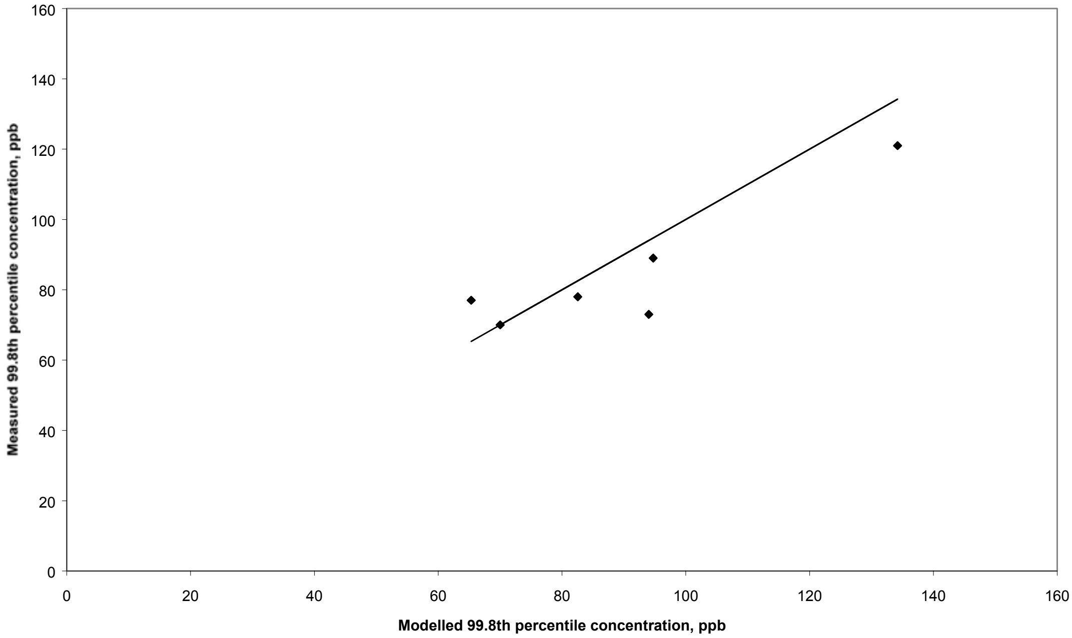


Fig. A3.2 Comparison of modelled and measured 99.8th percentile hourly average nitrogen dioxide concentrations

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

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

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

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

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

where c_{1996} is the concentration in 1998;

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

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

Short periods of monitoring data

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

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

Confidence limits

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

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

where:

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

c is the concentration calculated for the modelled year;

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

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

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

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

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

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

In practical terms,

- there is less than 1:5 chance (i.e.100-80=20%) that the 40 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} 99.8^{th} 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 exceedences of the NO_2 objectives since a greater geographical area will be included using the smaller confidence intervals.

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

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

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

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

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

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

Appendix 4

Model validation
Particulate matter

CONTENTS

Calculation of the calibration curve for the modelled PM_{10} concentrations

Measurements of PM_{10} concentrations made at the Edward Benefer site and at Norwich Centre were used to calculate the bias in the modelled PM_{10} results.

An estimate was made of the fraction of the total PM_{10} concentration produced by emissions from the handling operations at the main port area. This estimate of PM_{10} emitted from the docks was made by subtracting the 24 hour mean concentrations recorded at the nearest suitable site that could be classed as a PM_{10} background site (Norwich Centre) from the hourly concentrations recorded at the Edward Benefer site. Where the commodity handling operation overlapped with the period of monitoring, the hourly estimates of PM_{10} concentrations from the docks were compared to the hourly concentrations predicted from the model. The relationship between these two estimates of PM_{10} (modelled and measured) emitted from the main port were used to correct the modelled estimates of PM_{10} concentration.

There was insufficient data to apply this approach to the South Quay dock area, as there were only two periods when the monitoring and ship loading operations overlapped. Therefore, the bias calculated for the main dock area was assumed to applied to the South Quay area.

Figure A4.1 shows the scatter plot to show the relationship between the measured (estimated) and modelled primary emissions at the Edward Benefer monitoring station. When the data is presented in this way, there is no obvious relationship between the measured and modelled estimates of PM_{10}. This is not unexpected, as the monitor at the Edward Benefer site is close to the source (approximately 0.5 km). Over this short distance, the plume (body of air containing the PM_{10} emitted from the docks) will be relatively narrow and so the chances of the monitor not sampling the plume are relatively high. Therefore, small errors in the wind direction assumed in the model will results in large errors in predicted PM_{10} concentrations.

An alternative approach to assessing the bias in the modelled results is to order each set of estimates of the primary PM_{10} from the monitoring and modelling in terms of magnitude, and produce a scatter plot of the ordered concentrations. This tests whether the frequency of specific elevated concentrations the monitoring site is correctly predicted by the model. The results of this assessment are shown in **Figure A4.2.** There is a good relationship between the ranked measured estimates and modelled estimates of the primary PM_{10} component (slope of almost unity). There is an offset of approximately 6 $\mu g\ m^{-3}$ because of the higher PM_{10} background in Norwich.

Using a similar approach, we attempted to assess the bias for the South Quay docks. However, there was only a limited overlap between the ship loading activity data available at the time of assessment and the monitoring data, and only two data points were available.

Therefore, the bias calculated for the main dock area was assumed to applied to the South Quay area. However, the limited data suggest that the model may be under-predicting the concentrations at South Quay by up to 50%.

Figure A4.1 Scatter plot to show the relationship between the measured (estimated) and modelled primary emissions at the Edward Benefer monitoring station

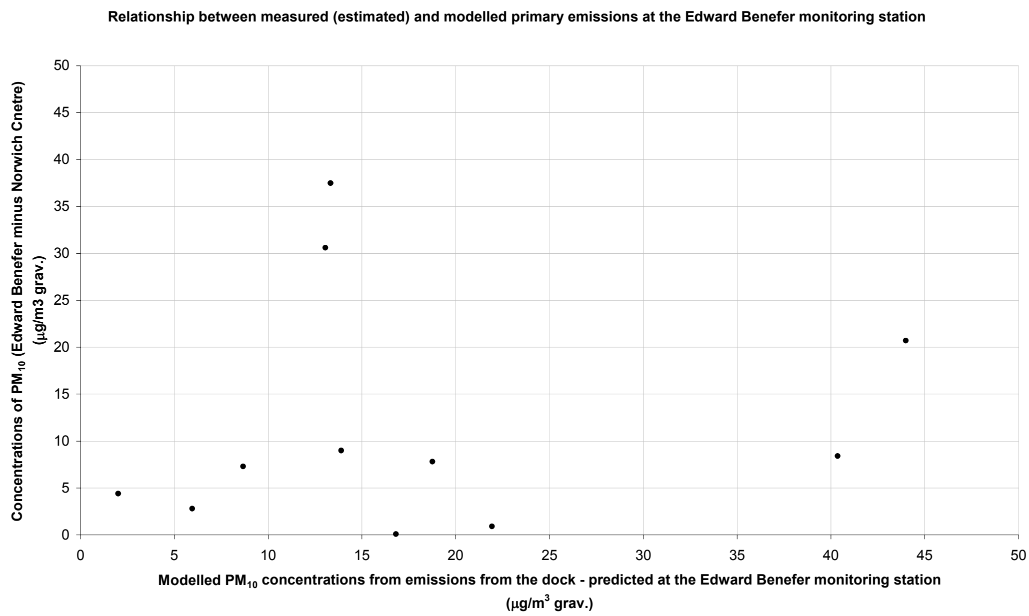
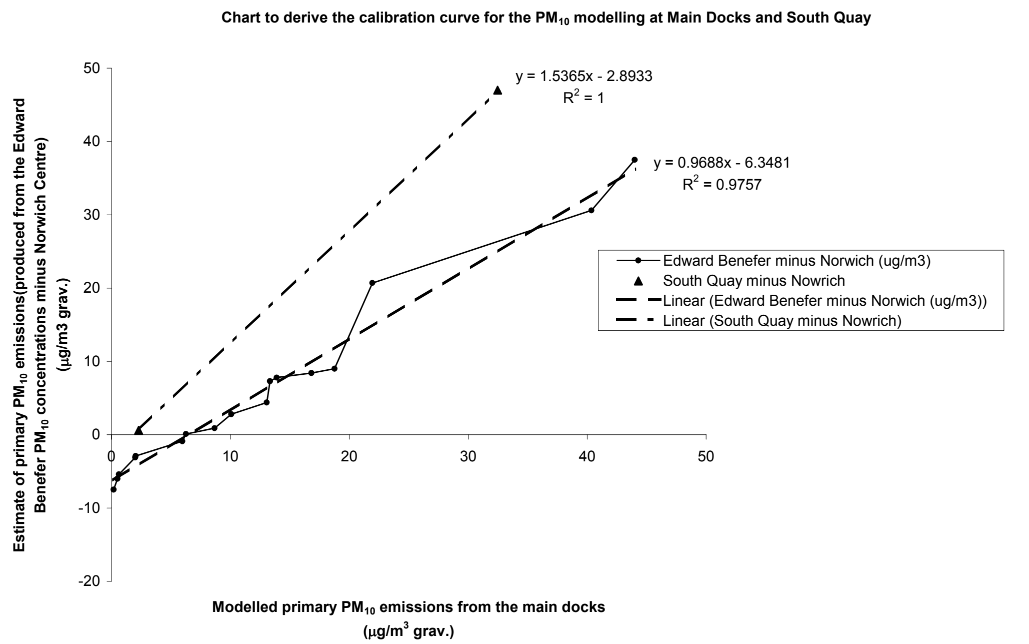


Figure A4.2 Calibration curve to derive the bias in the modelled PM_{10} concentrations



Appendix 5

Descriptions of selected models

CONTENTS

Dispersion models

ADMS V3.0 (Atmospheric Dispersion Modelling System)

This is a new generation multi-source dispersion model using an up-to-date representation of atmospheric dispersion. Specific features include the ability to treat both wet and dry deposition, building wake effects, complex terrain and coastal influences. ADMS-3 can model releases from point, area, volume and line sources and can predict long-term and short-term concentrations, Urban and rural dispersion coefficients are included and calculations of percentile concentrations are possible.

DISP A Tool for Calculating Atmospheric Dispersion using a Point-Source Kernel

Overview

A road is defined as a series of straight-line segments $\{S_i$, where i = 1 to $n\}$ with length L_i m a uniform width W_i m. The road is assigned an emission rate per unit length E g m-^{1}s-^{1}. The emission rate is calculated using the DMRB.

Each segment is then converted to a regularly spaced matrix of $N \times M$ points running parallel and perpendicular to line such that the distance between adjacent points is less than 1 m. Each point has a emission rate of $(L_i \times E) \div (N \times M)$ g s-^{1}.

A 10 m × 10 m grid covering all the roads to be modelled is defined and the emissions all the points within each grid cell are summed to produce a matrix of emissions on a 10 m × 10 m grid. This matrix is used as input to the "disp" tool.

The "disp" tool also takes, as input, the results from the dispersion modelling of a 10 m 10 m × 3 m volume source using ADMS.

The LADS model is used to provide background concentrations.

The contribution from the local sources to the LADS background is calculated by aggregating the 10 m × 10 m grid emissions onto a 1 km × 1 km grid and using these emissions as input to LADS with background NO_X concentrations set to zero. The resulting NO_X concentrations are the contribution from the local sources to the LADS background.

1. Outline Methodology

1.1 DISP relies on the linearity of passive atmospheric dispersion. External to DISP, a complex set of sources, including points, lines and areas is discretised into a set of point sources (with spacing chosen carefully to avoid artefacts of the discretisation, whilst at the same time using as few point sources as possible). The set of point sources is fed as input to DISP.

1.2 DISP also takes as input the annual-average concentration on a polar grid (non-uniform in radius), for a unit point source at the origin of co-ordinates. In addition, a set of receptors is input at which the total concentration resulting from the set of sources is required.

1.3 DISP then proceeds to take each source in turn and calculates its contribution to annual average concentration at each receptor, using interpolation of the dispersion kernel to calculate the concentration at an arbitrary distance and angle from a particular source.

2. Interpolation Method

2.1 In the **radial** direction, a linear interpolation is carried out on log-transformed variables (both concentration and radius). This procedure anticipates that the behaviour will approximate power-law. For ground-level sources, the behaviour is expected to be similar to a power-law behaviour for an individual weather condition, so the actual behaviour is more like a sum over power laws. For an elevated source, similar behaviour is expected beyond the point of maximum concentration on the ground, but not before it. In either case, the accuracy of the log-log interpolation for a given radial spacing has to be determined by inspection (see Section 5).

2.2 In the angular direction, a linear interpolation is used.

2.3 In height, a log-concentration/linear height interpolation is used.

3. The Dispersion Matrix Grid

3.1 The dispersion matrix is generated using ADMS 3, for which the output grid is limited to 32*32 points. The radial co-ordinate needs to cover a wide range – with the minimum set at typically 10 m (in this assessment, set at 10 m) and the maximum at 20 km – so the spacing is chosen to be non-uniform. The radii are defined so that the fractional change (delta-radius divided by mean radius) stays the same. This leads to logarithmically-spaced radii. Radii chosen according to the prescription

$$r_n = r_0 \exp(\alpha\, n)$$

where r_n is the n^{th} radius, r_0 is the first radius (lowest of interest) and α is a constant. Typically α is around 0.25 for 32 radii and r_0 =10m. Thus only two parameters define the set of radii.

3.2 It would have been preferable to choose the angular spacing to be 10° when sequential meteorological data are used, but only 32 angles are allowed by ADMS 3. In this case, the angular spacing is chosen as 13.3°, given that ADMS chooses to send auxiliary plumes 3.3 degrees on either side of the centreline of an angular sector. This will minimise artefacts in the variation with angle, caused by the choice of a discrete number of plumes to represent the integration over the sector. Alternatively, two runs of ADMS can be done, with 18 angles in each. In this assessment, one run of ADMS was sufficient.

3.3 In height, a logarithmic spacing is again used, except for near the ground, where there is a lower limit on spacing set by the initial vertical sigma. A suggested list of heights is 2.5, 3.5, 5.0, 7.0, 10.0, 14.0, 20.0, 28.0, 40.0, 55.0, 75.0, 100.0, 140.0, 200.0, 280.0, 400.0, 550.0, 750.0, 1000. (all heights in m). This assumes an initial vertical standard deviation of 2.5 m.

4. Code Design

4.1 The code starts by reading in the set of dispersion matrices (corresponding to various heights), taking the logarithm of the concentration magnitudes for the interpolation process later (*being careful about zeroes). It then reads in the receptor co-ordinates, and writes a header in the log file.

4.2 The code then reads in the number of sources (which it uses to check the integrity of the source file) and starts an 'outer' loop over sources. Point sources are read in and used one at a time (so the code is not dimensioned on the number of sources). For each source, the first task is to calculate a 2-dimensional dispersion matrix (concentration as a function of radius and angle), which is interpolated in height from the dispersion matrices.

4.3 The code then starts an 'inner' loop over receptors, adding a contribution to the concentration counter for each receptor in turn from the current point source. The contribution is worked out by finding the radial distance and angle (on a horizontal plane) from the current point source to the current receptor, bracketing these values by values in the dispersion matrix and carrying out a 2-dimensional interpolation (log-log in radius, lin-lin in angle) to get the contribution per unit emission. The result is then multiplied by the emission strength of the source and the contribution added to the receptor's counter (provided it is not too small).

4.4 After looping over all receptors, another source is read from the source file and the process repeated. After all sources have been read in, the results in the receptor concentration counters are output to a results file (and also samples of the results are output to the log file for checking purposes).

5. Overview of the Test Strategy

5.1 Test 1 checks the reading in of the dispersion matrix, and writing to an output file. The receptors are set to be the precise locations used for the dispersion matrix, and a unit source at the origin is used, so the output should echo exactly the dispersion matrix values.

5.2 Test 2 checks that the interpolation in angle is working properly by introducing a simple dispersion matrix (only one radius, 24 angles, with the concentration increasing linearly with angle); a single source is put at the origin and receptors are placed at the half-angles. The concentrations should come out half way between the values at the bounding angles (since lin-lin interpolation is used).

5.3 Test 3 checks that the interpolation in radius is working properly by introducing a simple dispersion matrix with only two angles (6 radii); the concentrations increase exponentially. Receptors are placed at the mid radii (in log space). The concentrations should be at the mid values (in log space).

5.4 Test 4 checks that the interpolation is height is working properly by introducing an especially simple dispersion matrix with only two levels, which is constant with angle and radius at each level (but a different value at the two levels); the single point source is put at the mid height. the concentrations are set at 1 and e^1, so the mid-point concentration should be $e^{0.5}$.

5.5 Test 5 tests the summing over source magnitudes for a given receptor concentration counter. Uses the same dispersion matrix as Test 4, but introduces 3 point sources at the same location: the concentration result should be 3 times as large.

5.6 Test 6 checks the warnings on height and distance. Uses the same matrix as for Test 4. Sets the source above 3.5 m (the height of the highest level) and sets the last radial receptor beyond the last radius of the matrix.

5.7 Test 7 checks that the source switch that selects which set of data to be used works correctly. A special dispersion matrix with 3 sets of data, each one a uniform matrix but with the three sets having different values. The 3 sources in the source file each select a different set. The summed concentration is checked.

5.8 Test 8 fabricates a line source at 45 degrees to the axes and introduces a dispersion matrix with a cut off to zero beyond a fairly short radius. This should lead to an elongated concentration pattern, which falls to zero within a certain distance of the line.

5.9 Tests 9-24 examine the accuracy of the interpolation process with a 'real' dispersion matrix – actually one that mimics the LPAM dispersion model. Tests 9-15 look at radial interpolation for sources at various heights; Tests 16-24 examine height interpolation.

5.10 For Tests 9-15, two matrices are set up, based on the same dispersion process but with radii displaced such that the second matrix has radii at the mid points (in log space) of the radial bands of the first matrix. The receptors are placed at the 'matrix points' of the second matrix, at a selected height, and the concentrations are worked out two ways, once using the first dispersion matrix – which will involve interpolation – and once using the second matrix – with no interpolation. The results are differenced in a spreadsheet and the fractional error examined. This is repeated for a range of heights.

5.11 For Tests 16-24, another two matrices are used, with the second having levels which are at the mid points (linear) of the height bands of the first (but with all radii and angles the same). Again the concentration at a selected height is worked out two ways, once with each matrix (i.e. with and without interpolation), the results differenced in a spreadsheet and the fractional error examined. This is repeated for a range of heights.

Local Area Dispersion System (LADS) model

Background concentrations of oxides of nitrogen were calculated on a 1 km x 1 km grid using results from the dispersion model ADMS 3. The estimates of emissions of oxides of nitrogen for each 1 km x 1 km area grid square were obtained from the 1997 National Atmospheric Emission Inventory disaggregated inventory. Large individual point sources emitting in excess of 15 g/s of nitrogen oxides were excluded from the modelled inventory. Each 1 km x 1 km grid square in the emission inventory was treated as a volume source with height of 10 m to allow for the initial mixing of pollutants. A surface roughness value of 1 m was used to represent surface conditions and is typical of urban areas.

Hourly sequential meteorological data has been used as part of this model.

The model calculated concentrations of oxides of nitrogen: a non-linear relationship derived from monitoring data obtained from the Department of the Environment, Transport and the Regions Automatic Urban Network was used to convert annual average oxides of nitrogen concentrations to annual average nitrogen dioxide concentrations.

The validation of the model is shown in Appendix 3.

DETR's TEMPRO traffic forecast model

TEMPRO V3.1 was made available by DETR in November 1997. It is based on the 1997 National Road Traffic Forecasts, i.e. the most recent version of the NRTF used for the National Atmospheric Emissions Inventory forecasts.

According to the supporting documentation, TEMPRO is linked to the National Trip End Model forecasts of growth in car traffic and underlying car ownership within specified areas in an average weekday. The trip ends are not constrained by the capacity of the network, but the trip distance does seem to take account of capacity constraints and congestion at district level.

In summary, it seems that TEMPRO is based on a "demand to travel" and car ownership basis on a district level, with actual traffic flow constrained by current road capacity in the area. It is primarily designed as a tool for local planners to use for evaluating land use changes and traffic redistribution schemes.