AEAT/ENV/R/0922

Air Quality Review and Assessment - Stage 3

A report produced for Suffolk Coastal District Council

December 2001

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Executive Summary

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

The 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 National 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.

This report is a supplementary stage three air quality review for Suffolk Coastal District Council (SCDC). It is submitted in addition to the Stage 3 report produced in June 2001 (SCDC & Entec 2001). DEFRA identified the need for further work to be carried out to fully complete the Stage 3 Review and Assessment. Only nitrogen dioxide is considered in this report. This is because the Stage 3 Report carried out for SCDC showed that nitrogen dioxide was the only pollutant for which the air quality standards might be exceeded in 2005. This report investigates current and potential future nitrogen dioxide levels through an examination of the location and size of principal traffic emission sources, emissions modelling exercises and by reference to monitored air quality data.

Annual mean nitrogen dioxide concentrations were predicted for the SCDC in the Stage 3 air quality review using the Breeze Roads Model[3]. That analysis showed that there was a risk of exceedence in 2005 of the annual nitrogen dioxide objective at two road junctions:

- Melton road junction
- Woodbridge road junction

As part of this report, detailed modelling using ADMS version 3.1 has therefore been undertaken at these two locations.

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

Nitrogen Dioxide

Consideration has been given to the possibility of designating Air Quality Management Areas at the locations assessed. Factors to be taken into account include:

- the likelihood that members of the public will be exposed over the relevant averaging time;
- the likelihood that the objective will be met;
- the physical boundaries that might be used to define Air Quality Management Areas

The results of our model validation which takes into account uncertainty based on model errors, year to year variability and errors due to short period monitoring suggest that only areas within the 40 $\mu g\ m^{-3}$ contour are more likely than not to exceed and only areas within the 46 $\mu g\ m^{-3}$ contour are likely or very likely to exceed the objective in 2005. It would be recommended that Suffolk Coastal District Council only considered declaring AQMAs where the probability of exceedance in 2005 is greater than 50%.

Modelling showed that it was unlikely (with a probability of between 5% and 20%) that an exceedence of the annual mean objective for nitrogen dioxide will occur at the Melton and Woodbridge road junctions in 2005.

Therefore it is suggested that Suffolk Coastal District Council do not consider declaring an air quality management area for nitrogen dioxide.

Maps reproduced within this document

Acronyms and definitions

AADTF	annual average daily traffic flow
ADMS	an atmospheric dispersion model
AQDD	Common Position on Air Quality Daughter Directives
AQMA	Air Quality Management Area
AQS	Air Quality Strategy
AUN	Automatic Urban Network
CNS	central nervous system
CO	Carbon monoxide
D1	HMIP dispersion modelling notes; Technical Guidance Note (Dispersion) D1
d.f.	degrees of freedom
DEFRA	Department for the Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DMRB	Design Manual for Roads and Bridges
EA	Environment Agency
EPA	Environmental Protection Act
EPAQS	Expert Panel on Air Quality Standard
GIS	Geospatial Information System
HA	Highways Agency
kerbside	0 to 5 m from the kerb
LADS	Urban background model specifically developed for Stage 3 Review and Assessment work. This model allowed contributions of the urban background and road traffic emissions to be calculated
n	number of pairs of data
NAEI	National Atmospheric Emission Inventory
NAQS	National Air Quality Strategy (now called the Air Quality Strategy)
NETCEN	National Environmental Technology Centre
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NRTF	National Road Traffic Forecast
ppb	parts per billion
r	the correlation coefficient
roadside	1 to 5 m from the kerb
SCDC	Suffolk Coastal District Council
SD	standard deviation
TEMPRO	A piece of software produced by the DETR used to forecast traffic flow increases

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1. Introduction

1.1 PURPOSE OF THE STUDY

Suffolk Coastal District Council (SCDC) completed a Stage three Air Quality Review within the local authority area [SCDC & Entec 2001]. However, DEFRA identified the need for further work to be carried out to fully complete the Stage 3 Review and Assessment. AEA Technology's National Environmental Technology Centre (NETCEN) was commissioned by SCDC to complete this supplementary third stage review and assessment.

1.2 GENERAL APPROACH TAKEN

The approach taken in this study was to:

- Collect and interpret additional data to support the third stage assessment, including detailed traffic flow data around locations where exceedences were predicted;
- Utilise the monitoring data from the neighbouring Council - Babergh Distict to assess the ambient concentrations produced by the road traffic and to validate the output of the modelling studies.
- Model the concentrations of NO_2 around the selected roads, concentrating on the locations (receptors) where people might be exposed over the relevant averaging times of the air quality objectives;
- Present the concentrations as contour plots of concentrations and assess the uncertainty in the predicted concentrations

1.3 VERSION OF THE POLLUTANT SPECIFIC GUIDANCE USED IN THIS ASSESSMENT

The Air Quality Strategy (AQS) for the UK has been revised and reissued (DETR, 2000) and the strategy contains some new objectives for some pollutants (see Table 2.2). The Pollutant Specific Guidance (LAQM.TG4(00)) has been revised and reissued to match the AQS.

This report has used the guidance in LAQM.TG4(00), published in May 2000.

1.4 NUMBERING OF FIGURES AND TABLES

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

1.5 UNITS OF CONCENTRATION

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

1.6 STRUCTURE OF THE REPORT

This document is a supplementary Third Stage Air Quality review for Suffolk Coastal District Council for nitrogen dioxide. This chapter, Chapter 1 has summarised the need for the work and the approach to completing the study.

Chapter 2 of the report describes the most recent developments in the UK's Air Quality Strategy (AQS) and presents the latest objectives for NO_2. In addition, it discusses when implementation of an AQMA is required.

Chapter 3 contains details of the information used to conduct the stage 3 review and assessment for Suffolk Coastal District Council.

Chapter 4 describes the results of the assessment and discusses whether the nitrogen dioxide objective will be exceeded in SCDC in 2005. The results of the analysis are displayed in tabular form and as contour plots.

2 The updated Air Quality Strategy

2.1 THE NEED FOR AN AIR QUALITY STRATEGY

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

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

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

Table 2.1 Major elements of the Environment Act 1995

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

2.2 OVERVIEW OF THE PRINCIPLES AND MAIN ELEMENTS OF THE NATIONAL AIR QUALITY STRATEGY

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

- The use of a health effects based approach using national air quality standards and objectives.
- The use of policies by which the objectives can be achieved and which include the input of important 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 AQS will provide a framework for the improvement of air quality that is both clear and workable. In order to achieve this, the Strategy is based on several principles which include:

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

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

2.2.1 National Air Quality Standards

At the centre of the AQS is the use of national air quality standards to enable air quality to be measured and assessed. These also provide the means by which objectives and timescales for the achievement of objectives can be set. Most of the proposed standards have been based on the available information concerning the health effects resulting from different ambient concentrations of selected pollutants and are the consensus view of medical experts on the Expert Panel on Air Quality Standards (EPAQS). These standards and associated specific objectives to be achieved between 2003 and 2008 are shown in Table 2.2. The table shows the standards in ppb and $\mu g\ m^{-3}$ with the number of exceedences that are permitted (where applicable) and the equivalent percentile.

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

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

Pollutant	Concentration limits ($\mu g\ m^{-3}$)	Concentration limits (ppb)	Averaging period	Objective [number of permitted exceedences a year and equivalent percentile] ($\mu g\ m^{-3}$)	Objective 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.

2.2.2 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 which already exist provide a good basis for progress towards the air quality objectives set for 2003 to 2008. For example, the

Environmental Protection Act 1990 allows for the monitoring and control of emissions from industrial processes and various EC Directives have ensured that road transport emission and fuel standards are in place. These policies are being developed to include more stringent controls. Developments in the UK include the announcement by the Environment Agency in January 2000 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 Borough. 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.

2.2.3 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 guidance.

The primary objective of undertaking a review of air quality is to identify any areas that are unlikely to meet national air quality objectives and ensure that air quality is considered in local authority decision making processes. The complexity and detail required in a review depends on the risk of failing to achieve air quality objectives and it has been proposed 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.	• Use of validated modelling and quality-assured monitoring methods to determine current and future pollutant concentrations.	
	• Identify the geographical boundary of any exceedences, and description of those areas, if any, proposed to be designated as an AQMA.	• 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 where the public would not be expected to have regular access.
		• Kerbside sites (e.g. pavements of busy shopping streets).	
		• Those parts of car parks and railway stations etc. which are not fully enclosed.	
		• Any outdoor locations to which the public might reasonably expected to have access.	
15 minute mean	• Sulphur dioxide	• All locations where members of the public might reasonably be exposed for a period of 15 minutes or longer.	

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

Key Points

- The Environment Act 1995 has required the development of a National Air Quality Strategy for the control of air quality.
- A central element in the Strategy is the use of air quality standards and associated objectives based on human health effects that have been included in the Air Quality Regulations.
- The Strategy uses a local air quality management approach in addition to existing national and international legislation. It promotes an integrated approach to air quality control by the various actors and agencies involved.
- Air quality objectives, with the exception of ozone, are to be achieved by specified dates up to the end of 2005 (2008 for one lead objective).
- A number of air quality reviews are required in order to assess compliance with air quality objectives. The number of reviews necessary depends on the likelihood of achieving the objectives.

3 Information used to support this assessment

This Chapter presents the information used to support this review and assessment.

3.1 MAPS

Suffolk Coastal District Council provided detailed maps of the road junctions identified in the Stage 3 Review and Assessment. The GIS base - map of the area was also provided which enabled accurate road widths to be determined.

3.2 ROAD TRAFFIC DATA

This section summarises road traffic data used in this assessment. Further details can be found in Appendix 1.

3.2.1 Average flow, hourly fluctuations in flow, speed and fraction of HGV's.

Traffic count data were provided by SCDC for the roads at the Melton and Woodbridge junctions. In addition, traffic data was provided by Babergh district council (BDC) for Cross Street in Sudbury so that the model bias could be calculated. The traffic flows around the Melton and Woodbridge junctions and Cross Street in Babergh are similar and so therefore it is appropriate to apply the model bias estimated at the Cross Street site to the two areas of interest in SCDC. To determine the hourly fluctuations in traffic flow the DETR's diurnal traffic variation default figures were used (DETR 1999b).

BDC and SCDC supplied average speeds at the junctions and the number of queuing vehicles at different hours of the day.

Data on the percentage of HGVs in the traffic was available from traffic counts for the roads of concern.

3.2.2 Bus stops

Detailed information on the location of bus stops at the Melton and Woodbridge junctions and the number of buses travelling through both junctions was provided by SCDC. Only bus stops within 100 metres of the junctions were modelled in the assessment as stops further away than this will have little influence on concentrations at the junctions. First Eastern Counties Omnibus Limited which is the largest bus provider in the area provided a breakdown of their fleet by Euro standard. Data on the proportion of the bus fleet by Euro standard in 2005 was not available and so the predicted national UK bus fleet composition has been used in this assessment. It has been assumed that each school bus idles outside Melton County Primary School for 5 minutes.

3.2.3 Traffic Growth

As the modelling has been done for a base year of 1999 the traffic counts provided by SCDC in 2000 have been converted to 1999 figures using the DETR's TEMPRO traffic flow forecast database which provides regional traffic growth statistics. There are planned developments at Sutton Hoo and St. Audrey's in Melton. For the projected increase of traffic by 2005 taking into account the proposed developments, SCDC provided their own growth factors. Details of TEMPRO and the predicted flows at the two junctions in 2005 are given in Appendix 1.

3.3 METEOROLOGICAL DATA USED IN THE DISPERSION MODELLING

The nearest site for which meteorological data was available was Waddington. Hourly data was obtained for 1999 from the Meteorological Office for input into the ADMS dispersion model.

3.4 AMBIENT MONITORING

3.4.1 Nitrogen dioxide

Nitrogen dioxide concentrations were monitored:

- By diffusion tubes at eight locations relevant to this study. Monitoring began in Woodbridge in 1997 and in Melton in December 1999. To provide a reasonable estimate of the annual mean concentration, concentrations for at least 6 months of the year are needed. Therefore, annual means have not been presented where there are less than 6 months of data.

- By continuous monitoring from the 26th October 2000 to 31st January 2001 inclusively on Cross Street in Sudbury in the neighbouring authority of Babergh.

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

4 Review and Assessment for Nitrogen Dioxide

4.1 INTRODUCTION

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

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

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

4.2 LATEST STANDARDS AND OBJECTIVES FOR NITROGEN DIOXIDE

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

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

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

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

The National Air Quality Strategy was reviewed in 1999 (DETR, 1999). The Government proposed that the annual objective of 40 $\mu g\ m^{-3}$ be retained as a provisional objective and that the original hourly average be replaced with the AQDD objective. The revised Air Quality Strategy for England, Scotland, Wales and Northern Ireland (DETR, 1999; 2000) 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.

4.3 THE NATIONAL PERSPECTIVE

The main source of NO_x in the United Kingdom is road transport, which, in 1996 accounted for approximately 47% of the emissions of 2.1 million tonnes per year as NO_2. Power generation contributed 22% and domestic sources 4% of the remainder. In urban areas, the proportion of local emissions due to road transport sources is larger.

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

4.4 SUMMARY OF INITIAL STAGE 3

A Stage 3 Review and Assessment for nitrogen dioxide was carried out for SCDC in June 2001. The Stage 3 Review considered the impact of nitrogen dioxide concentrations in the vicinity of major roads in the district. The Review recommended that a supplementary Stage 3 Review and Assessment be carried out for two road junctions:

- Melton road junction
- Woodbridge road junction

4.5 MONITORING DATA

Nitrogen dioxide concentrations were monitored at one site within the neighbouring authority of Babergh by continuous monitoring and by diffusion tubes at sites in SCDC.

4.5.1 Continuous monitoring

Location of the continuous monitor

Nitrogen dioxide was measured by a Monitor Labs NOx analyser (ML9841B) for the period 26^{th} October 2000 to 31^{st} January 2001 at a site (Grid Ref: 586808 241040) adjacent to Cross Road in Sudbury in the neighbouring authority of Babergh.

Measurement technique and QA/QC

Equipment installation, commissioning and local site operation (calibrations and maintenance) was undertaken by the ETI Group Ltd. Calibration of equipment using span gases of NO and NO2 were made on a monthly basis over the course of the three month programme. Data collection and data ratification was performed by Stanger Science and the Environment.

Summary statistics
Table 4.5 shows the measured concentrations throughout the three months of monitoring.

Table 4.5 Summary of continuous nitrogen dioxide ratified data from the 26th October 2000 to January 31st 2001 in Babergh.

	Concentration, μg m^{-3}	
	Nitrogen dioxide	Oxides of nitrogen
Average	40.3	81.9
Minimum hourly	2	3
Maximum hourly	126	441
Data capture	100%	100%

4.5.2 Diffusion tubes

Monthly average concentrations of nitrogen dioxide are measured by diffusion tubes at 8 locations throughout SCDC which are relevant to this study. The measurement data for 2000 is summarised in Table 4.5.2 below. Appendix 2 provides data for other years where available and a breakdown on a monthly basis. A map is also provided which shows the locations of the diffusion tubes exposed in SCDC.

Diffusion tubes can under or over-read and if possible should be referred to continuous results. This may be done in two ways: either by using results from a tube co-located with a continuous analyser or by using the results of the UK National Diffusion Tube Survey Field Intercomparison exercise. Since October 1998, Harwell Scientifics have analysed the diffusion tubes for SCDC. For the year 2000, the National Diffusion Tube Survey Field Intercomparison exercise reported a lab bias of +65.5%. This result was significantly different to the previous years results. Therefore this figure has not been used to correct the diffusion tube results for this year. Harwell Scientifics also analyse the diffusion tubes in the adjacent authority of Babergh. Three diffusion tubes were placed alongside the continuous monitor in Babergh during November 2000 until January 2001, so the bias calculated here has been applied to the SCDC diffusion tube results.

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

4.5.2.1 Co-located Bias

Three diffusion tubes have been co-located with the continuous automatic monitoring site in Babergh. The period average (uncorrected for analyst bias) for the period November 2000 – January 2001 inclusively was 54.8 μg m^{-3} which is 25% higher than the result from the continuous analyser (40.8 μg m^{-3}) for the same period. The diffusion tube results corrected for co-located bias are shown in Table 4.5.2 below.

4.5.2.2 Diffusion tube results

NO_2 levels for 2005 were predicted using values from the PSG. The diffusion tubes placed at roadside and kerbside locations were multiplied by 0.79/0.9 to give the predicted values for 2005. Those placed in urban background locations were multiplied by 0.74/0.97 to give the predicted values for 2005. The results are shown in Table 4.5.2 below.

Table 4.5.2 Nitrogen dioxide diffusion tube survey 2000 results corrected for co-located bias and predictions for 2005 (μg/m^3).

Location	E	N	Annual average 2000 uncorrected for bias	Annual average 2000 corrected for bias	Predicted conc. In 2005 (μg/m^3)
Melton 1 (K)	628149	250402	50	37	32
Melton 2 (B)	627932	250803	21	15	11
Woodbridge 1b (K)	627597	249262	52	39	34
Woodbridge 2 (I)	627592	249308	31	23	20
Woodbridge 3 (B)	627001	248493	23	17	13
Woodbridge 4 (B)	626373	249852	25	18	14

Note: K = kerbside, I = intermediate B = background

Monitoring was started at a third kerbside site in Melton in 2001. The period average over 5 months was 50 μg/m^3 uncorrected for bias.

The above table shows that if the diffusion tube results are corrected for co-located bias no locations are predicted to exceed the nitrogen dioxide annual mean standard of 40 μg/m^3 in 2005.

In the modelling the contribution from urban background sources was calculated by using the NETCEN 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 1999 National Atmospheric Emission Inventory. The model estimated a background NO_2 concentration of 19 μg/m^3. This figure compares well with the diffusion tubes corrected for co-located bias.

4.5.3 Comparison of measured concentrations with objectives

Continuous monitoring data was obtained from the Babergh site from 26th October 2000 to January 31st 2001 inclusively. Because the modelling in this study was carried out for 1999, a comparison of the monitoring data in 2000/2001 with the 1999 annual average was made. This has been achieved by examining data recorded at other continuous monitoring sites around the UK, which were operating for a full year. Continuous monitoring data is carried out at 85 sites in DEFRAs UK automatic monitoring network. Figure 4.5.3 shows the 26th October 2000 to 31st January 2001 average concentrations against average concentrations for 1999 at a number of automatic monitoring sites in the South of England plus the Sudbury site in Babergh. The period average concentration (26th October 2000 to 31st January 2001) corresponds to the sampling time when the Babergh sampler was operating.

The data shows that there is a fair relationship between the annual averages and the period averages (n = 15, d.f. = 14**)**. The period average NO_2 concentration (26th October 2000 to

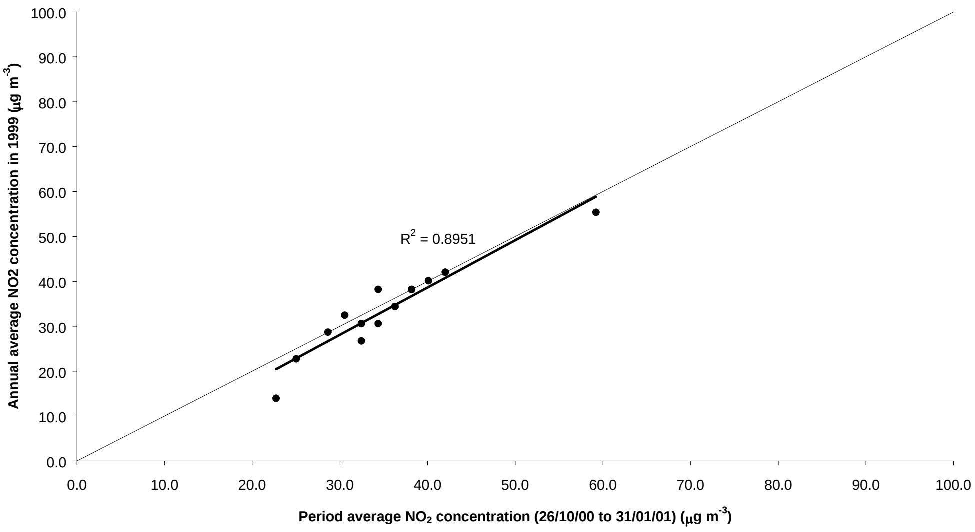
31st January 2001) was on average 4.8 % higher than the 1999 annual average concentration. The relationship between the annual average NO_2 and the period average seems little affected by the distance from the road at which the measurements were made (kerbside to suburban) or size of town and geographical location in the UK. The best-fit line between all the annual and period averages is shown on the chart. This best-fit line has been derived from linear regression analysis.

The period average for 26th October 2000 to 31st January 2001 at the Babergh site was 40.3 μgm^{-3}. Based on the relationship between the annual average and the period average derived from the DEFRA automatic monitoring data, we predict that the annual average concentration at the Babergh site in 1999 (see Table 4.6) was 38.4 $\mu g\ m^{-3}$.

The standard deviation of the difference between the period average and the 1999 annual average was 12% on the basis of data from 15 sites. The standard deviation is a measure of the scatter of the points shown in Figure 4.5.3 about the mean line through the points.

Corrected diffusion tube measurements (Tables 4.5.2) show that the annual average objective of 40 $\mu g/m^3$ was unlikely to have been exceeded at the six sites in 2000 for which there was data available. When the results are corrected for co-located bias and projected forward to 2005 it is concluded that it is likely that these six sites will not exceed the objective in 2005.

Figure 4.5.3: Relationship between the annual average NO_2 concentration in 1999 at a range of sites and the period average NO_2 concentration (26/10/00 to 31/01/01) at the same measurement sites



4.6 DETAILED MODELLING

The dispersion model ADMS-3.1 was used to predict nitrogen dioxide concentrations at receptor areas close to the major roads of concern. ADMS-3.1 is a PC-based model that includes an up-to-date representation of the atmospheric processes that contribute to pollutant dispersion. The locations at which detailed modelling was carried out are as follows:

- Melton road junction
- Woodbridge road junction

Predictions of traffic flow in 2005 were provided by SCDC.

4.6.1 Meteorological data

Hourly sequential meteorological data for 1999 for Waddington near Newark, was obtained from the Meteorological Office who recommended this as the nearest suitable site. The meteorological data provided information on wind speed and direction and the extent of cloud cover for each hour of 1999. Waddington is the nearest meteorological station that provides data suitable for dispersion modelling.

The surface roughness of the urban and suburban terrain in Melton and Woodbridge was estimated to be approximately 1.0 m. This is greater than the more open terrain of Waddington, estimated to be approximately 0.2 m. The ADMS meteorological pre-processor was used to compensate for the difference in surface roughness between the two sites.

4.6.2 Overview of the modelling approach

Two models have been used to predict the NO_2 levels in the SCDC region, both specially developed for Stage 3 Review and Assessment by NETCEN. Both models have made use of ADMS-3 to provide dispersion kernels over a grid.

- The contribution from urban background sources was calculated by using the NETCEN 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 1999 National Atmospheric Emission Inventory (projected forward to 2005 using factors in the PSG).
- The contribution from traffic was calculated by using the *DISP model*. This model is a tool for calculating atmospheric dispersion using a point-source kernel.

Further detailed information about the LADS and the DISP model and the validation of these models are given in Appendix 3.

Meteorological data for the Waddington site in 1999 was used to represent meteorological conditions in SCDC. The data set included wind speed and direction and cloud cover for each hour of the year. Surface roughness is used in dispersion modelling to represent the roughness of the ground. A surface roughness of 1 metre was assumed to be representative of the area.

4.6.3 Traffic modelling in detail.

In this study, the concentration of NO_2 at the monitoring site on Cross Street in the neighbouring authority of Babergh and concentrations of NO_2 at receptors close the Melton and Woodbridge road junctions have been modelled. Busy road links connecting to the junctions were also included in the model to ensure that concentrations were not underestimated.

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

In addition, information was provided by SCDC on the location of bus stops, the composition of the fleet by Euro standard for the largest bus provider in the area and the number of buses passing through the junctions each day. Further information can be found in Appendix 1. Only bus stops within 100 metres of the junctions have been included in this assessment. In 2005 it has been assumed that the bus fleet in SCDC is representative of the predicted national UK bus fleet composition in this year. It has been assumed that each school bus idles outside Melton County Primary School for 5 minutes.

4.6.4 Model bias

The monitoring site in the neighbouring authority of Babergh will be used as a reference site: e.g. model concentrations will be adjusted by subtracting the difference between the modelled concentration at the site and the measured value from the modelled values at other locations. The purpose of this adjustment was to ensure that the modelled concentrations equalled the measured values at the monitoring site. Table 4.6 shows the main elements of the calculation.

Table 4.6 Main elements of the reference calculation for NO_2

Element	NO_x concentration ($\mu g\ m^{-3}$)	Factor used	NO_2 concentration (1dp) ($\mu g\ m^{-3}$)	Source of factor or Model used
Measured concentration				
Measured concentration at the Babergh site (2000/2001)			40.3	
Predicted measured concentration at the Babergh Site (1999)		Comparison with other UK automatic monitoring sites	38.4	Year correction factor
Modelled concentrations at the Babergh site				
Total modelled background concentration at the Babergh site			19	LADS
Modelled contribution of traffic emissions at the Babergh site	28.2			ADMS & DISP
		x 0.162	4.6	Factor from work of Stedman *et al.*
Modelled contribution of traffic emissions contributing to background concentrations at the Babergh site	6.9			LADS
		from PSG	2.4	NO_x to NO_2 at backgrour sites
Model bias correction				
Total modelled background concentration at the Babergh site.			19	LADS
Less local road contribution			2.4	LADS
Equals …			16.6	
Plus modelled contribution of traffic emissions at the Babergh site			4.6	ADMS & DISP
Equals …			**21.2**	
Measured concentration at the Babergh site (includes background & roads)			**38.4**	Monitoring data
Difference (bias in the model)		(38.4 – 21.2) =	**17.2**	Model under predicting at the Babergh site

Notes :

- ***Concentrations have been referenced to 1999 as the ADMS modelling was carried out for this year.***
- ***Totals may not necessarily agree with the sum of their components due to rounding.***
- ***The work of Stedman* et al*. has presented a factor which gives the incremental increase in NO_2 for an incremental increase in NO_x near roads.***
- ***LADS was the NETCEN urban background model specifically developed for Stage 3 Review and Assessment work. This model allowed contributions of the urban background emissions to be calculated.***

The model was found to be under reading by 17.2 μg/m^3. Although this is a large bias it was felt to be appropriate as when this bias was applied at the Melton and Woodbridge road junctions the resulting concentrations were similar (but tended to slightly overestimate) to that denoted by the diffusion tube results when corrected for co-located bias. Using a model bias of -17.2 μg/m3 is therefore a conservative approach.

For the prediction of concentrations in 2005, the calculated 1999 background concentration was multiplied by a factor of 0.82, based on advice in Pollutant Specific Guidance.

4.6.5 Model validation

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 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.

Table 4.6.4: The confidence limits.

Description	Chance of exceeding objective	Modelled annual average concentrations, $\mu g/m^3$	
		Annual average objective	Hourly average objective
Very unlikely	Less than 5%	<28	<39
Unlikely	5-20%	28-34	39-52
Possible	20-50%	34-40	52-67
Probable	50-80%	40-46	67-81
Likely	80-95%	46-52	81-94
Very likely	More than 95%	>52	>94

The confidence limits for the ‘probable’ and ‘likely’ annual average and hourly objective concentrations have been set equal to those for ‘possible’ and ‘unlikely’, respectively. In reality, the intervals of concentration increase as the probability of exceeding the annual and hourly objective increases from ‘unlikely’ to ‘likely’. The advantage to setting symmetrical concentration intervals is that the concentration contours on the maps become simpler to interpret. This is a mildly conservative approach to assessing the likelihood of 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 99.8th percentile concentration of NO_2 from the annual concentration: the 99.8th percentile is three times the annual mean at kerbside/roadside locations. Therefore, plots of the modelled annual mean NO_2 concentrations can be used to show 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. Pollutant emissions are expected to decrease generally due to national measures and this can be seen in the generally lower concentrations in the results of the modelling for 2005 compared with 1999.

4.6.6 Limitations of the modelling and artefacts on the plots of concentrations

In the centre of the roads in some plots, the concentration contours take on the appearance of circles. This feature would not be observed in reality, and is an artefact of the modelling process. This limitation has little effect on the accuracy of the modelled concentrations beyond the kerbside of the road.

4.7 RESULTS OF MODELLING

4.7.1 Melton Road Junction

Figure 4.7.1 shows modelled nitrogen dioxide concentrations around the Melton road junction in SCDC for 1999. The model predicts that the annual average objective for nitrogen dioxide is currently exceeded outside number 4 on The Street.

Figure 4.7.1a shows modelled annual average concentrations for 2005. The model predicts that the annual average concentration will not exceed the standard of 40 $\mu g\ m^{-3}$ at houses near the junction.

Table 4.7.1 Probability of exceeding the objectives for nitrogen dioxide in 2005 around the Melton Road junction.

Location	**Probability of exceedence, P**	
	Annual average objective	**99.8th %ile hourly average**
Melton Hall,A1152 Woods Lane	5%<P<20% Unlikely	P< 5% V. Unlikely
Melton County Primary School	5%<P<20% Unlikely	P< 5% V. Unlikely
4, The Street	5%<P<20% Unlikely	P< 5% V. Unlikely
1, The Street	5%<P<20% Unlikely	P< 5% V. Unlikely

4.7.2 Woodbridge Road junction

Figure 4.7.2 shows modelled nitrogen dioxide concentrations around the Woodbridge road junction in SCDC for 1999. The model predicts that the annual average objective for nitrogen dioxide is currently exceeded outside Suffolk Place on Lime Kiln Road.

Figure 4.7.2a shows modelled annual average concentrations for 2005. The model predicts that the annual average concentration will not exceed the standard of 40 $\mu g\ m^{-3}$ at houses nearest the junction.

Table 4.7.2 below shows the risk of exceeding the objectives for nitrogen dioxide at the nearest houses to the area assessed. It is “unlikely” that the annual objective will be exceeded.

Table 4.7.2 Probability of exceeding the objectives for nitrogen dioxide in 2005 around the Woodbridge road junction.

Location	**Probability of exceedence, P**	
	Annual average objective	**99.8th %ile hourly average**
Suffolk Pl, Lime kiln Rd.	5%<P<20% Unlikely	P< 5% V. Unlikely
The pub on Throughfare	5%<P<20% Unlikely	P< 5% V. Unlikely
100 Melton Hill	5%<P<20% Unlikely	P< 5% V. Unlikely
Surgery, St. John's St	5%<P<20% Unlikely	P< 5% V. Unlikely

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

Detailed modelling using ADMS version 3 has been undertaken at locations where the Stage 3 results indicated that there will be exceedances of the objective in 2005. The modelling results showed that it was unlikely (with probability between 5% and 20%) that an exceedence of the annual objective could occur at houses closest to the:

- Melton Road junction
- Woodbridge Road junction

At all locations the hourly objective is very unlikely to be exceeded.

In support of this finding, the neighbouring authority of Babergh (from which the continuous monitoring has been utilised in this assessment) is not predicted to exceed the standard for nitrogen dioxide in 2005. The traffic flows on Cross Street in Babergh are greater than that experienced on any of the roads at either the Melton or Woodbridge road junctions. In addition, the model was found to be under reading by 17.2 $\mu g/m^3$. Although this is a large bias it was felt to be appropriate as when this bias was applied at the Melton and Woodbridge road junctions the resulting concentrations were similar (but tended to slightly overestimate) to that denoted by the diffusion tube results when corrected for co-located bias. Even when this model bias is used no exceedences are predicted in SCDC in 2005 for nitrogen dioxide.

4.9 RECOMMENDATIONS

The model predicts that it is **unlikely** that an exceedence of the annual average objective for NO_2 will occur at ***buildings close to the Melton and Woodbridge road junctions***.

The Government has decided that the objective should apply in the non-occupational outdoor locations where a person might reasonably be expected to be exposed (e.g. in the vicinity of housing, schools or hospitals etc) over the averaging time of the objective. Consideration should therefore be given to possible patterns of personal exposure and the potential for non-occupational exposure in assessing the risk to human health in using these results to declare an Air Quality Management Area.

Predicted concentrations of nitrogen dioxide are presented as “contour” plots extending over the areas of concern. An estimate of the likelihood of meeting the air quality objective has been assigned to each ‘contour’, based on statistical analysis of model validation studies and of monitoring data. The contour plots allow an assessment of the likelihood of meeting the air quality objectives to be made at each location. Recommendation is given to consider declaration of air quality management area in locations where there is more than a 50 % chance of exceeding the objective.

The results indicate that it is likely that the air quality objectives for nitrogen dioxide will be met at all the locations assessed in SCDC where members of the public might be exposed for the relevant periods**.**
Therefore it is suggested that Suffolk Coastal District Council do not consider declaring an air quality management area for nitrogen dioxide.

5 Other pollutants

The Stage 3 Review concluded that the Air Quality Regulations, 1997 objectives for other regulated pollutants were likely to be met. This conclusion is reviewed below for each of the pollutants.

5.1.1 Benzene

The main sources of benzene in the United Kingdom are petrol-engined vehicle exhaust, petrol refining, distribution and uncontrolled emissions from petrol station forecourts without vapour recovery systems. Measurements at UK national network monitoring sites are already below the 2003 objective, even close to heavily trafficked roads. The increasing numbers of vehicles equipped with three way catalysts will significantly reduce emissions of benzene in future years. Recently agreed additional reductions in vehicle emissions as part of the Auto-Oil programme are expected to further reduce emissions of benzene from vehicle exhausts, and proposals to control emissions from petrol station forecourts during vehicle refuelling are expected to lead to significant reductions in uncontrolled emissions. These existing and proposed measures are expected to deliver the revised air quality objective by the end of 2003, and no further measures are thought to be needed (DETR, 2000).

Only those authorities with major industrial processes in the near vicinity which handle, store or emit benzene are expected to be at risk of exceeding the objective for benzene. In the SCDC Stage 2 Review and assessment, it was reported that there were no major industrial processes which either handled, stored or emitted benzene, which had the potential, in conjunction with other sources, to result in elevated levels of benzene in relevant locations in the SCDC area. Therefore, it is likely that national policies will deliver the prescribed air quality objective for benzene by the end of 2005.

5.1.2 1,3 Butadiene

The main source of 1,3 butadiene in the United Kingdom is from motor vehicle exhausts. 1,3-butadiene is also an important industrial chemical and is handled in bulk at as mall number of industrial premises. Measurements at UK national network monitoring sites are already well below the 2003 objective at all urban background/centre and roadside locations. The increasing numbers of vehicles equipped with three way catalysts will significantly reduce emissions of 1,3-butadiene in future years. Recently agreed additional reductions in vehicle emissions as part of the Auto-Oil programme are expected to further reduce emissions of 1,3-butadiene from vehicle exhausts. These measures are expected to deliver the revised air quality objective by the end of 2003, and no further measures are thought to be needed (DETR, 1999).

Only those authorities with major industrial processes in the near vicinity which handle, store or emit 1,3-butadiene are expected to be at risk of exceeding the revised objective. There are no major industrial processes which either handle, store or emit 1,3-butadiene, which have the potential, in conjunction with other sources, to result in elevated levels of 1,3-butadiene in relevant locations in the SCDC area. Therefore, it is likely that national policies will deliver the prescribed air quality objective for 1,3 butadiene by the end of 2005.

5.1.3 Lead

The agreement reached between the European Parliament and the Environment Council on the Directive on the Quality of Petrol and Diesel Fuels (part of the Auto-Oil programme) has lead to the ban on the sale of leaded petrol in the United Kingdom with effect from 1 January 2000. Emissions of lead are now restricted to a variety of industrial applications, for example in the manufacture of batteries, pigments in paints and glazes, alloys, radiation-shielding, tank lining and piping. No sites were identified at Stage 2 as having the potential to emit lead in significant quantities and there are no new developments which would lead to lead emissions in SCDC. No further assessment was therefore considered necessary.

5.1.4 Carbon monoxide

The main source of carbon monoxide in the United Kingdom is currently road transport, in particular petrol-engined vehicles. The contribution from major roads to carbon monoxide concentrations was assessed in the Stage 2 Review: exceedence of the objective for 2005 was considered unlikely. Recently agreed reductions in vehicle emissions as part of the Auto-Oil programme are expected to deliver the revised air quality objective by the end of 2003, even at roadside locations, and no further measures are considered necessary (DETR, 1999).

The Stage 2 Review did not identify any significant industrial sources of carbon monoxide in the Borough or nearby.

5.1.5 PM_{10}

PM_{10} particles (the fraction of particulates in air of very small size (<10 µm)) are of major current concern, as they are small enough to penetrate deep into the lungs and so potentially pose significant health risks. 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). The major sources of PM_{10} are from road transport (24%), industrial sources (38%), power stations (16%) and from domestic and other low-power combustion (17%).

The initial Stage 3 Review and Assessment concluded that the objective will not be exceeded at any near road locations in SCDC by 2004. In addition there were no industrial sources in or near the borough with significant emissions of PM_{10}. It was therefore recommended that SCDC need not conduct a third stage review and assessment of PM_{10}.

5.1.6 Sulphur Dioxide

Sulphur dioxide is a corrosive acid gas which combines with water vapour in the atmosphere to produce acid rain. Both wet and dry deposition have been implicated in the damage and destruction of vegetation and in the degradation of soils, building materials and watercourses. SO_2 in ambient air is also associated with asthma and chronic bronchitis. The principal source of this gas is power stations burning fossil fuels which contain sulphur.

There are no significant industrial sources of sulphur dioxide in or near the SCDC and therefore it was recommended that there was no need to proceed beyond a Stage 3 for sulphur dioxide.

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Appendices

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Appendix 2 Diffusion tube and continuous monitoring results
Appendix 3 Description of models used in analysis

Appendix 1
Detailed traffic flow data

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Summary of AADTFs, %HGV, and bus stop information used in the assessment.

Traffic data used in the assessment

Babergh traffic flows

	AADTF (1999)	% HDV	speed (kph)
Cross Street, Sudbury	14359	6.6	32.2

Woodbridge traffic flows

	AADTF (2000)	AADTF (1999)	% HDV	AADTF (2005)	% HDV	Junction speed (kph)
St. John's Street (west)	4220	4121	5	4701	5	16
Lime Kiln Quay Rd (east)	10442	10197	5	11633	5	16
Melton Hill (north)	10421	10176	5	11609	5	16
Throughfare (south)	848	828	5	945	5	16

Melton traffic flows

	AADTF (2000)	AADTF (1999)	% HDV	AADTF (2005)	% HDV	Junction speed (kph)
A1152 Woods Lane (west)	9599	9374.023438	8.3	11413	8.3	24
Wilford Bridge Rd (east)	11389	11122.07031	8.3	13407	8.3	24
The Street (north)	5546	5416.015625	8.3	6897	8.3	24
Melton Rd (south)	9768	9539.0625	8.3	11601	8.3	24

DEFRA's TEMPRO model provides a figure of 1.024 to convert from 1999 AADTF to 2000 AADTF

Bus information

Main provider of buses - First Eastern Counties Omnibus Ltd
Proportion by Euro standard:

Pre Euro I	0.493
Euro I	0.188
Euro II	0.319

There is only one bus stop within 100 metres from either junction and that is Melton county primary school.
Grid Ref: 628188, 250376. 30 buses stop at the school a day.

In 2005, the following fleet by Euro standards have been used (based on NAEI projections)

Pre-1988	0.04
Pre-Euro I	0.06
Euro I (91/	0.09
Euro II	0.39
Euro III	0.43
Euro IV	0

Appendix 2
Monitoring Data

CONTENTS

Results of the diffusion tube and continuous monitoring of nitrogen dioxide concentrations in SCDC between 1997 and 2001.

Monitoring data summary:

Summary statistics for NOx and NO2 hourly means , Cross Street, Babergh (October 2000 to January 2001)
Units are micrograms per cubic metre

	NOx	NO2
Mean	81.9	40.3
19th highest hour	329	97.8
Minimum hourly	3	2
Maximum hourly	441	126
Data capture (%)	100	100

Annual mean nitrogen dioxide diffusion tube results (values in brackets show the number of months of monitoring data from which the annual mean is derived)

Tube Ref	Site	X	Y	1997	1998	1999	2000	2001
WBG1a	K	627606	249249	22.7 (9)	26.0 (10)	41.4 (4)	-	-
WBG1b	K	627596	249261	-	-	52.1 (6)	52.1 (11)	54.8 (5)
WBG2	I	627592	249307	15.9 (8)	24.3 (10)	31.5 (12)	30.6 (12)	-
WBG3	B	626997	248485	13.4 (8)	22.2 (10)	21.6 (12)	22.7 (11)	23.3 (5)
WBG4	B	626375	249849	13.6 (8)	20.8 (10)	25.0 (11)	24.6 (12)	28.7 (4)
MEL1	K	628150	250402	-	-	51.6 (1)	49.5 (12)	50.0 (5)
MEL2	B	627933	250803	-	-	-	20.6(12)	19.3 (5)
MEL3	K	628156	250405	-	-	-	-	49.7 (5)

Appendix 3
Descriptions of selected models

CONTENTS

Simple screening models	Design Manual for Roads and Bridges (DMRB)
More sophisticated dispersion models	ADMS V3.0
DISP	Model developed by NETCEN (A tool for calculating atmospheric dispersion using a point source kernal)
Local Area Dispersion System (LADS) model	Model developed by NETCEN (A model to predict background concentrations of pollutants)

Simple screening models

Design Manual for Roads and Bridges (DMRB) - This screening method was formulated by the former Department of Transport. The method gives a preliminary indication of air quality near roads, and is more suited to rural motorways and trunk roads than city centre traffic conditions. It is a simple procedure based on tables and nomograms; originally published in August 1994, a revision has been produced in 1999, which is more applicable to urban road situations. The DMRB method requires information on vehicle flow, HGV mix, vehicle speed and receptor-road distances. It contains a useful database of vehicular emission factors for future years.

In the revision of the DMRB method the following pollutants can be estimated:

- the maximum 8-hour mean CO concentration;
- the 98th percentile and the maximum of hourly mean NO2 concentrations;
- the annual average benzene and annual average 1,3 butadiene concentration;
- the annual mean and the fourth highest daily mean PM10 concentrations.

The method adopts the annual mean concentration as the base statistic. Background pollutant levels are included explicitly in the calculations by adding an amount to the annual mean traffic contribution using the Air Quality Archive (paragraph 6.09) or default values. Surrogate statistics are used to convert annual means to National Air Quality Strategy statistics. Details of the road layout cannot be specified.

More sophisticated 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 co-efficients are included and calculations of percentile concentrations are possible.

DISP A Tool for Calculating Atmospheric Dispersion

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 coordinates, 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, bracketting 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

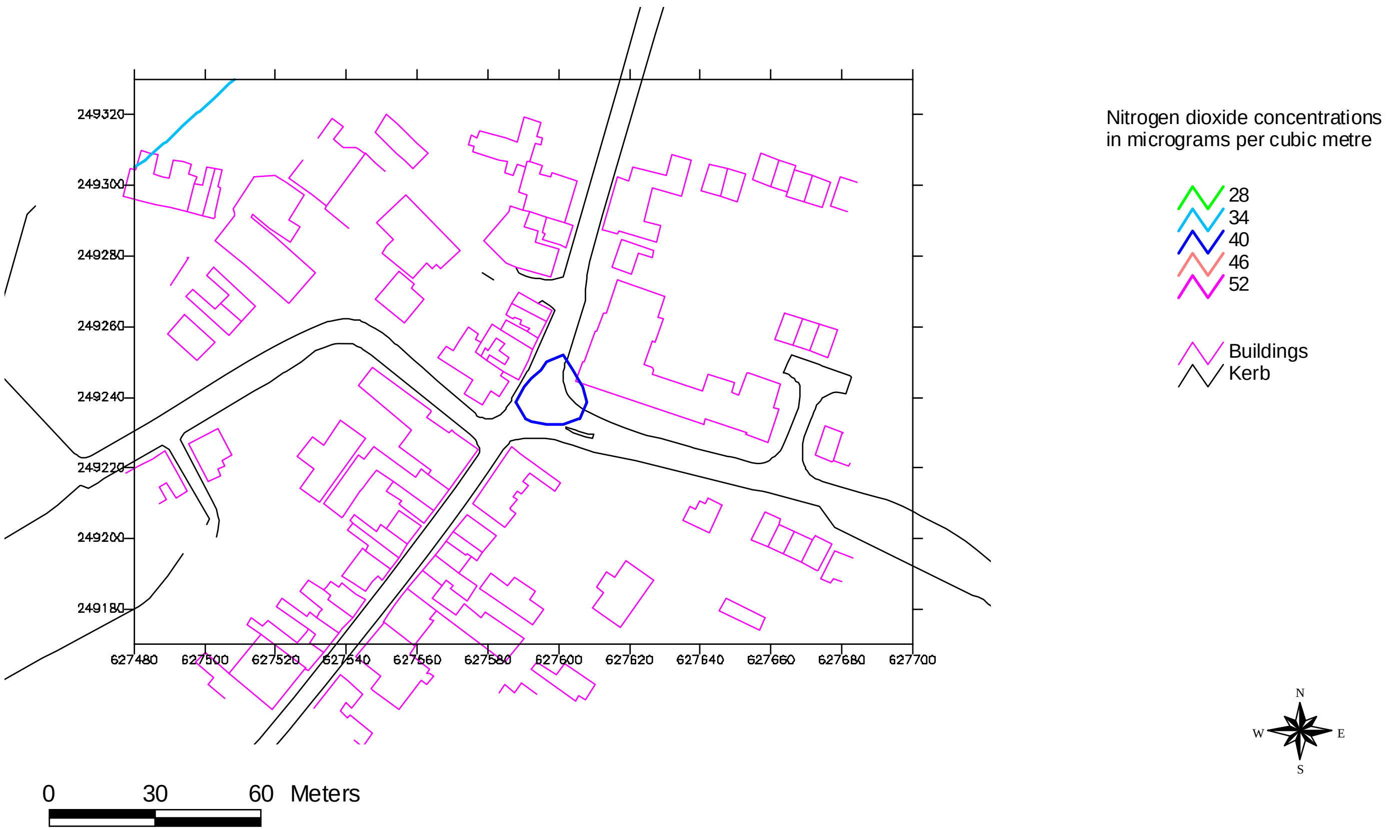
Background concentrations of oxides of nitrogen were calculated on a 1 km x 1 km grid using results from the dispersion model ADMS 3. The estimates of emissions of oxides of nitrogen for each 1 km x 1 km area grid square were obtained from the 1998 National Atmospheric Emission Inventory disaggregated 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 from the Ringway site was used.

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.

Predicted nitrogen dioxide concentrations in Melton in 1999.

Predicted nitrogen dioxide concentrations in Melton in 2005.

Predicted nitrogen dioxide concentrations in Woodbridge in 1999.



Predicted nitrogen dioxide concentrations in Woodbridge in 2005.