Report

Air Quality Review and Assessment - Detailed

A Report produced for Scottish Borders Council

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Executive Summary

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

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

Following the outcome of their updating and screening report of November 2003, Scottish Borders Council have commissioned **netcen** to undertake a Detailed Assessment for nitrogen dioxide at two locations in the Council's area:

Nitrogen Dioxide

In this assessment modelling of NO_2 concentrations has been undertaken using the ADMS v3.2 and LADS-URBAN kernel models and the most recent set of emission factors for road vehicles. The model results have been adjusted in the light of automatic monitoring results to take account of model bias.

It is predicted that the UK annual average objective of 40 $\mu g\ m^{-3}$ for nitrogen dioxide in 2005 will not be exceeded at any relevant receptor in the areas studied. At all locations it is at most "possible" that the annual objective will be exceeded.

It is predicted that the UK hourly objective for nitrogen dioxide in 2005 will not be exceeded at any relevant receptor in the areas studied. At most it is "unlikely" that the annual objective will be exceeded at any location.

Furthermore, it is predicted that the annual mean and hourly EU Limit Values for nitrogen dioxide in 2010 will not be exceeded at any relevant receptor in the areas studied. At most it is "unlikely" that the annual limit value will be exceeded at any location, and "very unlikely" that the hourly limit value will be exceeded at any location.

Maps reproduced within this document

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[1] Refers to standards recommended by the Expert Panel on Air Quality Standards. Recommended standards are set purely with regard to scientific and medical evidence on the effects of the particular pollutants on health, at levels at which risks to public health, including vulnerable groups, are very small or regarded as negligible.

[2] Refers to objectives in the Strategy for each of the eight pollutants. The objectives provide policy targets by outlining what should be achieved in the light of the air quality standards and other relevant factors and are expressed as a given ambient concentration to be achieved within a given timescale.

Acronyms and definitions

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

Contents

1 Introduction

1.1 PURPOSE OF THE STUDY

Following the outcome of their updating and screening report of November 2003, Scottish Borders Council have commissioned **netcen** to undertake a Detailed Assessment for nitrogen dioxide at two locations in the Council's area:

- A7 Albert Place Galashiels; and
- A7 Galashiels High Street

The risk of an exceedance of the 2005 UK objective for annual mean NO_2 was predicted in the Updating and Screening Report at these two locations.

1.2 GENERAL APPROACH TAKEN

The approach taken in this study was to:

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

1.3 VERSION OF THE POLLUTANT SPECIFIC GUIDANCE USED IN THIS ASSESSMENT

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

1.4 NUMBERING OF FIGURES AND TABLES

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

1.5 UNITS OF CONCENTRATION

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

1.6 STRUCTURE OF THE REPORT

This document is a detailed Air Quality review for Scottish Borders 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 developments in the UK's Air Quality Strategy (AQS). In addition, it discusses when implementation of an AQMA is required.

Chapter 3 contains details of the information used to conduct the Detailed Assessment for Scottish Borders Council.

Chapter 4 introduces the latest standards and objectives for nitrogen dioxide and summarises the monitoring of NO_2 that has taken place in Scottish Borders in the areas of concern.

Chapter 5 describes the results of the modelling assessment and discusses whether the nitrogen dioxide objectives are considered likely to be exceeded in Scottish Borders in 2005 and 2010. The results of the analysis are displayed in tabular form and as contour plots. It also presents the recommendations from the assessment.

1.7 GIS DATA USED

Scottish Borders Council provided the Ordnance Survey landline data for use in this project.

1.8 EXPLANATION OF THE MODELLING OUTPUT

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

2 The updated Air Quality Strategy

2.1 THE NEED FOR AN AIR QUALITY STRATEGY

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

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

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

Table 2.1 Major elements of the Environment Act 1995

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

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

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

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

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

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

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

2.2.1 National Air Quality Standards

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

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

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

Pollutant	Air Quality Objective		Date to be achieved by
	Concentration	Measured as	
Benzene All authorities	16.25 μg/m^3	running annual mean	31.12.2003
Authorities in England and Wales only	5.00 μg/m^3	annual mean	31.12.2010
Authorities in Scotland and Northern Ireland only[a]	3.25 μg/m^3	running annual mean	31.12.2010
1,3 Butadiene	2.25 μg/m^3	running annual mean	31.12.2003
Carbon monoxide Authorities in England, Wales and Northern Ireland only[a]	10.0 mg/m^3	maximum daily running 8-hour mean	31.12.2003
Authorities in Scotland only	10.0 mg/m^3	running 8-hour mean	31.12.2003
Lead	0.5 μg/m^3 0.25 μg/m^3	annual mean annual mean	31.12.2004 31.12.2008
Nitrogen dioxide[b]	200 μg/m^3 not to be exceeded more than 18 times a year 40 μg/m^3	1 hour mean annual mean	31.12.2005 31.12.2005
Particles (PM_{10}) (gravimetric)[c] All authorities	50 μg/m^3 not to be exceeded more than 35 times a year 40 μg/m^3	24 hour mean annual mean	31.12.2004 31.12.2004
Authorities in Scotland only[d]	50 μg/m^3 not to be exceeded more than 7 times a year 18 μg/m^3	24 hour mean annual mean	31.12.2010 31.12.2010
Sulphur dioxide	350 μg/m^3 not to be exceeded more than 24 times a year 125 μg/m^3 not to be exceeded more than 3 times a year 266 μg/m^3 not to be exceeded more than 35 times a year	1 hour mean 24 hour mean 15 minute mean	31.12.2004 31.12.2004 31.12.2005

a. In Northern Ireland none of the objectives are currently in regulation. Air Quality (Northern Ireland) Regulations are scheduled for consultation early in 2003.
b. The objectives for nitrogen dioxide are provisional.
c. Measured using the European gravimetric transfer sampler or equivalent.
d. These 2010 Air Quality Objectives for PM_{10} apply in Scotland only, as set out in the Air Quality (Scotland) Amendment Regulations 2002.

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

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

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

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

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

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

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

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

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

For particulates (as PM_{10}) further new objectives have been introduced which are not in Regulations with regard to local authority air quality management.

- For all parts of the UK, except London and Scotland, a 24 hour mean of 50 $\mu g/m^3$ not to be exceeded more than 7 times a year and an annual mean of 20 $\mu g/m^3$, both to be achieved by the end of 2010;
- For London, a 24 hour mean of 50 $\mu g/m^3$ not to be exceeded more than 10 times a year and an annual mean of 23 $\mu g/m^3$, both to be achieved by the end of 2010;
- For London, an annual mean of 20 $\mu g/m^3$, to be achieved by the end of 2015;

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

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

Local air quality management provides a strategic role for local authorities in response to particular air quality problems experienced at a local level. This builds upon current air quality control responsibilities

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

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.

2.2.5 Timescales to achieve the objectives

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

2.3 AIR QUALITY REVIEWS

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

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

Table 2.3: The phased approach to review and assessment.

Level of assessment	Objective	Approach
Updating and screening assessment (USA)	To identify those matters that have changed since the last review and assessment, which might lead to a risk of the air quality objective being exceeded.	Use a check list to identify significant changes that require further consideration. Where such changes are identified, apply simple screening tools to decide whether there is sufficient risk of an exceedance of an objective to justify a detailed assessment
Detailed assessment	To provide an accurate assessment of the likelihood of an air quality objective being exceeded at locations with relevant exposure. This should be sufficiently detailed to allow the designation or amendment or any necessary AQMAs.	Use quality-assured monitoring and validated modelling methods to determine current and future pollutant concentrations in areas where there is a significant risk of exceeding an air quality objective.

2.4 LOCATIONS THAT THE REVIEW AND ASSESSMENT MUST CONCENTRATE ON

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

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

Averaging Period	Pollutants	Objectives *should* apply at …	Objectives should *not* generally apply at …
Annual mean	• 1,3 Butadiene • Benzene • Lead • Nitrogen dioxide • Particulate Matter (PM_{10})	• All background locations where members of the public might be regularly exposed.	• Building facades of offices or other places of work where members of the public do not have regular access.
		• Building facades of residential properties, schools, hospitals, libraries etc.	• Gardens of residential properties.
			• Kerbside sites (as opposed to locations at the building facade), or any other location where public exposure is expected to be short term
24 hour mean and 8-hour mean	• Carbon monoxide • Particulate Matter (PM_{10}) • Sulphur dioxide	• All locations where the annual mean objective would apply.	• Kerbside sites (as opposed to locations at the building facade), or any other location where public exposure is expected to be short term.
		• Gardens of residential properties.	

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

Averaging Period	Pollutants	Objectives should apply at …	Objectives should generally not apply at …
1 hour mean	• Nitrogen dioxide • Sulphur dioxide	• All locations where the annual mean and 24 and 8-hour mean objectives apply.	• Kerbside sites where the public would not be expected to have regular access.
		• Kerbside sites (e.g. pavements of busy shopping streets).	
		• Those parts of car parks and railway stations etc. which are not fully enclosed.	
		• Any outdoor locations to which the public might reasonably be expected to have access.	
15 minute mean	• Sulphur dioxide	• All locations where members of the public might reasonably be exposed for a period of 15 minutes or longer.	

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

Key Points

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

3 Information used to support this assessment

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

3.1 MAPS

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

3.2 ROAD TRAFFIC DATA

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

AADT traffic flow data and percentage HDV flows were provided by the Scottish Borders Council and the NAEI for the roads of concern, and used to estimate flows in 2005 and 2010. To determine the hourly fluctuations in traffic flow the (then) DETR's diurnal traffic variation default figures were used (DETR 1999b). In the absence of measured speed data from Scottish Borders Council, estimated speeds for the roads of concern were taken from the National Atmospheric Emissions Inventory (NAEI). No information was available regarding queuing and congestion at the locations of concern. Appendix 1 summarises the traffic flow data used.

3.2.2 Traffic Growth

Traffic flow data was used to estimate flows in 2005 and 2010 using traffic growth factors derived from the NRTF and the TEMPRO v4 model. TEMPRO provides regional traffic growth statistics. Details of the growth factors used in the assessment to predict traffic flows in Scottish Borders in 2005 and 2010 are given in Appendix 1.

3.3 METEOROLOGICAL DATA USED IN THE DISPERSION MODELLING

Hourly meteorological data for Eskdalemuir 2004 was used to undertake the modelling. This was the latest year for which adequate data capture rates (over 90%) were available.

3.4 AMBIENT MONITORING

3.4.1 Nitrogen dioxide

Nitrogen dioxide concentrations are monitored by diffusion tube at a number of locations throughout the Council's region, including near to the two locations of concern. Scottish Borders Council have also undertaken an automatic monitoring survey with triplicate co-located diffusion tubes at a -roadside location approximately 5m from the kerbside of A7 High Street Galashiels (Figure 3.1).

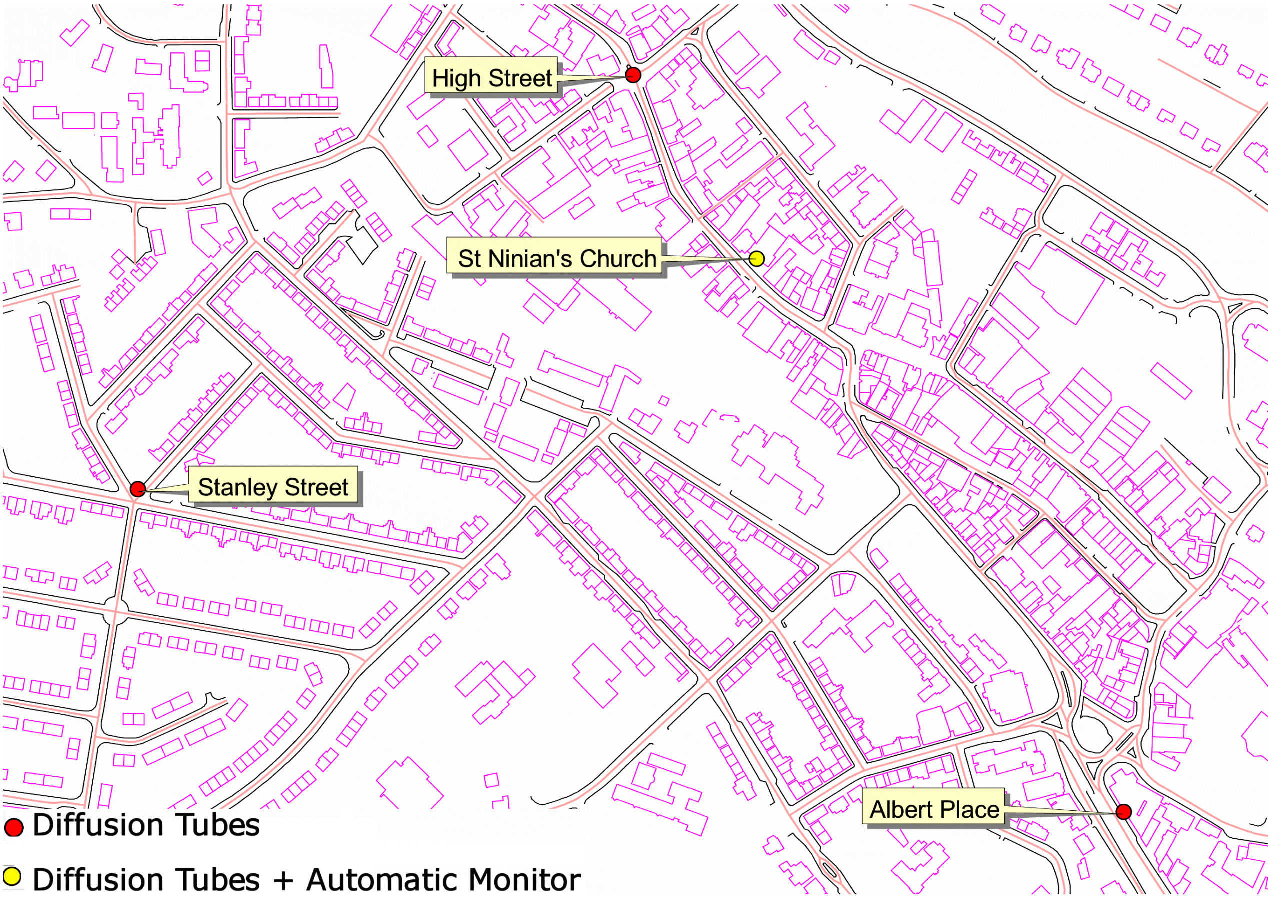

Figure 3.1 NO_2 Monitoring Locations in Galashiels

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

3.5 MODELLING METHODOLOGY

The air quality impact from road traffic emissions in this 'detailed' assessment was calculated using **netcen**'s proprietary urban model. There are two parts to this model:

- ***The Local Area Dispersion System (LADS) model.*** This model was used to calculate background concentrations of oxides of nitrogen on a 1 km x 1 km grid. Estimates of emissions of oxides of nitrogen for each 1 km x 1 km area grid square were obtained from the 2002 National Atmospheric Emission Inventory disaggregated inventory, projected forward to 2005 and 2010 using factors in the **defra** Technical Guidance.

- ***The LADS-URBAN model.*** This model is a tool for calculating atmospheric dispersion using a point-source kernel. Estimates of emissions from vehicles were calculated using the latest emission factors. The dispersion kernels for the LADS-URBAN model were derived from model runs using ADMS V3.2.

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

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

3.6 COMPUTER MODELLING

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

4 Nitrogen dioxide

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 exceedances 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) included the proposed changes. Modelling studies suggest that in general achieving the annual mean of 40 $\mu g\ m^{-3}$ is more demanding than achieving the hourly objective. If the annual mean is achieved, the modelling suggests the hourly objectives will also be achieved. Furthermore, monitoring studies suggest that the hourly objective is likely to be exceeded only in cases where the annual mean NO_2 concentration is of the order of 60 $\mu g/m^3$ or greater.

4.3 THE NATIONAL PERSPECTIVE

The main source of NO_x in the United Kingdom is road transport, which, in 2000 accounted for approximately 42% of emissions. Power generation contributed approximately 29% and domestic sources 5%. In urban areas, the proportion of local emissions due to road transport sources is larger (NAEI, 2000).

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

4.4 SUMMARY OF PREVIOUS AIR QUALITY REVIEW AND ASSESSMENT REPORTS

Following the outcome of their updating and screening report of June 2003, Scottish Borders Council have commissioned **netcen** to undertake a Detailed Assessment for nitrogen dioxide at two locations in the Council's area:

- A7 Albert Place Galashiels; and
- A7 Galashiels High Street

The risk of an exceedance of the 2005 UK objective for annual mean NO_2 was predicted in the Updating and Screening Report at these two locations.

4.5 MONITORING DATA

Nitrogen dioxide concentrations have been monitored at one automatic -roadside site close to the A7 Galashiels High Street with co-located diffusion tube monitoring, and by diffusion tubes at a number of other sites in the areas of interest.

4.5.1 Continuous monitoring

Nitrogen dioxide is measured by ozone chemiluminescence at a -roadside site located at St Ninian's Church High Street Galashiels (Figure 4.1).

Figure 4.1 Location of Automatic Monitor St Ninian's Church

Table 4.2 shows the measured concentrations in 2004. From the period mean (16/11/04 – 31/03/05) an estimate has been made of the likely annual average value for the whole of 2004, based on the relationship between the same period mean, and the 2004 annual mean at the surrounding AURN national network automatic monitoring sites: Dumfries Glasgow Centre, Glasgow City Chambers, and Edinburgh St Leonards. (Table 4.1).

Table 4.1 – Comparison of annual mean 2004 and period mean (16/11/04 – 31/03/05) at four AURN automatic monitoring stations surrounding Scottish Borders

AURN Site	NO_2 µg/m^3		Ratio Am/Pm (annual mean/period mean)
	Annual Mean 2004	Period Mean 2004	NO_2
Dumfries	37.0	39.7	0.93
Edinburgh St Leonards	25.0	30.0	0.83
Glasgow City Chambers	49.0	49.9	0.98
Glasgow Centre	36	40.5	0.89
Average			**0.91**

The results of the automatic monitoring in Scottish Borders indicate that at this roadside location, the UK objective for annual mean NO_2 in 2005 is unlikely to be exceeded, and that the hourly objective for NO_2 in 2005 is unlikely to be exceeded (Table 4.2 below). It is expected that NO_2 concentrations will have declined sufficiently by 2010 that the EU Limit Values for this year will be met by a clear margin.

Further evidence for roadside concentrations is provided by diffusion tube monitoring and modelling.

Table 4.2 Summary of continuous nitrogen dioxide monitoring data at High Street Galashiels (ratified data 16th November 2004 to 31st May 2005)

Statistic	**Concentration (µg/m^3)**			
	Period Mean 16/11/04 – 31/03/05	Estimate of Year Mean 2004	Estimate of Year Mean 2005	Estimate of Year Mean 2010
Annual Mean NO_x (as NO_2)	75	-	-	-
Annual Mean NO_2	35.8	32.5	31.7	26.1
Maximum Hour NO_2	130	-	-	-
Data Capture (%) NO_2	96.9	-	-	-

4.5.2 Diffusion tubes

Diffusion tubes at three locations in Galashiels measure monthly average concentrations of nitrogen dioxide at or near the areas of interest for this study. A further three tubes were co-located with the automatic monitor in St Ninian's Galashiels Church High Street.

For 2005, 3 months of data are available for the collocation study at Galashiels, from 16 January to 29 March 2005. The diffusion tubes were supplied and analysed by South Yorkshire Laboratory using the 50% v/v TEA in water method. Information regarding the typical bias of these tubes was sought for - 2004 from the database of co-location studies issued by UWE on behalf of DEFRA (UWE (2005)). The mean bias figure quoted on the UWE web site for 2004 was 0.77. However, comparison of the diffusion tube with the automatic data for the three month monitoring period indicates that the tubes under-read by approximately 21% (Table 4.3).

A bias adjustment factor of 1.27 has therefore been applied to the diffusion tube results for 2004. This figure is not in good agreement with the figures quoted by UWE for 2004. However, based on the advice supplied on the Air Quality Review and Assessment Website the local factor of 1.27 was considered to be the most appropriate factor to use.

The measurement data for 2004 is summarised in Table 4.4 below. Appendix 2 provides a breakdown of the raw monitoring data on a monthly basis and the OS grid co-ordinates of sites.

Table 4.3 Nitrogen dioxide results (concentrations in $\mu g/m^3$) for St Ninian's Church

Location	Type(1)	Diffusion Tube 6/1/2005- 29/3/2005	Automatic Monitor 6/1/2005- 29/3/2005	Bias
St Ninian's Church	R	32.6	41.5	1.27

Table 4.4 Nitrogen dioxide diffusion tube survey 2004 results (concentrations in $\mu g/m^3$) for Galashiels, corrected for bias with predictions for 2005 and 2010.

Location	Type(1)	2004 Unbiased	2004 Bias-adjusted(2)	2005 Estimate based on 2004	2010 Estimate based on 2004
Council Chambers, Albert Place, Galashiels	K	28.2	35.8	35.1	30.1
Stanley/Meigle Street, Galashiels	B	10.5	13.3	13.1	11.2
High Street Galashiels	K	**41.5**	**52.7**	**51.6**	**44.2**

Predicted exceedances of UK objective in **BOLD**

(1) K=Kerbside; R=Roadside B=Background
(2) Bias adjustment factor of 1.27

4.5.3 Comparison of monitoring data with AQ objectives

A7 Galashiels High Street

The results from the diffusion tube located in the High Street junction with Bridge Place indicates that the Annual Mean Objective for NO_2 may be exceeded in 2005 and 2010. It should be noted that the diffusion tube is located on a traffic island in the centre of the road junction.

A7 Albert Place

The results from the diffusion tube located in the Council Chambers, Albert Place indicate that it is unlikely that there will be exceedences of the Annual Mean Objective for NO_2 in 2005 or 2010.

5 Detailed modelling of NO_2

The locations at which detailed modelling was carried out are as follows:

- A7 Albert Place Galashiels; and
- A7 Galashiels High Street

5.1 METEOROLOGICAL DATA

Hourly sequential meteorological data for the nearest suitable meteorological station, Eskdalemuir was obtained for 2004. This was the latest year for which good data capture was available for this site. The meteorological data provided information on wind speed and direction and the extent of cloud cover for each hour of 2004.

5.2 TRAFFIC MODELLING SUMMARY

In this study, the concentrations of NO_2 at receptors close to the roads and junctions of interest have been modelled using ADMS-3.2 as a dispersion kernel model.

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

Where queuing of vehicles was reported, emissions from stationary vehicles exhausts were estimated on the basis that the engine power output and hence emissions were the same as those at a speed of 5 kph. Queuing vehicles were assumed to be 5 m apart.

5.3 SOURCES OF BACKGROUND (NON-TRAFFIC) EMISSIONS DATA

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

5.4 MODEL BIAS

Predictions of the NO_2 concentrations at the automatic monitoring site were used to predict the model bias, and thereby to bias adjust the model results. Table 5.1 shows the values used in the calculation. This procedure assumed that the modelling error was primarily in the calculation of the local background.

Table 5.1 Calculation of Bias Adjustment for NO_2.

Annual Average NO_2 (ug/m^3)				
Automatic Monitor Galashiels 2004	**Model Prediction at Automatic Monitoring Site in 2004**	**Bias Adjustment of Background for 2004**	**Bias Adjustment of Background for 2005***	**Bias Adjustment of Background for 2010***
32.5	21.8	10.7	10.5	8.8

5.5 MODEL VALIDATION

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

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

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

It would be recommended that Scottish Borders Council generally consider declaring an AQMA where the probability of exceedance in 2005 is greater than 50% ("Probable").

Table 5.2: Uncertainties in the modelled concentrations for NO_2.

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

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

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

5.5.1 Model Verification

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations. Overall agreement is variable with the model over predicting at background locations. However at roadside sites agreement is reasonable with the model predicting in the range +3 to -25%

Table 5.3 below further compares the estimates of concentrations in 2005 made using bias-adjusted diffusion tube data and the modelling results for that year.

Table 5.3 - Comparison of estimates of concentrations in 2005 from modelling and bias adjusted diffusion tube measurement

Site Name	Type	Nitrogen dioxide concentration, $\mu g\ m^{-3}$ Modelled 2005	Measured 2005	%Difference
Council Chambers, Albert Place,	R	36.2	35.1	3.1
Stanley/Meigle Street,	B	24.8	13.1	89.8
High Street, Galashiels	K	43.4	51.6	-15.9
St Ninian's Church	R	32.3	41.5*	-22.1

% Difference = ((modelled – measured)/measured) as percentage
Diffusion tube results reported are bias-adjusted results for 2004 projected forward to 2005
K=Kerbside
R=Roadside

*3 months data only

Comparison of the modelling and monitoring results suggest that the model is generally performing well at locations close to roadside, with the model predicting to within 25% of measured concentrations. The model does however appear to be over-predicting significantly at the background site at Stanley Street/ Meigle Street. Any differences may result from traffic conditions at roadside locations being different from those assumed in the modelling.

5.5.2 A7 High Street Galashiels

Figures 5.1-5.2 show modelled nitrogen dioxide concentrations in the area of the A7 Galashiels High Street in 2005 and 2010 and Tables 5.4 and 5.5 below summarise the risk of exceeding the objectives for nitrogen dioxide at the nearest houses to the roadside in 2005 and 2010.

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Figure 5.1 Predicted Concentrations of Nitrogen Dioxide in 2005 High Street Galashiels

Figure 5.2 Predicted Concentrations of Nitrogen Dioxide in 2010 High Street Galashiels

The model predicts that the UK annual average objective of 40 µg m^{-3} for nitrogen dioxide in 2005 will not be exceeded at any relevant receptor. At all relevant locations it is at most "possible" that the annual objective will be exceeded.

It is predicted that the UK hourly objective for nitrogen dioxide in 2005 will not be exceeded at any relevant receptor. At most it is "unlikely" that the annual objective will be exceeded at any relevant location

Table 5.4 Probability of exceeding the objectives for nitrogen dioxide in 2005 near the A7 High Street Galashiels.

Location	Probability of exceedance, P	
	Annual average objective	99.8th %ile hourly average
Relevant receptors closest to Road	20% <P< 50% Possible	5% < P <20% Unlikely

Furthermore, it is predicted that the annual mean and hourly EU Limit Values for nitrogen dioxide in 2010 will not be exceeded at any relevant receptor. At most it is "unlikely" that the annual limit value will be exceeded at any location, and "very unlikely" that the hourly limit value will be exceeded at any location.

Table 5.5 Probability of exceeding the objectives for nitrogen dioxide in 2010 near the A7 High Street Galashiels.

Location	Probability of exceedance, P	
	Annual average objective	99.8th %ile hourly average
Relevant receptors closest to Road	5% <P< 20% Unlikely	5% > P Very Unlikely

The model has predicted concentrations lower than those estimated for 2005 based on diffusion tube results for 2004 at the High Street/Bridge Place junction. The reason for the difference between the modelled and measured results is not clear but it may be that the bias adjustment factor applied to the tubes is overestimating concentrations. If the factor of 0.77 taken from the is UWE database is applied, the 2005 diffusion tube concentration at this location is estimated as 32 µg m^{-3} which is in good agreement with modelled result. There was also no information available on the likelihood of traffic queues and congestion on these roads. However it should be noted that the location of this tube in the middle of a traffic island is likely to record high concentrations not representative of concentrations at nearby receptors and it is recommended that the tube should therefore be re-located to the façade of the nearest relevant receptor.

5.5.3 A7 Albert Place

Figures 5.3-5.4 show modelled nitrogen dioxide concentrations in the area of Albert Place , Galashiels in 2005 and 2010 and Tables 5.6 and 5.7 below summarise the risk of exceeding the objectives for nitrogen dioxide at the nearest houses to the roadside in 2005 and 2010.

The model predicts that the UK annual average objective of 40 µg m^{-3} for nitrogen dioxide in 2005 will not be exceeded at any relevant receptor. At all relevant locations it is at most "possible" that the annual objective will be exceeded.

It is predicted that the UK hourly objective for nitrogen dioxide in 2005 will not be exceeded at any relevant receptor. At most it is "unlikely" that the annual objective will be exceeded at any relevant location.

Figure 5.3 Predicted Concentrations of Nitrogen Dioxide in 2005 Albert Place Galashiels

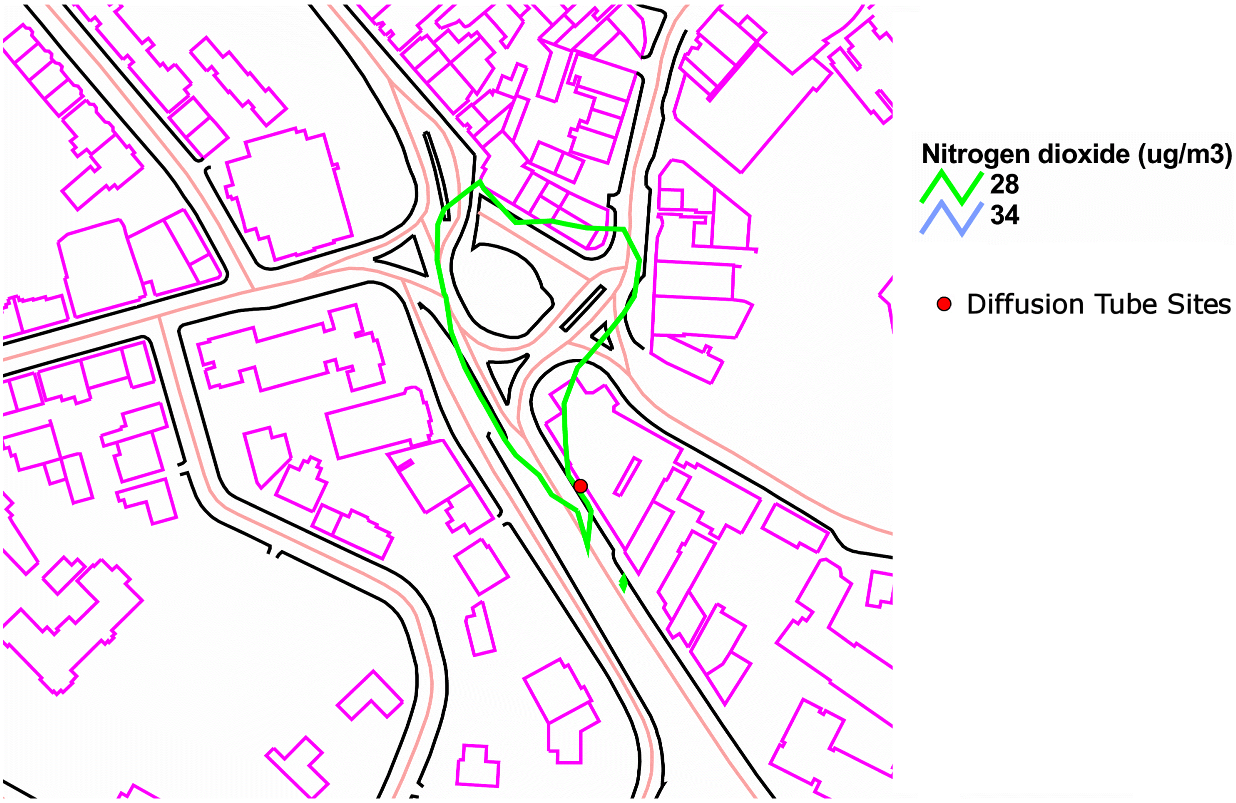

Figure 5.4 Predicted Concentrations of Nitrogen Dioxide in 2010 Albert Place Galashiels

The model predicts that the UK annual average objective of 40 μg m^{-3} for nitrogen dioxide in 2005 will not be exceeded at any relevant receptor. At all relevant locations it is at most "possible" that the annual objective will be exceeded.

It is predicted that the UK hourly objective for nitrogen dioxide in 2005 will not be exceeded at any relevant receptor. At most it is "unlikely" that the annual objective will be exceeded at any relevant location

Table 5.6 Probability of exceeding the objectives for nitrogen dioxide in 2005 near the Albert Place Galashiels.

Location	Probability of exceedance, P	
	Annual average objective	**99.8th %ile hourly average**
Relevant receptors closest to Road	20% <P< 50% Possible	5% < P <20% Unlikely

Furthermore, it is predicted that the annual mean and hourly EU Limit Values for nitrogen dioxide in 2010 will not be exceeded at any relevant receptor. At most it is "unlikely" that the annual limit value will be exceeded at any location, and "very unlikely" that the hourly limit value will be exceeded at any location.

Table 5.7 Probability of exceeding the objectives for nitrogen dioxide in 2010 near the Albert Place Galashiels.

Location	Probability of exceedance, P	
	Annual average objective	**99.8th %ile hourly average**
Relevant receptors closest to Road	5% <P< 20% Unlikely	5% > P Very Unlikely

The model has predicted concentrations close to those estimated for 2005 based on diffusion tube results for 2004. The agreement between the diffusion tube and modelling results is within 5%.

5.6 RECOMMENDATIONS

This detailed assessment has not identified a significant risk of exceedance of the UK objectives for NO_2 in 2005 or the EU Limit values for NO_2 in 2010 in Scottish Borders at the locations studied in this detailed assessment. At all relevant locations considered it is at most "possible" that the annual objective will be exceeded in 2005.

Both monitoring and modelling generally indicate that by 2005, concentrations will be below the required concentrations. It is not therefore recommended that Scottish Borders Council declare any air quality management areas for NO_2 in Galashiels.

The Council should continue diffusion tube monitoring, and in particular relocate the diffusion tube located at the High Street/Bridge Place junction to the façade of the nearest relevant receptor.

5.7 FURTHER ACTIONS TO BE TAKEN

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

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

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Appendices

CONTENTS

Appendix 1

Traffic Data

CONTENTS

Table A1.1 - Traffic data for Scottish Borders from the NAEI and SBC.

Road No	Name	Sources	Speed	%HDV	AADT 2000	AADT 2005
A7	Albert Pl	NAEI	51	6.4	8971	9787
A7	Bank St	NAEI	51	6	7000	7637
A7	High St	SBC	NA	NA	NA	12200
A7	Ladhope Vale	NAEI	51	6	6000	6546
A7	Magdala Terrace	NAEI	51	7.8	4987	5441
A72	Wilderhaugh St	NAEI	80	6.6	4065	4435

Table A1.2 - Traffic Growth Factors used to predict traffic flows in future years

From	To	Growth
1999	2000	1.017
1999	2001	1.034
1999	2002	1.053
1999	2003	1.072
1999	2004	1.091
1999	2005	1.110
1999	2010	1.197

Appendix 2

Monitoring Data

CONTENTS

Table A2.1 - Monthly diffusion tube data for Galashiels in 2004

	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Galashiels Council Chamber	K	25	36	29	30	31	21	25	36	21	33	28	23
Galashiels Stanley Street	B	10	16	12	10	7	7	8	8	8	15	13	12
Galashiels High Street	K	13	53	45	48	40	36	39	47	40	49	50	38

K – kerbside
R - Roadside
B - Background

Table A2.2 - Diffusion tube locations Galashiels

Location	Site Reference	Grid Reference
Council Chambers, Albert Place, Galashiels	G1 1N	349 298 635 927
Stanley/Meigle Street, Galashiels	GS 2N	348 605 636 154
High Street – Junction with Bridge Place and Island Street, Galashiels	GH 3N	348 953 636 445
St Ninian's Church, High Street, Galashiels		349 040 936 316

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 area 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 $\mu g\ m^{-3}$ was added to the urban background oxides of nitrogen concentration.

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

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

For $NO_x > 23.6$ μg m^{-3}

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

For $NO_x < 23.6$ μg m^{-3}

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

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

$$NO_2 = 0.162.NO_x$$

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

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

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

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

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

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

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

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

RESULTS

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

Table A3.6 Comparison of modelled and measured concentrations

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

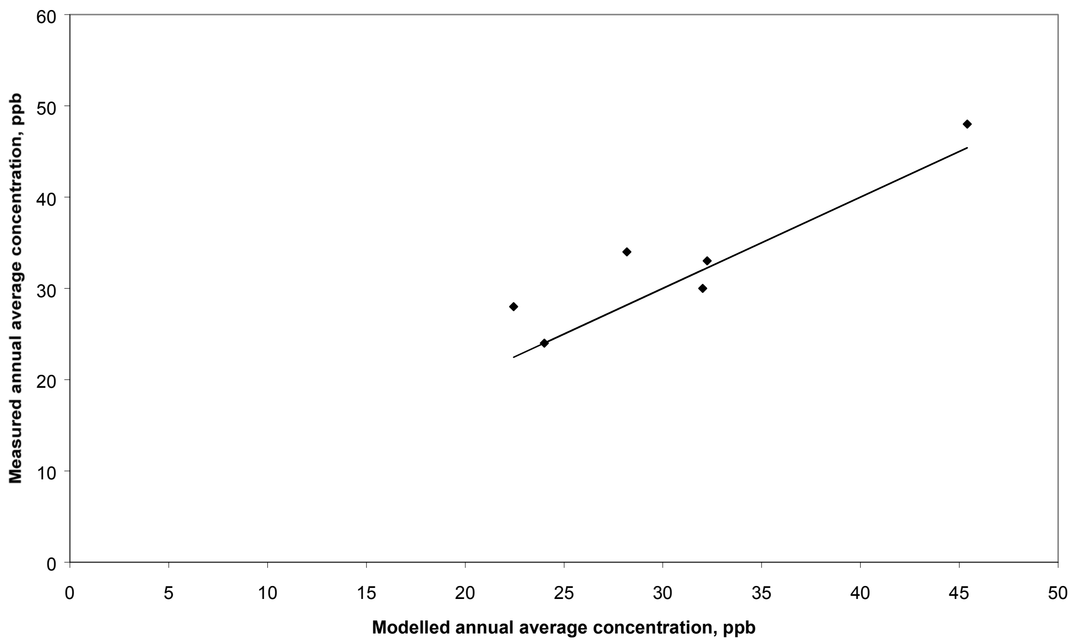

Fig. A3.1 Comparison of modelled and measured annual average nitrogen dioxide concentrations

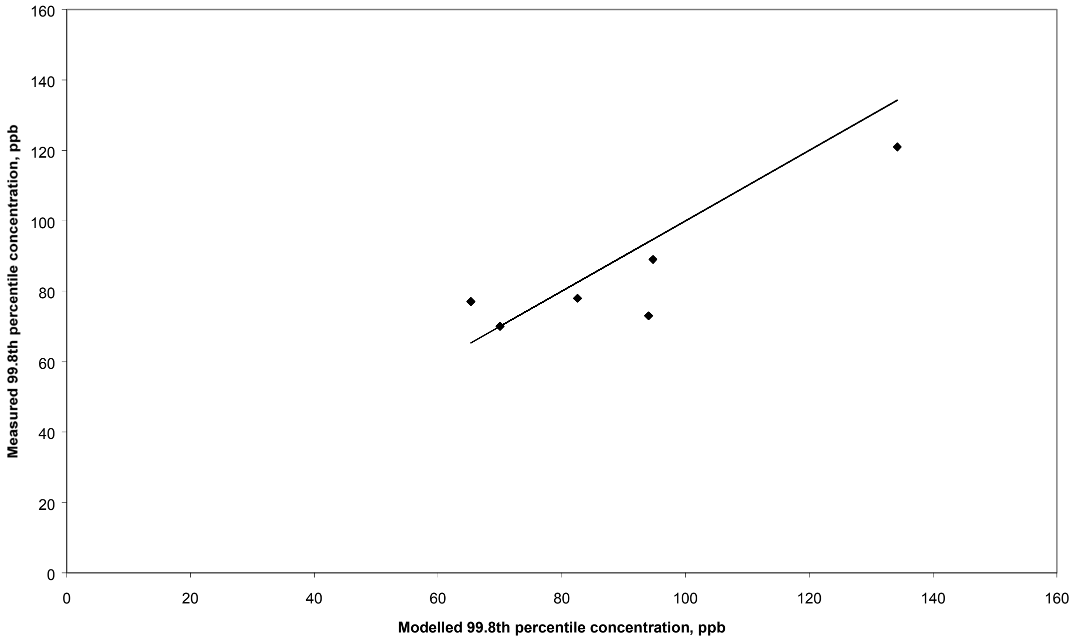

Fig. A3.2 Comparison of modelled and measured 99.8th percentile hourly average nitrogen dioxide concentrations

DISCUSSION

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

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

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

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

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

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

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

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

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

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

Confidence limits
Upper confidence limits for annual mean and 99.8th 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	99.8th percentile
80 %	+19%	+27%
90%	+31%	+47%
95%	+44%	+70%

In practical terms,

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

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

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

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

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

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

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

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

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