Report

UK air quality modelling for annual reporting 2001 on ambient air quality assessment under Council Directives 96/62/EC and 1999/30/EC

Report to The Department for Environment, Food and Rural Affairs, Welsh Assembly Government, The Scottish Executive and the Department of the Environment for Northern Ireland

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Executive Summary

Directive 96/62/EC on Ambient Air Quality Assessment and Management (the Framework Directive) establishes a framework under which the EU sets limit values or target values for the concentrations of specified air pollutants. Directive 1999/30/EC (the first Daughter Directive) sets the limit values to be achieved for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particles and lead.

The first year for which an annual air quality assessment for the first Daughter Directive pollutants is required is 2001. A questionnaire has been completed for submission to the EU containing the results of this air quality assessment. The assessment takes the form of comparisons of measured and modelled air pollutant concentrations with the limit values set out in the Directive. Air quality modelling has been carried out to supplement the information available from the UK national air quality monitoring networks.

This report provides a summary of key results from the questionnaire and additional technical information on the modelling methods that have been used to assess SO_2, NO_2 and NO_x and PM_{10} concentrations throughout the UK. This includes:

- Details of modelling methods
- Information on the verification of the models used and comparisons with data quality objectives
- Detailed modelling results and comparison with limit values.

Maps of background concentrations of SO_2, NO_2 and PM_{10} in 2001 on a 1 km x 1 km grid have been prepared. Maps of roadside concentrations of NO_2 and PM_{10} have been prepared for 9088 built-up major road links (A-roads and motorways).

The dominant contributions to measured SO_2 concentrations in the UK are typically from major point sources such as power stations and refineries, particularly in terms of high percentile concentrations. Emissions of SO_2 from point sources were therefore modelled in some detail. Area sources have been modelled using a dispersion matrix approach. For NO_2, NO_x and PM_{10} there is also an important contribution to ambient concentrations from area sources, particularly traffic sources and a slightly different modelling approach has therefore been adopted. The area source contribution has been modelled using an area source model, which has been calibrated empirically using automatic measurement data. Roadside concentrations of NO_2, NO_x and PM_{10} have been estimated by adding a roadside increment to the modelled background concentrations. This roadside increment has been calculated from road link emission estimates using dispersion coefficients derived empirically using data from roadside monitoring sites.

The UK has been divided into 43 zones for air quality assessment. There are 28 agglomeration zones and 15 non-agglomeration zones. The status of the zones in relation to the limit values for all of the first Daughter Directive pollutants have been listed and reported to the EU in the questionnaire. The status has been determined from a combination of monitoring data and model results.

An exceedence of the 24-hour limit value for SO_2 was measured in one zone (Belfast Urban Area). Modelled SO_2 concentrations were below the limit values in all zones in 2001.

There were measured exceedences of the 1-hour limit value for NO_2 in 4 zones in 2001. There were measured exceedences of the annual mean NO_2 limit value + margin of

tolerance in 4 zones and modelled exceedences in 17 zones. Concentrations (either measured or modelled) were between the annual mean limit value and the limit value + margin of tolerance for 17 zones. Concentrations were below the annual mean limit value in 5 zones. NO_x concentrations were below the annual mean limit value for vegetation areas in all relevant zones.

There were no modelled or measured exceedences of the stage 1 24-hour limit value + margin of tolerance for PM_{10} in 2001. Exceedences of the stage 1 24-hour limit value were measured or modelled in 26 zones. Concentrations were below this limit value in 17 zones. There were no measured exceedences of the stage 1 annual mean limit value. There was a modelled exceedence of the stage 1 annual mean limit value + margin of tolerance in one zone (Greater London Urban Area) and the modelled concentration was between the limit value and the limit value + margin of tolerance in one zone (West Yorkshire Urban Area).

There were no measured exceedences of the limit value for lead.

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1 Introduction

1.1 THE FRAMEWORK AND FIRST DAUGHTER DIRECTIVES

Directive 96/62/EC on Ambient Air Quality Assessment and Management (the Framework Directive (Council Directive 96/62/EC)) establishes a framework under which the EU sets limit values or target values for the concentrations of specified air pollutants. Directive 1999/30/EC (the first Daughter Directive, AQDD1 (Council Directive1999/30/EC)) sets the limit values to be achieved for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particles and lead.

The Framework Directive includes a requirement (Article 5) for Member States to undertake preliminary assessments of ambient air quality, prior to the implementation of the Daughter Directives. The objectives of these assessments are to establish estimates for the overall distribution and levels of pollutants, and to identify additional monitoring required to fulfil obligations under the Framework Directive. A report describing the preliminary assessment for the UK for AQDD1 has been prepared (Bush 2000). AQDD1 defines the number of air quality monitoring sites required on the basis of the concentrations of pollutants and population statistics. The number of monitoring sites required is significantly reduced if other means of assessment, in addition to fixed monitoring sites, are also available. Air quality modelling has therefore been carried out to supplement the information available from the UK national air quality monitoring networks and contribute to the assessments required by the Framework and first Daughter Directives.

1.2 THIS REPORT

The first year for which an annual air quality assessment for the AQDD1 pollutants is required is 2001. A questionnaire has been completed for submission to the EU containing the results of this air quality assessment. The assessment takes the form of comparisons of measured and modelled air pollutant concentrations with the limit values set out in the Directive. This report provides a summary of key results from the questionnaire and additional technical information on the modelling methods that have been used to assess concentrations throughout the UK.

Sections 2, 3 and 4 describe the modelling methods for SO_2, NO_2 and NO_x and PM_{10}. This includes

- Details of modelling methods
- Information on the verification of the models used and comparisons with data quality objectives
- Detailed modelling results.

The status of zones in relation to the limit values for all of the first Daughter Directive pollutants have been listed and reported to the EU in the questionnaire. This status has been determined from a combination of monitoring data and model results and is included in Section 5.

1.3 PRELIMINARY ASSESSMENT AND DEFINITION OF ZONES

The preliminary assessment carried for AQDD1 (Bush, 2000) defined a set of zones to be used for air quality assessments in the UK. These zones are listed in Table 1.1 and illustrated in Figure 1.1. Information on the definition of zones is included in form 2 of the questionnaire. The zone codes listed in Table 1.1 are used throughout the questionnaire. The population (1991 census), area and the number of built-up major road links in each zone are also shown. The zones are of two types: agglomeration zones (continuous urban areas with populations in excess of 250,000) and non-agglomeration zones. There are 28 agglomeration zones and 15 non-agglomeration zones, giving a total of 43. The non-agglomeration zones in England correspond to the Government Office Regions, while those in Scotland, Wales and Northern Ireland were defined in conjunction with the Devolved Administrations.

The preliminary assessment also defined the monitoring and modelling requirements for each zone based on an assessment of concentrations in relation to upper and lower assessment threshold concentrations for AQDD1. The minimum monitoring requirement for most pollutants in the majority of zones was found to be at least one monitoring site per zone, with the monitoring results to be supplemented with information from modelling studies. The preliminary assessment for lead indicated that concentrations in many zones were less than the lower assessment threshold. There is therefore no requirement to monitor lead concentrations in these zones (Bush 2000).

The limit values for the protection of ecosystems and vegetation only apply in ecosystems and vegetation areas, which are defined in the Directive as areas which are 20 km from agglomerations and 5 km from motorways, other urban areas and industrial installations.

Table 1.1 Zones for AQDD1 reporting

Zone	Zone code	Ag or nonag*	Population	Area (km^2)	Number of built –up road links	Length of built –up road links (km)
Greater London Urban Area	UK0001	ag	7650944	1591	1888	1766.9
West Midlands Urban Area	UK0002	ag	2296180	603	396	565.0
Greater Manchester Urban Area	UK0003	ag	2277330	519	528	632.9
West Yorkshire Urban Area	UK0004	ag	1445981	336	259	392.3
Tyneside	UK0005	ag	885981	203	123	158.1
Liverpool Urban Area	UK0006	ag	837998	190	265	211.3
Sheffield Urban Area	UK0007	ag	633362	164	94	146.6
Nottingham Urban Area	UK0008	ag	613726	141	101	102.8
Bristol Urban Area	UK0009	ag	522784	129	115	117.4
Brighton/Worthing/Littlehampton	UK0010	ag	437592	93	46	77.1
Leicester Urban Area	UK0011	ag	416601	90	60	82.3
Portsmouth Urban Area	UK0012	ag	409341	86	47	67.1
Teesside Urban Area	UK0013	ag	369609	103	44	59.0
The Potteries	UK0014	ag	367976	87	95	116.3
Bournemouth Urban Area	UK0015	ag	358321	109	45	54.4
Reading/Wokingham Urban Area	UK0016	ag	335757	87	60	74.8
Coventry/Bedworth	UK0017	ag	331248	76	26	27.2
Kingston upon Hull	UK0018	ag	310636	83	36	43.1
Southampton Urban Area	UK0019	ag	276752	70	54	65.2
Birkenhead Urban Area	UK0020	ag	270207	58	60	51.5
Southend Urban Area	UK0021	ag	266749	63	30	50.2
Blackpool Urban Area	UK0022	ag	261355	63	45	62.7
Preston Urban Area	UK0023	ag	256411	65	32	43.4
Glasgow Urban Area	UK0024	ag	1315544	444	182	280.5
Edinburgh Urban Area	UK0025	ag	416232	127	56	99.0
Cardiff Urban Area	UK0026	ag	306904	70	32	46.7
Swansea Urban Area	UK0027	ag	272456	77	25	55.5
Belfast Urban Area	UK0028	ag	475987	112	10	114.9
Eastern	UK0029	nonag	4788766	19073	530	1070.6
South West	UK0030	nonag	3728319	23486	483	1094.5
South East	UK0031	nonag	3702634	18637	810	1681.6
East Midlands	UK0032	nonag	2923045	15512	370	869.2
North West & Merseyside	UK0033	nonag	2823559	13171	525	1152.3
Yorkshire & Humberside	UK0034	nonag	2446545	14774	311	910.8
West Midlands	UK0035	nonag	2154783	12193	312	631.7
North East	UK0036	nonag	1287979	8264	158	310.9
Central Scotland	UK0037	nonag	1628460	9210	167	360.6
North East Scotland	UK0038	nonag	933485	18541	137	296.7
Highland	UK0039	nonag	364639	38327	42	161.2
Scottish Borders	UK0040	nonag	246659	11120	41	112.8
South Wales	UK0041	nonag	1623660	12192	232	631.3
North Wales	UK0042	nonag	713762	8355	102	288.5
Northern Ireland	UK0043	nonag	1101868	13515	114	835.3
Total			55088127	242209	9088	15972.4

* ag = agglomeration zone, nonag = non-agglomeration zone

1.4 MONITORING SITES

The sites and measurements operating during 2001 for the purpose of AQDD1 reporting are listed in Table A1.1 in Appendix 1. This information is included in form 3 of the questionnaire. Not all sites had sufficient data capture during 2001 for data to be reported. The data quality objective for AQDD1 measurements is 90 % data capture. We have included all measurements with at least 75 % data capture in the analysis in order to ensure that we can make use of data from the sites commissioned during 2001 specifically for AQDD1 reporting purposes (data capture was less a 90% at a number of these sites). Table A1.2 lists the measurements with more than 75% but less than 90 % data capture and therefore included in the analysis. Table A1.3 lists measurements with less than 75 % data capture.

A detailed scrutiny of the exceedence status of each zone with respect to the limit values listed in section 5 and the list of sites with data capture between 75% and 90% has been carried out. This shows that the exceedence status of the zones has not been changed by the inclusion of these sites in the analysis. Exclusion would have left several zones without monitoring data and placed a heavier reliance on the modelling results. Data capture at all lead monitoring sites was more than 75%. We intend to adopt a 90% data capture threshold for reporting of all 2002 monitoring data. Northampton has both TEOM and gravimetric PM_{10} measurements.

1.5 LIMIT VALUES AND MARGINS OF TOLERANCE

The limit values (LV) and limit values + margins of tolerance (LV + MOT) included in AQDD1 are listed in Tables 1.2, 1.3, 1.4 and 1.5. Stage 1 limit values for achievement by 2005 and indicative stage 2 limit values for achievement by 2010 have been set for PM_{10}. The limit value + margin of tolerance varies from year to year from the date the Directive came into force until the date by which the value is to be met. Values for 2001 are listed in these tables. Where no margin of tolerance has been defined the limit value + margin of tolerance is effectively the same as the limit value. All exceedences of the limit value must be reported to the EU. Exceedences of the limit value + margin of tolerance (or limit value if no limit value + margin of tolerance has been set) must be reported to the EU and trigger the preparation of a ‘plan and programme’ for attaining the limit value within the specified time limit and a report to the EU on this ‘plan and programme’.

Table 1.2. Limit values for SO_2

	Averaging period	**LV**	**LV + MOT 2001**	**Date by which LV is to be met**
1. Hourly LV for the protection of human health	1 hour	350 μgm^{-3}, not to be exceeded more than 24 times a calendar year	470 μgm^{-3}, not to be exceeded more than 24 times a calendar year	1 January 2005
2. Daily LV for the protection of human health	24 hour	125 μgm^{-3}, not to be exceeded more than 3 times a calendar year	None	1 January 2005
3. LV for the protection of ecosystems	Calendar year and winter	20 μgm^{-3}	None	19 July 2001

Table 1.3. Limit values for NO_2 and NO_x

	Averaging period	LV	LV + MOT 2001	Date by which LV is to be met
1. Hourly LV for the protection of human health	1 hour	200 μgm^{-3} NO_2 not to be exceeded more than 18 times a calendar year	290 μgm^{-3}, NO_2 not to be exceeded more than 18 times a calendar year	1 January 2010
2. Annual LV for the protection of human health	Calendar year	40 μgm^{-3} NO_2	58 μgm^{-3}, NO_2	1 January 2010
3. LV for the protection of vegetation	Calendar year	30 μgm^{-3} NO_x, as NO_2	None	19 July 2001

Table 1.4a. Limit values for PM_{10} (Stage 1)

	Averaging period	LV	LV + MOT 2001	Date by which LV is to be met
1. 24-hour LV for the protection of human health	24 hour	50 μgm^{-3} not to be exceeded more than 35 times a calendar year	70 μgm^{-3} not to be exceeded more than 35 times a calendar year	1 January 2005
2. Annual LV for the protection of human health	Calendar year	40 μgm^{-3}	46 μgm^{-3}	1 January 2005

Table 1.4b. Indicative limit values for PM_{10} (Stage 2)

	Averagin g period	LV	LV + MOT 2001	Date by which LV is to be met
1. 24-hour LV for the protection of human health	24 hour	50 μgm^{-3} not to be exceeded more than 7 times a calendar year	N/A	1 January 2010
2. Annual LV for the protection of human health	Calendar year	20 μgm^{-3}	N/A	1 January 2010

Table 1.5. Limit values for lead

	Averaging period	LV	LV + MOT 2001	Date by which LV is to be met
Annual LV for the protection of human health	Calendar year	0.5 μgm^{-3}	0.9 μgm^{-3}	1 January 2005

1.6 DATA QUALITY OBJECTIVES FOR MODELLING RESULTS AND MODEL VERIFICATION

The first Daughter Directive sets data quality objectives for the required accuracy of assessment methods to guide quality assurance programmes. These are 50-60% (we have compared with 50%) for hourly averages, 50% for daily averages and 30 % for annual averages of SO_2, NO_2 and NO_x. For PM_{10} and lead the data quality objective for annual averages is 50%, none have been defined for daily averages at present. The accuracy for modelling is defined in the Directive as the maximum deviation of the measured and calculated concentration levels, over the period considered by the limit value, without taking into account the timing of events.

The empirical models used to calculate the maps of air pollutant have been calibrated using the national network monitoring data (from sites listed in appendix 1 of this report). Data from these sites alone cannot, therefore, be used to assess the reliability of the mapped estimates in relation to the data quality objectives for modelling. Measurement data from sites not included in the calibration are required to make this assessment. Data from sites quality assured by netcen under contract, but not part of the national network, including Local Authority sites in the netcen Calibration Club, have therefore been used for the verification of the modelled estimates. The description 'Calibration Club' is used to describe all the monitoring sites included in the verification analysis, although only a subset of these sites quality assured under contract by netcen are formally members of the Calibration Club. The monitoring sites used for this comparison are listed in Appendix 2. Sites with a data capture of at least 25% have been included in the verification analysis. A much higher data capture threshold of 75% has been applied for the national network sites used to calibrate the models. Model verification results are listed in the following sections on each pollutant. A report describing the verification of maps prepared for 1999 has been presented by Stedman and Handley (2001).

1.7 AIR QUALITY MODELLING

Full details of the modelling methods used are given in the sections below. A brief introduction is presented here. Maps of background concentrations of SO_2, NO_2 and PM_{10} have been prepared on a 1 km x 1 km grid for the 2001 calendar year. Maps of roadside concentrations of NO_2 and PM_{10} have also been prepared for 9088 built-up major road links (A-roads and motorways).

The dominant contributions to measured SO_2 concentrations in the UK are typically from major point sources such as power stations and refineries, particularly in terms of high percentile concentrations. Emissions of SO_2 from point sources were therefore modelled explicitly in some detail. Area sources have been modelled using a dispersion matrix approach. The residual concentration from sources not modelled has been estimated from rural network measurements, corrected for the contributions to concentrations at these locations from the modelled sources. For NO_2, NO_x and PM_{10} there is also an important contribution to ambient concentrations from area sources, particularly traffic sources and a slightly different modelling approach has therefore been adopted. Point sources have been modelled explicitly and rural network measurements used to define regional concentrations. The area source contribution has been modelled using a dispersion matrix approach. The coefficients calibrating this area source model have been determined empirically using automatic measurement data. Roadside concentrations of NO_2, NO_x and PM_{10} have been estimated by adding a roadside increment to the modelled background concentrations. The roadside increment has been calculated from road link emission estimates using dispersion coefficients derived empirically using data from roadside monitoring sites.

Emissions estimates for the UK are provided by the National Atmospheric Emission Inventory (NAEI Goodwin, et al, 2001) Emission maps from the 2000 NAEI have been used for the modelling work described here. Emission estimates have been scaled to values appropriate to 2001, where practicable, using UK sector total emissions from 2000 and 2001.

2 SO_2

2.1 INTRODUCTION

A map of annual mean SO_2 concentration has been calculated using a method based on that described by Abbott and Vincent (1999). Emissions from point and area sources were modelled separately. Emissions from point sources were modelled explicitly using the dispersion model ADMS 3.1. Emissions from area sources were modelled using 1 km x 1 km emission grids and a dispersion matrix approach.

The method to predict the 99.73 percentile of hourly values and 99.18 percentile of daily mean concentrations differed slightly to that used predict annual mean concentrations. These percentile concentrations correspond to the number of allowed exceedences of the 1-hour and 24-hour limit values for SO_2. Instead of modelling emissions from individual sources, a number of receptor areas were defined, which together covered the country. Each receptor area was 100 km x 100 km square, extending out to 150 km to cover coastal areas where appropriate. All sources within the receptor area and sources in the adjoining 100 km x 100 km squares were included. Concentrations were calculated on a regular 5 km x 5 km grid throughout the receptor areas. This ensures that the combined impact of several sources on ambient high percentile concentrations is estimated correctly (it is not possible to add together the percentiles from different sources at an individual receptor because the percentiles are unlikely to correspond to the same hour of the year). The contribution from area sources to high percentile concentrations was then added as twice the modelled annual mean concentration from area sources.

There were a number of enhancements to the method used previously, namely:

- An updated version of the dispersion model (ADMS 3.1) was used to predict annual mean, 99.73 percentile of hourly values and 99.18 percentile of daily concentrations.
- Sequential meteorological data (wind directions at 10^o intervals) was used instead of the statistical summary data used in previous studies (Abbot and Vincent, 1999) (wind directions at 30^o intervals).
- Source profiles for the diurnal and seasonal variation in emissions from the power station and domestic area source categories were used. These profiles have been described previously in Coleman et al (2001).

Concentrations were predicted using the most recent meteorology and emission data (2000). Meteorological data and emission releases for individual point sources were not available for 2001, so modelled concentrations for 2000 have been fitted to the 2001 measured concentrations.

2.2 MAP OF ANNUAL MEAN CONCENTRATIONS

A map of annual mean SO_2 concentration for 2001 in ecosystem areas is shown in Figure 2.1. A map of winter mean SO_2 concentrations for the period October 2000 to March 2001 is not required because assessment under AQDD1 did not start until 1 January 2001.

Sulphur dioxide concentrations measured in rural areas were used to calibrate the annual mean SO_2 model output to ensure that the final predicted concentrations matched the concentrations measured at these sites. Most of the monitoring sites in rural locations form part of the Rural SO_2 Monitoring Network (Hasler et al, 2001) and are situated away from local sources. The remainder are automatic monitoring sites and form part of either rural networks maintained by the electricity generating companies (JEP) or DEFRA and the Devolved Administrations. A list of the sites and the concentrations measured is provided in Table 2.1. The calibration plot for 2001 is shown in Figure 2.2. Linear regression analysis of modelled and measured concentrations at rural monitoring sites was carried out to establish the value of coefficient, B and constant A in the equation:

Annual average = Modelled Area Sources + A + B ´ Modelled Part A

A value of 1.29 was obtained for A and a value of 0.66 was obtained for B.

Table 2.1. Annual mean sulphur dioxide concentrations (mgm^{-3}) at rural sites in 2001

Site	Annual mean SO_2 2001 (mgm^{-3})
Appleacre	1.6
Barcombe Mills	1.6
Benniguinea	0.8
Bentra	2.9
Brockhill 1	-
Bush	2.4
Bylchau	1.6
Caenby 1	5.3
Cam Forest	0.5
Camborne 1	1.3
Camphill 1	2.1
Corpach 1	1.1
Crai	1.9
Cresselly 1	2.1
Cwmystwyth	1.3
Eskdalemuir	0.8
Etton 1	-
Fairseat	-
Forsainin	0.5
Fort Augustus 1	0.3
Glen Dye	1.1
Hebden Bridge 2	3.5
High Muffles	2.9
Husborne Crawley 1	2.9
Ladybower Reservoir	5.1
Little Horkesley	2.7
Loch Leven 2	2.4

Site	Annual mean SO_2 2001 (mgm^{-3})
Lough Navar	0.5
Lullington Heath	2.9
Marshfield 1	3.2
Pitlochry	0.5
Preston Montford 2	2.1
Ratcliffe 13	4.8
Redesdale 2	0.5
Rockborne 1	2.1
Rosemaund	1.3
Stoke Ferry	1.9
Strathvaich Dam	0.5
Wakefield 24	5.1
Waunfawr 1	6.1
Yarner Wood	1.3

Where '-'indicates missing data.

The number of sites used to derive the calibration plots is significantly fewer than for previous years. Figure 2.3 for example, shows the calibration plot for 1998, when the number of automatic monitors in rural areas was significantly higher.

The residual concentrations were then calculated at each monitoring site:

Residual = Measured - Regression Model

These residual contributions are associated partly with errors in the model and partly with the contributions from more distant sources, not modelled in this study. They include, for example, contributions from emissions from sources on continental Europe. The residual concentrations were interpolated across the country to provide a map of residuals using simple kriging. The final map was calculated from:

Mapped Value = Modelled Area Sources + A + B ´ Modelled Part A + Residual

2.3 MAPS OF PERCENTILE CONCENTRATIONS FOR COMPARISON WITH THE 1-HOUR AND 24-HOUR LIMIT VALUES

Maps of 99.73 percentile of 1-hour mean and 99.18 percentile of 24-hour mean SO_2 concentration in 2001 are shown in Figures 2.4 and 2.5 and were calculated for comparison with the 1-hour and 24-hour limit values for SO_2.

Hourly or daily percentile values cannot be derived from measurements made at sites with weekly or fortnightly measurements. The monitoring sites available for calibration of this model are the automatic monitoring stations only. In addition only those sites classified as rural, industrial or suburban were used in the calibration. These are presented in Table 2.2. The relative contribution to high percentile concentrations from point source emissions will be greatest at this sub-set of monitoring sites, where the contributions from areas sources will generally be lower than at urban sites.

Table 2.2. 99.73 percentiles of hourly values and 99.18 percentiles of daily values of SO_2 concentrations measured at the sampling sites in 2001 used in the model calibration. (mg m^{-3}).

Site	99.73 percentile of hourly SO_2 values (mg m^{-3})	99.18 percentile of daily SO_2values (mg m^{-3})
Harwell	58	20
Ladybower	77	37
Lullington Heath	28	16
Rochester	69	25
Wicken Fen	23	13
London Bexley	96	43
London Eltham	72	27
London Hillingdon	43	24
Manchester South	48	24
Redcar	133	53
Grangemouth	88	35
Middlesbrough	88	37
Salford Eccles	69	32
Scunthorpe	130	64

Figure 2.6 shows a comparison of 99.73 percentiles measured at all UK automatic monitoring sites for 2000 and 2001. It is clear that the concentrations were generally consistent between the two years and this suggests that the errors introduced by using sequential meteorological data for 2000 instead of for 2001 should not be great.

The calibration plots for the 99.73 percentile of hourly mean concentrations and 99.18 percentile of daily means are presented in Figures 2.7 and 2.8, respectively. Regression analyses were carried out to find the values of the coefficient B and constant A in the following equation:

Predicted %ile = B ´ Modelled Point Sources 99.73 %ile +
Modelled Annual Mean for Area Sources ´ 2
+ A
+ Residual of percentile

The values of the residual at the calibration monitoring sites were then interpolated so that maps of percentile concentrations could be calculated as follows:

Predicted 99.73 %ile = 0.78 ´ Modelled Point Sources 99.73 %ile +
Modelled Annual Mean for Area Sources ´ 2
+ 29.41
+ Residual of 99.73 percentiles of hourly concentrations

Predicted 99.18 %ile = 1.17 ´ Modelled Point Sources 99.18 %ile +
Modelled Annual Mean for Area Sources ´ 2
+ 12.75
+ Residual of 99.18 percentiles of daily concentrations

An alternative method was used to predict the high percentile concentrations in Northern Ireland. This was required because area sources, predominately consisting of emission from domestic coal fires, make a more significant contribution to observed high percentile concentrations in Northern Ireland than in the rest of the United Kingdom. Conversely, the smaller number of point sources in Northern Ireland means that these sources make a smaller contribution to the observed high percentiles.

This alternative method for Northern Ireland method involved estimating the high percentile concentrations from the mapped annual mean SO_2 concentrations in Northen Ireland and the relationships between measured annual mean and measured high percentile concentrations observed for national network monitoring sites between 1997 and 2001. The relationships:

Percentile = A + C x annual mean

are listed in Table 2.3.

Table 2.3. The relationships between high percentile and annual mean SO_2 concentrations

Statistic	C	A (mgm^{-3})
P99.73 (Hourly)	7	13
P99.18 (Daily)	3.5	3

2.4 VERIFICATION OF MAPPED VALUES

Figures 2.9, 2.10 and 2.11 show comparisons of modelled and measured annual mean, 99.73 percentile of 1-hour mean and 99.18 percentile of 24-hour mean SO_2 concentration in 2001 at monitoring site locations in the UK. Both the national network sites used to calibrate the models and the Calibration Club sites (and other sites quality assured by netcen) which provide an independent verification of the modelled concentrations are shown. Lines representing y = x – 30 % and y = x + 30% and y = x – 50 % and y = x + 50% are also shown (the AQDD1 data quality objective for modelled annual mean and percentile SO_2 concentrations respectively).

The agreement between modelled and measured annual mean SO_2 is very poor, particularly at the higher modelled or measured concentrations. This is thought to be largely due to the poor characterisation of emission sources in each locality. This is a particular issue in locations where area sources such as domestic heating or part B industrial emissions make a significant contribution to ambient concentrations. The information available from the NAEI at a 1 km x 1 km level is insufficiently detailed to characterise domestic emissions at the level of fuel use within individual housing estates. The annual mean SO_2 map is, however, only required for comparison with the limit value for the protection of ecosystems in ecosystem areas, which are outside of urban areas. Indeed the great majority of the measured and modelled annual mean SO_2 concentrations, even in urban areas, are below 20 μgm^{-3}, the limit value for ecosystem areas.

The agreement between modelled and measured high percentile SO_2 concentrations is much better than for annual means. This shows that the emissions from the major point sources are well characterised within the inventory and that the model methods are able to estimate the impact of these emissions on high percentile concentrations. The modelled 99.73 percentile of 1-hour mean concentration has an error of more than 50% of the measured concentration at 10% of the national network and 13% of the verification monitoring sites. The modelled 99.18 percentile of 24-hour mean concentration has an error of more than 50% of the measured concentration at 8% of the national network and 17% of the verification monitoring sites.

Summary statistics for the comparison between modelled and measured SO_2 concentrations are listed in Tables 2.4, 2.5 and 2.6.

Table 2.4 Summary statistics for comparison between modelled and measured annual mean concentrations of SO_2 at background sites

	Mean of measurements (mgm^{-3})	Mean of model estimates (mgm^{-3})	r^2	Number of sites
National Network	8.9	5.3	0.10	72
Calibration Club	8.3	5.2	0.08	24

Table 2.5 Summary statistics for comparison between modelled and measured 99.73 percentile of 1-hour mean concentrations of SO_2 at background sites

	Mean of measurements (mgm^{-3})	Mean of model estimates (mgm^{-3})	r^2	Number of sites
National Network	70.7	66.0	0.70	72
Calibration Club	71.3	64.5	0.22	24

Table 2.6 Summary statistics for comparison between modelled and measured 99.18 percentile of 24-hour mean concentrations of SO_2 at background sites

	Mean of measurements (mgm^{-3})	Mean of model estimates (mgm^{-3})	r^2	Number of sites
National Network	33.2	29.2	0.64	72
Calibration Club	31.3	29.3	0.03	23

2.5 DETAILED COMPARISON OF MODELLING RESULTS WITH LIMIT VALUES

We have not tabulated the SO_2 modelling results here because the modelled SO_2 concentrations were below the limit values for all zones.

3 NO_2 / NO_x

3.1 INTRODUCTION

Maps of annual mean NO_2 concentrations at background and roadside locations in 2001 are presented in Figures 3.1 and 3.2. A detailed description of the modelling methods used is available from earlier publications (Stedman et al, 1997, Stedman et al, 2001c, Stedman and Bush, 2000, Stedman et al, 2001b). A summary is provided here with a particular emphasis given to revisions to the methods for the 2001 maps.

The modelling presented in this report for NO_x and NO_2 has been restricted to estimation of annual mean concentrations for comparison with the annual mean limit value. No attempt has been made to model hourly concentrations for comparison with the 1-hour limit value.

It has been considered that annual mean background NO_x concentrations are made up of contributions from

- Distant sources (characterised by the rural background concentration)
- Large point sources
- Local area sources.

Hence, NO_x concentrations at locations away from busy roads may be estimated as:

Estimated background NO_x concentration (mg/m^3, as NO_2) = corrected rural NO_x concentration (mg/m^3, as NO_2) + contributions from major point sources (mg/m^3, as NO_2) + contributions from area sources (mg/m^3, as NO_2)

The area source model has been calibrated using data from the national automatic monitoring networks.

At locations close to busy roads an additional roadside contribution is added to account for contributions to total NO_x from road traffic sources.

In order to estimate the NO_2 concentrations, modelled NO_x concentrations estimated by the approach outlined above must then be converted to NO_2 using empirically derived conversion factors.

A map of annual mean NO_x concentrations in vegetation areas is presented in Figure 3.3. This map has been calculated by interpolation of rural NO_2 measurements followed by multiplication by an empirically derived factor to estimate NO_x from the interpolated NO_2 concentration.

3.2 EMPRICAL RELATIONSHIPS BETWEEN NO_2 AND NO_X CONCENTRATIONS

3.2.1 NO_x to NO_2 relationships at background locations

The map of estimated annual mean background NO_2 concentration shown in Figure 3.1 was calculated from modelled NO_x concentration using the following relationships

Rural Background NO_2 (mg/m^3) = 0.7835.NO_x (mg/m^3, as NO_2)
(Elsewhere) Background NO_2 (mg/m^3) = 1.9301.(NO_x (mg/m^3, as NO_2))$^{0.6887}$
Central London Background NO_2 (mg/m^3) = 2.28.(NO_x (mg/m^3, as NO_2))$^{0.6887}$

These relationships have been derived from monitoring data from 1998 to 2001 inclusive and are presented in Figures 3.4 and 3.5. The relationships reflect the contrast between the behaviour of NO_x, which can be treated as a conserved pollutant, and NO_2 for which the ambient concentration is dependent on the availability of oxidant and the distance from source.

The majority of NO_x is present as NO_2 at rural background locations (Figure 3.4) because such areas are generally distant from sources and oxidant (ozone) is available in excess. Annual mean NO_2 concentrations in urban areas (Figure 3.5) are, however, limited by the availability of oxidant. From Figure 3.5 it is also notable that measured NO_2 concentrations in Central London are higher than in other urban areas of the UK. This is thought to be due to the large size of the Greater London urban area, which enables relatively aged NO_x from other parts of London to contribute to NO_2 in Central London. This relationship has been applied to grid squares forming a circle, of approximate radius 3 km, centred on the middle of London.

3.2.2 NO_x to NO_2 relationships at roadside locations

The map of estimated annual mean roadside NO_2 concentration shown in Figure 3.2 was calculated as the sum of the modelled background NO_2 concentration and an NO_2 roadside increment derived from a modelled NO_x roadside increment using the following equation:

NO_2 Roadside increment (mg/m^3) = NO_x Roadside increment (mg/m^3, as NO_2) . (-0.068.ln(total roadside NO_x concentration (mg/m^3, as NO_2)) + 0.53)

This method (developed by Laxen (2002) from a method proposed by Stedman et al (2001c)) takes into account that the NO_2 to NO_x ratio at high NO_x locations (close to major roads) will be lower than the same ratio at lower NO_x areas as a result of oxidant limiting. The NO_x to NO_2 relationship for the roadside increment is based on a natural logarithmic best-fit curve as shown in Figure 3.6. Thus the percentage of the roadside increment of NO_x represented by NO_2 falls from about 25% at low total NO_x concentrations to about 10% at the highest concentrations close to busy roads in large urban areas.

3.3 CONTRIBUTIONS FROM POINT SOURCES

3.3.1 Introduction

Contributions to ground level annual mean NO_x concentrations from point sources in the 2000 NAEI were estimated by modelling each source explicitly using an atmospheric dispersion model. Two approaches to dispersion modelling were implemented and are summarised below. Prior to these modelling exercises a survey of Part A authorisation notices held by the Environment Agency was conducted for all point sources >250 tonnes per annum NO_x emission as identified in the 2000 NAEI. Parameters characterising the release to atmosphere were collected. Parameters collected were:

- Stack height
- Stack diameter
- Discharge velocity
- Discharge temperature.

Where release parameters were unavailable, engineering assumptions were applied. Previously collated datasets on emission release parameters from large SO_2 point sources were also used to characterise the release of emission (Abbott and Vincent, 1999).

This approach represents a refinement of the modelling approach for annual mean NO_x and NO_2 concentrations used previously (Stedman et al, 2001b). This update of the model will enable the impact of policy scenarios for the reduction of emissions from point sources to be assessed with greater certainty.

3.3.2 Modelling of contributions from NO_x point sources >250 tonnes per annum emission

The contribution to annual mean NO_x concentrations from NO_x point sources with >250 tonnes per annum emission, was modelled using ADMS 3.1. A total of 191 point sources were modelled. 10-year average, statistical meteorological data from the Elmdon weather station were used for each point source. Surface roughness was assumed to be 0.1 metres. Concentrations were calculated for a 100 km x 100 km square , composed of a regularly spaced 5 km x 5 km resolution receptor grid. Each receptor grid was centred on the point source.

3.3.3 Modelling of contributions from NO_x point sources <250 tonnes per annum emission

Contributions from NO_x point sources with <250 tonnes per annum release were modelled using a dispersion matrix approach, at a 1 km receptor resolution. Each source was assumed to emit into a nominal 1 km x 1 km x 50 metre volume. Meteorological conditions throughout the UK were represented by 10-year average statistical data from the Whatnall weather station 1985-94. A total of 575 point sources were modelled using this dispersion matrix approach.

3.4 CONTRIBUTIONS FROM RURAL BACKGROUND CONCENTRATIONS

Diffusion tube measurement data from the Acid Deposition Monitoring Network (Hayman et al, 2001) were used to estimate rural annual mean background NO_2 concentrations. In a number of instances, measurements from this network are influenced by contributions from nearby point and area sources. Hence, for this modelling exercise, in which contributions to ground level concentrations are modelled explicitly by dispersion modelling techniques, it is necessary to remove contributions from point and area sources from the rural background measurement data to avoid double counting of these contributions. The correction procedure is as follows:

Corrected rural background (mg/m^3) = Uncorrected rural background (mg/m^3) – (A + B + C)

Where: A = an estimate of the contribution from area source components, derived using the area source model described below but with the empirical coefficients derived from a previous study of concentrations in 1999 (Stedman et al, 2001b).

B = sum of contributions from all point sources components modelled explicitly using ADMS (those with annual NO_x emissions > 250 tonnes)
C = sum of contributions from all point sources components modelled using the dispersion matrix approach (those with annual NO_x emissions < 250 tonnes).

Corrected rural measurement data were interpolated to obtain estimates of corrected regional background concentrations throughout the UK.

Vegetation zones, as defined by the Directive, are protected by a limit value for annual mean NO_x concentrations. The NO_x map for vegetation areas shown in Figure 3.3 has been calculated by interpolation of uncorrected rural NO_2 measurements followed by multiplication by an empirically derived factor to estimate NO_x from the interpolated NO_2 concentration.

3.5 CONTRIBUTIONS FROM AREA SOURCES

Figure 3.7 shows the calibration of the area source model. The modelled point source and corrected rural NO_x concentrations have been subtracted from the measured annual mean NO_x concentration at background sites. This is compared with the modelled area source contribution to annual mean NO_x concentration. We have used an empirical method, in which an ADMS derived dispersion matrix is applied in order to weight emissions from area sources within a 35 km x 35 km square surrounding each monitoring site. Emissions have been weighted according to distance and direction from the central receptor. 10-year average meteorological data from Heathrow has been used to construct this dispersion matrix and represents the contribution from unit emission in each 1 km x 1 km square to concentrations at the receptor. Emissions from traffic sources have been dispersed from a volume source of height 10 m and stationary area sources have been dispersed from a volume source of height 30 m. Estimates of NO_x emissions for 2000 have been adjusted to values for 2001 using UK sector total emission estimates for 2000 and 2001 available from the NAEI. The modelled area source contribution is therefore directly comparable with the measured concentrations in 2001.

Examination of Figure 3.7 shows that the monitoring sites fall into three groups related to the size of urban area:

- London and Birmingham
- Manchester Leeds and Newcastle
- Elsewhere.

The elsewhere slope is close to unity, showing that in these locations the un-calibrated model is quite successful in predicting the concentration. The other slopes are lower, reflecting the different meteorological and dispersion conditions in larger cites. Meteorological data from Heathrow is not expected to be representative of central London, for example. The effective roughness in large urban areas is also greater than in rural or smaller urban areas, leading to more efficient dispersion of pollutants.

Adjustment factors were applied to the emissions from selected sources. NO_x emission from aircraft were multiplied by 0.36, the proportion total that takes place while the aircraft wheels are on the ground. The contribution to ground level concentrations from emissions while the aircraft is airborne will be much smaller and has not been modelled. (By convention, emission inventories include emissions from aircraft both on the ground and on take off and landing up to 1000 m.) An empirical factor of 0.25 was applied to NO_x emissions from ships.

The modelled area source contribution was multiplied by the relevant empirical coefficient to calculate the calibrated area source contribution for each grid square in the country.

The corrected rural point source contributions were then added, resulting in a map of background NO_x concentrations. The map of background NO_2 concentrations was then calculated from this NO_x map using the NO_x to NO_2 relationships.

3.6 ROADSIDE CONCENTRATIONS

We have considered that the annual mean concentration of NO_x at a roadside location is made up of two parts: the background concentration (as described above) and a roadside increment:

roadside NO_x concentration = background NO_x concentration + NO_x roadside increment

The NAEI provides estimates of NO_x emissions for major road links in the UK for 2000 (Goodwin et al, 2001) and these have been adjusted to provide estimates of emissions in 2001. Figure 3.8 shows a comparison of the roadside increment of annual mean NO_x concentrations at roadside or kerbside national automatic monitoring sites with NO_x emission estimates for the individual road links alongside which these sites are located. The background NO_x component at these roadside monitoring sites was derived from the map described above.

The roadside increments of annual mean NO_x concentrations adjacent to motorways and non-built-up dual carriageways are considerably smaller per unit emissions than for built-up roads in urban areas. This is due to a combination of the wider traffic lanes, faster speeds and the more open aspects typically found on this type of road. An empirically derived factor of 0.25 was therefore applied to emissions from motorways and non-built-up dual carriageways prior to inclusion in the calibration. No attempt has been made to calculate roadside concentrations for non-built-up single carriageway roads. The roadside concentrations for built-up roads only are reported to the EU and included in this report.

The roadside increment of NO_2 was calculated from the roadside increment of NO_x using the relationships described in section 3.2.2. This was then added to the mapped background NO_2 concentration:

roadside NO_2 concentration = background NO_2 concentration + NO_2 roadside increment

3.7 VERIFICATION OF MAPPED VALUES

Figures 3.9 and 3.10 show comparisons of modelled and measured annual mean NO_x and NO_2 concentration in 2001 at background monitoring site locations. Figure 3.11 and 3.12 show similar comparisons for roadside sites. Both the national network sites used to calibrate the models and the Calibration Club sites (and other sites quality assured by netcen) which provide an independent verification of the modelled concentrations are shown. Lines representing y = x – 30 % and y = x + 30% are also shown (this is the AQDD1 data quality objective for modelled annual mean NO_2 and NO_x concentrations). There is no requirement to report modelled annual mean NO_x concentrations for comparison with limit values for the protection of human health (the NO_x limit value for the protection of vegetation only applies in vegetation areas). However, comparisons of modelled and measured NO_x concentrations and of the modelled NO_x concentrations with the data quality objectives are presented alongside the comparisons for NO_2. This provides an additional check on the reliability of our modelled estimates of NO_2 because the non-linear relationships between NO_x and NO_2 tend to cause modelled NO_2 concentrations to be relatively insensitive to errors in the dispersion modelling of NO_x.

The percentages of monitoring sites for which the modelled annual mean concentrations fall outside the data quality objectives are summarised in Tables 3.1 and 3.2. This percentage is generally greater for NO_x than for NO_2, for the reasons discussed above. It is also greater for the verification sites. This is, in part, due to the model overestimating concentrations at monitoring sites close to airports, where more detailed emission inventory and dispersion modelling studies would be required to fully characterise the ambient concentration.

Table 3.1 The percentages of background monitoring sites for which the modelled annual mean NO_x and NO_2 concentrations are outside the data quality objectives.

	NO_x	NO_2
National Network	16%	11%
Calibration Club	36%	40%

Table 3.2 The percentages of roadside monitoring sites for which the modelled annual mean NO_x and NO_2 concentrations are outside the data quality objectives.

	NO_x	NO_2
National Network	22%	0%
Calibration Club	38%	23%

Summary statistics for the comparison between modelled and measured NO_x and NO_2 concentrations are listed in Tables 3.3 and 3.4.

Table 3.3 Summary statistics for comparison between modelled and measured NO_x and NO_2 concentrations at background sites (mgm^{-3}, as NO_2)

		Mean of measurements (mgm^{-3}, as NO_2)	Mean of model estimates (mgm^{-3}, as NO_2)	r^2	Number of sites
National Network	NO_x	63.3	62.6	0.72	62
Calibration Club	NO_x	51.3	61.0	0.77	25
National Network	NO_2	32.1	33.0	0.70	62
Calibration Club	NO_2	27.1	32.2	0.55	25

Table 3.4 Summary statistics for comparison between modelled and measured NO_x and NO_2 concentrations at roadside sites (mgm^{-3}, as NO_2)

		Mean of measurements	Mean of model estimates	r^2	Number of sites
National Network	NO_x	168.0	160.5	0.79	18
Calibration Club	NO_x	120.2	131.7	0.55	13
National Network	NO_2	55.3	42.4	0.79	18
Calibration Club	NO_2	41.4	45.1	0.57	13

3.8 DETAILED COMPARISON OF MODELLING RESULTS WITH LIMIT VALUES

The modelling results, in terms of a comparison of modelled concentrations with the annual mean limit value by zone, are summarised in Table 3.5. These data have also been presented in form 11 of the questionnaire. We have added the number of road links exceeding the limit value for comparison with other UK studies. The NO_x annual mean limit value for the protection of vegetation was not exceeded in vegetation areas in any of the non-agglomeration zones in 2001. This limit value does not apply in agglomeration zones, since there are no vegetation areas in these zones. Method A in this table refers to the modelling method described in this report.

Table 3.5 Tabular results of and methods used for supplementary assessment (1999/30/EC Article 7(3) and Annex VIII(II))								
- Form 11b Results of and methods used for supplementary assessment for NO_2/NO_x								
Zone	Zone code	Above LV for health (annual mean)						
		Area		Road length			Population exposed	
		km^2	Method	links	km	Method	Number	Method
Greater London Urban Area	UK0001	182	A	1771	1587.7	A	1414938	A
West Midlands Urban Area	UK0002	9	A	282	378.9	A	35922	A
Greater Manchester Urban Area	UK0003	101	A	479	531.3	A	334570	A
West Yorkshire Urban Area	UK0004	29	A	219	290.5	A	67397	A
Tyneside	UK0005	0	A	33	27.9	A	0	A
Liverpool Urban Area	UK0006	1	A	237	176.5	A	962	A
Sheffield Urban Area	UK0007	39	A	89	127.0	A	72096	A
Nottingham Urban Area	UK0008	33	A	94	91.0	A	122362	A
Bristol Urban Area	UK0009	0	A	90	85.0	A	0	A
Brighton/Worthing/Littlehampton	UK0010	0	A	5	9.6	A	0	A
Leicester Urban Area	UK0011	15	A	59	81.1	A	80649	A
Portsmouth Urban Area	UK0012	0	A	25	27.8	A	0	A
Teesside Urban Area	UK0013	1	A	17	10.3	A	6133	A
The Potteries	UK0014	0	A	72	62.2	A	0	A
Bournemouth Urban Area	UK0015	0	A	3	4.2	A	0	A
Reading/Wokingham Urban Area	UK0016	0	A	45	52.7	A	0	A
Coventry/Bedworth	UK0017	2	A	26	27.2	A	6863	A
Kingston upon Hull	UK0018	0	A	17	19.5	A	0	A
Southampton Urban Area	UK0019	0	A	40	44.3	A	0	A
Birkenhead Urban Area	UK0020	0	A	20	12.8	A	0	A
Southend Urban Area	UK0021	0	A	6	6.0	A	0	A
Blackpool Urban Area	UK0022	0	A	0	0.0	A	0	A
Preston Urban Area	UK0023	0	A	21	23.3	A	0	A
Glasgow Urban Area	UK0024	17	A	113	155.5	A	52500	A
Edinburgh Urban Area	UK0025	0	A	14	25.8	A	0	A
Cardiff Urban Area	UK0026	1	A	15	19.6	A	4336	A
Swansea Urban Area	UK0027	0	A	0	0.0	A	0	A
Belfast Urban Area	UK0028	0	A	5	39.2	A	0	A
Eastern	UK0029	12	A	149	222.6	A	12662	A
South West	UK0030	1	A	28	44.1	A	992	A
South East	UK0031	65	A	199	304.5	A	61906	A
East Midlands	UK0032	36	A	140	207.5	A	36857	A
North West & Merseyside	UK0033	122	A	209	330.9	A	151836	A
Yorkshire & Humberside	UK0034	68	A	122	297.4	A	50866	A
West Midlands	UK0035	22	A	81	114.4	A	8227	A
North East	UK0036	3	A	7	34.7	A	532	A
Central Scotland	UK0037	1	A	27	15.6	A	684	A
North East Scotland	UK0038	0	A	11	19.0	A	0	A
Highland	UK0039	0	A	0	0.0	A	0	A
Scottish Borders	UK0040	0	A	0	0.0	A	0	A
South Wales	UK0041	1	A	12	28.8	A	1844	A
North Wales	UK0042	0	A	0	0.0	A	0	A
Northern Ireland	UK0043	0	A	1	9.8	A	0	A
Total number of links				4783				

4 PM_{10}

4.1 INTRODUCTION

Maps of annual mean PM_{10} in 2001 at background and roadside locations are shown in Figures 4.1 and 4.2. Detailed descriptions of the modelling methods used are available (Stedman and Bush, 2000, Stedman, et al 2001b). A summary is provided here with a particular emphasis given to revisions to the methods for the 2001 maps.

The information on the source apportionment of ambient particle concentrations in the UK available from the APEG receptor model (APEG, 1999, Stedman et al, 2001a) has been applied to the calculation of maps of annual mean concentrations. A regression analysis has been carried out to divide measured daily average PM_{10} concentrations (as measured by TEOM or equivalent monitor at selected monitoring sites) into three components:

- primary combustion PM_{10} (from co-located NO_x measurements)
- secondary PM_{10} (from rural sulphate measurements)
- 'other' PM_{10} (the residual).

The regression analysis was carried out for the calendar year of monitoring data for each site to determine the coefficients A and B:

[measured PM_{10} (mg m^{-3}, TEOM)] = A [measured NO_x (mg m^{-3}, as NO_2)] + B [measured sulphate (mg m^{-3})] + C (mg m^{-3}, TEOM)

These coefficients can then be used to divide the measured concentration into the three components and the contributions from each component to the annual mean concentration can be calculated. The maps of background concentrations are made up of contributions from

- Point sources of primary particles
- Area sources of primary particles
- Secondary particles
- Coarse particles.

An additional roadside increment is added for roadside locations.

24-hour mean concentrations have not been explicitly modelled for comparison with the 24-hour limit values. An annual mean concentration of 31.5 μgm^{-3}, gravimetric has been taken to be equivalent to 35 days with 24-hour mean concentrations greater than 50 μgm^{-3} gravimetric (the stage 1 24-hour limit value). This equivalence is derived from an analysis of recent monitoring data (Stedman et al, 2001b) and is reproduced in Figure 4.3. The relationship between the number of days with concentrations greater than 50 μgm^{-3}, gravimetric and annual mean is less certain at lower numbers of exceedences and no attempt has been made to model exceedences of the indicative stage 2 24-hour limit value of 7 exceedences of 50 μgm^{-3}, gravimetric. The stage 2 annual mean limit value is expected to be more stringent than the stage 2 24-hour limit value in any case.

The reference method for the limit values for PM_{10} is the use of a gravimetric instrument. The analysis presented here is based on TEOM (Tapered Element Oscillating Microbalance) instruments, which are currently widely used with in the UK national monitoring networks. We have applied a scaling factor of 1.3 to all data before comparing with the limit value, as suggested by APEG (1999), and recommended as an interim measure by the EC Working Group set up to address the issue of scaling automatic PM measurements in advance of Member States undertaking their own detailed inter-comparisons with the Directive Reference Method.

4.2 SECONDARY PARTICLE CONTRIBUTIONS

For simplicity secondary particles are assumed to consist of sulphates and nitrates only. A map of secondary PM_{10} particle concentrations across the UK has been calculated from rural measurements of sulphate and nitrate concentrations by interpolation onto a 20 km x 20 km grid. Sulphate concentrations were measured on a daily basis at eight rural sites using 8-port bubblers during 2001 (RGAR, 1997). Sulphate was assumed to be largely present as ammonium sulphate and sulphate concentrations were multiplied by 1.354 to take the presence of the counter ion into account. Nitrate concentrations were measured on a monthly basis at 12 rural sites using a denuder method during 2001 (CEH, 2002).

The mean value of the APEG receptor model coefficient, B , relating secondary PM_{10} concentrations to sulphate concentrations in 2001 was 2.49, averaged over 11 background monitoring sites. A comparison of interpolated sulphate and nitrate concentrations at these locations indicates that a scaling factor for nitrate concentrations of 1.0 is equivalent (along with a sulphate scaling factor of 1.354) to the sulphate to nitrate ratio implied by the coefficient derived from the APEG receptor model. TEOM instruments are known to be subject to partial losses of the more volatile particle components, such as ammonium nitrate. This is the reason why a scaling factor of greater than 1.0 is not required to take account of the counter ions associated with the measured nitrate concentrations. In this instance the losses of nitrate mass have been found to be approximately equivalent to the mass of the counter ions associated with the remaining nitrate. It is quite possible that a scaling factor different from 1.0 would be found for other years or locations.

4.3 CONTRIBUTIONS FROM POINT SOURCES

4.3.1 Introduction

Contributions to the primary PM_{10} component of ground level concentrations from point sources were modelled in a similar way as the point source contributions for NO_x, (see section 3.3). Point source contributions were estimated by modelling each source explicitly using an atmospheric dispersion model. Two approaches were implemented and are summarised below.

As for NO_x, the modelling parameters characterising the release of emission were taken from a survey of Part A authorisation notices. Where release parameters were unavailable, engineering assumptions were applied. Previously collated datasets on emission release parameters for large SO_2 point sources were also used to characterise the release of PM_{10} emission (Abbott and Vincent, 1999).

4.3.2 Modelling contributions to primary PM_{10} from point sources with emissions >100 tonnes per annum

For PM_{10} point sources with >100 tonnes per annum release, each point sources was modelled using ADMS 3.1. A total of 87 point sources were modelled. 10-year average, statistical meteorological data from the Elmdon weather station were used for each point source. Surface roughness was assumed to be 0.1 metres. Concentrations were calculated for a 100 km x 100 km square, composed of a regularly spaced 5 km x 5 km resolution receptor grid. Receptor grids were centred on each point source.

4.3.3 Modelling contributions to primary PM_{10} from point sources with emissions <100 tonnes per annum

For PM_{10} point sources with <100 tonnes per annum release, each point source was modelled using a dispersion matrix approach, at a 1km x 1 km receptor resolution. Each source was assumed to emit into a nominal 1 km x 1 km x 50 metre volume. Meteorological conditions throughtout the UK were represented by 10-year average statistical data from the Whatnall weather station 1985-94. A total of 728 point sources were modelled using this dispersion matrix approach.

4.4 CONTRIBUTIONS FROM AREA SOURCES

Figure 4.4 shows the calibration of the area source model. The modelled point source and mapped secondary PM_{10} has been subtracted from the measured annual mean PM_{10} concentration at background sites. This is compared with the modelled area source contribution to annual mean PM_{10} concentration. Calibration and verification plots are shown in μgm^{-3}, TEOM, since TEOM measurements have been used to calibrate and verify the models. (Concentrations have been converted to μgm^{-3}, gravimetric before comparison with the limit values.) We have used an empirical method in which an ADMS derived dispersion matrix is applied to weight emissions from area sources within a 35 km x 35 km square surrounding each monitoring site according to distance and direction of the emissions from the central receptor. 10-year average meteorological data from Heathrow has been used to construct this dispersion matrix and represents the contribution from unit emission in each 1 km x 1 km square to concentrations at the receptor. Emissions from traffic sources have been dispersed from a volume source of height 10 m and stationary area sources have been dispersed from a volume source of height 30 m. Estimates of PM_{10} emissions for 2000 have been adjusted to values for 2001 using UK sector total emission estimates for 2000 and 2001 available from the NAEI. The modelled area source contribution is therefore directly comparable with the measured concentrations in 2001.

Examination of Figure 4.4 shows that the monitoring sites fall into three groups related to the size of urban area:

- London and Birmingham
- Manchester Leeds and Newcastle
- Elsewhere.

The elsewhere slope is close to unity, showing that in these locations the un-calibrated model is quite successful in predicting the concentration. The other slopes are lower, reflecting the different meteorological and dispersion conditions in larger cites. Meteorological data from Heathrow is not expected to be representative of central London, for example. The effective roughness in large urban areas is also greater than in rural or smaller urban areas, leading to more efficient dispersion of pollutants.

Adjustment factors were applied to the emissions from selected sources. Particle emission from aircraft were multiplied by 0.5, the proportion total that takes place while the aircraft wheels are on the ground. The contribution to ground level concentrations from emissions while the aircraft is airborne will be much smaller and has not been modelled. (By convention, emission inventories include emissions from aircraft both on the ground and on take off and landing up to 1000 m.) Factors of 0.25 and 0.5 were applied to particle emissions from ships and quarries. These factors were chosen empirically to provide the best fit to measured concentrations data.

Emissions from the construction, break and tyre wear and quarry sectors have been included in the 2001 maps of background PM_{10} concentrations for the first time. The majority of the emissions from these 'non-combustion' source sectors will be in the form of coarse particles (between 2.5 and 10 μm in diameter) and were not explicitly included in the PM_{10} maps published previously (Stedman et al, 2001b).

The modelled area source contribution was multiplied by the relevant empirical coefficient to calculate the calibrated area source contribution for each grid square in the country. The modelled point source and mapped secondary particle concentrations were then added.

A constant coarse particle concentration of 8.8 μgm^{-3}, gravimetric (6.75 μgm^{-3}, TEOM) is the final component of the mapped PM_{10} concentration at background locations. This value was derived from the intercept of the regression analyses to determine the empirical dispersion coefficients. It is somewhat smaller than values used previously (Stedman et al, 2001b) and the residuals obtained from the 2001 APEG receptor modelling. This is because of the inclusion of some coarse particle emissions in the area source modelling. These contributions were assigned to the residual in the APEG receptor modelling approach and in earlier mapping studies. Emissions of coarse particles form other sources such as wind blown dusts, sea salt and agricultural activities are not well characterised in emission inventires and are therefore included in this constant 8.8 μgm^{-3}, gravimetric contribution, and not modelled explicitly.

4.5 ROADSIDE CONCENTRATIONS

We have considered that the annual mean concentration of PM_{10} at a roadside location is made up of two parts: the background concentration (as described above) and a roadside increment

roadside concentration = background concentration + roadside increment

The NAEI provides estimates of PM_{10} emissions for major road links in the UK for 2000 (Goodwin et al, 2001) and these have been adjusted to provide estimates of emissions in 2001. Figure 4.5 shows a comparison of the roadside increment of annual mean PM_{10} concentrations at roadside or kerbside national automatic monitoring sites with PM_{10} emission estimates for the individual road links alongside which these sites are located. The background PM_{10} component at these roadside monitoring sites was derived from the map described above. The roadside increments of annual mean PM_{10} concentrations adjacent to motorways and non-built-up dual carriageways are considerably smaller per unit emissions than for built-up roads in urban areas. This is due to a combination of the wider traffic lanes, faster speeds and the more open aspects typically found on this type of road. An empirically derived factor of 0.25 was therefore applied to emissions from motorways and non-built-up dual carriageways prior to inclusion in the calibration. No attempt has been made to calculate roadside concentrations for non-built-up singe carriageway roads. The roadside concentrations for built-up roads only are reported to the EU and included in this report.

4.6 VERIFICATION OF MAPPED VALUES

Figures 4.6 and 4.7 show comparisons of modelled and measured annual mean PM_{10} concentration in 2001 at both background and roadside monitoring site locations. Both the national network sites used to calibrate the models and the Calibration Club sites (and other sites quality assured by netcen) which provide an independent verification of the modelled concentrations are shown. Lines representing y = x – 50 % and y = x +

50% are also shown because 50% is the AQDD1 data quality objective for modelled annual mean PM_{10} concentrations. All of the modelled values are within the data quality objectives.

Summary statistics for the comparison between modelled and measured PM_{10} concentrations are listed in Tables 4.1 and 4.2.

Table 4.1 Summary statistics for comparison between modelled and measured concentrations of PM_{10} at background sites

	Mean of measurements (mgm^{-3}, TEOM)	Mean of model estimates (mgm^{-3}, TEOM)	r^2	Number of sites
National Network	17.8	17.3	0.51	47
Calibration Club	17.1	16.6	0.63	25

Table 4.2 Summary statistics for comparison between modelled and measured concentrations of PM_{10} at roadside sites

	Mean of measurements (mgm^{-3}, TEOM)	Mean of model estimates (mgm^{-3}, TEOM)	r^2	Number of sites
National Network	23.4	22.6	0.34	11
Calibration Club	20.1	19.4	0.06	13

4.7 DETAILED COMPARISON OF MODELLING RESULTS WITH LIMIT VALUES

The modelling results, in terms of a comparison of modelled concentrations with the stage 1 limit values by zone, are summarised in Table 4.3. These data are also presented in form 11 of the questionnaire. We have added the number of road links exceeding the limit value for comparison with other UK studies. We have not carried out a detailed comparison of the model results with the indicative stage 2 limit values. Method A in this table refers to the annual mean modelling methods described in this report. Method C refers to the annual mean modelling methods described in this report and the use of an annual mean threshold concentration as equivalent to the 24-hour limit value.

Table 4.3 Tabular results of and methods used for supplementary assessment (1999/30/EC Article 7(3) and Annex VIII(II))														
- Form 11c.1 Results of and methods used for supplementary assessment for PM_{10} (Stage 1)														
Zone	Zone code	Above LV (24hr mean)							Above LV (annual mean)					
		Area		Road length			Population exposed		Area		Road length			Population exposed	
		km^2	Method	links	km	Method	Number	Method	km^2	Method	links	km	Method	Number	Method
Greater London Urban Area	UK0001	0	C	433	240.9	C	0	C	0	A	41	23.3	A	0	A
West Midlands Urban Area	UK0002	0	C	16	19.8	C	0	C	0	A	0	0	A	0	A
Greater Manchester Urban Area	UK0003	1	C	5	6.3	C	3694	C	0	A	0	0	A	0	A
West Yorkshire Urban Area	UK0004	0	C	5	3.1	C	0	C	0	A	1	0.1	A	0	A
Tyneside	UK0005	0	C	1	1.4	C	0	C	0	A	0	0	A	0	A
Liverpool Urban Area	UK0006	1	C	6	8.0	C	2241	C	0	A	0	0	A	0	A
Sheffield Urban Area	UK0007	1	C	8	7.4	C	944	C	0	A	0	0	A	0	A
Nottingham Urban Area	UK0008	0	C	2	1.5	C	0	C	0	A	0	0	A	0	A
Bristol Urban Area	UK0009	0	C	2	0.8	C	0	C	0	A	0	0	A	0	A
Brighton/Worthing/Littlehampton	UK0010	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Leicester Urban Area	UK0011	0	C	3	1.9	C	0	C	0	A	0	0	A	0	A
Portsmouth Urban Area	UK0012	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Teesside Urban Area	UK0013	1	C	1	2.1	C	0	C	0	A	0	0	A	0	A
The Potteries	UK0014	0	C	9	8.2	C	0	C	0	A	0	0	A	0	A
Bournemouth Urban Area	UK0015	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Reading/Wokingham Urban Area	UK0016	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Coventry/Bedworth	UK0017	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Kingston upon Hull	UK0018	0	C	1	0.7	C	0	C	0	A	0	0	A	0	A
Southampton Urban Area	UK0019	0	C	1	0.8	C	0	C	0	A	0	0	A	0	A
Birkenhead Urban Area	UK0020	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Southend Urban Area	UK0021	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Blackpool Urban Area	UK0022	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Preston Urban Area	UK0023	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Glasgow Urban Area	UK0024	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A

Table 4.3 Tabular results of and methods used for supplementary assessment (1999/30/EC Article 7(3) and Annex VIII(II))

- Form 11c.1 Results of and methods used for supplementary assessment for PM_{10} (Stage 1)

Zone	Zone code	Above LV (24hr mean)							Above LV (annual mean)						
		Area		Road length			Population exposed		Area		Road length			Population exposed	
		km^2	Method	links	km	Method	Number	Method	km^2	Method	links	km	Method	Number	Method
Edinburgh Urban Area	UK0025	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Cardiff Urban Area	UK0026	1	C	0	0.0	C	4336	C	0	A	0	0	A	0	A
Swansea Urban Area	UK0027	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Belfast Urban Area	UK0028	0	C	4	28.3	C	0	C	0	A	0	0	A	0	A
Eastern	UK0029	4	C	0	0.0	C	9955	C	0	A	0	0	A	0	A
South West	UK0030	1	C	0	0.0	C	85	C	0	A	0	0	A	0	A
South East	UK0031	4	C	4	13.8	C	1991	C	0	A	0	0	A	0	A
East Midlands	UK0032	1	C	1	2.2	C	43	C	0	A	0	0	A	0	A
North West & Merseyside	UK0033	3	C	7	10.7	C	3808	C	0	A	0	0	A	0	A
Yorkshire & Humberside	UK0034	2	C	3	9.0	C	640	C	0	A	0	0	A	0	A
West Midlands	UK0035	0	C	3	4.3	C	0	C	0	A	0	0	A	0	A
North East	UK0036	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Central Scotland	UK0037	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
North East Scotland	UK0038	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Highland	UK0039	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Scottish Borders	UK0040	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
South Wales	UK0041	2	C	0	0.0	C	155	C	0	A	0	0	A	0	A
North Wales	UK0042	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Northern Ireland	UK0043	0	C	0	0.0	C	0	C	0	A	0	0	A	0	A
Total number of links				515							42				

5 Lists of zones in relation to Limit Values and Margins of Tolerance

5.1 INTRODUCTION

The tables included in this section are from form 5 of the questionnaire. A ‘+’ indicates that the concentration of the pollutant with respect to the limit value in that zone has been determined by measurements. A ‘m’ indicates that the concentration of the pollutant with respect to the limit value in that zone has been determined by modelling. If both measurements and model calculations show that a threshold has been exceeded then the measurements are regarded as the primary basis for compliance status and ‘+’ is therefore used. An ‘m’ in the columns marked >LV + MOT or ≤LV + MOT; > LV indicates that modelled concentrations were higher than measured concentrations or on rare occasions that measurements were not available for that zone and modelled values were therefore used. Modelled concentration may be higher than measured concentrations because the modelling studies provide estimates of concentrations over the entire zone. It is possible that the locations of the monitoring sites do not correspond to the location of the highest concentration in the zone. There may, for example, be no roadside monitoring sites in a zone. An ‘m’ in the columns marked ≤LV indicates that measurements were not available for that zone and modelled values were therefore used. A blank cell indicates that no assessment has been made.

5.2 SO_2

The compliance status of each zone in relation to the limit values for SO_2 is shown in Table 5.1. An exceedence of the 24-hour limit value for SO_2 was measured in the Belfast Urban Area zone. Modelled SO_2 concentrations were below the limit values in all zones in 2001.

5.3 NO_2 / NO_X

The compliance status of each zone in relation to the limit values for NO_2 and NO_x is shown in Table 5.2. There were measured exceedences of the 1-hour limit value for NO_2 in 4 zones in 2001. There were measured exceedences of the annual mean NO_2 limit value + margin of tolerance in 4 zones and modelled exceedences in 17 zones. Concentrations (either measured or modelled) were between the annual mean limit value and the limit value + margin of tolerance for 17 zones. Concentrations were below the annual mean limit value in 5 zones. NO_x concentrations were below the annual mean limit value for vegetation areas in all relevant zones.

5.4 PM_{10}

The compliance status of each zone in relation to the limit values for PM_{10} is shown in Table 5.3. There were no modelled or measured exceedences of the stage 1 24-hour limit value + margin of tolerance for PM_{10} in 2001. Exceedences of the stage 1 24-hour limit value were measured or modelled in 26 zones. Concentrations were below this limit value in 17 zones. There were no measured exceedences of the stage 1 annual mean limit value. There was a modelled exceedence of the stage 1 annual mean limit value + margin of tolerance in one zone (Greater London Urban Area) and the modelled concentration was between the limit value and the limit value + margin of tolerance in one zone (West Yorkshire Urban Area).

5.5 LEAD

The compliance status of each zone in relation to the limit values for lead is shown in Table 5.4. There were no measured exceedences of the limit value for lead in 2001.

Table 5.1. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)

- Form 5a List of zones in relation to limit value exceedences for SO_2

Zone	Zone code	LV for health (1hr mean)			LV for health (24hr mean)		LV for ecosystems (annual mean)		LV for ecosystems (winter mean)	
		>LV+ MOT	≤LV+MOT; >LV	≤LV	>LV	≤LV	>LV	≤LV	>LV	≤LV
Greater London Urban Area	UK0001			+		+				
West Midlands Urban Area	UK0002			+		+				
Greater Manchester Urban Area	UK0003			+		+				
West Yorkshire Urban Area	UK0004			+		+				
Tyneside	UK0005			+		+				
Liverpool Urban Area	UK0006			+		+				
Sheffield Urban Area	UK0007			+		+				
Nottingham Urban Area	UK0008			+		+				
Bristol Urban Area	UK0009			+		+				
Brighton/Worthing/Littlehampton	UK0010			+		+				
Leicester Urban Area	UK0011			+		+				
Portsmouth Urban Area	UK0012			+		+				
Teesside Urban Area	UK0013			+		+				
The Potteries	UK0014			+		+				
Bournemouth Urban Area	UK0015			+		+				
Reading/Wokingham Urban Area	UK0016			+		+				
Coventry/Bedworth	UK0017			+		+				
Kingston upon Hull	UK0018			+		+				
Southampton Urban Area	UK0019			+		+				
Birkenhead Urban Area	UK0020			+		+				
Southend Urban Area	UK0021			+		+				
Blackpool Urban Area	UK0022			+		+				
Preston Urban Area	UK0023			+		+				
Glasgow Urban Area	UK0024			+		+				

Table 5.1. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)										
- Form 5a List of zones in relation to limit value exceedences for SO_2										
Zone	Zone code	LV for health (1hr mean)			LV for health (24hr mean)		LV for ecosystems (annual mean)		LV for ecosystems (winter mean)	
		>LV+ MOT	≤LV+MOT; >LV	≤LV	>LV	≤LV	>LV	≤LV	>LV	≤LV
Edinburgh Urban Area	UK0025			+		+				
Cardiff Urban Area	UK0026			+		+				
Swansea Urban Area	UK0027			+		+				
Belfast Urban Area	UK0028			+	+					
Eastern	UK0029			+		+		+		
South West	UK0030			+		+		m		
South East	UK0031			+		+		+		
East Midlands	UK0032			+		+		m		
North West & Merseyside	UK0033			+		+		m		
Yorkshire & Humberside	UK0034			+		+		m		
West Midlands	UK0035			+		+		m		
North East	UK0036			+		+		m		
Central Scotland	UK0037			+		+		m		
North East Scotland	UK0038			+		+		m		
Highland	UK0039			m		m		m		
Scottish Borders	UK0040			m		m		m		
South Wales	UK0041			+		+		+		
North Wales	UK0042			m		m		m		
Northern Ireland	UK0043			+		+		m		

Table 5.2. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)									
- Form 5b List of zones in relation to limit value exceedences for NO_2/NOx									
Zone	Zone code	LV for health (1hr mean)			LV for health (annual mean)			LV for vegetation	
		>LV+MOT	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV	>LV	≤LV
Greater London Urban Area	UK0001		+		+				
West Midlands Urban Area	UK0002			+	m				
Greater Manchester Urban Area	UK0003		+		+				
West Yorkshire Urban Area	UK0004			+	m				
Tyneside	UK0005			+	m				
Liverpool Urban Area	UK0006			+	m				
Sheffield Urban Area	UK0007			+	m				
Nottingham Urban Area	UK0008			+	m				
Bristol Urban Area	UK0009		+		m				
Brighton/Worthing/Littlehampton	UK0010			+		m			
Leicester Urban Area	UK0011			+	m				
Portsmouth Urban Area	UK0012			+		m			
Teesside Urban Area	UK0013			+		m			
The Potteries	UK0014			+	m				
Bournemouth Urban Area	UK0015			+		m			
Reading/Wokingham Urban Area	UK0016			+		m			
Coventry/Bedworth	UK0017			+		m			
Kingston upon Hull	UK0018			+	m				
Southampton Urban Area	UK0019			+	m				
Birkenhead Urban Area	UK0020			+		m			
Southend Urban Area	UK0021			+		m			
Blackpool Urban Area	UK0022			+			+		
Preston Urban Area	UK0023			+		m			
Glasgow Urban Area	UK0024		+		+				
Edinburgh Urban Area	UK0025			+		+			
Cardiff Urban Area	UK0026			+		m			
Swansea Urban Area	UK0027			+			+		
Belfast Urban Area	UK0028			+	m				
Eastern	UK0029			+	m				+

Table 5.2. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)

- Form 5b List of zones in relation to limit value exceedences for NO_2/NOx

Zone	Zone code	LV for health (1hr mean)			LV for health (annual mean)			LV for vegetation	
		>LV+MOT	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV	>LV	≤LV
South West	UK0030			+		+			m
South East	UK0031			+	+				+
East Midlands	UK0032			+	m				m
North West & Merseyside	UK0033			+	m				m
Yorkshire & Humberside	UK0034			+	m				m
West Midlands	UK0035			+	m				m
North East	UK0036			+		m			m
Central Scotland	UK0037			+		m			m
North East Scotland	UK0038			+		m			m
Highland	UK0039			+			+		m
Scottish Borders	UK0040			+			+		m
South Wales	UK0041			+		m			+
North Wales	UK0042						m		m
Northern Ireland	UK0043			+		m			m

Table 5.3. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)

- Form 5c List of zones in relation to limit value exceedences for PM_{10}

Zone	Zone code	LV (24hr mean) Stage 1			LV (annual mean) Stage 1			LV (24hr mean) Stage 2			LV (annual mean) Stage 2		
		>LV+MOT	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV
Greater London Urban Area	UK0001		+		m				+			+	
West Midlands Urban Area	UK0002		m				+		+			+	
Greater Manchester Urban Area	UK0003		+				+		+			+	
West Yorkshire Urban Area	UK0004		m			m			+			+	
Tyneside	UK0005		m				+			+		m	
Liverpool Urban Area	UK0006		m				+		+			+	
Sheffield Urban Area	UK0007		m				+		+			+	
Nottingham Urban Area	UK0008		m				+		+			+	
Bristol Urban Area	UK0009		m				+		+			+	
Brighton/Worthing/Littlehampton	UK0010			m			m					m	
Leicester Urban Area	UK0011		m				+			+		+	
Portsmouth Urban Area	UK0012			+			+		+			+	
Teesside Urban Area	UK0013		m				+		+			+	
The Potteries	UK0014		m				+		+			+	
Bournemouth Urban Area	UK0015			m			m					m	
Reading/Wokingham Urban Area	UK0016			+			+		+			+	
Coventry/Bedworth	UK0017			+			+			+		m	
Kingston upon Hull	UK0018		m				+		+			+	
Southampton Urban Area	UK0019		m				+		+			+	
Birkenhead Urban Area	UK0020			+			+			+		m	
Southend Urban Area	UK0021			+			+			+		m	
Blackpool Urban Area	UK0022			+			+		+			+	

Table 5.3. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)

- Form 5c List of zones in relation to limit value exceedences for PM_{10}

Zone	Zone code	LV (24hr mean) Stage 1			LV (annual mean) Stage 1			LV (24hr mean) Stage 2			LV (annual mean) Stage 2		
		>LV+MOT	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV	>LV+MOT	≤LV+MOT; >LV	≤LV
Preston Urban Area	UK0023			+			+			+		m	
Glasgow Urban Area	UK0024		+				+		+			+	
Edinburgh Urban Area	UK0025			+			+		+			+	
Cardiff Urban Area	UK0026		m				+		+			+	
Swansea Urban Area	UK0027		+				+		+			+	
Belfast Urban Area	UK0028		m				+		+			+	
Eastern	UK0029		m				+		+			+	
South West	UK0030		m				+			+		m	
South East	UK0031		m				+			+		+	
East Midlands	UK0032		m				+			+		+	
North West & Merseyside	UK0033		m				+		+			+	
Yorkshire & Humberside	UK0034		+				+		+			+	
West Midlands	UK0035		m				+			+		+	
North East	UK0036			m			m					m	
Central Scotland	UK0037			+			+		+			m	
North East Scotland	UK0038			+			+			+		m	
Highland	UK0039			m			m					m	
Scottish Borders	UK0040			m			m					m	
South Wales	UK0041		m				+			+		m	
North Wales	UK0042			m			m					m	
Northern Ireland	UK0043			+			+		+			+	

Table 5.4. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)

- Form 5d List of zones in relation to limit value exceedences for lead

Zone	Zone code	LV		
		>LV+MOT	≤LV+MOT; >LV	≤LV
Greater London Urban Area	UK0001			+
West Midlands Urban Area	UK0002			+
Greater Manchester Urban Area	UK0003			+
West Yorkshire Urban Area	UK0004			+
Tyneside	UK0005			+
Liverpool Urban Area	UK0006			
Sheffield Urban Area	UK0007			
Nottingham Urban Area	UK0008			
Bristol Urban Area	UK0009			
Brighton/Worthing/Littlehampton	UK0010			
Leicester Urban Area	UK0011			
Portsmouth Urban Area	UK0012			
Teesside Urban Area	UK0013			
The Potteries	UK0014			
Bournemouth Urban Area	UK0015			
Reading/Wokingham Urban Area	UK0016			
Coventry/Bedworth	UK0017			
Kingston upon Hull	UK0018			
Southampton Urban Area	UK0019			
Birkenhead Urban Area	UK0020			
Southend Urban Area	UK0021			
Blackpool Urban Area	UK0022			
Preston Urban Area	UK0023			
Glasgow Urban Area	UK0024			+
Edinburgh Urban Area	UK0025			
Cardiff Urban Area	UK0026			+
Swansea Urban Area	UK0027			
Belfast Urban Area	UK0028			
Eastern	UK0029			+

Table 5.4. List of zones and agglomerations where levels exceed or do not exceed limit values (LV) or limit values plus margin of tolerance (LV+MOT) (96/62/EC Articles 8, 9 and 11 and 1999/30/EC Annexes I, II, III and IV)				
- Form 5d List of zones in relation to limit value exceedences for lead				
Zone	Zone code	LV		
		>LV+MOT	≤LV+MOT; >LV	≤LV
South West	UK0030			
South East	UK0031			+
East Midlands	UK0032			+
North West & Merseyside	UK0033			+
Yorkshire & Humberside	UK0034			
West Midlands	UK0035			
North East	UK0036			
Central Scotland	UK0037			
North East Scotland	UK0038			
Highland	UK0039			
Scottish Borders	UK0040			+
South Wales	UK0041			+
North Wales	UK0042			
Northern Ireland	UK0043			

5.6 MEASURED EXCEEDENCES OF LIMIT VALUES + MARGINS TOLERANCE

The reasons of the measured exceedences of limit value + margin of tolerance are listed in form 7 of the questionnaire. This information is summarised in Table 5.5.

Table 5.5 Individual exceedences of limit values plus margin of tolerance, 2001

Limit value + MOT	Site	Zone	Date	Level (mgm^{-3})	Reason code	Reason
SO_2 daily	Belfast East	Belfast Urban Area	18/01/01	226	S5	Domestic heating
SO_2 daily	Belfast East	Belfast Urban Area	19/01/01	226	S5	Domestic heating
SO_2 daily	Belfast East	Belfast Urban Area	20/01/01	142	S5	Domestic heating
SO_2 daily	Belfast East	Belfast Urban Area	11/12/01	129	S5	Domestic heating
SO_2 daily	Belfast East	Belfast Urban Area	12/12/01	169	S5	Domestic heating
NO_2 annual	Bury Roadside	Greater Manchester Urban Area		69	S2	Proximity to a major road
NO_2 annual	Camden Kerbside	Greater London Urban Area		66	S2	Proximity to a major road
NO_2 annual	Glasgow Kerbside	Glasgow Urban Area		71	S2	Proximity to a major road
NO_2 annual	London Bromley	Greater London Urban Area		61	S2	Proximity to a major road
NO_2 annual	London Cromwell Road 2	Greater London Urban Area		76	S2	Proximity to a major road
NO_2 annual	London Marylebone Road	Greater London Urban Area		84	S2	Proximity to a major road
NO_2 annual	Oxford Centre	South East		60	S2	Proximity to a major road
NO_2 annual	Southwark Roadside	Greater London Urban Area		65	S2	Proximity to a major road
NO_2 annual	Tower Hamlets Roadside	Greater London Urban Area		69	S2	Proximity to a major road

6 Acknowledgements

This work was funded by the UK Department for Environment, Food and Rural Affairs, Welsh Assembly Government, the Scottish Executive and the Department of the Environment in Northern Ireland. Permission to include monitoring data and detailed information on site locations for the verification sites was kindly provided by the Local Authorities and companies listed in Table A.2 in Appendix 2. Nitrate data was provided by CEH Edinburgh.

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Figure 1.1

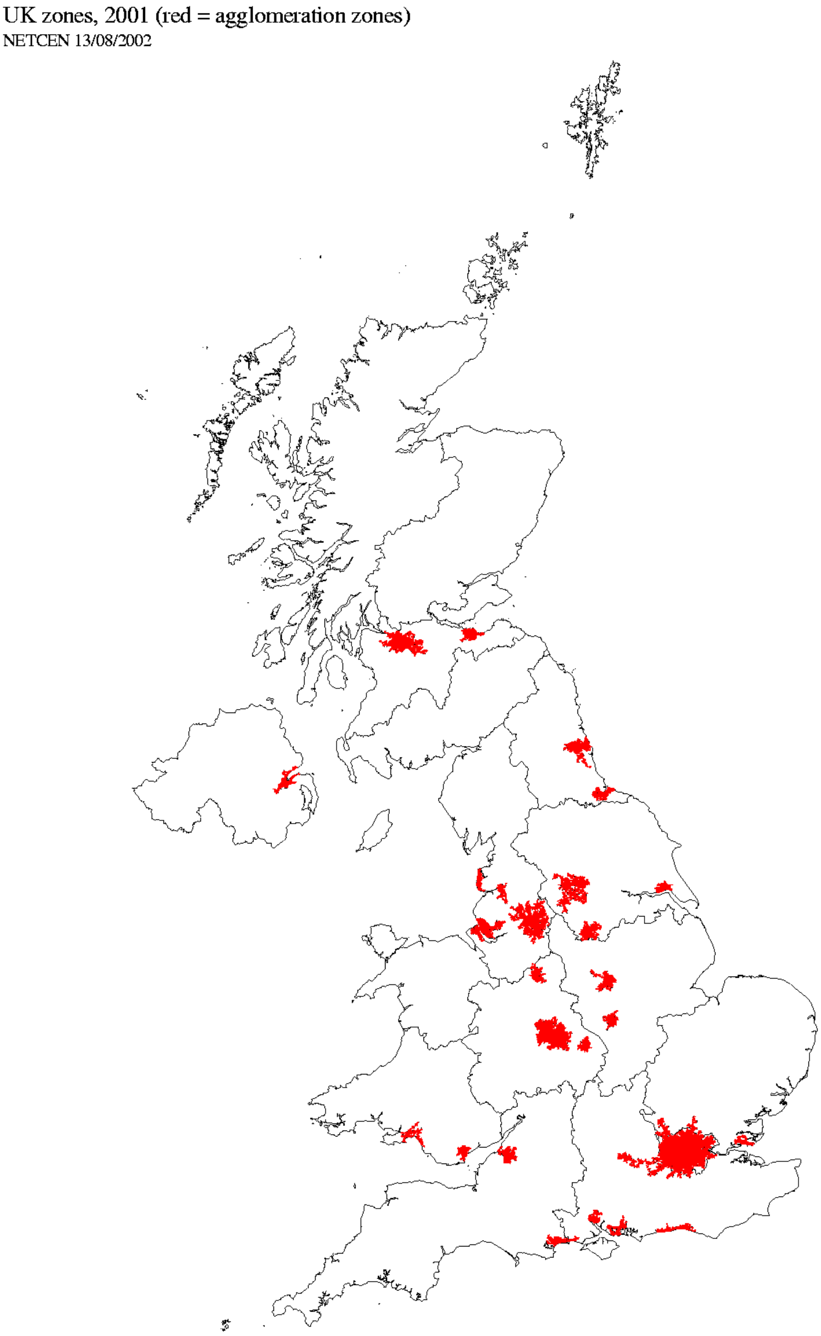


Figure 2.1

Estimated annual mean SO2 concentration, 2001 (ugm-3)

Ecosystem areas only. NETCEN 31/07/2002

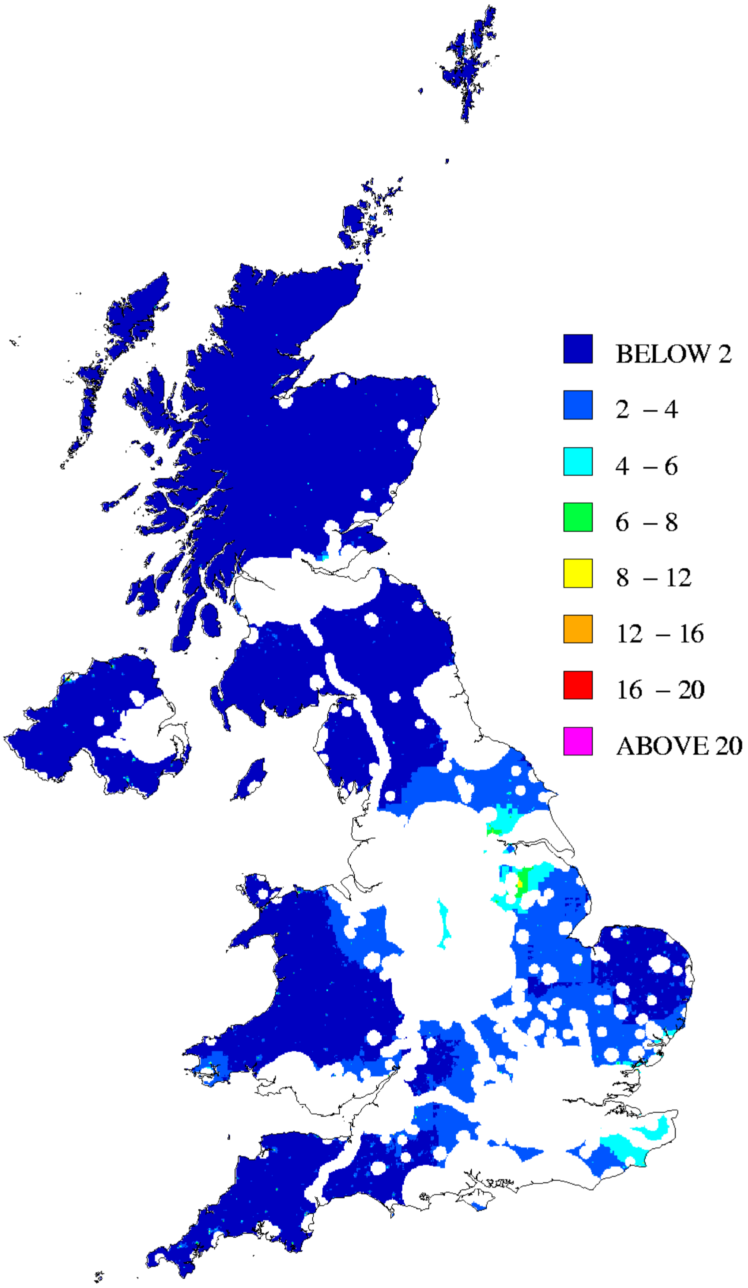


Figure 2.2. Calibration plot for 2001 annual mean SO_2 concentration

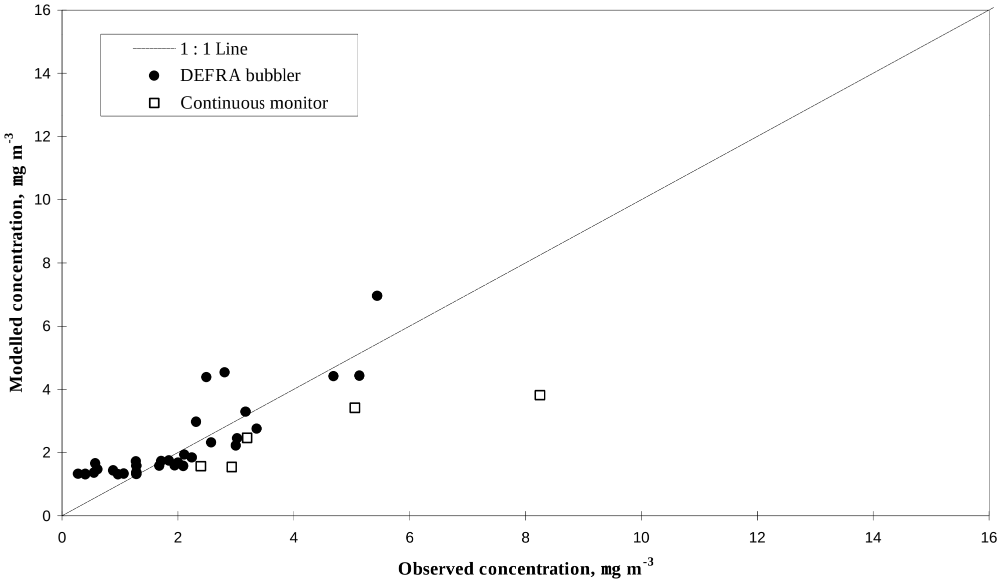


Figure 2.3. Calibration plot for 1998 annual mean SO_2 concentration

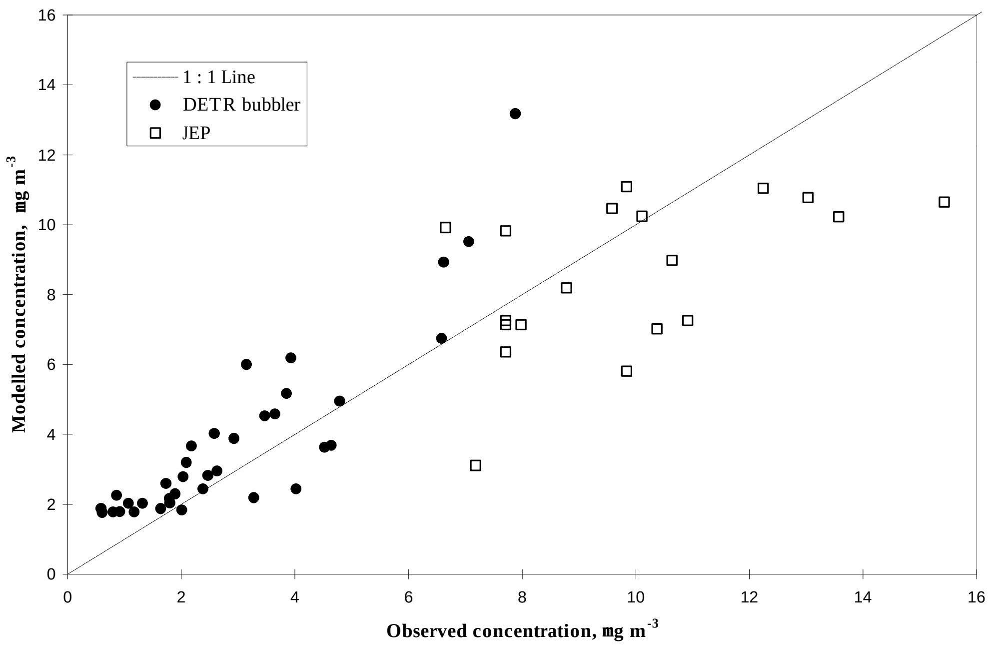


Figure 2.4

Estimated 99.73 percentile of 1-hour mean SO2 concentration, 2001 (ugm-3)
NETCEN 01/08/2002

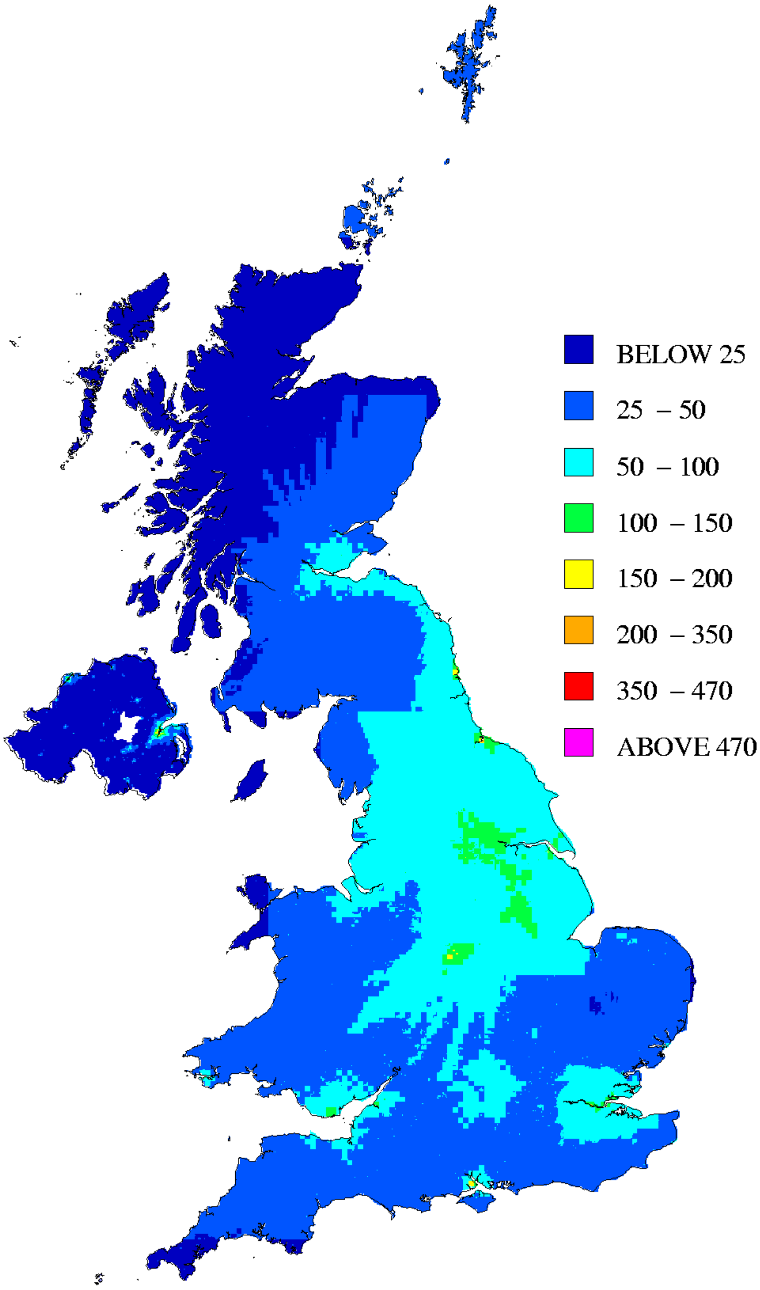


Figure 2.5

Estimated 99.18 percentile of 24-hour mean SO2 concentration, 2001 (ugm-3)
NETCEN 01/08/2002

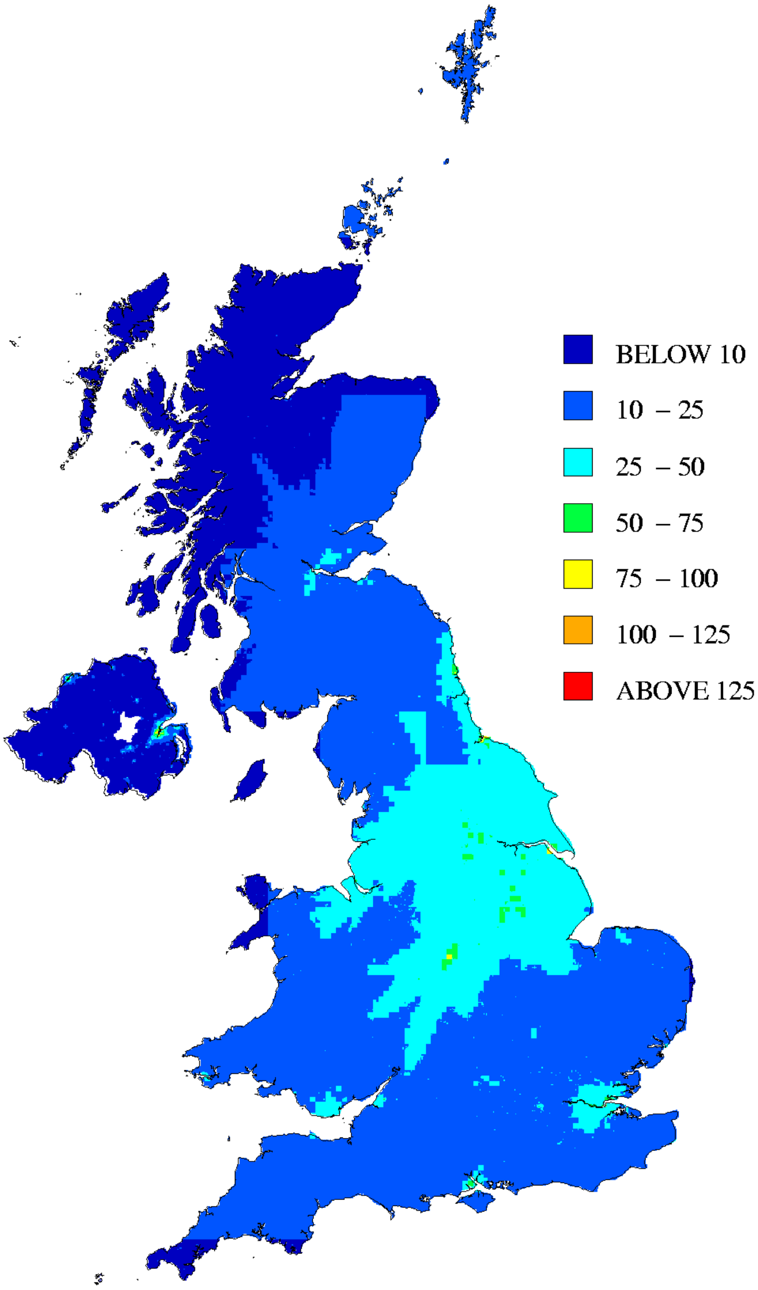


Figure 2.6: A plot of 99.73 percentile of daily mean SO_2 concentration in 2000 versus of 99.73 percentile of daily mean SO_2 concentration in 2001

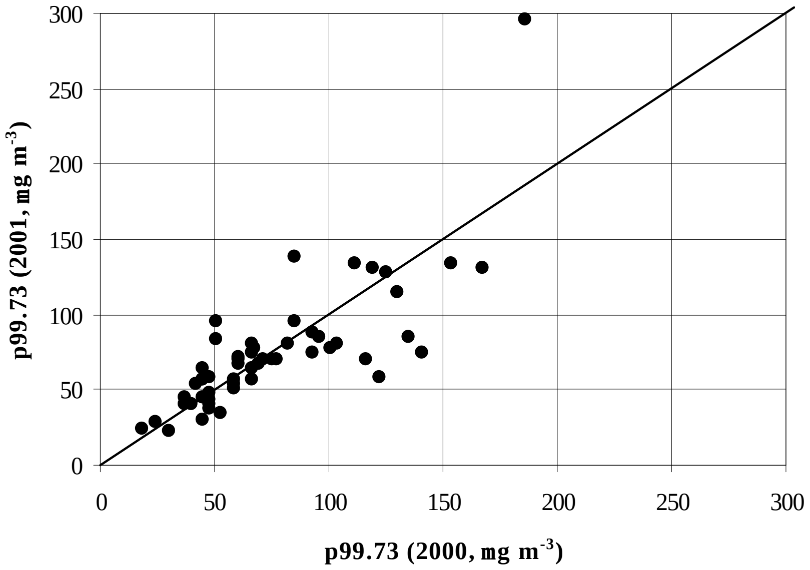


Figure 2.7. Calibration plot for 99.73 percentile of hourly mean SO_2 concentrations 2001

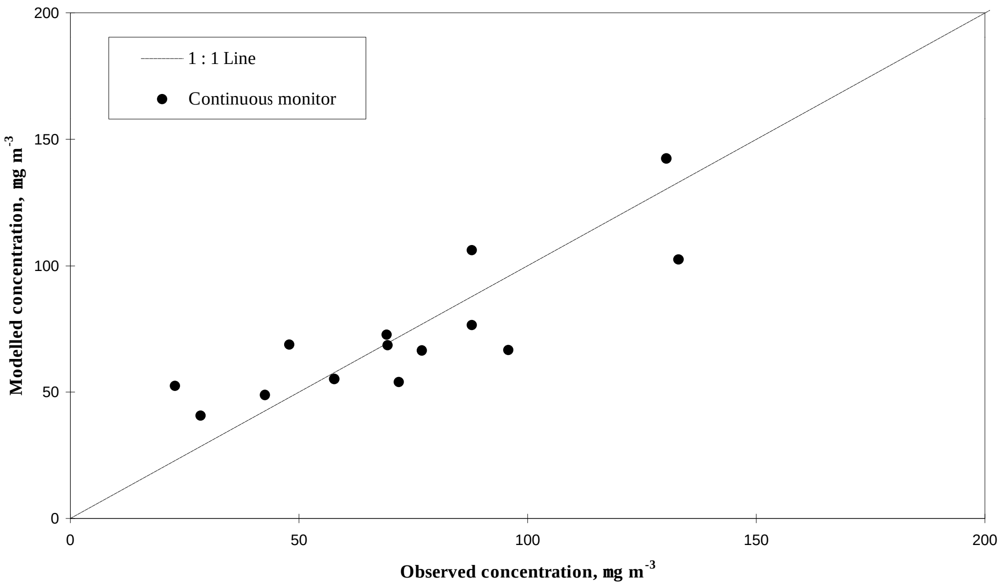


Figure 2.8. Calibration plot for 99.18 percentile of daily mean SO_2 concentrations 2001

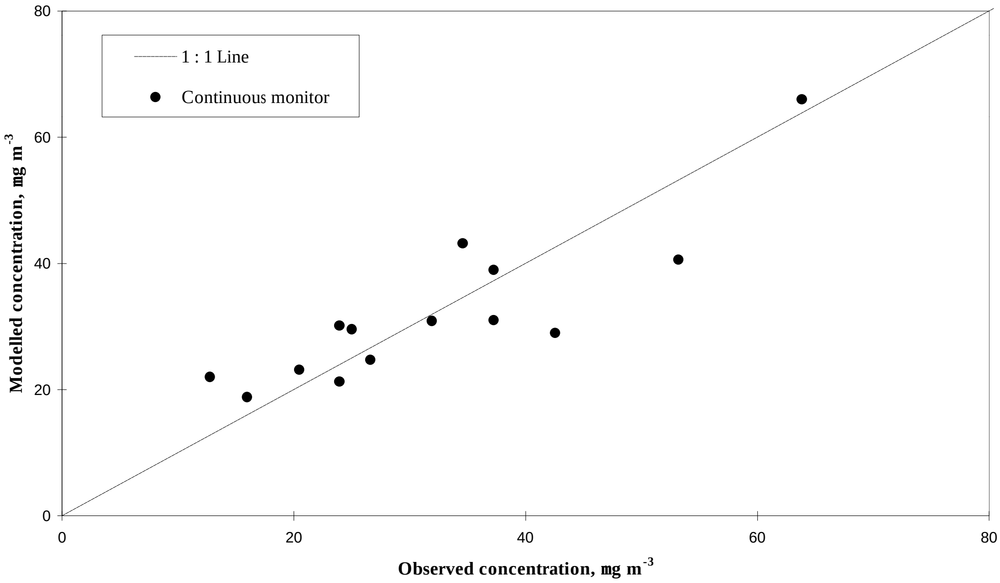


Figure 2.9

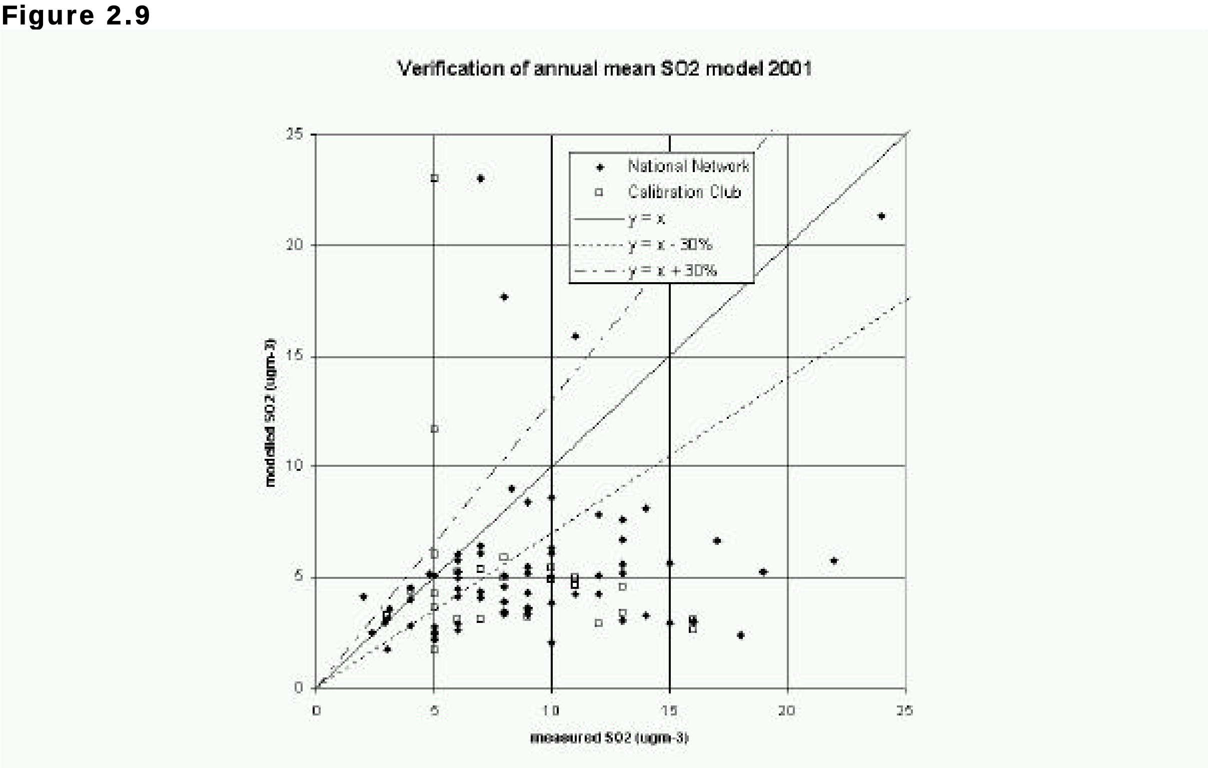


Figure 2.10

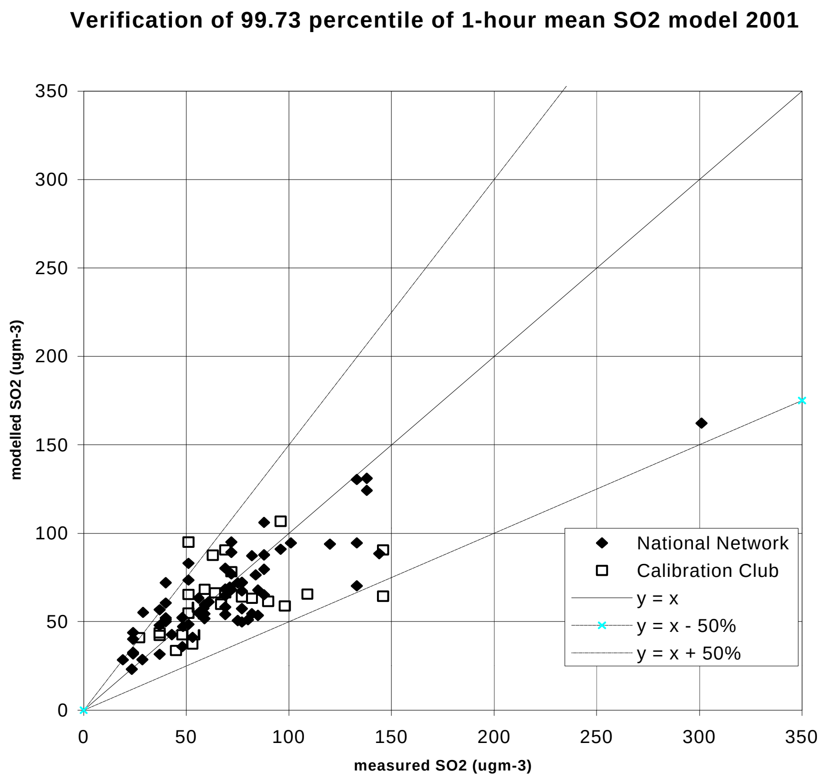


Figure 2.11

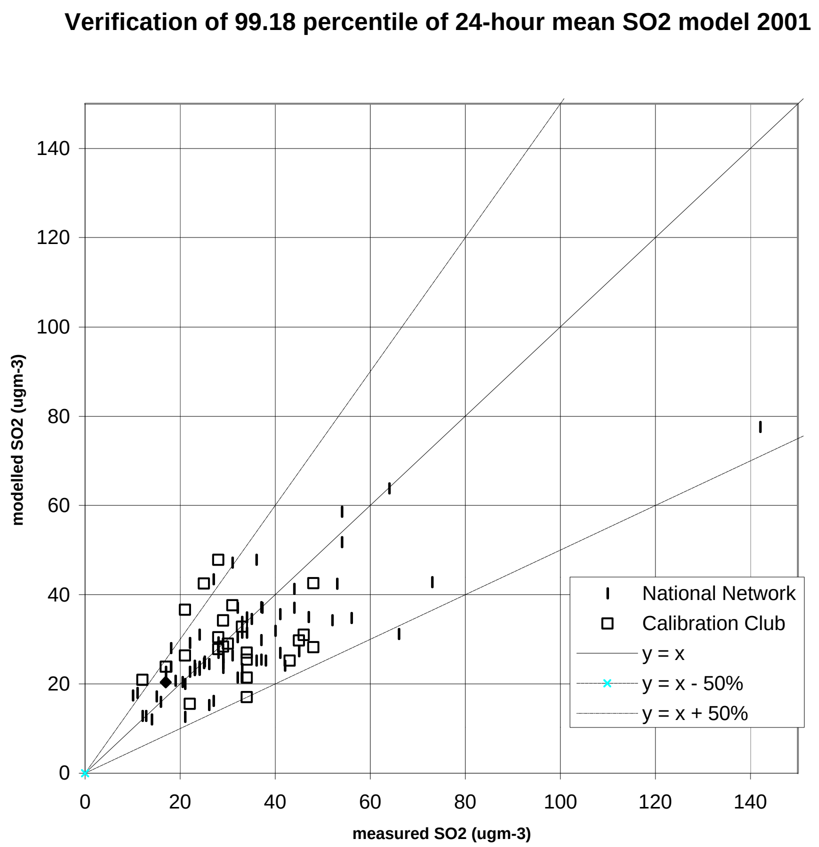


Figure 3.1

Estimated annual mean background nitrogen dioxide concentration, 2001 (ugm-3)
Ref NETCEN 17/09/2002

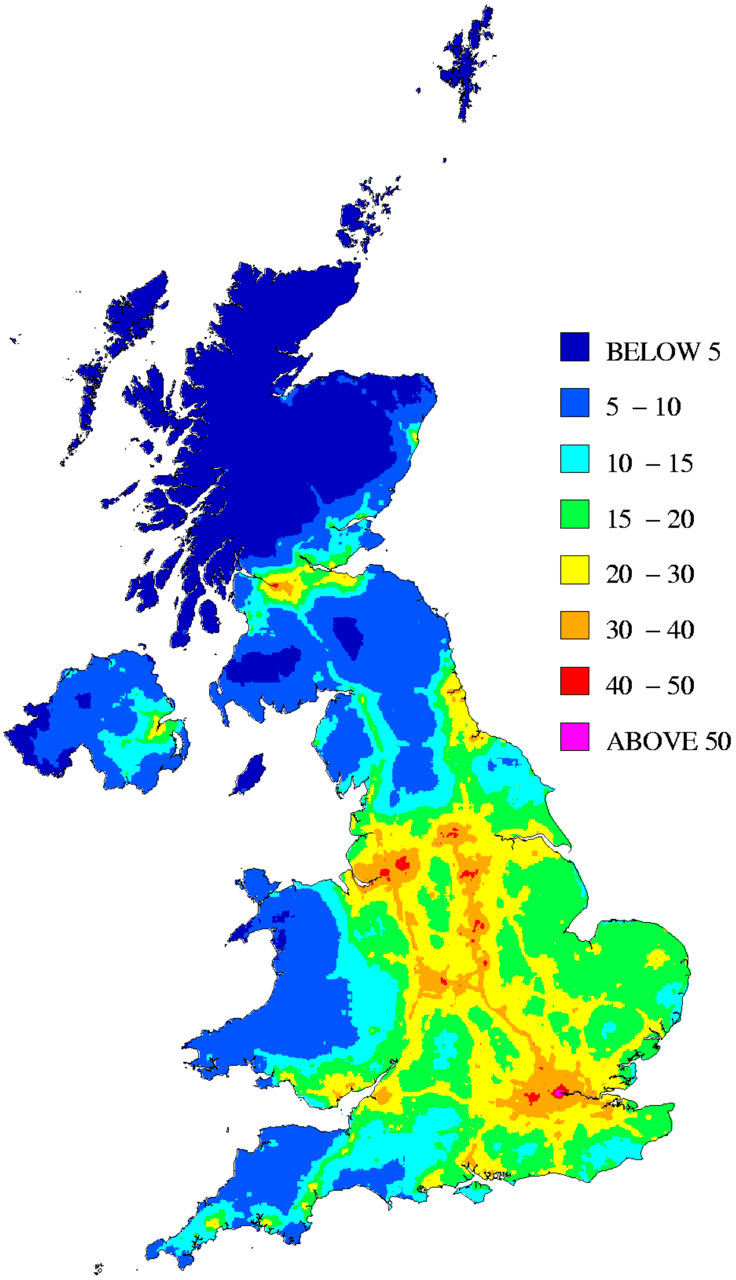


Figure 3.2

Major built-up roads, estimated annual mean roadside NO2 concentration, 2001 (ugm-3) Ref NETCEN 17/09/2002

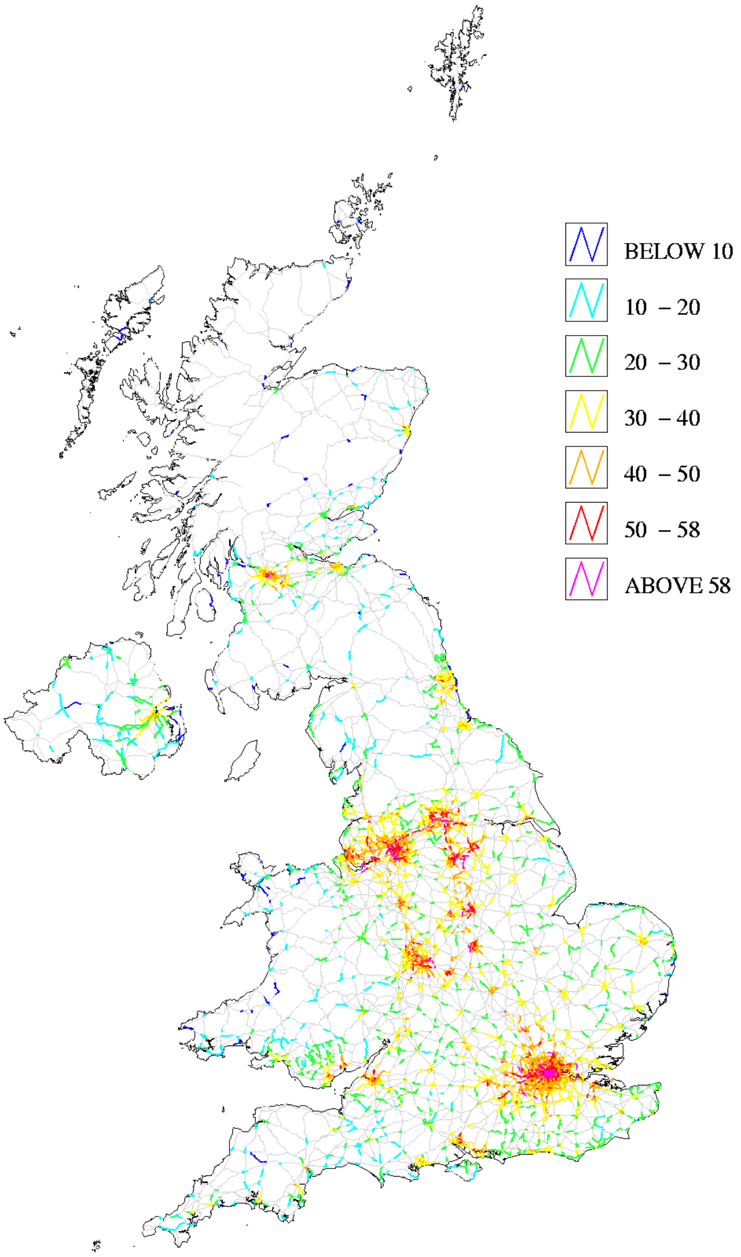


Figure 3.3

Interpolated annual mean rural NOx concentration, 2001 (ugm-3,as NO2)
Vegetation areas only. NETCEN 31/07/2002

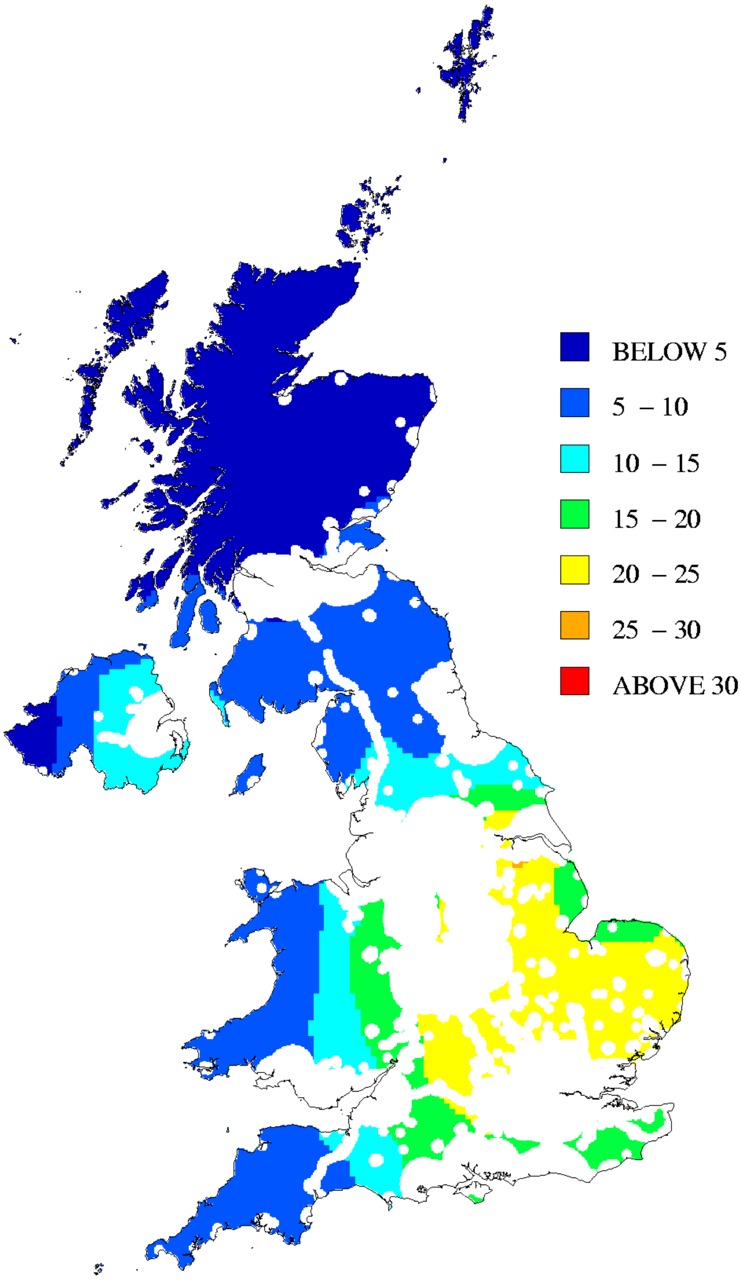


Figure 3.4 Relationship between annual mean NOx and NO_2 concentrations measured at rural background sites in the national networks 1998-2001

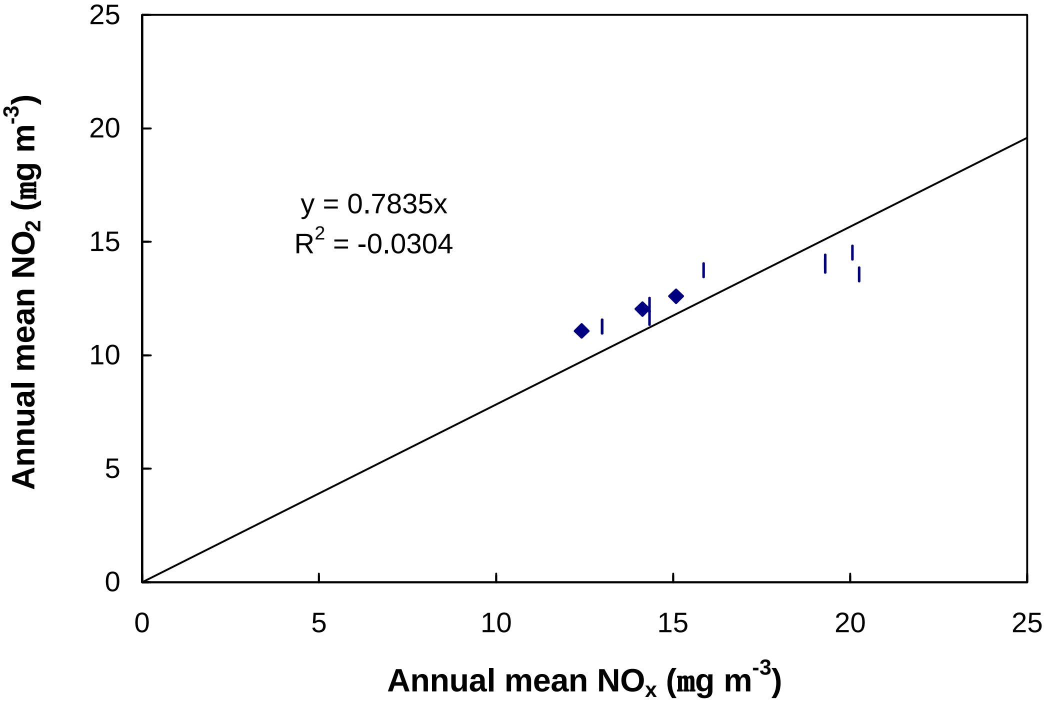


Figure 3.5 Relationship between annual mean NOx and NO_2 concentrations measured at urban background sites in the national networks 1998-2001

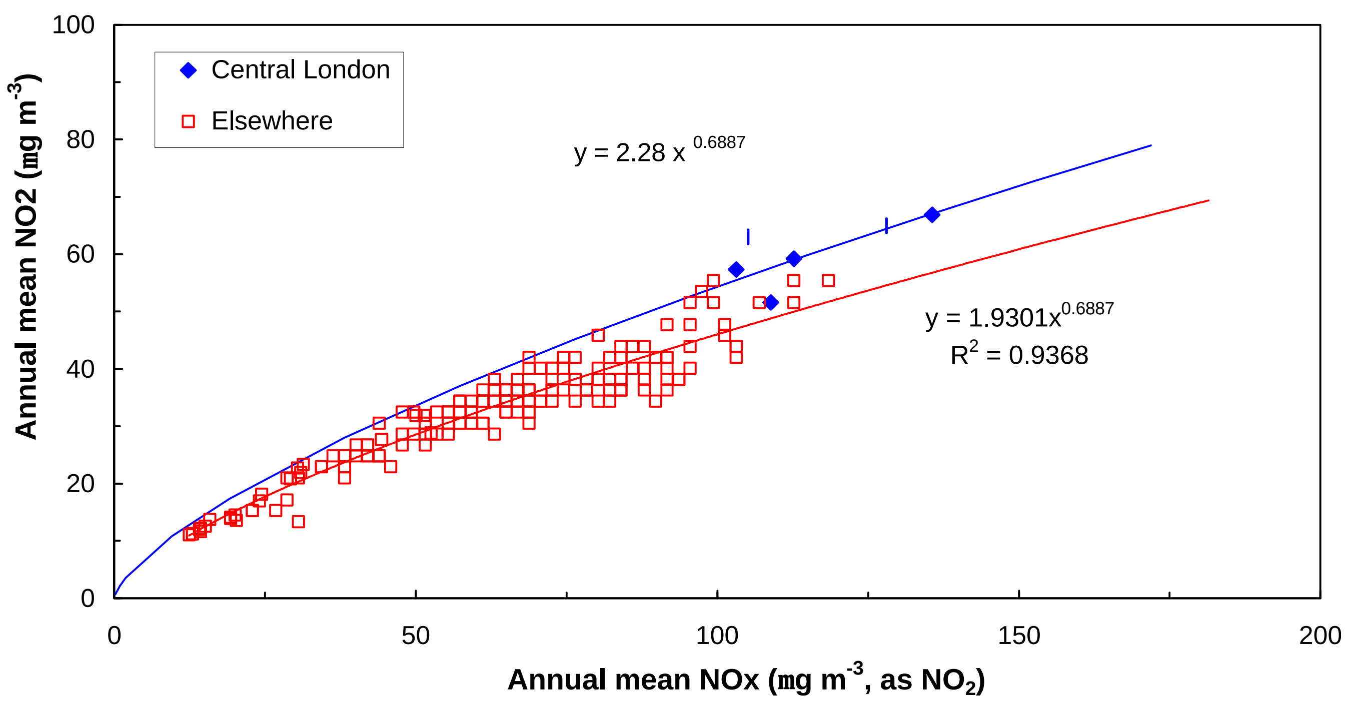


Figure 3.6 Relationship between the NOx: NO_2 ratio and NO_x concentrations at locations close to busy roads AUN and TRL road and kerbside sites 1999-2001

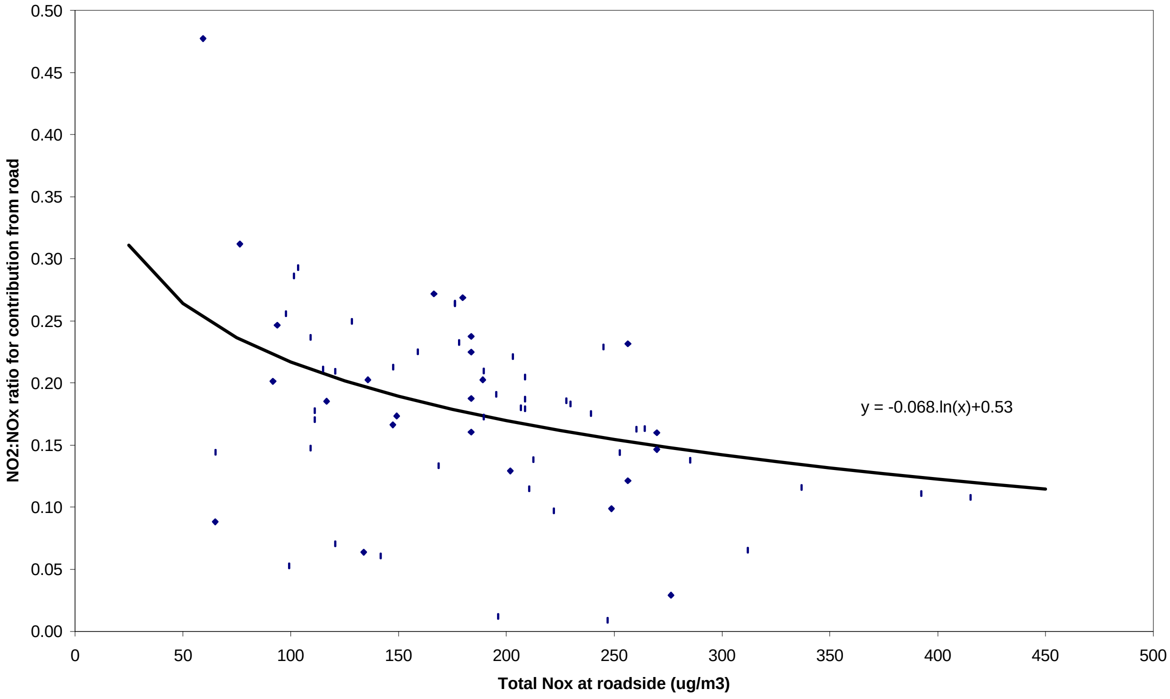


Figure 3.7

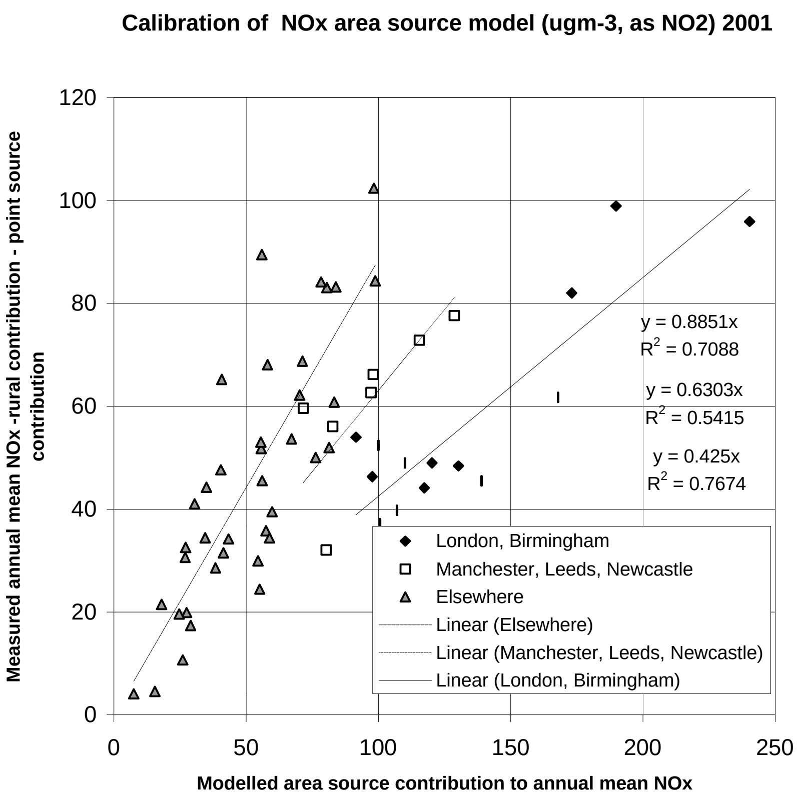


Figure 3.8

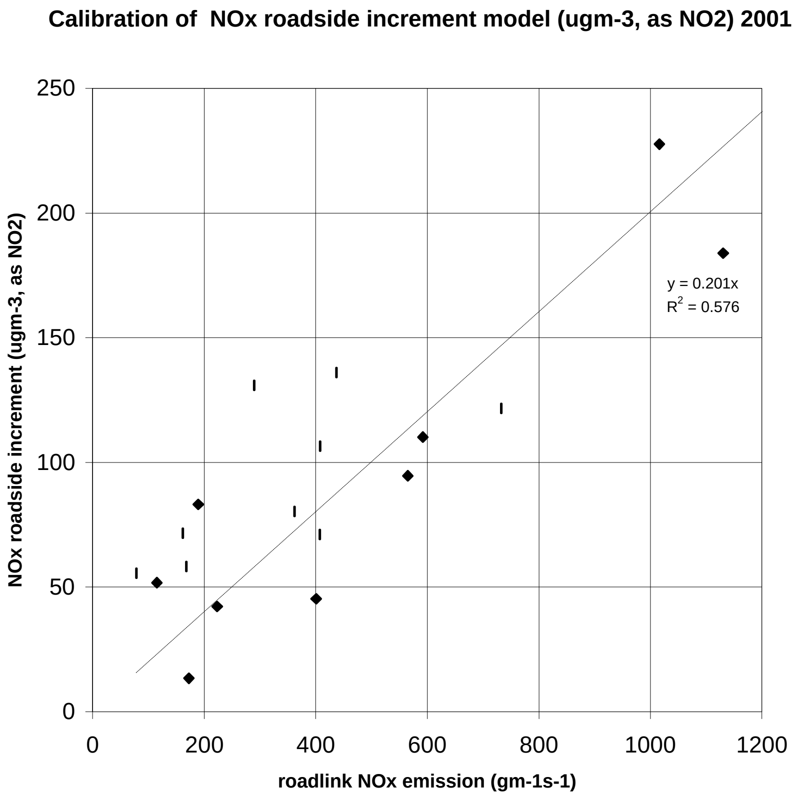

Calibration of NOx roadside increment model (ugm-3, as NO2) 2001
250
200
150
100
50
0
0
200
400
600
800
1000
1200
NOx roadside increment (ugm-3, as NO2)
roadlink NOx emission (gm-1s-1)
y = 0.201x
R2 = 0.576

Figure 3.9

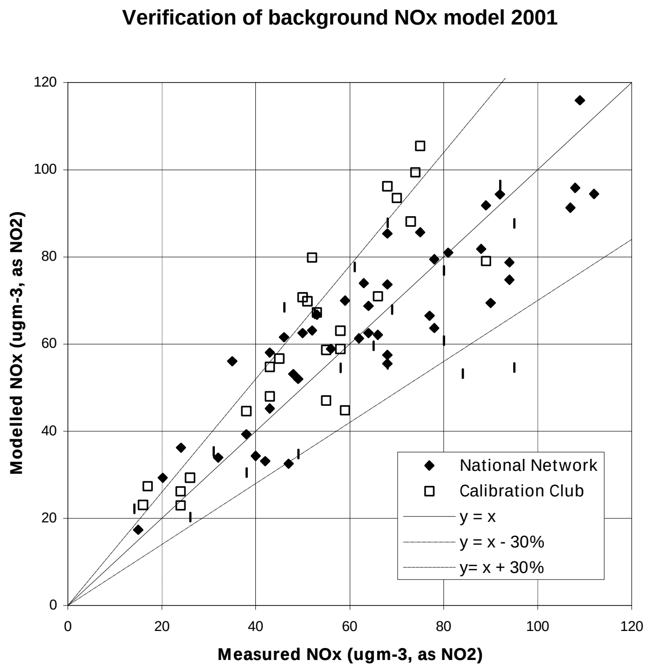


Figure 3.10

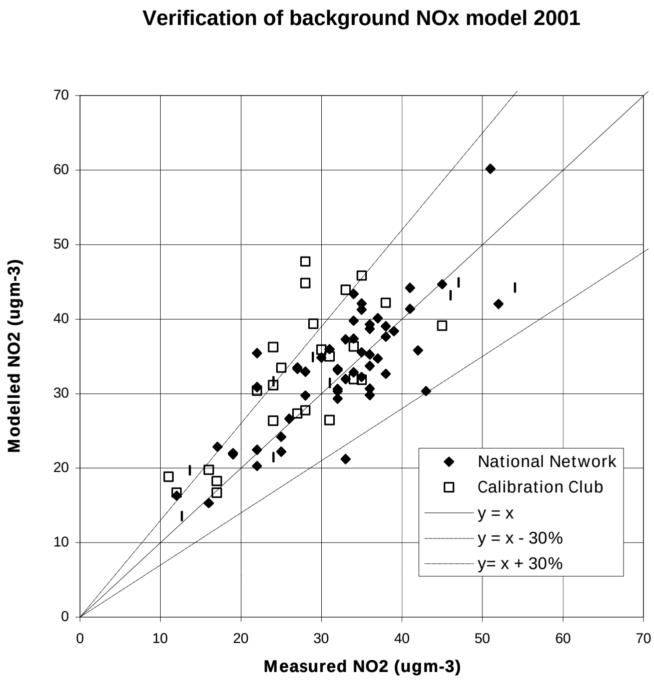


Figure 3.11

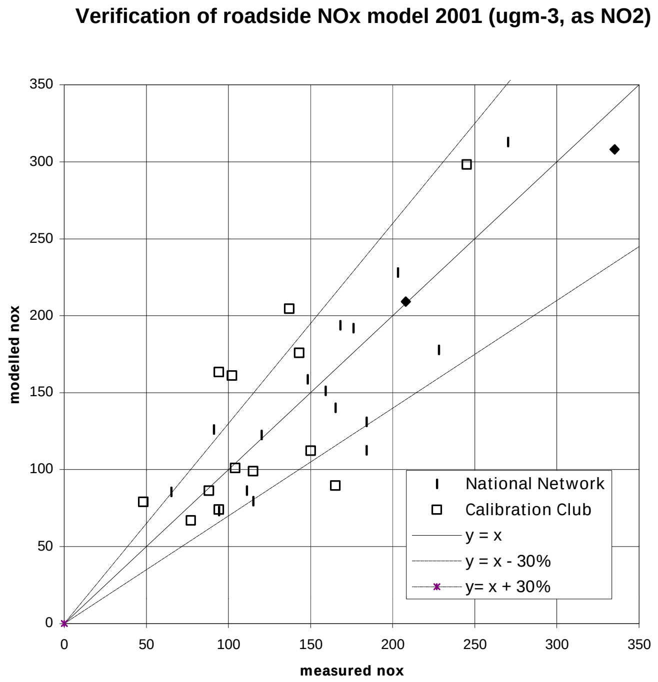


Figure 3.12

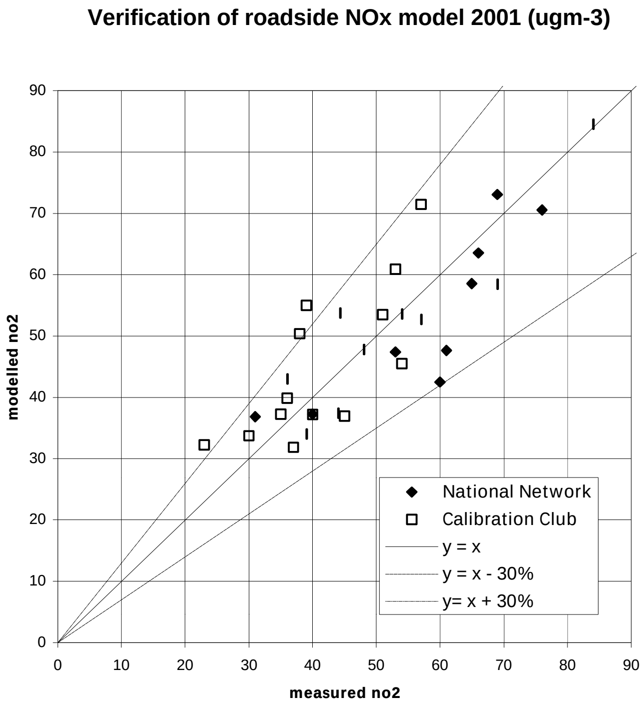


Figure 4.1

Estimated annual mean background PM10 concentration, 2001
(ugm-3, gravimetric) Ref NETCEN 23/07/2002

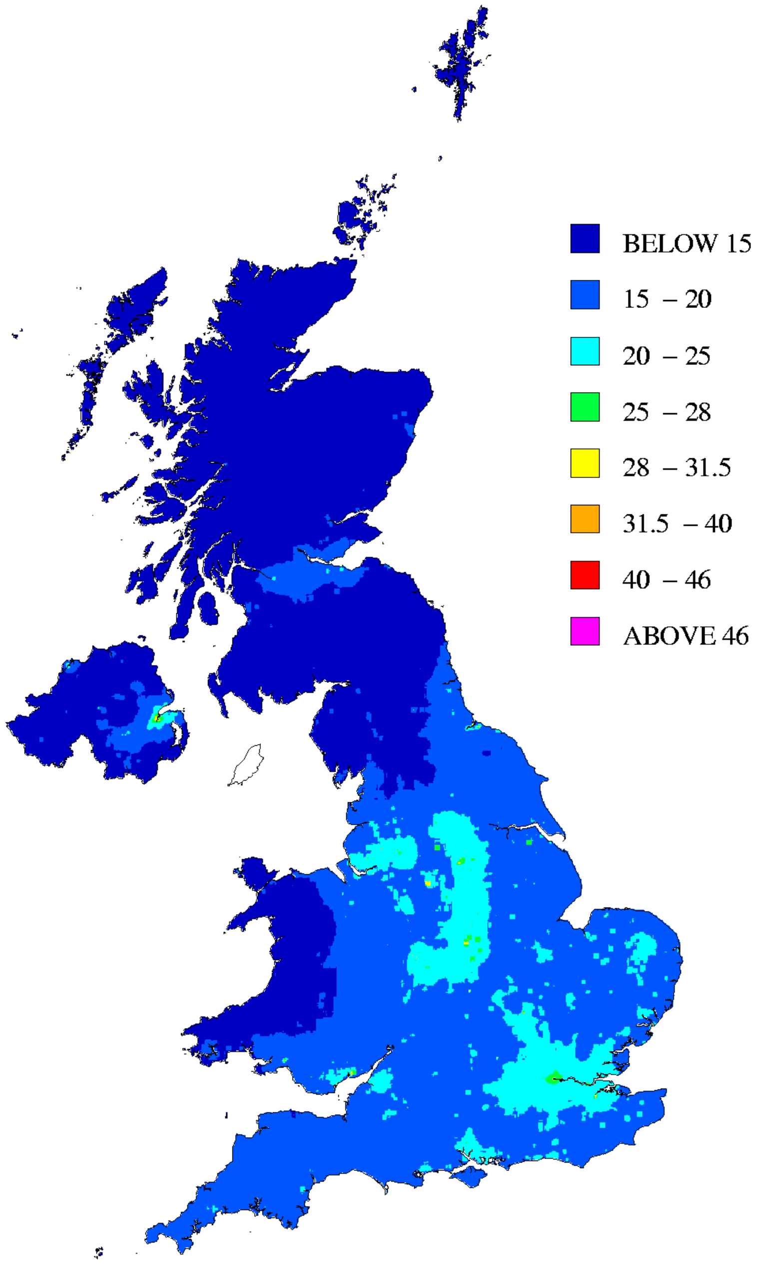


Figure 4.2

Major built-up roads estimated annual mean roadside PM10 concentration, 2001 (ugm-3, gravimetric) Ref NETCEN 23/07/2002

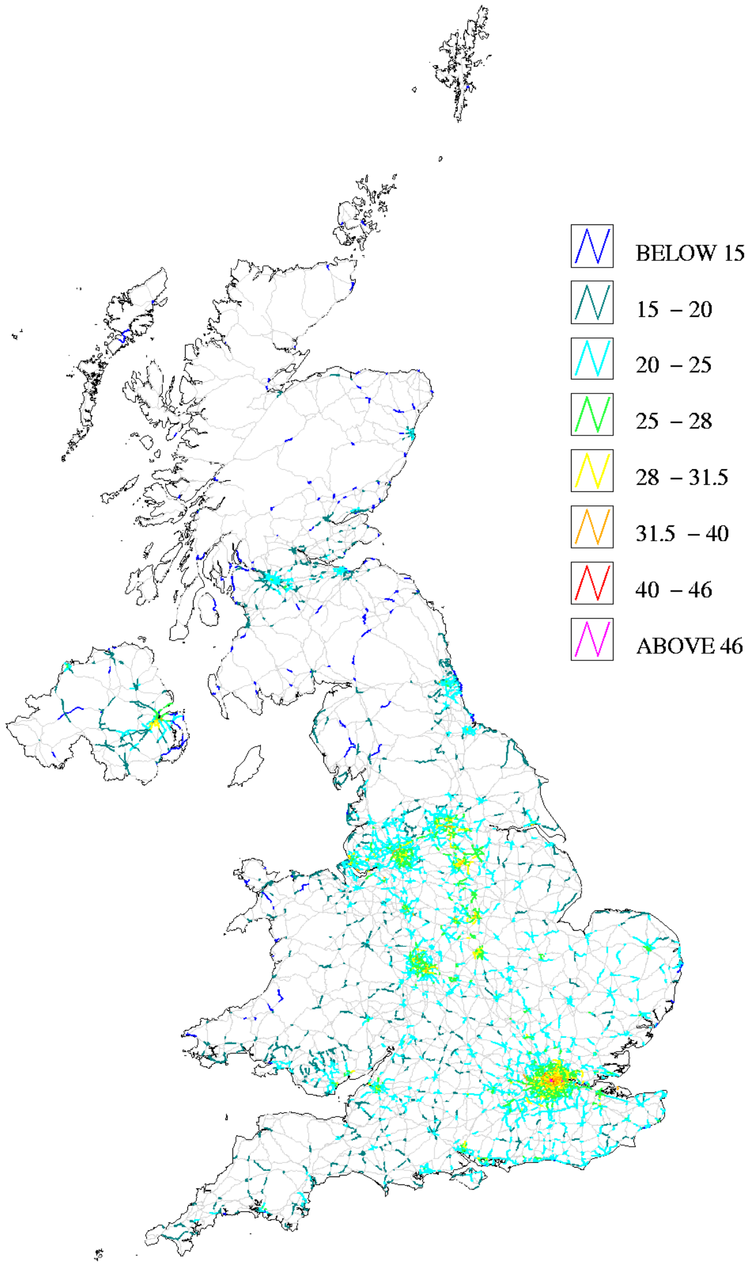


Figure 4.3. The relationship between the number of days with PM_{10} concentrations greater than or equal to 50 μgm^{-3} and annual mean concentration (1992 –1999)

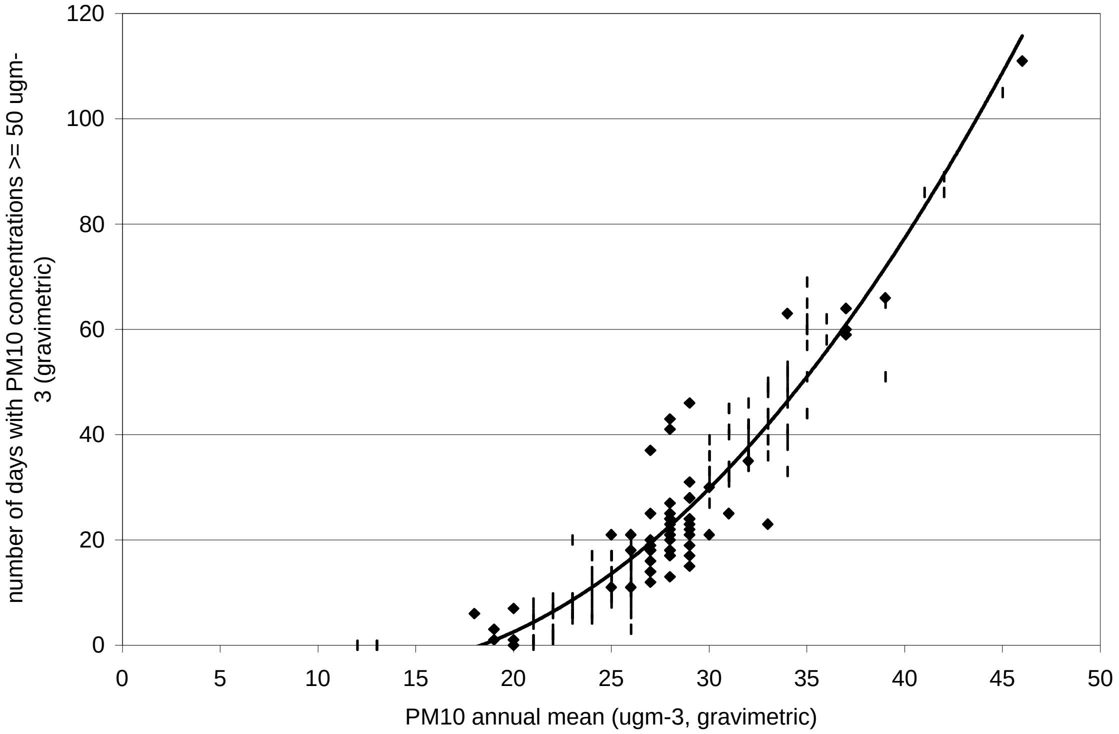


Figure 4.4

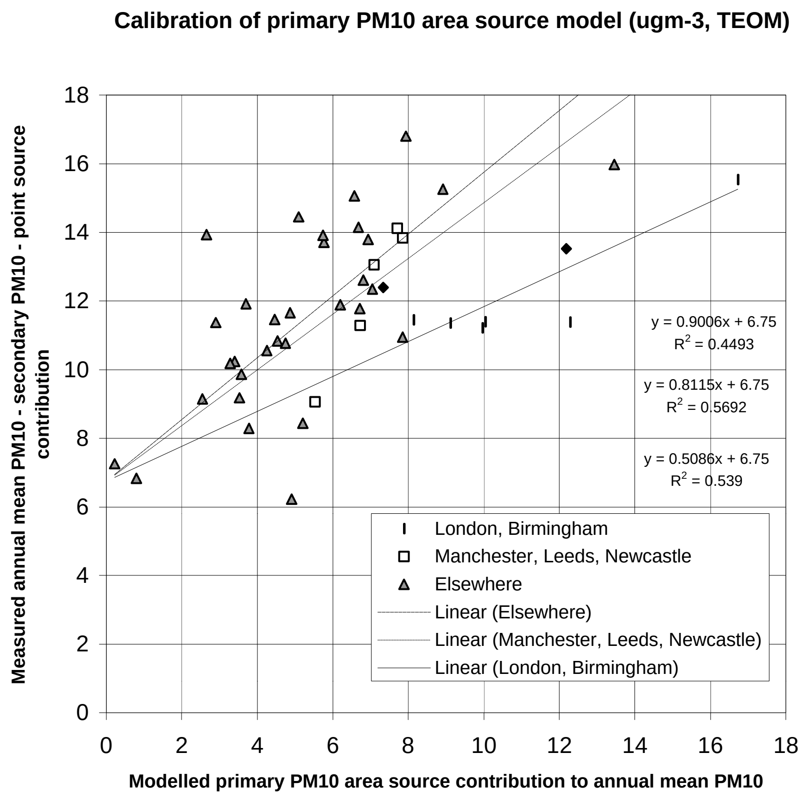


Figure 4.5

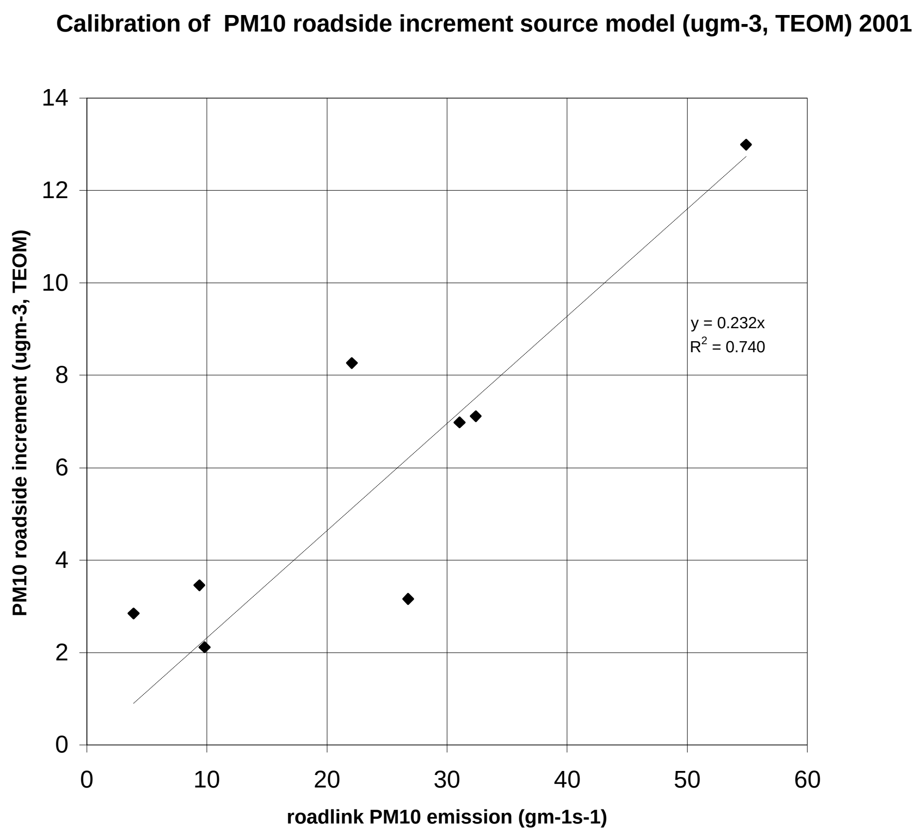


Figure 4.6

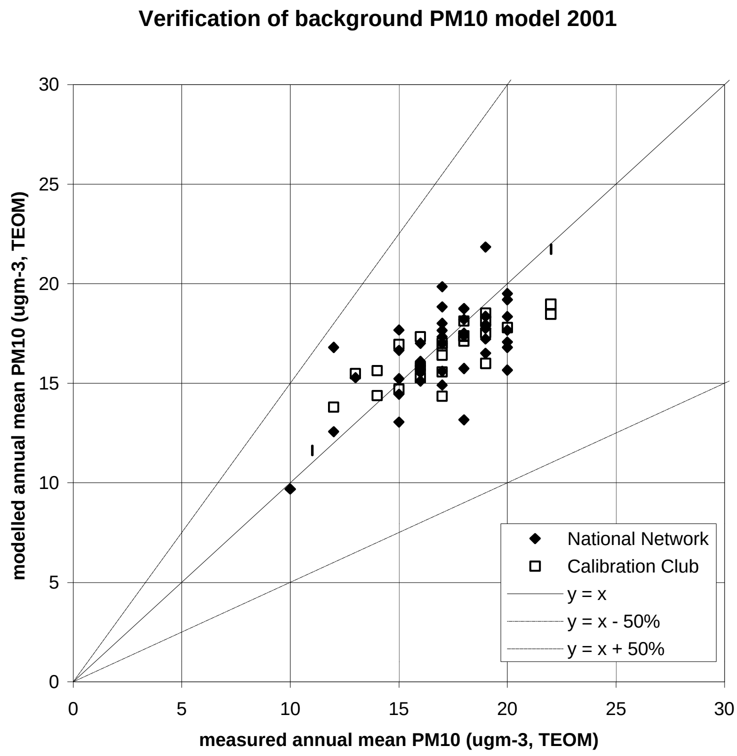
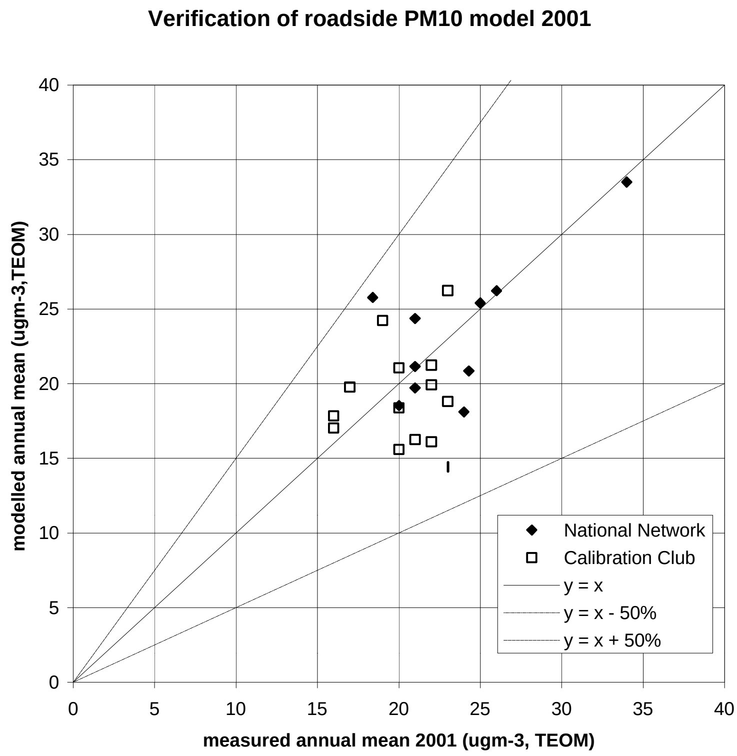


Figure 4.7



APPENDIX 1. NATIONAL NETWORK MONITORING SITES

Table A1.1. Monitoring sites operating during 2001 for AQDD1 reporting.

Station code	Local station code	Zone code	Zone	Use for Directive				Use for Directive / Measuring method
				SO_2	NO_2	NO_x	Lead	PM_{10}
GB0729A	Aberdeen	UK0038	North East Scotland	+	+			M3
GB0600A	Barnsley 12	UK0034	Yorkshire & Humberside	+				
GB0681A	Barnsley Gawber	UK0034	Yorkshire & Humberside	+	+			
GB0647A	Bath Roadside	UK0030	South West		+			
GB0567A	Belfast Centre	UK0028	Belfast Urban Area	+	+			M3
GB0696A	Belfast Clara St	UK0028	Belfast Urban Area					M1
GB0514A	Belfast East	UK0028	Belfast Urban Area	+				
GB0421A	Billingham	UK0013	Teesside Urban Area		+			
GB0569A	Birmingham Centre	UK0002	West Midlands Urban Area	+	+			M3
GB0595A	Birmingham East	UK0002	West Midlands Urban Area	+	+			M3
GB0727A	Blackpool	UK0022	Blackpool Urban Area	+	+			M3
GB0654A	Bolton	UK0003	Greater Manchester Urban Area	+	+			M3
GB0741A	Bournemouth	UK0015	Bournemouth Urban Area	+	+			M2
GB0689A	Bradford Centre	UK0004	West Yorkshire Urban Area	+	+			M3
GB0693A	Brighton Roadside	UK0010	Brighton/Worthing/Littlehampton		+			
GB0585A	Bristol Centre	UK0009	Bristol Urban Area	+	+			M3
GB0639A	Bristol Old Market	UK0009	Bristol Urban Area		+			
GB0416A	Brookside 1 lead site	UK0002	West Midlands Urban Area				+	
GB0417A	Brookside 2 lead site	UK0002	West Midlands Urban Area				+	
GB0652A	Bury Roadside	UK0003	Greater Manchester Urban Area	+	+			M3
GB0726A	Cambridge Roadside	UK0029	Eastern		+			
GB0636A	Camden Kerbside	UK0001	Greater London Urban Area		+			M3
GB0737A	Canterbury	UK0031	South East		+			M3
GB0580A	Cardiff Centre	UK0026	Cardiff Urban Area	+	+			M3
GB0369A	Cardiff lead site	UK0026	Cardiff Urban Area				+	
GB0194A	Chilton lead site	UK0031	South East				+	
GB0362A	Cottered lead site	UK0029	Eastern				+	
GB0739A	Coventry Memorial Park	UK0017	Coventry/Bedworth	+	+			M3
GB0744A	Cwmbran	UK0041	South Wales	+	+			M3
GB0673A	Derry	UK0043	Northern Ireland	+	+			M3
GB0740A	Dumfries	UK0040	Scottish Borders		+			M2
GB0581A	Edinburgh Centre	UK0025	Edinburgh Urban Area	+	+			M3
GB0410A	Elswick 1 lead site	UK0005	Tyneside				+	
GB0411A	Elswick 2 lead site	UK0005	Tyneside				+	
GB0419A	Elswick 3 lead site	UK0005	Tyneside				+	
GB0361A	Eskdalemuir lead site	UK0040	Scottish Borders				+	

Station code	Local station code	Zone code	Zone	Use for Directive				Use for Directive / Measuring method
				SO_2	NO_2	NO_x	Lead	PM_{10}
GB0640A	Exeter Roadside	UK0030	South West	+	+			
GB0641A	Glasgow Centre	UK0024	Glasgow Urban Area	+	+			M3
GB0452A	Glasgow City Chambers	UK0024	Glasgow Urban Area		+			
GB0657A	Glasgow Kerbside	UK0024	Glasgow Urban Area		+			M3
GB0260A	Glasgow lead site	UK0024	Glasgow Urban Area				+	
GB0735A	Grangemouth	UK0037	Central Scotland	+	+			M3
GB0637A	Haringey Roadside	UK0001	Greater London Urban Area		+			M3
GB0036R	Harwell	UK0031	South East	+	+	+		
GB0685A	Hounslow Roadside	UK0001	Greater London Urban Area		+			
GB0686A	Hove Roadside	UK0010	Brighton/Worthing/Littlehampton	+	+			
GB0596A	Hull Centre	UK0018	Kingston upon Hull	+	+			M3
GB0381A	IMI 1 lead site	UK0002	West Midlands Urban Area				+	
GB0382A	IMI 2 lead site	UK0002	West Midlands Urban Area				+	
GB0454A	IMI 5 lead site	UK0002	West Midlands Urban Area				+	
GB0742A	Inverness	UK0039	Highland		+			M2
GB0037R	Ladybower	UK0032	East Midlands	+	+			
GB0643A	Leamington Spa	UK0035	West Midlands	+	+			M3
GB0584A	Leeds Centre	UK0004	West Yorkshire Urban Area	+	+			M3
GB0248A	Leeds lead site	UK0004	West Yorkshire Urban Area				+	
GB0597A	Leicester Centre	UK0011	Leicester Urban Area	+	+			M3
GB0594A	Liverpool Centre	UK0006	Liverpool Urban Area	+	+			M3
GB0659A	London A3 Roadside	UK0001	Greater London Urban Area		+			M3
GB0608A	London Bexley	UK0001	Greater London Urban Area	+	+			M3
GB0566A	London Bloomsbury	UK0001	Greater London Urban Area	+	+			M3
GB0616A	London Brent	UK0001	Greater London Urban Area	+	+			M3
GB0635A	London Brent Park lead site	UK0001	Greater London Urban Area				+	
GB0697A	London Bromley	UK0001	Greater London Urban Area		+			
GB0695A	London Cromwell Road 2	UK0001	Greater London Urban Area	+	+			
GB0332A	London Cromwell Road lead site	UK0001	Greater London Urban Area				+	
GB0586A	London Eltham	UK0001	Greater London Urban Area	+	+			M3
GB0650A	London Hackney	UK0001	Greater London Urban Area		+			
GB0642A	London Hillingdon	UK0001	Greater London Urban Area	+	+			M3
GB0672A	London Lewisham	UK0001	Greater London Urban Area	+	+			
GB0682A	London Marylebone Road	UK0001	Greater London Urban Area	+	+			M3
GB0620A	London N. Kensington	UK0001	Greater London Urban Area	+	+			M3
GB0656A	London	UK0001	Greater London Urban	+	+			

Station code	Local station code	Zone code	Zone	Use for Directive				Use for Directive / Measuring method
				SO_2	NO_2	NO_x	Lead	PM_{10}
	Southwark		Area					
GB0621A	London Sutton	UK0001	Greater London Urban Area		+			
GB0644A	London Teddington	UK0001	Greater London Urban Area	+	+			
GB0622A	London Wandsworth	UK0001	Greater London Urban Area		+			
GB0743A	London Westminster	UK0001	Greater London Urban Area	+	+			
GB0006R	Lough Navar	UK0043	Northern Ireland					M3
GB0038R	Lullington Heath	UK0031	South East	+	+			
GB0370A	Manchester lead site	UK0003	Greater Manchester Urban Area				+	
GB0613A	Manchester Piccadilly	UK0003	Greater Manchester Urban Area	+	+			M3
GB0649A	Manchester South	UK0003	Greater Manchester Urban Area	+	+			
GB0453A	Manchester Town Hall	UK0003	Greater Manchester Urban Area		+			
GB0583A	Middlesbrough	UK0013	Teesside Urban Area	+	+			M3
GB0241A	Motherwell lead site	UK0024	Glasgow Urban Area				+	
GB0043R	Narberth	UK0041	South Wales	+	+	+		M3
GB0568A	Newcastle Centre	UK0005	Tyneside	+	+			M3
GB0365A	Newcastle lead site	UK0005	Tyneside				+	
GB0738A	Northampton	UK0032	East Midlands	+	+			M3,M2
GB0684A	Norwich Centre	UK0029	Eastern	+	+			M3
GB0678A	Norwich Roadside	UK0029	Eastern		+			
GB0646A	Nottingham Centre	UK0008	Nottingham Urban Area	+	+			M3
GB0633A	Oxford Centre	UK0031	South East	+	+			
GB0687A	Plymouth Centre	UK0030	South West	+	+			M3
GB0651A	Port Talbot	UK0027	Swansea Urban Area	+	+			M3
GB0733A	Portsmouth	UK0012	Portsmouth Urban Area	+	+			M3
GB0731A	Preston	UK0023	Preston Urban Area	+	+			M3
GB0683A	Reading	UK0016	Reading/Wokingham Urban Area	+	+			M3
GB0679A	Redcar	UK0013	Teesside Urban Area	+	+			M3
GB0617A	Rochester	UK0031	South East	+	+			M3
GB0677A	Rotherham Centre	UK0007	Sheffield Urban Area	+	+			
GB0660A	Salford Eccles	UK0003	Greater Manchester Urban Area	+	+			M3
GB0698A	Sandwell West Bromwich	UK0002	West Midlands Urban Area	+	+			
GB0690A	Scunthorpe	UK0034	Yorkshire & Humberside	+				M3
GB0615A	Sheffield Centre	UK0007	Sheffield Urban Area	+	+			M3
GB0538R	Sheffield Tinsley	UK0007	Sheffield Urban Area		+			
GB0598A	Southampton Centre	UK0019	Southampton Urban Area	+	+			M3
GB0728A	Southend-on-Sea	UK0021	Southend Urban Area	+	+			M3
GB0667A	Southwark Roadside	UK0001	Greater London Urban Area	+	+			
GB0648A	Stockport	UK0003	Greater Manchester Urban Area	+	+			M3

Station code	Local station code	Zone code	Zone	Use for Directive				Use for Directive / Measuring method
				SO_2	NO_2	NO_x	Lead	PM_{10}
GB0734A	Stockton-on-Tees Yarm	UK0036	North East		+			M3
GB0658A	Stoke-on-Trent Centre	UK0014	The Potteries	+	+			M3
GB0015R	Strath Vaich	UK0039	Highland	+	+			
GB0193A	Styrrup lead site	UK0032	East Midlands				+	
GB0582A	Sunderland	UK0036	North East	+				
GB0623A	Sutton Roadside	UK0001	Greater London Urban Area	+	+			M3
GB0609A	Swansea	UK0027	Swansea Urban Area	+	+			M3
GB0645A	Thurrock	UK0029	Eastern	+	+			M3
GB0642A	Tower Hamlets Roadside	UK0001	Greater London Urban Area		+			
GB0198A	Trebanos lead site	UK0041	South Wales				+	
GB0455A	Walsall Alumwell	UK0002	West Midlands Urban Area		+			
GB0674A	Walsall Willenhall	UK0002	West Midlands Urban Area		+			
GB0420A	West London	UK0001	Greater London Urban Area		+			
GB0045R	Wicken Fen	UK0029	Eastern	+	+	+		
GB0736A	Wigan Leigh	UK0033	North West & Merseyside	+	+			M3
GB0730A	Wirral Tranmere	UK0020	Birkenhead Urban Area	+	+			M3
GB0614A	Wolverhampton Centre	UK0002	West Midlands Urban Area	+	+			M3
GB0192A	Wraymires lead site	UK0033	North West & Merseyside				+	

+ = monitoring for the Directive at that site
M1 = Beta Attenuation Monitor, M2 =Gravimetric, M3 = TEOM measurements for PM_{10}

Table A1.2. Measurements with between 75 % and 90 % data capture (included in analysis)

Site	Zone code	Data capture SO_2 %	Data capture NO_2 %	Data capture PM_{10} TEOM %
Barnsley Gawber	UK0034		85.4	
Bath Roadside	UK0030		84.1	
Belfast Centre	UK0028	89.9	87.9	80.8
Blackpool	UK0022	89.4	89.6	
Bournemouth	UK0015	77.3		
Bradford Centre	UK0004	88.7		
Coventry Memorial Park	UK0017	75.3		81.3
Dumfries	UK0040		79.2	
Glasgow Centre	UK0024	75.7	85.6	
Grangemouth	UK0037	86.5		
Harwell	UK0031		84	
Ladybower	UK0032		88.4	
London Bloomsbury	UK0001		86.9	
London Brent	UK0001		88.9	
London Bromley	UK0001		88.5	
London Hillingdon	UK0001	80		
London Marylebone Road	UK0001	84.7		89.1
Newcastle Centre	UK0005		85.6	
Northampton	UK0032	86		
Norwich Centre	UK0029	75.9		
Nottingham Centre	UK0008	89.6	84.6	
Preston	UK0023	84.9		
Redcar	UK0013		82.6	
Rochester	UK0031	83.8		
Sutton Roadside	UK0001			86.2
Thurrock	UK0029			75.9
Tower Hamlets Roadside	UK0001		87.6	
Wicken Fen	UK0029		87.5	
Wirral Tranmere	UK0020	79.8		

Table A1.3. Measurements with less than 75 % data capture (not included in analysis but listed in Table A1.1 and form 3)

Site	Zone code	Data capture SO_2 %	Data capture NO_2 %	Data capture PM_{10} TEOM %	Data capture PM_{10} Gravimetric %
Bournemouth	UK0015		68.5		42
Coventry Memorial Park	UK0017		63.6		
Cwmbran	UK0041	42.9	42.7	43.5	
Dumfries	UK0040				40
Grangemouth	UK0037			74.9	
Inverness	UK0039		42.3		21
London Westminster	UK0001	44.9	35.3		
Manchester Piccadilly	UK0003		72.8		
Narberth	UK0041	40.5	64		
Northampton	UK0032		59.3		23
Stockton-on-Tees Yarm	UK0036			58.3	

APPENDIX 2. MONITORING SITES USED TO VERIFY THE MAPPED ESTIMATES

Table A2.1. Monitoring sites used to verify the mapped estimates (all PM_{10} measurements by TEOM).

Site	Authority or Company	Site Type	SO_2	NO_2	PM_{10}
Abingdon	Vale of White Horse DC	URBAN BACKGROUND	+	+	+
Aylesbury Walton St	Aylesbury Vale DC	KERBSIDE		+	
Bacton Gas Terminal	BP Amoco Exploration	RURAL	+	+	
Birmingham Airport	Birmingham International Airport	URBAN BACKGROUND	+	+	+
Brentwood	Brentwood BC	URBAN BACKGROUND		+	
Cambridge Gonville Place	Cambridge City Council	ROADSIDE		+	+
Cambridge Parker Street	Cambridge City Council	ROADSIDE	+	+	+
Cambridge Silver Street	Cambridge City Council	ROADSIDE		+	+
Frome	Mendip DC	KERBSIDE		+	+
Gatwick LGW3	BAA	URBAN BACKGROUND			+
Heathrow Bedfont Court	BAA	URBAN BACKGROUND			+
Heathrow Green Gates	BAA	URBAN BACKGROUND		+	+
Heathrow LHR2	BAA	URBAN BACKGROUND			+
Heathrow Main Road	BAA	URBAN BACKGROUND	+	+	
Heathrow Oaks Road	BAA	URBAN BACKGROUND		+	+
Kilroot	AES Kilroot	URBAN BACKGROUND			+
King's Lynn Ed Benefer	Kings Lynn and West Norfolk	KERBSIDE		+	+
King's Lynn South Quay	Kings Lynn and West Norfolk	ROADSIDE			+
Liverpool Islington	Liverpool City Council	ROADSIDE	+	+	+
Liverpool Vauxhall	Liverpool City Council	URBAN BACKGROUND	+		
Liverpool Victoria Street	Liverpool City Council	ROADSIDE	+	+	+
Newham Cam Road	London Borough of Newham	ROADSIDE	+	+	+
Newham Tant Avenue	London Borough of Newham	URBAN BACKGROUND	+	+	+
Norwich Bracondale	Norwich City Council	KERBSIDE	+	+	+
Norwich Rose Lane	Norwich City Council	ROADSIDE	+	+	+
Oldham West Endhouse	Oldham Metropolitan Borough Council	URBAN BACKGROUND	+	+	+
Oxford East	Oxford City Council	URBAN BACKGROUND		+	+
Oxford St Ebbes	Oxford City Council	URBAN BACKGROUND		+	+
Ribble Valley Chatburn	Ribble Valey Borough Council	RURAL	+	+	+
Ribble Valley Lillands	Ribble Valey Borough Council	RURAL	+	+	+
Salford M60	Salford MBC	ROADSIDE	+	+	+
Salisbury Wilton	Salisbury DC	ROADSIDE		+	+
Slough Colnbrook	Slough Borough Council	URBAN BACKGROUND		+	+
Slough Town Centre A4	Slough Borough Council	ROADSIDE		+	+
South Bucks Gerrards Cross	South Bucks District Council	ROADSIDE		+	+
South Cambs Bar Hill	South Cambridgeshire DC	KERBSIDE	+	+	+
South Holland	South Holland DC	URBAN BACKGROUND		+	+
Stert St	Vale of White Horse DC	ROADSIDE		+	
Stockport Bredbury	Stockport Metropolitan BC	URBAN BACKGROUND		+	+
Stockport Cheadle	Stockport Metropolitan BC	URBAN BACKGROUND		+	+
Stockport Marple	Stockport Metropolitan BC	URBAN BACKGROUND		+	+
Sutton Bridge (Petts	South Holland DC	URBAN BACKGROUND			+

Site	Authority or Company	Site Type	SO_2	NO_2	PM_{10}
Lane)					
Tameside Two Trees School	Tameside Metropolitan BC	SUBURBAN	+	+	+
Thorney (Peterborough)	Peterborough City Council	KERBSIDE		+	
Trafford	Trafford Metropolitan BC	URBAN BACKGROUND	+	+	+
V Glamorgan Font-y-Gary	Vale of Glamorgan Council	URBAN BACKGROUND	+		
Wigan	Wigan Metropolitan BC	URBAN BACKGROUND	+		
Winnersh	Wokingham DC	URBAN BACKGROUND		+	+
Wokingham Council Offices	Wokingham DC	URBAN BACKGROUND		+	+
York Bootham	York City Council	URBAN BACKGROUND	+	+	+
York City Centre	York City Council	URBAN BACKGROUND	+	+	
York Dunnington	York City Council	SUBURBAN	+	+	
York Fishergate	York City Council	ROADSIDE		+	+
York Rawcliffe	York City Council	ROADSIDE		+	+