## Executive Summary

This is the technical report for the third and final Stage of the Review and Assessment of air quality for the London Borough of Waltham Forest. The Local Air Quality Management process under Part IV of the Environment Act 1995 requires that each local authority reviews and assesses air quality within its geographical area against the standards and objectives given in the Air Quality Regulations 1997.

The National Air Quality Strategy is currently undergoing a revision, which is not expected to be complete until the early part of this year. Despite this the DETR have written to all local authorities to advise that they should consider the proposed revision for the PM10 objective, rather than the existing objective. This report considers both the existing objective and the proposed revision for PM10.

The third stage of the review and assessment process requires a detailed assessment of both current air quality and future air quality across the Council's geographical area. This stage is only undertaken for those air pollutants identified by the previous reports. These are as follows:

- Nitrogen dioxide
- PM10
- Sulphur Dioxide

Full details of the modelling process are given in the appendices to the report, along with details of the assumptions used, model inputs and the uncertainty analysis. These should be carefully studied to understand the full basis and limitations of the predictions. The modelling system, which has been developed by the SEIPH-ERG, relies heavily on our understanding of air quality in London and the south east, and has been gained from operating the London and other neighbouring air quality networks.

Model assessments have been undertaken for "worst case" meteorological years. This assumes that the meteorological conditions in, for example, 1995 are repeated in 2004/5. In summary the "worst case" years are:

- ***Met. Year 1995*** for the prediction of the highest 15 minute concentration of $SO_2$;
- ***Met. Year 1996*** for the prediction of both the existing and proposed NAQS objectives for PM10;
- ***Met. Year 1997*** for the prediction of annual average concentration of $NO_2$;
- ***December 1991*** which represents the period where the highest hourly concentration of $NO_2$ was recorded, in the UK.

Predictions for a "typical" pollution year are also included for comparison purposes. In summary these are, met. year 1997 for PM10 and 1996 for $NO_2$.

The inputs used in the traffic modelling process have been obtained from the LTS transportation model, DETR's Rotating Census traffic data and local authority traffic counts. Input data for modelling the Part A industrial sources has been taken from the LRC's London Emission Inventory, local authority information and through the Environment Agency, via access to the Public Register and numerous personal communications.

An uncertainty analysis of $NO_x$ and $NO_2$ has been undertaken to improve understanding of the inherently uncertain prediction of air quality into the future. This is over and above validation of the model itself.

The report has been laid out to allow for a rapid examination of the results of the review and assessment and for a more thorough examination of the methodology used, etc as required.

The main findings of the report are that exceedences of the NAQS objectives are predicted for the following pollutants:

- Nitrogen dioxide (annual average)
- PM10 ($99^{th}$ Percentile and Daughter Directive)
- Sulphur dioxide ($99.9^{th}$ Percentile of 15 minute means)

On this basis the Council are advised to confirm that there is exposure as defined by the LAQM. TG4 (98) guidance and once satisfied to begin the process of consultation leading to the declaration of Air Quality Management Area.

## 1.1 Introduction

1.1.1 This report provides the final part of the three-stage review and assessment process for the London Borough of Waltham Forest, which assists with the local air quality management process, laid down by Part IV of the Environment Act 1995.

1.1.2 The purpose of the Review and Assessment of air quality is to enable local authorities to appraise current and future air quality for their geographical area, against the current NAQS objectives, for the year 2005. These are set out in the Air Quality Regulations 1997. If the results of this assessment are such that the objectives are unlikely to be met by the year 2005, the local authority is then required to designate an Air Quality Management Area (AQMA) and prepare a written action plan.

1.1.3 The Council has followed the phased approach required by the Government and has undertaken the first and second stages of the review and assessment. The Stage 2 review and assessment report for the London Borough of Waltham Forest indicated the possibility of an exceedence of the NAQS objectives for the following pollutants:

- *Nitrogen dioxide*
- *PM10*
- *Sulphur dioxide*

1.1.4 The review and assessment process is itself under review and the revised strategy is not expected to come into force until early this year (see letter to all CEHO's from DETR dated 21 July 1999). In anticipation of this, the DETR has written to all local authorities to advise that the current PM10 objective is to be replaced with the EC Air Quality Daughter Directive Stage 1 limit value (simplified to 'Daughter Directive', throughout the document). It has further advised that local authorities should focus on this suggested revision and has provided a document containing informal assistance (Assistance with the Review and Assessment of PM10 Concentrations in relation to the proposed EU Stage 1 Limit Values (99)).

1.1.5 This report has used the most up to date, known information and methods currently available to assess air quality in the London Borough of Waltham Forest. Although the report provides a comprehensive modelling prediction it has, of course, not been possible to model every potential source and circumstance.

## 1.2 Development of Review and Assessment

1.2.1 In the third stage of review and assessment, local authorities are required to undertake an accurate and detailed review and assessment of current and future air quality. The above-mentioned Guidance (paragraph 9.1 of LAQM.TG4 (98)) advises that:

- "Local authorities will need to predict whether a failure to achieve an air quality objective by the end of 2005 is likely. This will be a crucial factor, which will trigger the designation of air quality management areas (AQMAs)."

1.2.2 The guidance further advises that a local authority should investigate the areas within its boundaries where there is the likelihood of a failure to achieve air quality objectives and the potential for exposure of individuals. The authority should also estimate the magnitude and geographical extent of such exceedences.

## 1.3 Exposure

1.3.1 The NAQS objectives are based on the recommendations of the DETR's Expert Panel on Air Quality Standards (EPAQS), European Union standards and WHO guidelines. These all recognise that the potential impact on human health is a crucial factor and hence it is human exposure to air pollutants in non-occupational settings that needs assessment. The exposure of individuals to air pollution is highly complex however and dependant on many individual factors. Therefore, to simplify this issue, the DETR have established the following criteria, which assess the exposure of individuals, over the averaging time of the prescribed objective and are defined in the guidance (paragraph 1.14 of LAQM TG4):

- For objectives with short averaging times ($SO_2$ and peak hour $NO_2$), the review and assessment should focus on any non-occupational, ground level, outdoor location, given that exposures over such a short period are potentially likely;

- For objectives with longer averaging times (lead, PM10 and annual average $NO_2$), the review and assessment should focus on the following ground level, outdoor, non-occupational locations: background and roadside locations and other areas of elevated pollutant concentrations. This is applicable only where a person might reasonably be exposed (e.g. in the vicinity of housing, schools or hospitals, etc) over the relevant averaging time of the objective.

1.3.2 London is highly urbanised with a high population density. In the Stage 1 and 2 reports, prepared previously, the focus was to identify and then screen the major pollution sources, on the assumption that there is a likelihood of human exposure within such a dense conurbation. This assumption however is no longer sufficient for Stage 3, which seeks to determine the geographical extent of areas of exceedence of the NAQS objectives. To facilitate this assessment for the local authority, the SEIPH has determined the extent of the exceedence, in terms of distance (metres) from the kerb to the limit of the predicted exceedence. For $SO_2$ the extent of the area of exceedence has been identified, although the nature of this prediction is such that is the precise extent of the exceedence is uncertain. Contour maps have also been produced to show the geographic extent of exceedences.

## 1.4 DETR Guidance

1.4.1 Reference was made earlier to DETR LAQM guidance TG4 (98), which refers in general terms to the use of detailed emission inventories, validated dispersion models and high quality continuous monitoring. Separate LAQM guidance notes have been produced for each of these aspects. Importantly the issue of background pollution is also addressed in LAQM.TG4 (98). There is however limited Stage 3 guidance for each specific pollutant.

1.4.2 The exception to the above is for PM10, where the informal assistance document highlights the importance of making clear the assumptions used and also the concerns surrounding the treatment of emissions and background concentrations.

1.4.3 Paragraph 2.04 of circular 15/97 however advises that the guidance is not prescriptive and that local authorities should use professional and technical judgement to decide how best to conduct an air quality review and assessment, in the light of local circumstances

**Table 1.1** LTS Roads Predicted to Exceed the Daughter Directive for PM10 in 2004 based on 1996 Met. Year

| Junction Description A | Junction Description B | Road_number | Distance (m) from the kerb at which the Daughter Directive is met |
|---|---|---|---|
| HACKNEY M11 LINK RD/HACKNEY-M11 | HACKNEY-M11 LINK RD | | 23.2 |
| HACKNEY-M11 LINK RD | EASTWAY SLIPS EAST/*BDY HACKNEY | | 8.2 |
| HOLLYBUSH HILL/NEW WANSTEAD | HACKNEY M11 LINK RD SLIP | | 3.2 |
| RUCKHOLT RD SLIP/*BDY HACKNEY | HACKNEY-M11 LINK RD | | 13.2 |
| HACKNEY M11 LINK RD SLIP | HACKNEY M11 LINK RD/HACKNEY-M11 | | 0.2 |
| HACKNEY - M11 LINK RD (EASTBOUND | HACKNEY M11 LINK RD/HACKNEY-M11 | | 15.2 |
| HIGH ST, WANSTEAD SLIP | HACKNEY - M11 LINK RD (EASTBOUND | | 10.2 |
| HACKNEY - M11 LINK RD (EASTBOUND | EASTERN AV E'BND | | 10.2 |
| HACKNEY - M11 LINK RD (EASTBOUND | HACKNEY M11 LINK RD SLIP | | 10.2 |
| HIGH RD, LEYTON/LEYTON GREEN RD | LEYTON GREEN RD/LEA BRIDGE RD | B159 | 4.2 |
| EASTWAY/RUCKHOLT RD/DUMMY/*BDY H | SLIP TO LEYTON RELIEF RD | | 14.2 |
| RUCKHOLT RD/OLIVER RD | OLIVER RD/CHURCH RD | unclassified | 4.2 |
| SLIP TO LEYTON RELIEF RD | RUCKHOLT RD/OLIVER RD | | 9.2 |
| HIGH RD, LEYTONSTONE/CHURCH LA | HIGH RD, LEYTONSTONE/BUSH RD | | 4.2 |
| HACKNEY M11 LINK RD SLIP | HIGH RD, LEYTONSTONE/BUSH RD | | 24.2 |
| WADHAM RD/WINCHESTER RD/FULBOURN | THE BROADWAY/HALE END RD/LARKSHA | unclassified | 2.2 |

**Table 1.2** Rotating Census Roads Predicted to Exceed the Daughter Directive for PM10 in 2004 based on 1996 Met. Year

| Road Name | Road Number | Distance (m) from the kerb at which the Daughter Directive is met |
|---|---|---|
| HIGH ROAD LEYTONSTONE | A11 | 14.2 |
| HOE STREET | A112 | 4.2 |
| WALTHAMSTOW AVENUE (NORTH CIRCULAR ROAD) | A406(T) | 13.2 |
| BLACKHORSE ROAD | A1006 | 4.2 |
| MARKHOUSE ROAD | A1006 | 4.2 |
| ST JAMES'S STREET | A1006 | 4.2 |
| LEA VALLEY ROAD | A110 | 9.2 |
| SOUTHEND ROAD | A406(T) | 38.2 |
| SOUTHEND ROAD (NORTH CIRCULAR ROAD) | A406(T) | 38.2 |
| FRANCIS ROAD | A106 | 1.2 |
| WARREN ROAD | A106 | 1.2 |
| LEYTONSTONE ROAD | A11 | 9.2 |
| NEW WANSTEAD HILL | A11 | 3.2 |
| CAMBRIDGE PARK | A12 | 14.2 |
| CAMBRIDGE PARK ROAD | A12 | 14.2 |
| WOODFORD NEW ROAD | A104 | 13.2 |
| LEA BRIDGE ROAD | A104 | 14.2 |
| ANGEL ROAD (NORTH CIRCULAR ROAD) | A406(T) | 13.2 |
| WALTHAMSTOW AVENUE (NORTH CIRCULAR ROAD) | A406(T) | 13.2 |
| LEA BRIDGE ROAD | A104 | 8.2 |
| NORTH CIRCULAR ROAD | A406(T) | 13.2 |
| SOUTHEND ROAD (NORTH CIRCULAR ROAD) | A406(T) | 13.2 |
| CHURCH ROAD | A1006 | 4.2 |
| RUCKHOLT ROAD | A106 | 1.2 |
| HIGH ROAD LEYTON | A112 | 4.2 |
| GROVE GREEN ROAD | A106 | 1.2 |
| HIGH ROAD LEYTON | A112 | 9.2 |
| LEA BRIDGE ROAD | A104 | 8.2 |
| WOODFORD NEW ROAD | A104 | 8.2 |
| LEA BRIDGE ROAD | A104 | 8.2 |
| FERRY LANE | A503 | 9.2 |
| FOREST ROAD | A503 | 9.2 |
| HIGH ROAD LEYTON | A112 | 9.2 |

**Table 1.3** LTS Roads Predicted to Exceed the Daughter Directive for PM10 in 2004 based on 1997 Met. Year

| Junction Description A | Junction Description B | Road_number | Distance (m) from the kerb at which the Daughter Directive is met |
|---|---|---|---|
| HACKNEY M11 LINK RD/HACKNEY-M11 | HACKNEY-M11 LINK RD | | 7.2 |
| HACKNEY - M11 LINK RD (EASTBOUND | HACKNEY M11 LINK RD/HACKNEY-M11 | | 5.2 |
| HIGH ST, WANSTEAD SLIP | HACKNEY - M11 LINK RD (EASTBOUND | | 0.2 |
| HACKNEY M11 LINK RD SLIP | HIGH RD, LEYTONSTONE/BUSH RD | | 8.2 |

**Table 1.4** Rotating Census Roads Predicted to Exceed the Daughter Directive for PM10 in 2004 based on 1997 Met. Year

| Road Name | Road Number | Distance (m) from the kerb at which the Daughter Directive is met |
|---|---|---|
| HIGH ROAD LEYTONSTONE | A11 | 4.2 |
| WALTHAMSTOW AVENUE (NORTH CIRCULAR ROAD) | A406(T) | 5.2 |
| SOUTHEND ROAD | A406(T) | 12.2 |
| SOUTHEND ROAD (NORTH CIRCULAR ROAD) | A406(T) | 12.2 |
| CAMBRIDGE PARK | A12 | 3.2 |
| CAMBRIDGE PARK ROAD | A12 | 3.2 |
| WOODFORD NEW ROAD | A104 | 5.2 |
| LEA BRIDGE ROAD | A104 | 2.2 |
| ANGEL ROAD (NORTH CIRCULAR ROAD) | A406(T) | 2.2 |
| WALTHAMSTOW AVENUE (NORTH CIRCULAR ROAD) | A406(T) | 2.2 |
| NORTH CIRCULAR ROAD | A406(T) | 3.2 |
| SOUTHEND ROAD (NORTH CIRCULAR ROAD) | A406(T) | 3.2 |
| FERRY LANE | A503 | 1.2 |
| FOREST ROAD | A503 | 1.2 |

**Table 1.5** LTS Roads Predicted to Exceed the NAQS Annual Average $NO_2$ Objective based on 1996 Met. Year

| Junction Description A | Junction Description B | Road_number | Distance (m) from the kerb at which the NAQS objective is met |
|---|---|---|---|
| HACKNEY M11 LINK RD/HACKNEY-M11 | HACKNEY-M11 LINK RD | | 14.2 |
| HACKNEY-M11 LINK RD | EASTWAY SLIPS EAST/*BDY HACKNEY | | 6.2 |
| RUCKHOLT RD SLIP/*BDY HACKNEY | HACKNEY-M11 LINK RD | | 5.2 |
| HACKNEY - M11 LINK RD (EASTBOUND | HACKNEY M11 LINK RD/HACKNEY-M11 | | 12.2 |
| HIGH ST, WANSTEAD SLIP | HACKNEY - M11 LINK RD (EASTBOUND | | 7.2 |
| HACKNEY - M11 LINK RD (EASTBOUND | EASTERN AV E'BND | | 6.2 |
| HACKNEY - M11 LINK RD (EASTBOUND | HACKNEY M11 LINK RD SLIP | | 4.2 |
| EASTWAY/RUCKHOLT RD/DUMMY/*BDY H | SLIP TO LEYTON RELIEF RD | | 3.2 |
| SLIP TO LEYTON RELIEF RD | RUCKHOLT RD/OLIVER RD | | 1.2 |
| HIGH RD, LEYTONSTONE/CHURCH LA | HIGH RD, LEYTONSTONE/BUSH RD | | 2.2 |
| HACKNEY M11 LINK RD SLIP | HIGH RD, LEYTONSTONE/BUSH RD | | 11.2 |

**Table 1.6** Rotating Census Roads Predicted to Exceed the NAQS Annual Average $NO_2$ Objective based on 1996 Met. Year

| Road Name | Road Number | Distance (m) from the kerb at which the NAQS objective is met |
|---|---|---|
| HIGH ROAD LEYTONSTONE | A11 | 8.2 |
| WALTHAMSTOW AVENUE (NORTH CIRCULAR ROAD) | A406(T) | 7.2 |
| SOUTHEND ROAD | A406(T) | 17.2 |
| SOUTHEND ROAD (NORTH CIRCULAR ROAD) | A406(T) | 17.2 |
| LEYTONSTONE ROAD | A11 | 0.2 |
| CAMBRIDGE PARK | A12 | 5.2 |
| CAMBRIDGE PARK ROAD | A12 | 5.2 |
| WOODFORD NEW ROAD | A104 | 7.2 |
| LEA BRIDGE ROAD | A104 | 2.2 |
| ANGEL ROAD (NORTH CIRCULAR ROAD) | A406(T) | 3.2 |
| WALTHAMSTOW AVENUE (NORTH CIRCULAR ROAD) | A406(T) | 3.2 |
| LEA BRIDGE ROAD | A104 | 2.2 |
| NORTH CIRCULAR ROAD | A406(T) | 6.2 |
| SOUTHEND ROAD (NORTH CIRCULAR ROAD) | A406(T) | 6.2 |
| LEA BRIDGE ROAD | A104 | 0.2 |
| WOODFORD NEW ROAD | A104 | 0.2 |
| FERRY LANE | A503 | 1.2 |
| FOREST ROAD | A503 | 1.2 |

**Table 1.7** LTS Roads Predicted to Exceed the NAQS Annual Average $NO_2$ Objective based on 1997 Met. Year

| Junction Description A | Junction Description B | Road_number | Distance (m) from the kerb at which the NAQS objective is met |
|---|---|---|---|
| HACKNEY M11 LINK RD/HACKNEY-M11 | HACKNEY-M11 LINK RD | | 25.2 |
| HACKNEY-M11 LINK RD | EASTWAY SLIPS EAST/*BDY HACKNEY | | 11.2 |
| HOLLYBUSH HILL/NEW WANSTEAD | HACKNEY M11 LINK RD SLIP | | 1.2 |
| RUCKHOLT RD SLIP/*BDY HACKNEY | HACKNEY-M11 LINK RD | | 10.2 |
| HACKNEY - M11 LINK RD (EASTBOUND | HACKNEY M11 LINK RD/HACKNEY-M11 | | 17.2 |
| HIGH ST, WANSTEAD SLIP | HACKNEY - M11 LINK RD (EASTBOUND | | 13.2 |
| HACKNEY - M11 LINK RD (EASTBOUND | EASTERN AV E'BND | | 11.2 |
| HACKNEY - M11 LINK RD (EASTBOUND | HACKNEY M11 LINK RD SLIP | | 9.2 |
| HIGH RD, LEYTON/LEYTON GREEN RD | LEYTON GREEN RD/LEA BRIDGE RD | B159 | 2.2 |
| EASTWAY/RUCKHOLT RD/DUMMY/*BDY H | SLIP TO LEYTON RELIEF RD | | 9.2 |
| RUCKHOLT RD/OLIVER RD | OLIVER RD/CHURCH RD | unclassified | 2.2 |
| SLIP TO LEYTON RELIEF RD | RUCKHOLT RD/OLIVER RD | | 7.2 |
| HIGH RD, LEYTONSTONE/CHURCH LA | HIGH RD, LEYTONSTONE/BUSH RD | | 7.2 |
| HACKNEY M11 LINK RD SLIP | HIGH RD, LEYTONSTONE/BUSH RD | | 17.2 |
| WADHAM RD/WINCHESTER RD/FULBOURN | THE BROADWAY/HALE END RD/LARKSHA | unclassified | 1.2 |

**Table 1.8** Rotating Census Roads Predicted to Exceed the NAQS Annual Average $NO_2$ Objective based on 1997 Met. Year

| Road Name | Road Number | Distance (m) from the kerb at which the NAQS objective is met |
|---|---|---|
| HIGH ROAD LEYTONSTONE | A11 | 13.2 |
| HOE STREET | A112 | 3.2 |
| WALTHAMSTOW AVENUE (NORTH CIRCULAR ROAD) | A406(T) | 12.2 |
| BLACKHORSE ROAD | A1006 | 2.2 |
| MARKHOUSE ROAD | A1006 | 2.2 |
| ST JAMES'S STREET | A1006 | 2.2 |
| LEA VALLEY ROAD | A110 | 3.2 |
| SOUTHEND ROAD | A406(T) | 32.2 |
| SOUTHEND ROAD (NORTH CIRCULAR ROAD) | A406(T) | 32.2 |
| LEYTONSTONE ROAD | A11 | 5.2 |
| NEW WANSTEAD HILL | A11 | 1.2 |
| CAMBRIDGE PARK | A12 | 10.2 |
| CAMBRIDGE PARK ROAD | A12 | 10.2 |
| WOODFORD NEW ROAD | A104 | 12.2 |
| LEA BRIDGE ROAD | A104 | 8.2 |
| ANGEL ROAD (NORTH CIRCULAR ROAD) | A406(T) | 8.2 |
| WALTHAMSTOW AVENUE (NORTH CIRCULAR ROAD) | A406(T) | 8.2 |
| LEA BRIDGE ROAD | A104 | 7.2 |
| NORTH CIRCULAR ROAD | A406(T) | 11.2 |
| SOUTHEND ROAD (NORTH CIRCULAR ROAD) | A406(T) | 11.2 |
| CHURCH ROAD | A1006 | 0.2 |
| HIGH ROAD LEYTON | A112 | 0.2 |
| HIGH ROAD LEYTON | A112 | 2.2 |
| LEA BRIDGE ROAD | A104 | 5.2 |
| WOODFORD NEW ROAD | A104 | 5.2 |
| LEA BRIDGE ROAD | A104 | 4.2 |
| FERRY LANE | A503 | 6.2 |
| FOREST ROAD | A503 | 6.2 |
| HIGH ROAD LEYTON | A112 | 4.2 |

## 3.1 Summary of Continuous Monitoring within the London Borough of Waltham Forest

3.1.1 The Council has operated an urban background monitoring site, which monitors nitrogen dioxide and PM10 since July 1998. A full year of ratified data was not available for 1998 for either nitrogen dioxide or PM10 to allow comparison with the NAQS standards and objectives.

3.1.2 This section also considers measurements in other boroughs in order to assist the London Borough of Waltham Forest in establishing the context of the Borough's air pollution.

## 3.2 Summary of Air Pollution Measurements in London

3.2.1 During 1997 almost all sites in the LAQN exceeded the NAQS objectives for 2005. A comparison with previous pollution years shows very little trend in these statistics, as expected, due to the varying meteorological conditions during the different years. The comparison does however permit the selection of a 'worst case' year, which can then be used for the 2005 prediction. The key conclusions of this examination are as follows:

- the annual average objective for $NO_2$ was exceeded at all sites in Greater London, except Sutton 3, and the maximum hour objective was exceeded at around half of the sites;
- the objective for PM10 was exceeded at all sites in the LAQN by a large margin;
- all sites measuring $SO_2$ in Greater London were below the objective in 1997, although Bexley and Greenwich sites exceeded the objective during 1996. These exceedences are associated with large industrial processes in the East Thames region;
- the base year for predictions of the NAQS objectives in 2005 will be the years: 1996 for PM10, 1997 for annual average $NO_2$, 1991 for peak hour $NO_2$ and 1995 and 1996 for $SO_2$.

## 3.3 Detailed Analysis of the Monitoring Results in London

3.3.1 In the third stage of the review and assessment the Council is required to undertake an accurate and detailed review and assessment of current and future air quality. This section examines the current air quality within the Councils' area by focussing on the high quality monitoring that has taken place both within the Borough and across the wider London area, by the London Air Quality Network (LAQN).

3.3.2 The DETR guidance LAQM. TG1 (98) gives local authorities guidance on the standards and procedures for monitoring ambient air quality so as to demonstrate the significant risk of a prescribed objective being exceeded in a relevant location. The guidance relates to the NAQS pollutants and reflects the staged review and assessment approach recognising that the most sophisticated monitoring and higher standards of QA/QC apply to the more detailed stage 3 review and assessments.

3.3.3 The monitoring strategy of the LAQN is designed to maximise the information available to local authorities within the network, recognising that pollution is not restricted to local authority boundaries. This relates to both site locations and pollutant requirements. Thus the purpose of the LAQN is to provide a comprehensive network, which enables a high standard of comparability between sites and data.

3.3.4 In all instances continuous monitoring sites within the LAQN meet the requirements of the above-mentioned guidance through meeting either the AUN and/or the London standard.

3.3.5 The LAQN was formed in 1993 to co-ordinate and improve air pollution monitoring in London. At the end of January 1999, 20 London Boroughs were supplying data to the LAQN. Increasingly these data are being supplemented by data from local authorities around London. The LAQN is facilitated by the Association of London Government on behalf of the thirty-three London Boroughs and is provided by the SEIPH-ERG.

3.3.6 The purpose of this section is to present results from the LAQN for the years 1994-1997. The results relate specifically to the NAQS objectives for $NO_2$, PM10 and $SO_2$, which are described in Table 3.1 below.

**Table 3.1:**The NAQS Existing and Proposed Objectives

| Pollutant | Existing NAQS Objective | Proposed AQS Objective |
|---|---|---|
| | To be achieved by 2005 | |
| $SO_2$ | 100 ppb, as 99.9$^{th}$ percentile of 15 minute means | To be agreed |
| $NO_2$ | 21 ppb annual mean<br>150 ppb, averaged over one hour | To be agreed |
| PM10 | 50 µg/m$^3$, as 99$^{th}$ percentile of 24 hour running means | 50 µg/m$^3$, as 24 hour means not to be exceeded 35 times/annum[1] |

ppb = parts per billion, µg/m$^3$ = micrograms per cubic metre
[1] Gravimetric measurement, to be achieved by the end of 2004

3.3.7 When examining data it is important to consider the location of the monitoring site e.g. kerbside, urban background, rural, etc. The implications of the quality assurance standard on data accuracy are discussed in the 1996 LAQN Annual Report (SEIPH, 1996). This report suggests that a working uncertainty of around 10 % should be considered when discussing high values and long-term averages such as the NAQS Objectives.

3.3.8 Each of the pollutants monitored by the LAQN require data, which is representative of the whole year. If insufficient data were available (i.e. a data capture of less than 75%), then comparison with the objective was not possible. This, for example, is the case for many of the new sites.

3.3.9 The following information relates to those sites which undertake continuous monitoring of the NAQS pollutants, which need further investigation under the Review and Assessment process. A short review of the continuous monitoring within the Council's area is followed by a more general London wide view of air quality.

## 3.4 Nitrogen Dioxide ($NO_2$)

3.4.1 The highest $NO_2$ concentrations are measured at roadside and central London locations. Lower concentrations were observed at urban background, suburban and rural areas. Generally, concentrations are found to decrease with distance from the central areas of London.

3.4.2 Figure 3.1 shows the annual average for sites in the network. The highest annual average (39 ppb) was measured at the kerbside in Camden. All sites within Greater London, except Sutton 3, exceeded the objective. Sites outside Greater London were

equal to or below the objective.

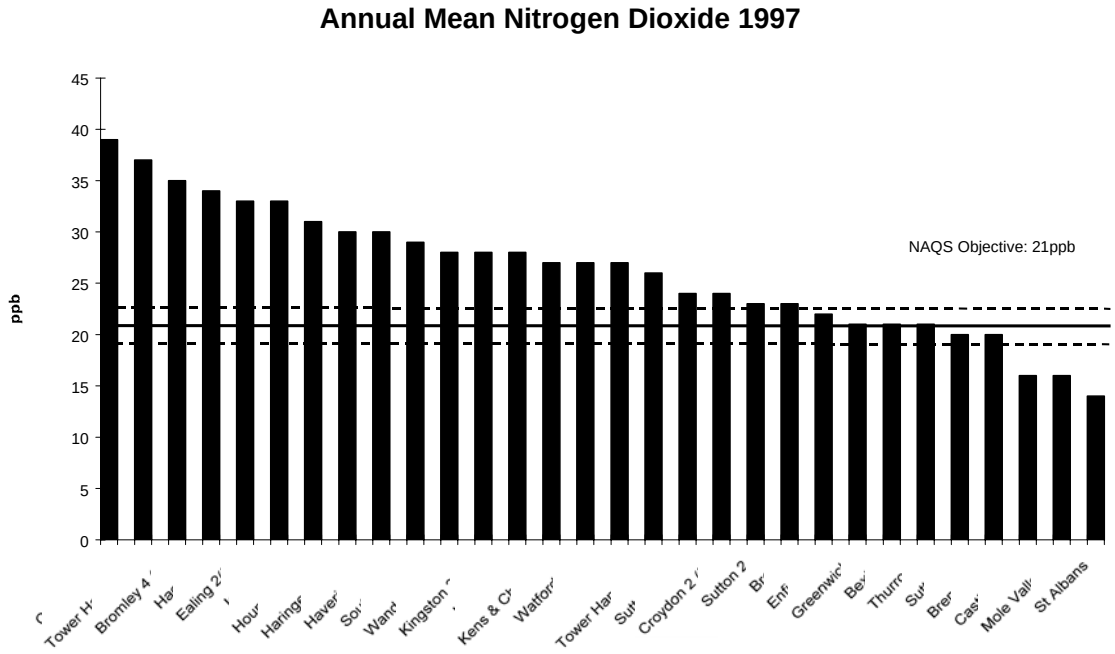



**Figure 3.1:** Annual Mean $NO_2$ (1997)

3.4.3 If a measurement uncertainty of 10 % is assumed, sites with annual averages above 23 ppb have exceeded the objective and those below 19 ppb are below the objective. A precautionary approach would therefore suggest that both Brentwood and Sutton 3 might also have exceeded the objective. Conversely, the exceedence at Enfield cannot be viewed as definite.

3.4.4 The distribution of the maximum hourly values for 1997 is different. The maximum hourly concentration at most sites occurred during the pollution incident in late October/early November or during the incident in mid November. The distribution is also affected by local incidents and the operational availability of each site during the episode e.g. if a site was not operating during an incident, the maximum hourly value may be lower than neighbouring sites that were operational.

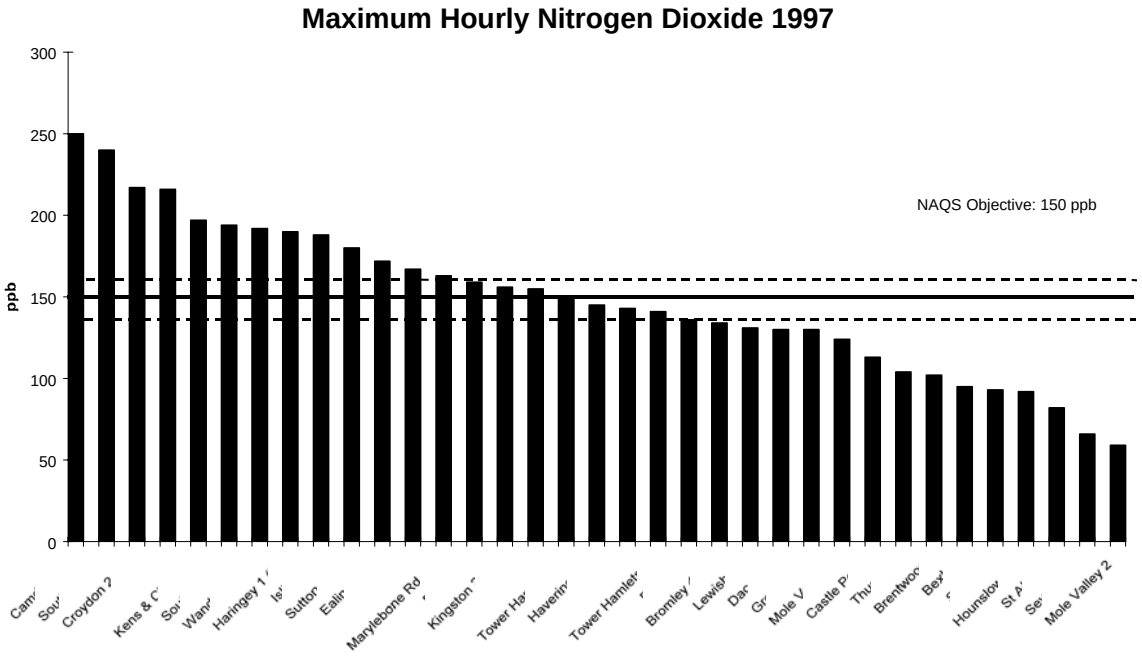



**Figure 3.2:** Maximum Hourly $NO_2$ Concentrations (1997)

3.4.5 The maximum hourly average objective was exceeded at around half of the LAQN sites during 1997, all within Greater London. The highest value (250 ppb) was measured at the roadside in Camden. Concentrations of over 200 ppb were also measured at the roadside in Croydon and at the background sites Southwark 1 and Sutton 2. Once again, if a measurement uncertainty of 10 % is assumed, we can be confident that those sites with an annual maximum below 135 ppb are below the objective and those above 165 ppb are above. This suggests that the exceedences of this objective at Brent and Enfield cannot be viewed as definite.

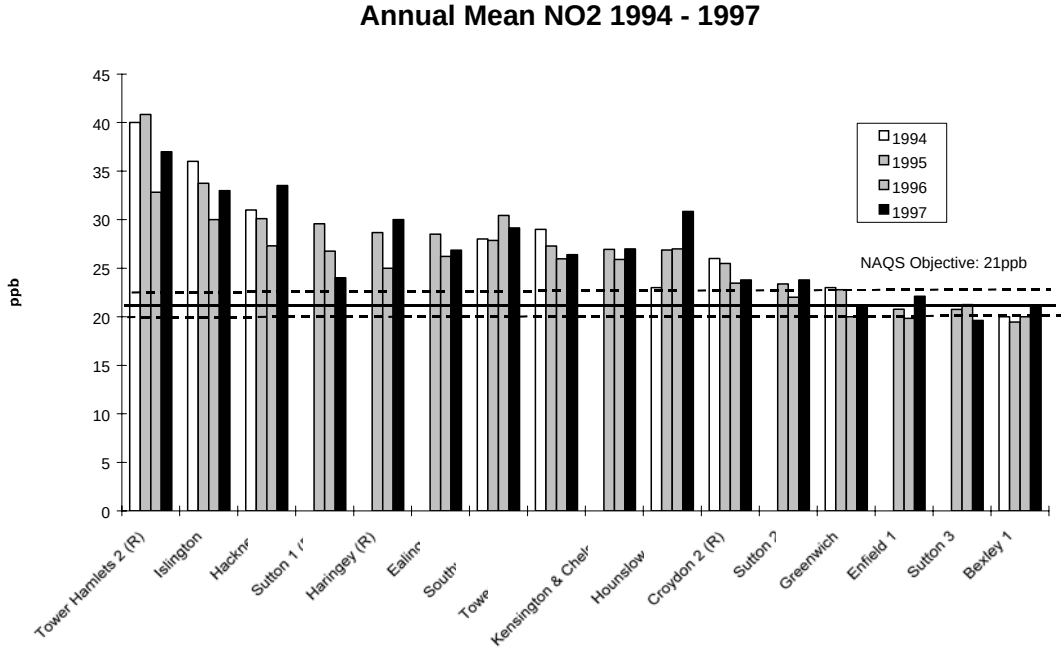



**Figure 3.3**: Annual Mean $NO_2$ (1994-1997)

3.4.6 Figure 3.3 demonstrates the inter-annual variability at the LAQN sites and, as expected, no trend in either direction can be seen between the pollution years 1994 to 1997. The majority of sites indicate 1997 to be the most polluted year, and therefore this will be chosen as the basis for the Stage 3 assessment.

## 3.5 Sulphur Dioxide ($SO_2$)

3.5.1 The annual average concentrations of $SO_2$ do not vary to any significant degree over the network.

3.5.2 The majority of the sites in the LAQN measured moderate $SO_2$ during 1997. High $SO_2$ was measured at Bexley, Castle Point and Sevenoaks (Scudders Hill). The NAQS objective was exceeded at the Castle Point site on Canvey Island in Essex only. This is almost certainly due to its proximity to industrial sources in the East Thames Corridor. Results from 1996 and 1997 are shown for comparison in Figure 3.4.

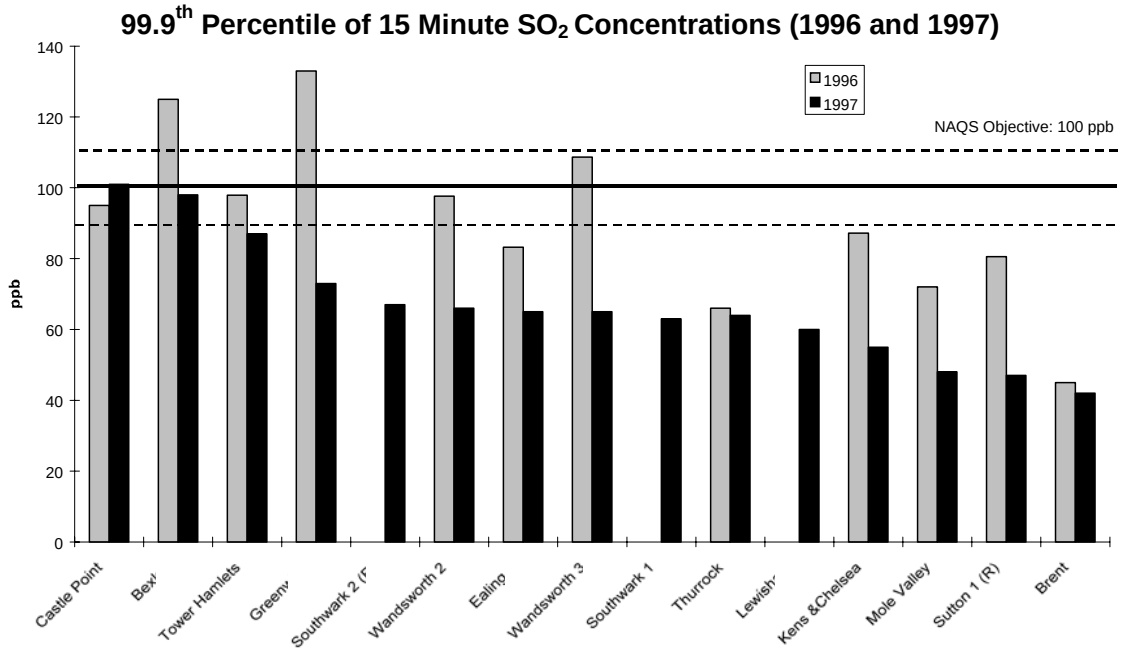



**Figure 3.4:** 99.9th Percentile of 15 Minute $SO_2$ Concentrations (1996-1997**)**

3.5.3 All sites except Castle Point show a reduction in 1997 compared with 1996. The NAQS objective is measured against the 99.9th percentile of 15 minutes averages during the year and is therefore mainly determined by a small number of plume grounding incidents. Although results for 1997 are very much less than 1996 at most sites, it is not possible to infer that it is solely due to a reduction in emissions. It is considered that meteorological factors will provide the most likely explanation for this reduction.

3.5.4 If the measurement uncertainty of 10 % is applied then it is not possible to state with certainty that Castle Point exceeded the objective or that Bexley was below the objective.

3.5.5 Comparison between 1996, 1997 and the year 1995 shows that the 'worst case' year for the east Thames area was 1995, with the highest result being Bexley (153 ppb as a 99.9th percentile of 15 minute averages). The largest sources of $SO_2$ are also found in this area and therefore the greatest impact expected in this area. On this basis 1995 was chosen for the Stage 3 assessment.

## 3.6 Particles (PM10)

3.6.1 All sites in the LAQN exceeded the NAQS objective during 1997. The variation between sites is considered to be due to differences in the directly emitted component, within the LAQN area, mainly from road transport. This is reflected in the results below, with the greatest exceedence of the objective being seen at roadside and central areas.

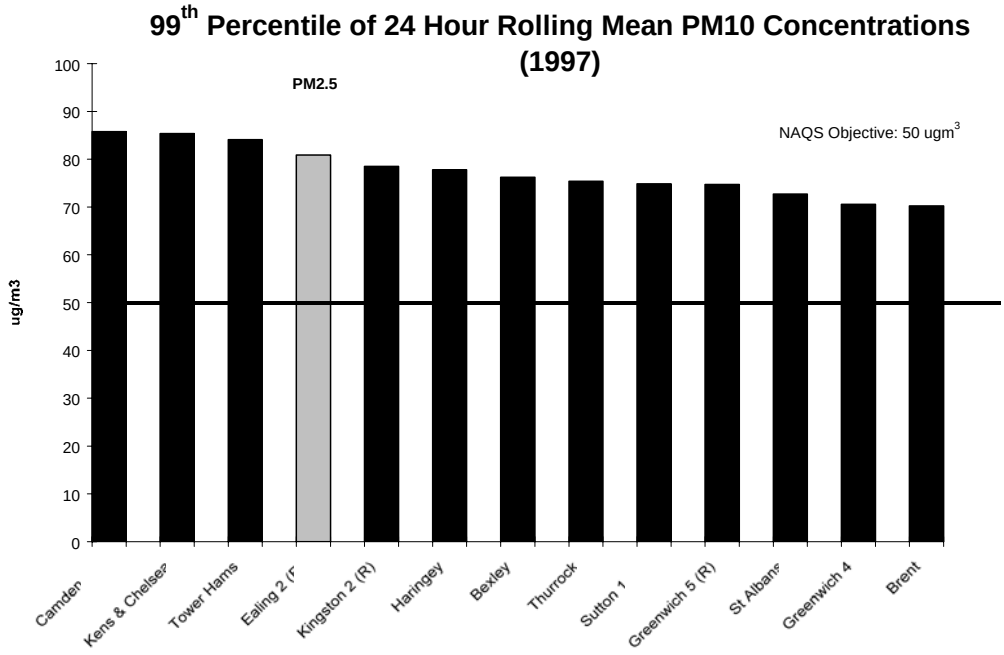



**Figure 3.5:** 99th Percentile of 24 Hour Rolling Mean PM10 Concentrations (1997)

3.6.2 Exceedences of the NAQS objective are more widespread than suggested here; the objective was also exceeded at all sites in the Kent Air Quality Monitoring Network. For comparison the results from the PM2.5 (a sub group of PM10) monitoring at the Ealing 2 roadside site have been included.

3.6.3 All sites would still exceed the objective even with a 10 % measurement uncertainty, since all measurements were far in excess of the objective.

3.6.4 An inter-annual comparison of data between 1995 and 1997 for the objective is shown in Figure 3.6. This shows that there was a marginal improvement in 1997 over 1996 results for most sites with 1995 results mostly either similar or below the 1997 results. !996 was therefore chosen as the basis for the Stage 3 assessment.

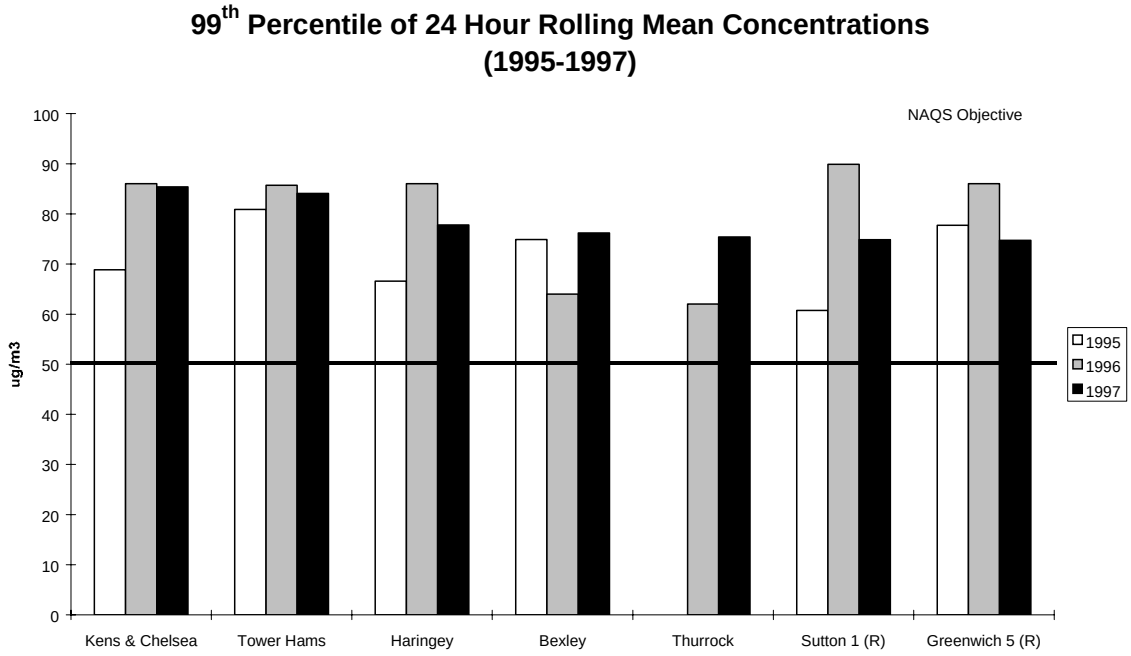



**Figure 3.6:** 99th Percentile of 24 Hour Rolling Mean PM10 Concentrations (1995-1997)

## References

Barratt, B (1998) ***SEIPH The Kent Air Quality Monitoring Network Annual Report 1997***

SEIPH (1995) ***SEIPH Air Quality in London 1994***

SEIPH (1996) ***SEIPH Air Quality in London 1995***

SEIPH (1997) ***The AIM Project and Air Quality in London 1996***

Stedman J (1998) ***The Secondary Particle Contribution to Elevated PM10 Concentrations in the UK***

## 4.1 Conclusion and Recommendation

4.1.1 This Stage 3 Review and Assessment report assesses those pollutants identified in the earlier Stage 2 report. It has been undertaken in accordance with the LAQM guidance provided by the DETR and the informal assistance document produced for the proposed PM10 revised objective. The assumptions and methodology used are fully explained in the appendices at the end of the report.

4.1.2 The results indicate that areas of exceedence are predicted to arise in 2005 for each of the following pollutants:

Nitrogen dioxide
PM10
Sulphur dioxide

4.1.3 The Council is therefore recommended to undertake the following actions for these pollutants:

- Assess the potential for personal exposure at each of the sites identified as exceeding the NAQS objectives
- Undertake consultation on the findings arising from this report with the statutory and other consultees as required
- Initiate procedures within the Council to designate an Air Quality Management Areas, based on the areas of exceedence identified

## A1.1.Summary

A1.1.1 This appendix describes the methods used to estimate the concentrations of $NO_2$, PM10, and $SO_2$ for the time scales required by the NAQS. Many of the techniques described have been used for work on behalf of the DETR e.g. evaluation of local transport measures in tackling NAQS objectives, as well on behalf of the Government Office for London e.g. Meeting air quality targets in London.

A1.1.2 London is unique in the UK in having such a comprehensive network of high quality air pollution monitoring sites. The number of monitoring locations for $NO_X$ and $NO_2$ has increased dramatically during the 1990s: in 1990 there were 4 sites, whereas in 1999 there were around 41 sites, with several more to be added later this year.

A1.1.3 Thus there are sufficient monitoring data available in London to justify considering London in isolation and to build 'ambient data models' for the prediction of current and future concentrations of PM10, $NO_X$ and $NO_2$. This has led to the development of London specific 'pollution climate mapping' for the prediction of annual average background concentrations.

A1.1.4 London-specific pollution climate mapping produces reliable estimates of PM10 and $NO_X$ at background locations in London. The approach adopted for London is different in several important respects compared with national mapping. The most significant difference is that a 5x5 $km^2$ area cannot account for the difference between the local background concentration and the underlying rural concentration, as other areas of high emissions surround the area itself.

A1.1.5 London's measurements have also shown that there is a distinct difference between $NO_X$-$NO_2$ relationships at roadside and background locations: roadside concentrations of $NO_2$ are always lower than background concentrations for a particular concentration of $NO_X$. This difference reflects important atmospheric chemistry, which occurs over both small spatial (metres) and temporal (seconds to minutes) scales. That is, it takes time to convert NO to $NO_2$ away from a road. The predictions made within this document have included this important difference in the modelling method used.

A1.1.6 The prediction of the peak hour value of $NO_2$ at a location is problematic. Under such conditions it is unreasonable to expect dispersion model predictions to be accurate (+/- 100 % or more). The approach taken considers the $NO_X$-$NO_2$ relationships at different monitoring sites and explores how the peak $NO_2$ concentration is likely to change as $NO_X$ concentrations reduce.

A1.1.7 Predictions from Part A processes, i.e. large industrial plant, have been made using both the ADMS and AERMOD stack models. The predictions are for the NAQS objectives for $NO_2$, PM10, and $SO_2$.

A1.1.8 For the predictions of the present NAQS PM10 objective as well as the Daughter Directive SEIPH have developed the receptor modelling technique described in Airborne Particles Expert Group (APEG, 1999). The model predicts daily average PM10 concentrations for 1995 to 1997 in the particle fractions, primary, secondary and coarse. The model was developed using measurements from the London AURN, from sites within the London Network, rural measurements from the EMEP acid rain monitoring network and black smoke measurement from London.

**A1.1.9** The approaches developed here are simple, robust, accurate and transparent and avoid many of the drawbacks of conventional dispersion modelling. The approaches are therefore ideally suited for use in support of the Review and Assessment process.

## A1.2. Prediction of Background PM10 and $NO_X$ Concentrations

A1.2.1 SEIPH has made predictions of PM10 and $NO_x$ at background locations i.e. greater than 50m from a major road, based on 'pollution climate mapping'. This approach was originally conceived by Stedman (Stedman, 1998). For $NO_x$ however, the approach developed by SEIPH is fundamentally different.

A1.2.2 The technique, suggested by Stedman, assumes that a 5 x 5 km area accounts for the difference between the measured concentration at a location and the underlying rural concentration. This is likely to be satisfactory for most of the landmass of the UK, but is unlikely to be appropriate for large urban areas such as London. The reason for this is that each 5 x 5 $km^2$ area is surrounded by many others, which also have relatively high emissions and therefore contribute to an additional background concentration. This is reflected when plotting the emissions versus concentration for London, shown in Figure A1.1, which does not go through the origin. The formulation used here is therefore:

*Estimated concentration = rural map + other London contribution + k* x *emissions* (kTonnes per 25 $km^2$ per year)

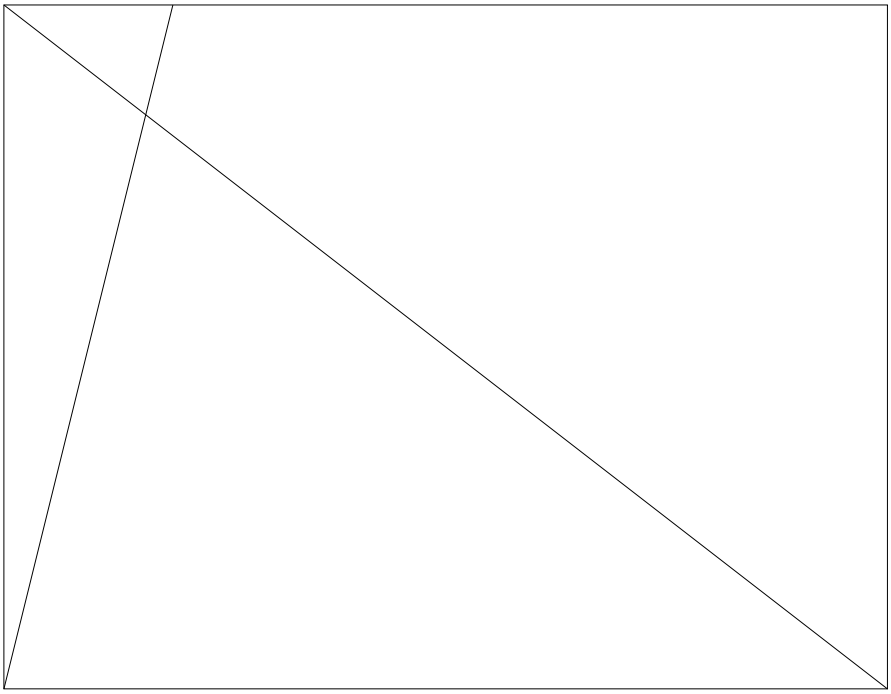


**Figure A1.1** Emissions per 25 $km^2$ Versus $NO_X$ Concentration (1996)

A1.2.3 For predictions in future years each part can be changed independently. For example, in 2005 it has been assumed that the rural $NO_X$ concentration reduces in line with national $NO_X$ emissions (50 %). The 'other London contribution' has been reduced in line with expected reductions in ground-level sources of $NO_X$ in London

as a whole (52 %). The 5x5 km area is simply reduced in line with the emissions change in that area.

A1.2.4 The mapping approach has not been used for predictions of $NO_2$, as its relationship with $NO_X$ is non-linear. Predictions of $NO_2$ are described below.

## A1.3.Prediction of Concentrations in the Vicinity of Roads

### A1.3.1 CAR International

A1.3.2 The dispersion element of the CAR international model has been used for the prediction of the annual average 'fall off' in concentration of $NO_x$ and PM10 from roadside locations. This is added to the predictions of 'pollution climate mapping' to give a total concentration.

A1.3.3 Before the CAR model was written a literature review of existing models was carried out. It was found that most models are limited to open highway situations and are poor at dealing with street canyons, which are common in cities. The CAR model has been derived from wind tunnel experiments of streets to investigate the flow around different configurations of street layout. Hence the model relies on actual measurements of pollutant concentrations in the city being considered and is therefore potentially more useful from the point of view of air quality management. CAR is calibrated each year against the Dutch National Air Quality Monitoring Network. The model is used by the Netherlands local authorities in the implementation of national air quality decrees and for traffic and environmental planning activities. Whilst the central government uses the model for the evaluation of existing policies and new policy proposals i.e. forecasting.

A1.3.4 The principal advantages of the model are:

- It is based on extensive wind tunnel modelling experiments, which are the most appropriate way of assessing flow around complex street canyons in urban areas. This is a pragmatic approach to a very complex problem which provides a better alternative than other approaches such as computational fluid dynamics.
- It considers the full range of street canyon configurations (see below).
- It has been extensively tested and validated by two large and well respected Dutch research establishments: TNO and RIVM. Furthermore, it is "calibrated" against real data, annually.

The CAR model is also able to model many different street canyon configurations:

- Roads in open terrain;
- Broad roads with buildings on both sides;
- Street canyon with buildings on both sides;
- Street with Buildings on one side;
- Basic street type, i.e. a "typical" urban road which exhibits a mix of those configurations

The basic street type has been used in this report.

### A1.3.5 Model Validation

A1.3.6 CAR has been validated against measurements made in streets by the Dutch National Air Quality Monitoring Network. The average, relative, differences between the calculated and measured values are -3±9 % for CO, 8±19 % for $NO_X$, and 6±9 % for $NO_2$. However these values have been calculated using data from the same

monitoring stations used to calibrate the model in the first instance and can therefore be considered as minimum errors. Based on measured data from 10 streets in Amsterdam differences were found of -10±12 % for 98th percentile of CO and 6±10 % for 98th percentile $NO_2$. The results indicate that the accuracy of the model is well within the limits set by the Dutch air quality decrees (30 % at 70 % confidence level).

## A1.4.Predictions of $NO_2$ at Background and Roadside Locations

A1.4.1 A new approach based on the use of ambient data in London has been used to make predictions of annual mean $NO_2$ at background and roadside locations.

A1.4.2 A useful way of viewing the resulting non-linear relationship between $NO_X$ and $NO_2$ is to place the $NO_X$ concentrations into different bins e.g. 0-5 ppb, 5-10 ppb…etc. and calculate the corresponding mean $NO_2$ concentration for each bin. Derwent and Middleton (1996) have done this for a site in central London. It is also possible to summarise the frequency of occurrences of $NO_X$ and $NO_2$ into the same bin sizes. The mean $NO_2$ is then calculated by 'multiplying' the two curves together and dividing by the number of readings. This is a useful way of summarising the data and results in less than 1 % inaccuracy when annual mean concentrations of $NO_2$ are estimated for current day concentrations.

A1.4.3 Derwent has shown through trajectory modelling in London that points move down the $NO_X$-$NO_2$ curve as $NO_X$ concentrations reduce (Derwent, 1999). Assuming that this is the case, then recalculating the frequency distribution allows for the assessment of the effects of reductions in $NO_X$. Figure A1.2 shows the three components of this approach for the Ealing roadside site. First, the familiar $NO_X$-$NO_2$ relationship shows that $NO_2$ concentrations increase at first with increasing $NO_X$, and then begins to level out. The frequency distribution for $NO_X$ in 1997 peaks at about 60 ppb i.e. most $NO_X$ concentrations are around 60 ppb. The new frequency distribution for a 50 % reduction in $NO_X$ peaks at about 30 ppb. Recalculating the annual mean $NO_2$ for the Ealing site shows that a 50 % reduction in $NO_X$ reduces the annual mean $NO_2$ from 33 ppb to 23 ppb, a reduction of 30 %.

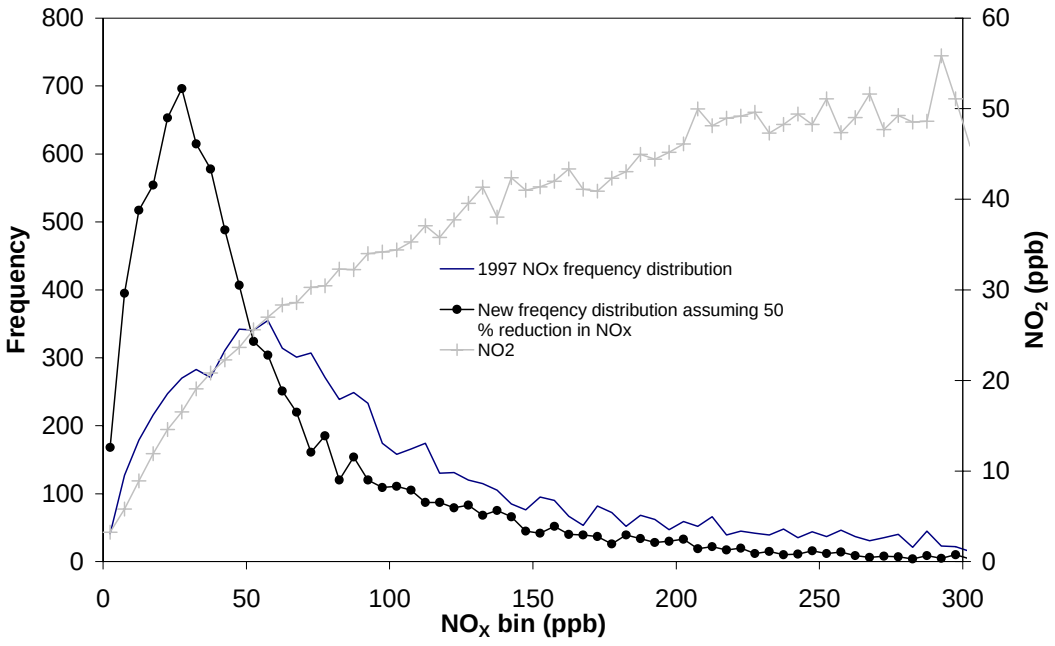



**Figure A1.2** Ealing Roadside $NO_X$ and $NO_2$ Relationships (1997)

A1.4.4 New $NO_X$-$NO_2$ points can therefore be generated for different $NO_X$ reductions e.g. from 10 to 80 % reduction, for background and roadside sites. A relationship between $NO_X$ and $NO_2$ can therefore be determined, which is based on considerably more data, for roadside and background locations for different years.

### A1.4.5 $NO_X$-$NO_2$ Relationships at Background and Roadside Locations

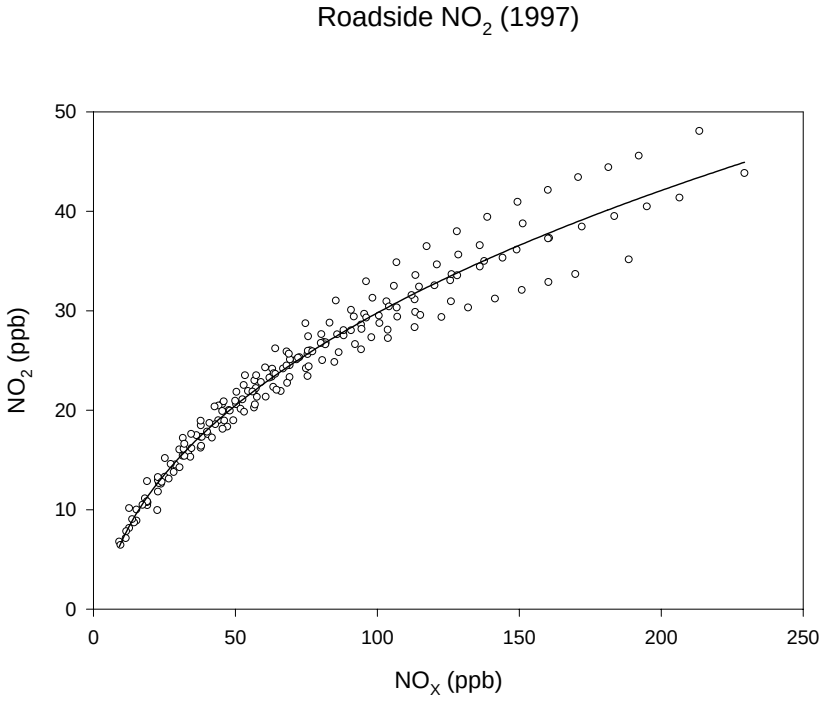



**Figure A1.3** $NO_X$-$NO_2$ Relationship at Roadside Locations (1997)

A1.4.6 Figure A1.3 shows how the extra $NO_X$ and $NO_2$ data points, calculated using the method described above, move down the curve towards zero $NO_X$. This process has been repeated for 1996 and 1997. For 1996 13 background and 8 roadside sites were used. Points were generated at 5 % intervals of $NO_X$ reductions, from 10 to 80 %. Therefore a total of 195 points are generated for background and 120 points at roadside. More sites were available for the analysis of 1997 data: 21 at background, including sites from the Kent Network, and 12 at roadside.

Each curve was fitted using a third order log function:

$$NO_2 \text{ (ppb)} = A + B\,[\ln(NO_X)] + C[\ln(NO_X)]^2 + D[\ln(NO_X)]^3$$

Where A, B, C and D are constants.

A1.4.7 As a check on whether the curve fit was influenced by the sites chosen, the same sites in 1996 were chosen for the 1997 analysis, which showed that there was very little difference when additional sites were added. The sites from the Kent Network

were also removed from the 1997 data and again very little difference in the fit equation was seen.

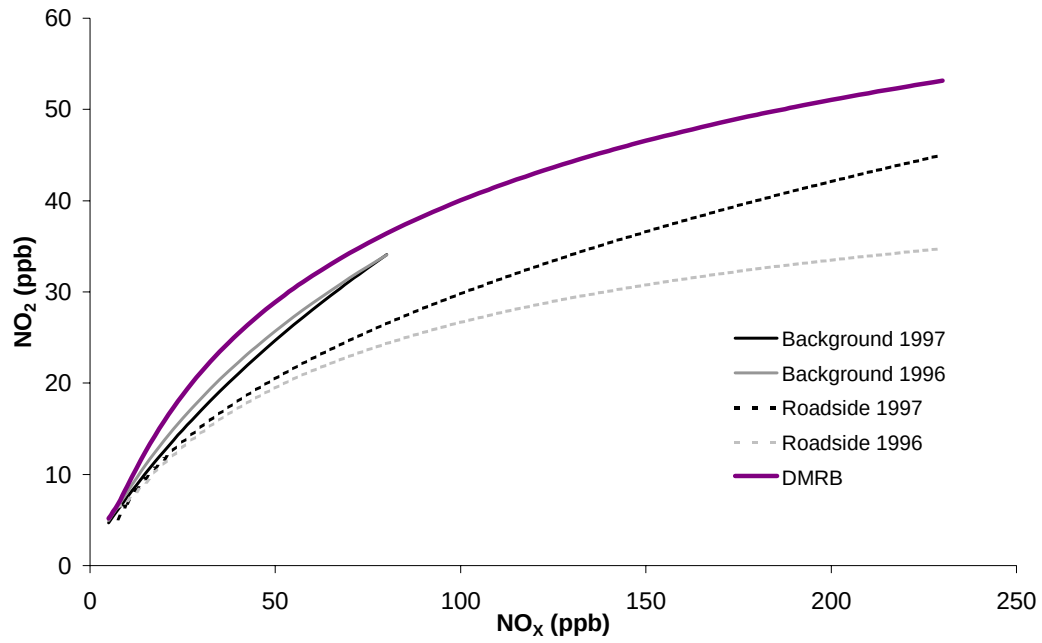



**Figure A1.4** $NO_X$-$NO_2$ Relationships at Roadside and Background Locations for 1996 and 1997

A1.4.8 Figure A1.4 shows the fit lines for 1996 and 1997. Several important features can be observed:

- The background and roadside points fall onto two distinctly different curves. Background $NO_2$ concentrations are always predicted to be higher than roadside concentrations for a particular concentration of $NO_X$. This is intuitively correct as very little time is given for the conversion of NO to $NO_2$ at roadside locations. It is also encouraging to note that even when points are 'artificially' generated, the distinct differences, as a result of atmospheric chemistry, are still observed between the two location types. For example, reducing $NO_X$ concentrations at a central London background location such as Bloomsbury by 50 % (taking the $NO_X$ concentration to that of background sites Greenwich or Bexley), results in a $NO_2$ concentration which is very similar to Greenwich or Bexley. Similarly, reducing $NO_X$ concentrations at a busy roadside site in London at some point results in similar $NO_2$ concentrations to less busy roadside sites - not a background site.
- The background curves are very close to being linear, which reinforces the original assumption used in pollution climate mapping that the background $NO_2$ concentration varies linearly with emissions. Nevertheless, they are curved enough to affect the $NO_2$ concentration predictions around 21 ppb, which tend to be higher using the non-linear approach. The difference is around 1 ppb, but is enough to significantly affect the number of roads which are estimated to exceed 21 ppb in London.
- The background lines for 1996 and 1997 are in very close agreement.
- Roadside $NO_2$ concentrations in 1997 are generally higher, which is in agreement with measurement data, which shows 1997 to be a tougher year for $NO_2$.

- A comparison has been made with the $NO_X$-$NO_2$ relationship used in the DMRB methodology. A comparison in London shows the DMRB methodology predicts significantly higher $NO_2$ concentrations at background and roadside locations. It appears therefore that the DMRB methodology produces very conservative estimates of $NO_2$.
- The mapping approach used by SEIPH has been revised to take account of these findings. Mapping is now only used for predictions of $NO_X$ and not $NO_2$. $NO_X$ can be more easily related to changes in emissions than $NO_2$. $NO_2$ is calculated directly from the predicted $NO_X$ concentration. This change has improved the robustness and transparency of the approach.

A1.4.9 An advantage of this approach is that it is easy to apply and reflects complex chemical reactions that occur over metres and seconds. Such a distinction between concentrations on this scale would not be possible through Normal modelling techniques such the use of trajectory models, which tend to rely on kilometre grid square averages.

A1.4.10 Figure A1.5 shows how well the mapping approach predicts annual mean $NO_X$ concentrations for background sites in London. It shows that the technique provides consistently good predictions across the entire London area. Using the $NO_2$ non-linear function, the annual mean $NO_2$ can be predicted as shown in Figure A1.6. Again, the predictions are very good: almost all are within 10 % of the measured values. Predictions of $NO_2$ at roadside locations have been made for 1996 and 1997 based on the LTS traffic model (Figure A1.7). In general there is good agreement between measured and predicted values. The technique has also been used in the Monte Carlo study, described in appendix 4, where it is applied to a number of roadside locations in London.

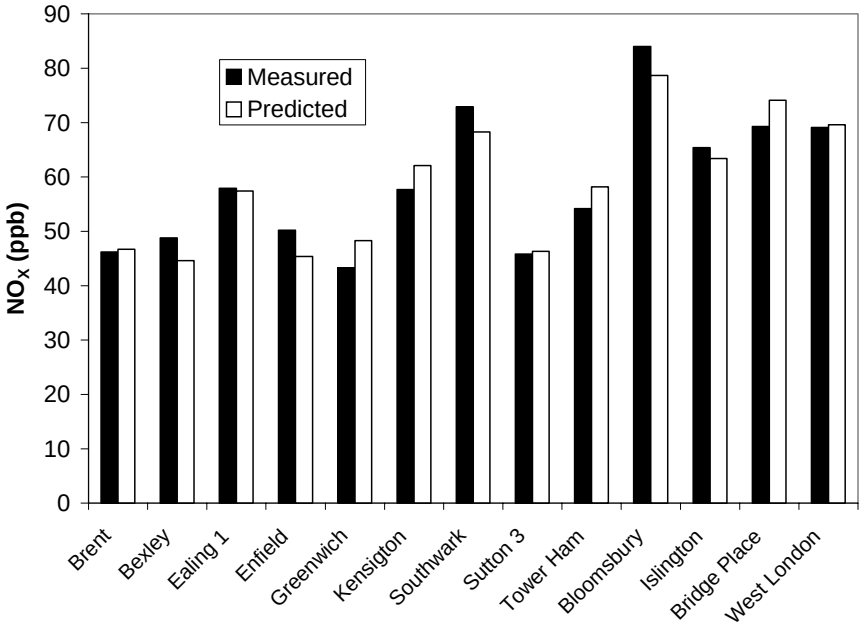



**Figure A1.5** Predicted and Measured $NO_X$ Concentrations at Background Locations in London (1997)

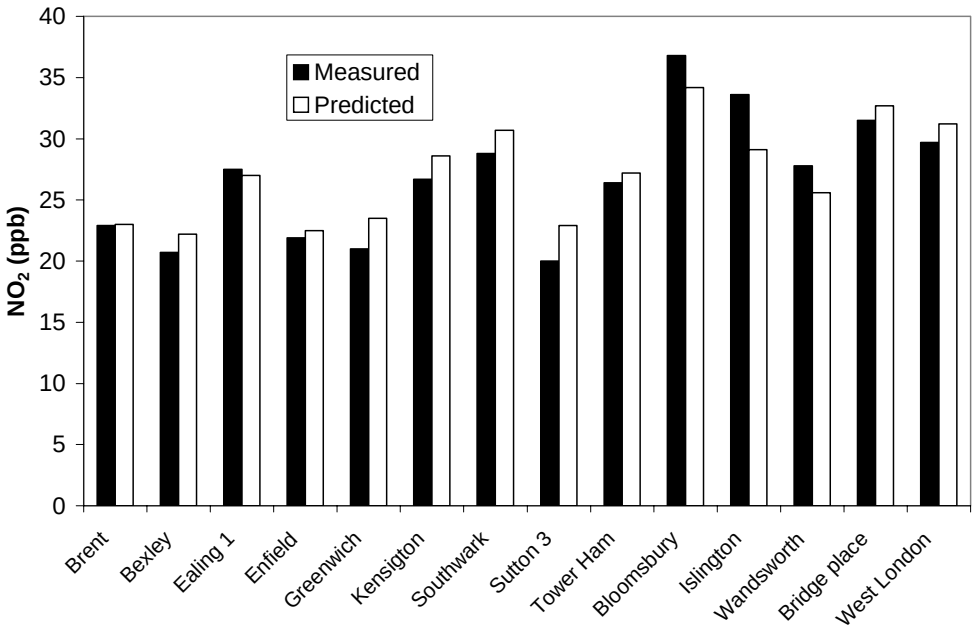



**Figure A1.6** Predicted and Measured $NO_2$ Concentrations at Background Locations in London (1997)

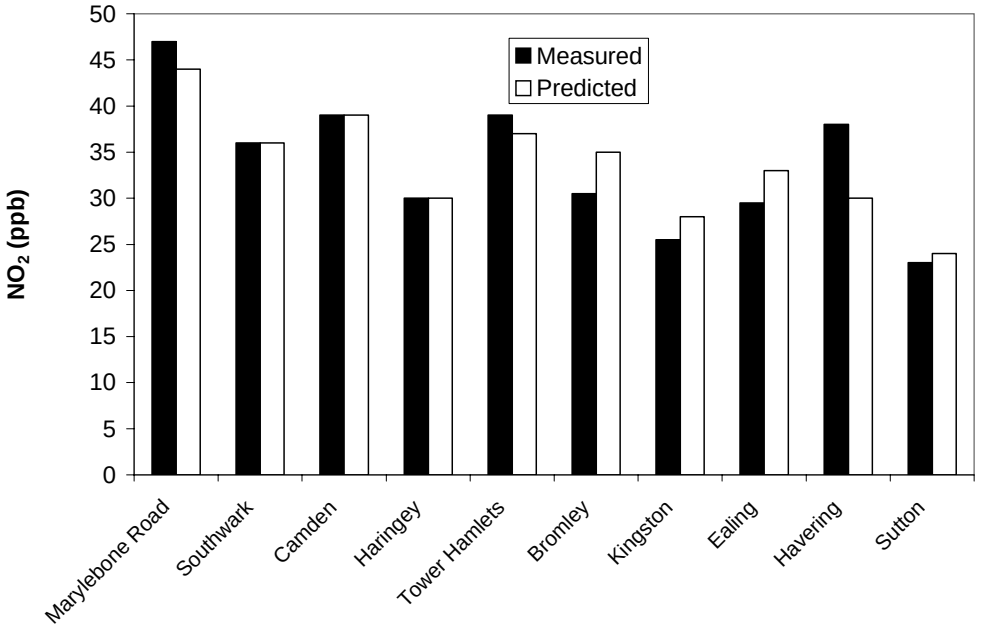



**Figure A1.7** Measured and Predicted $NO_2$ at London Roadside Locations (1997)

A1.4.11 *Important note* - Predictions at road junctions have not been modelled specifically for this study for the following reasons:

1) the high degree of complexity involved with modelling a road junction, which requires an understanding of acceleration and deceleration of vehicles, associated emission factors, geometry of the junction in question

2) the results of our work for the Government Office for London indicate that junctions are less important for both $NO_2$ and PM10, than for CO.

A1.4.12 Estimates of $NO_2$ concentrations have been made at background locations on a 1-$km^2$ basis, as described above. An analysis of the monitoring data shows that there is an order in the $NO_X$-$NO_2$ curves generated for each monitoring site. Those sites in central London have consistently higher $NO_2$ concentrations for a particular $NO_X$ concentration. This might be expected, as air travelling to central London must travel on average over the largest distances and over the path of highest emissions compared with any other area. Furthermore, air arriving at central London will have had more time for atmospheric chemistry to occur, converting $NO_X$ to $NO_2$. For this reason our predictions suggest that at central London background locations a $NO_X$ concentration as low as 30-33 ppb may be required to meet the 21 ppb objective. For inner London an analysis of the monitoring data suggest that a $NO_X$ value of around 36 ppb will be required to meet the objective.

A1.4.13 The estimation of background $NO_2$ concentrations has been refined to take account of the analysis above. Based on an analysis of the monitoring data, three different curves have been used, broadly consistent with areas covered by central, inner and outer London. The $NO_X$-$NO_2$ curve at London Bloomsbury is used for a distance of 4 km from the centre. The centre is defined as the centre of the City of London, located at (532500, 180500). Between 4 and 8 km the curve at Kensington and Chelsea is used, and beyond 8 km the Teddington curve is used.

## A1.5.Fall-off in $NO_2$ Concentration Away From a Road

**Note:** This appendix contains extracts of a report written on behalf of the Department of Environment, Transport and the Regions (DETR), entitled: ***$NO_2$ Model and Measurement Profiles from a Major Road in London.***

### A1.5.1 Summary

A1.5.2 The available literature indicates that $NO_2$ concentrations decrease rapidly away from the road centreline, and reach a maximum value at the road centreline.

A1.5.3 Measurements show that there are seasonal differences in the gradient of $NO_2$ away from a road. In wintertime, there is a smaller difference between roadside and background concentrations, compared with summertime. This is attributed to increased thermal mixing in summer resulting in rapidly decreasing concentrations away from a road, and increased photochemical reactions.

A1.5.4 Diffusion tube measurements at a central London location for a typical road suggests that $NO_2$ falls to background locations within about 15 m of the road centreline.

A1.5.5 SEIPH's approach to calculating the fall-off in concentration agrees very well with these findings.

### A1.5.6 Introduction

A1.5.7 The prediction of background and roadside $NO_X$ and $NO_2$ concentrations is challenging. In the case of $NO_2$, concentrations are determined by complex atmospheric reactions, driven by ambient ozone concentrations. The prediction of roadside concentrations in urban areas is particularly challenging given the complex dispersion involved.

A1.5.8 Many approaches can be used to predict concentrations of $NO_2$: simple dispersion models, empirical models, wind tunnel modelling and trajectory modelling. In the context of the National Air Quality Strategy, robust and reliable techniques are required in which all the assumptions are clearly identified.

### A1.5.9 Fall-Off in $NO_2$ Concentration Away From a Road

A1.5.10 Laxen and Noordally (1987) used $NO_2$ diffusion tubes at a central London location to determine vertical and horizontal distributions of $NO_2$ away from a typical urban street. The principal roads investigated were York Road with a traffic flow of 48,000 vpd, and roads around Mansion House carrying between 22,000 and 33,000 vpd. They found that concentrations of $NO_2$ were highest along the road centreline and decreased rapidly away from the street falling to background concentrations within about 15 m from the centre of the road. Along York Road the fall-off in concentration was established in a gap between buildings. Results for a 'true' street canyon without such gaps may be different. However, given the complex morphology of streets in urban areas, where very few 'true' street canyons exist, these results are probably typical of that expected in an urban area.

A1.5.11 The results from this experiment provide an opportunity for comparing SEIPH's predicted results with measurements. A road in central London with a traffic flow of 50,000 vpd was chosen and the fall-off in $NO_2$ concentration predicted. SEIPH's approach, which makes use of the CAR model for the fall-off in concentration away from a road, assumed the road to be type 2 i.e. a typical urban street. Figure A1.8 compares the excess $NO_2$ concentration i.e. the $NO_2$ concentration above background for the study. The SEIPH approach compares remarkably well with the measurements, although further comparisons would be required to gain full confidence in the findings presented here.

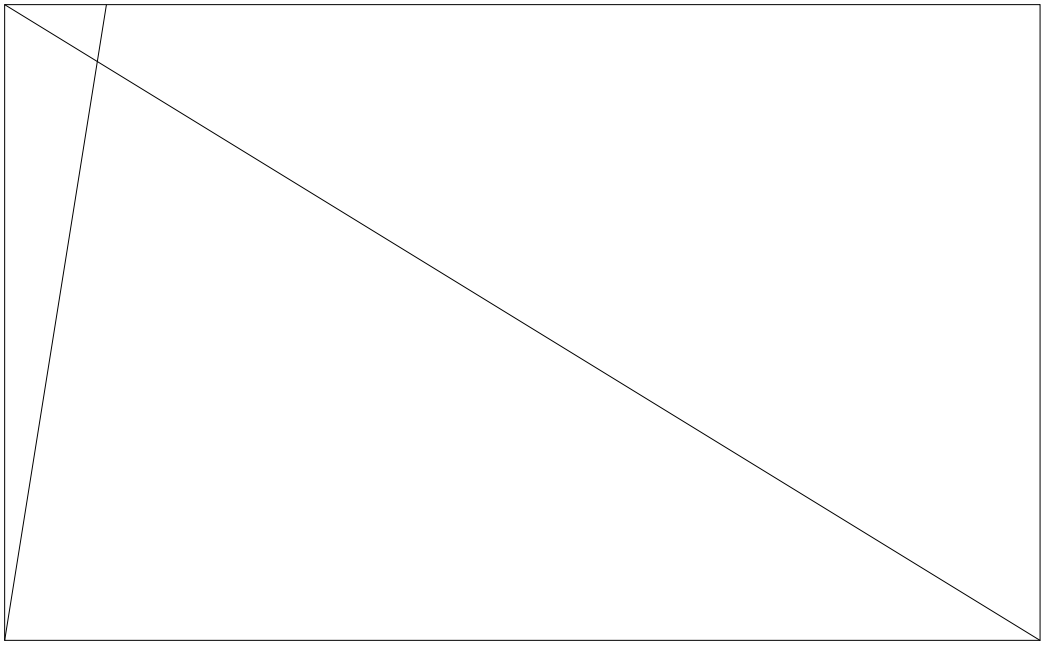


**Figure A1.8** : Excess $NO_2$ Concentration Away From a Typical Urban Street in London

## A1.6.Prediction of Peak Hour $NO_2$

A1.6.1 The prediction of the peak hour value of $NO_2$ at a location is problematic. The events that lead to such high concentrations are characterised by low wind speeds and by low vertical mixing. These conditions are generally considered to be outside the valid regime of dispersion models, which work best under typical "average" conditions i.e. wind speeds of 5 m/s and day-time conditions. Peak hour events also

tend to be associated with the accumulation and re-circulation of pollution as a result of a stagnated air mass; events which conventional dispersion models cannot replicate. An added complexity to the dispersion in urban areas is the presence of buildings, and additional chemical reactions forming $NO_2$. Under such conditions it is unreasonable to expect dispersion model predictions to be very accurate (+/- 100 % or more).

A1.6.2 An alternative approach however can be used, based on monitoring data. This approach considers $NO_X$-$NO_2$ relationships at different monitoring sites and explores how the peak $NO_2$ concentration is likely to change as $NO_X$ concentrations reduce and the highest hourly concentrations 'fall down' their individual curves.

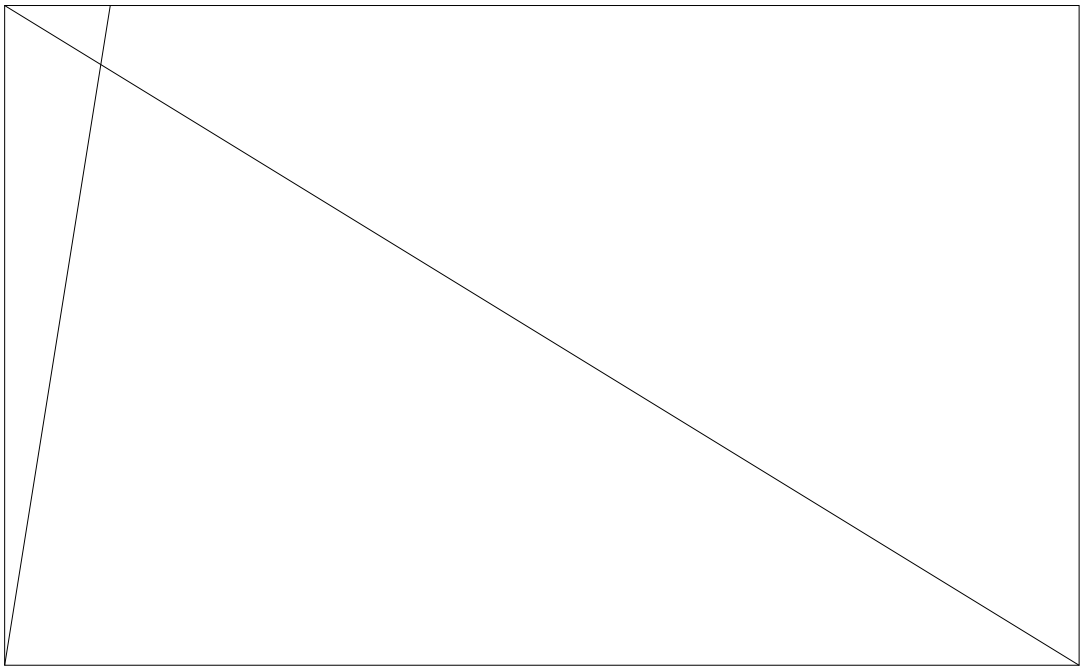


**Figure A1.9** NOx-$NO_2$ Relationships at three London Sites 1991 - 1997

A1.6.3 Figure A1.9 represents an average $NO_X$-$NO_2$ relationship for three sites in London. The data are summarised from the years 1991 to 1997. December 1991 is included in the data and represents the period, which gave the highest recorded hourly $NO_2$ concentration. During these cold and still winter time episodes, often associated with fog, the reaction between NO and $O_2$ becomes significant and is the cause of the steep section of the curve. This is evident at $NO_X$ concentrations greater than 1000 ppb.

A1.6.4 Between 1991 and 2005 the reduction of emissions of $NO_X$ (approximately 50 %) will significantly reduce the highest hourly concentrations. The effect, described by Derwent (1999), will be for a point to follow the curve down towards the flat section, reducing the $NO_2$ concentrations.

A1.6.5 This method provides the most robust way of firstly, estimating the concentration during winter time episodes and secondly predicting the future change expected through reduction in the emissions of $NO_X$.

**Table A1.1** Measured and Predicted Highest Hourly $NO_2$ in London

| | Measured Concentration 12th Dec 91 | Measured Concentration 13th Dec 91 | Measured Concentration 12th Dec 91 | Measured Concentration 13th Dec 91 | Predicted Concentration |
|---|---|---|---|---|---|
| | $NO_X$ | $NO_X$ | $NO_2$ | $NO_2$ | $NO_2$ |
| Bridge Place | 1566 | 1567 | 342 | 423 | 418 |
| Cromwell Road | 1708 | 1654 | 341 | 382 | 334 |
| West London | 1555 | 1511 | 323 | 388 | 369 |

A1.1.1 **Table A1.1** presents a number of important points:

- The highest concentrations are at the background sites of West London and Bridge Place. This is likely to be because of the increased period available for the oxidation of NO to take place, at these locations;
- The difference between concentrations of $NO_2$ for the same $NO_X$ prediction at Bridge Place. This is 81 ppb $NO_2$ for a 1 ppb change in $NO_X$ concentration, which clearly identifies the difficulty of predicting such events;
- The reasonable predictive capability of the $NO_X$-$NO_2$ relationships.

A1.1.2 A further point to note, from the measurements at Cromwell Road, is that the highest hourly measurement of $NO_X$ of 1746 ppb does not coincide with the highest hourly measurement of $NO_2$, it gives instead, 166 ppb. This occurred on the 15th December, during the break up of the episode. Dispersion models would be unable to predict such an event.

**Table A1.2** Predicted Highest Hourly $NO_2$ in London in 1991 and 2005

| | Predicted Concentration 1991 | Predicted Concentration 2005 |
|---|---|---|
| Bridge Place | 418 | 139 |
| Cromwell Road | 334 | 90 |
| West London | 369 | 117 |

A1.1.1 Predictions of future concentrations have shown that at roadside and background sites in central London, the highest hourly concentration of $NO_2$ is not predicted to exceed the NAQS objective in 2005. However because of the uncertainty of predictions of this objective and the proximity of the Bridge Place prediction to 150 ppb (< 10 %), it must be considered possible to exceed this objective in central London. This is considered unlikely in outer London.

## A1.2. Prediction of $NO_2$ Concentrations from Industrial Processes

A1.2.1 Emissions data for the modelled Part A industrial processes were taken from the London Atmospheric Emissions Inventory release 2a (LAEI). This data set includes stack parameters and emissions data for Part A processes within the M25, and data for some of those processes outside the M25 whose emissions may impact upon London.

A1.2.2 Data for some potentially significant processes were not available from the LAEI, and data were therefore obtained from the Environment Agency through personal communication and their website at http://www.environment-agency.gov.uk/ your_env/. Although less detailed than the LAEI data, emissions rates could still be calculated for the processes as a whole, but not for multi-flued stacks and multiple stacked processes. A summary of the data used in these assessments can be seen in appendix 2. The $NO_2$ concentrations were predicted using the ADMS Urban model.

### A1.2.3 **Model Results**

A1.2.4 Modelling was carried out for base years 1996 and 1997 at a range of locations across London. Hourly sequential meteorological data were used from the London Weather Centre. Valid data were available for 97 % of hourly values during 1996 and 94 % of values in 1997. Monitoring data were checked against meteorological data for both 1996 and 1997 to see whether any periods of invalid meteorological data coincided with any peak hourly $NO_2$ concentrations at the sites in Table A1.3. This was not the case for either of the years and therefore we can be confident that the worst case meteorological conditions have been taken into account when modelling these concentrations.

A1.2.5 It has been assumed that the emissions from each process are released continuously where data on operational periods was not available (operational hours = 8760/annum). Where these data were available, the emissions were calculated according on the operational time.

$$\text{Emission rate (g/s)} = \frac{\text{Emission (kg)} \times 1000}{\text{Operation (hours)} \times 3600}$$

**Table A1.3** Modelled $NO_2$ Concentrations for 1996 and 1997

| Site | 1996 (ppb) | | 1997 (ppb) | |
|---|---|---|---|---|
| | Annual mean | Peak hourly | Annual mean | Peak hourly |
| Bexley 1 | 0.4 | 8.0 | 0.6 | 2.1 |
| Bloomsbury | 0.5 | 4.3 | 0.7 | 2.4 |
| Sutton 1 | 0.5 | 3.2 | 0.5 | 3.1 |
| Ealing 1 | 0.6 | 3.8 | 0.5 | 3.5 |
| Greenwich 4 | 0.4 | 6.9 | 0.6 | 2.5 |
| Brent 1 | 0.8 | 3.8 | 1.0 | 3.8 |
| Tower Ham. 1 | 0.5 | 4.9 | 0.6 | 2.4 |
| Ken. & Chel. | 0.5 | 5.0 | 0.6 | 3.3 |

A1.1.1 The model predicts annual average and maximum 1 hour mean concentrations of $NO_x$ that were subsequently converted to annual average and maximum 1 hour mean concentrations of $NO_2$ by dividing the $NO_x$ concentration by 5. This is consistent with NAQS guidance on industrial processes (TG4).

A1.1.2 Table A1.3 shows that the contribution from industrial point source emissions to the annual mean concentration of $NO_2$ is insignificant compared to the contribution from traffic sources. Even accounting for the fact that the dispersion model under predicts, the impact of industrial sources in London provides < 5 % of the annual average $NO_2$ in all cases.

A1.1.3 Further modelling of the maximum 1 hour mean concentration was undertaken for the east London area shown in Figure A1.10 below. This was to ascertain whether or not the locations and results in Table A1.3 were representative of London as a whole and specifically of the east Thames region.

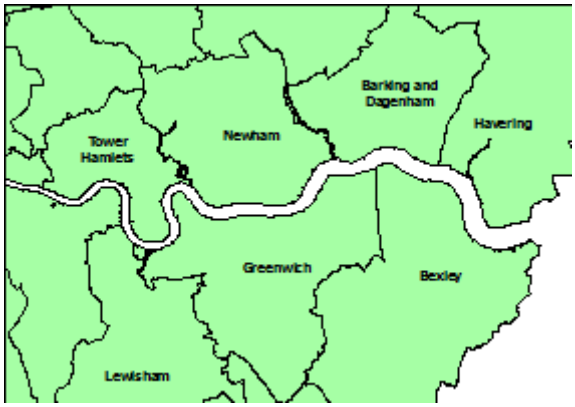



**Figure A1.10** Extent of area modelled for maximum 1 hour mean concentrations of $NO_2$

A1.1.4 The meteorological data used were from 29th October to the 3rd November 1997, as this represented a 'worst case' episode for $NO_2$ throughout London. As in earlier model runs above, the meteorological data used covers all periods of peak $NO_2$ values monitored in London. The maximum concentration predicted for the peak hour was 8 ppb. This agrees well with the concentrations predicted for the specific points in Table A1.3. The results of the modelling can be seen below in Figure A1.11.

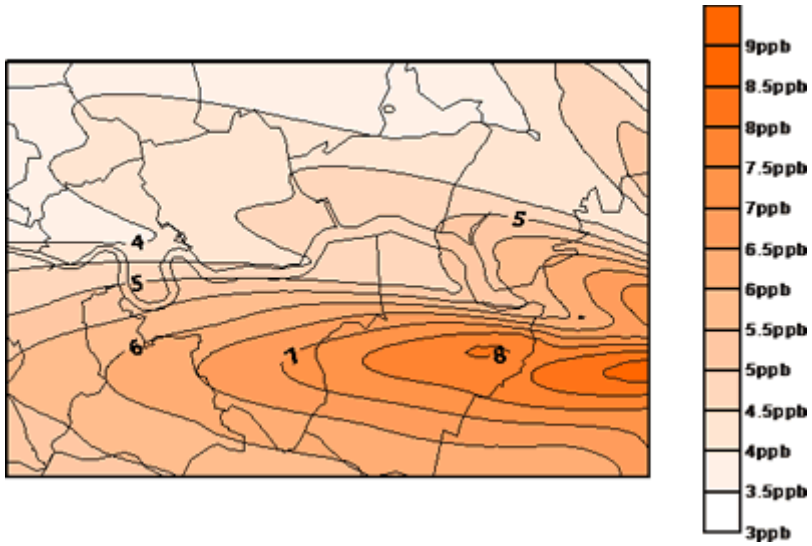



**Figure A1.11** Predicted Maximum 1 hour Mean Concentrations of $NO_2$ over East London

A1.1.5 The model predicts that industrial point source emissions contribute approximately 5% to the maximum hourly mean $NO_2$ concentration. This contribution can be considered to be small in comparison with the contribution from road traffic sources. However, the model has difficulty in predicting high percentile concentrations accurately and has been known to significantly under-predict these concentrations.

## A1.2. Prediction of $SO_2$ Concentrations from Industrial Processes

A1.2.1 $SO_2$ concentrations have been predicted using the AERMOD dispersion model. All of the major sources listed in Appendix 2 have been modelled.

A1.2.2 **Comparison of Model Results With Measurements**

A1.2.3 Modelling was carried out for base year 1997 at a range of locations across London. Hourly sequential meteorological data were used from the London Weather Centre. Valid data were available for 94% of values in 1997. The meteorological data for this year was also checked to confirm its validity for all of the $SO_2$ episodes. This was the case, and therefore all of the worst-case meteorological conditions in 1997 have been taken into consideration when modelling the $SO_2$ concentrations for this year.

A1.2.4 The Environment Agency Pollution Inventory was consulted in order to identify all large Part A industrial processes which release significant quantities of sulphur dioxide to air. The Environment Agency were then asked to supply the most up to date information held on record for these processes. Information on operational times was available for some processes and this was used to calculate emission rates accordingly.

A1.2.5 For several of the large power generators in the East Thames region, a factor was available which detailed the monthly and hourly variability in emissions from the processes, expressed as a percentage of the peak load emission rate. This was input into the model, therefore allowing the diurnal variation of emissions to be accounted for when predicting the shorter-term averages.

A1.2.6 Predictions of $SO_2$ concentrations were made at specific receptor points (the monitoring sites in **Table A1.4**) and over a grid of receptor points which covered the whole of Greater London, Thurrock and the Medway Towns.

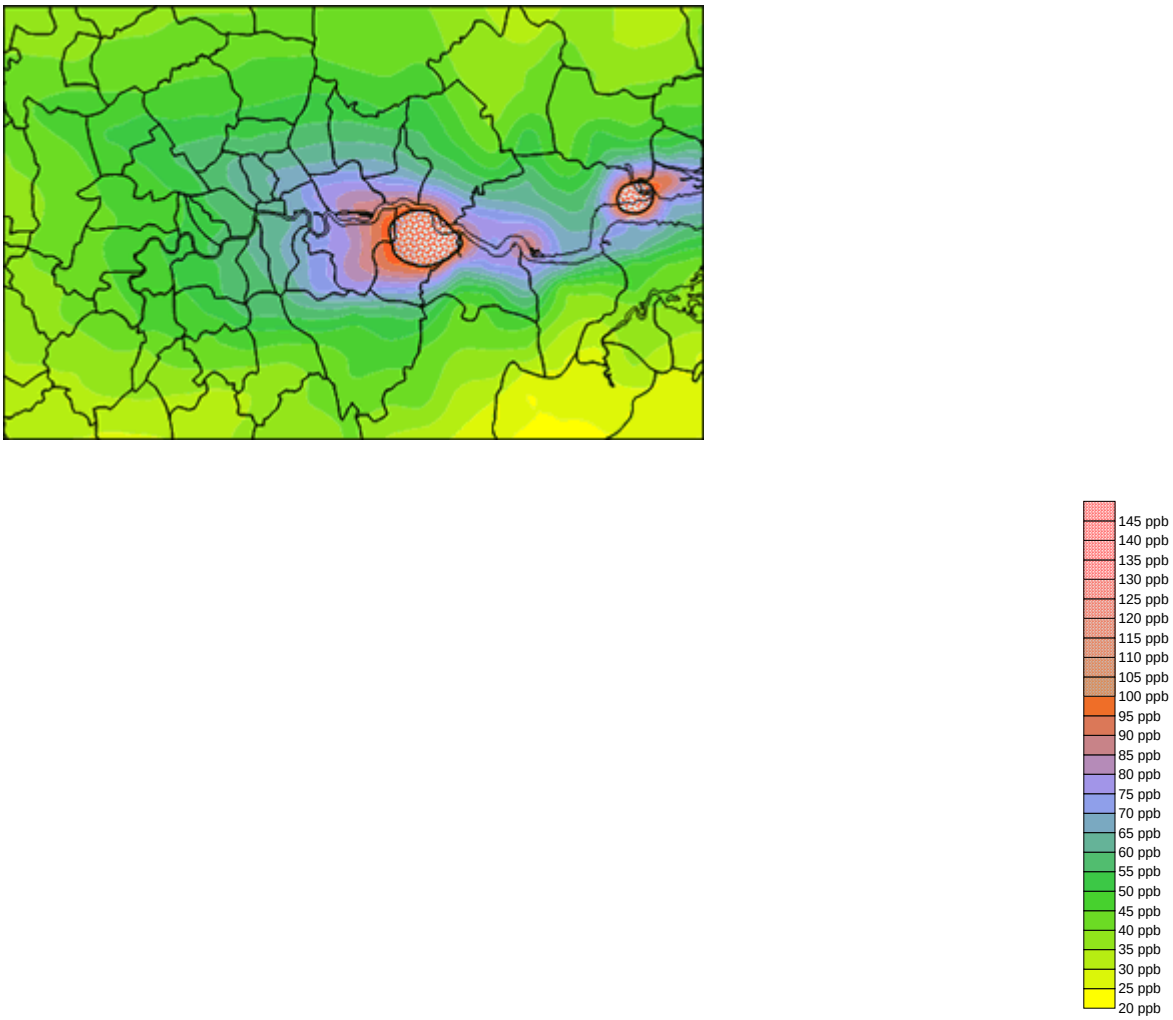
A1.2.7 shows that in general, the dispersion model tends to over predict the 99.9$^{th}$ percentile of hourly concentrations for 1997. An average over prediction of 22% was calculated tending to indicate that all of the major emissions sources have been included in the model run. The relationship between the modelled and measured values is not highly consistent, and therefore any conclusions drawn from it would be made with caution.

**Table A1.4**: Modelled and Monitored Peak Hour Concentrations of $SO_2$ in 1997 (1997 Met., 1997 emissions)

| **1997 99.9$^{th}$ Percentile of Hourly Mean Concentrations of $SO_2$** | | | |
|---|---|---|---|
| Site | Modelled Value | Measured Value | Prediction Accuracy |
| Bexley 1 | 147 | 89 | 66% over prediction |
| Bloomsbury | 67 | 66 | 2% over prediction |
| Brent | 58 | 41 | 44% over prediction |
| Ealing | 53 | 58 | 8% under prediction |
| Greenwich 4 | 101 | 71 | 44% over prediction |
| Kensington and Chelsea | 61 | 52 | 16% over prediction |
| Marylebone 1 | 66 | 46 | 43% over prediction |
| Sutton 1 | 50 | 43 | 17% over prediction |
| Tower Hamlets | 80 | 84 | 4% under prediction |
| Wandsworth 2 | 62 | 64 | 3% under prediction |
| **Average** | | | **22% over prediction** |

A1.1.1 Through this comparison of London's monitoring data and the model predictions, a factor was derived which was used to 'correct' the model predictions to agree with the measurements. Fifteen minute means were calculated by increasing the 99.9$^{th}$ hourly predictions by 10%, based on the relationship between the two statistics from monitoring data in London. This was considered to be a more reliable estimate of 15-minute values than the model predictions of very short-term statistics. The map shown below can be considered to be a 1997 case.

**Figure A1.12** Predicted Areas of Exceedence of the SO2 Limit Value (100ppb as a 99.9$^{th}$ percentile of 15-minute averages) 1997 case.

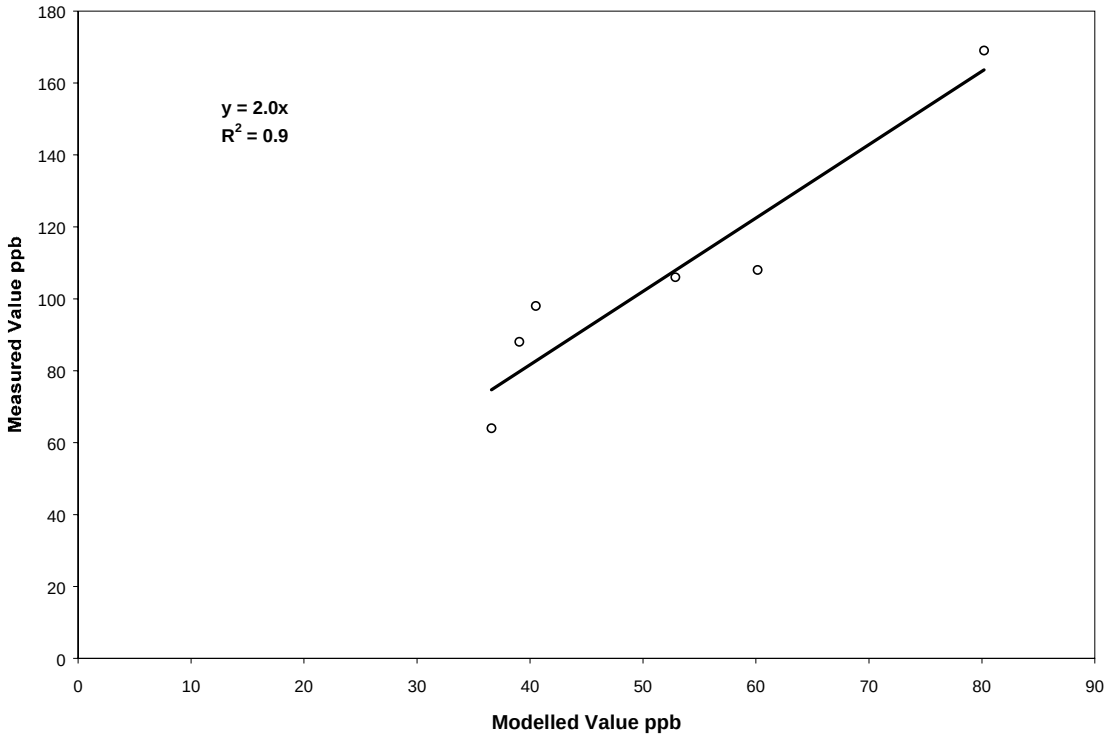



A1.1.2 1995 was the worst year in terms of exceedences of the $SO_2$ objective in London since widespread monitoring began. The reasons for this are not fully understood, but it is recognised that both emissions and meteorology play an important part.

A1.1.3 The model was run using 1997 emissions data and 1995 meteorology in order to simulate a possible "worst case" scenario. Valid meteorological data were available for 96% of hourly values in 1995. The data were checked to verify its validity for the $SO_2$ episodes in 1995.

A1.1.4 The maximum and 99.9th hourly values obtained from the model were compared with the measured data for 1995 in the same way as for 1997 and a multiplication factor was obtained.

**Figure A1.13** Relationship between Modelled and Measured 99.9th Hourly Values in 1995 Using 1995 Meteorology and 1997 Emissions Data

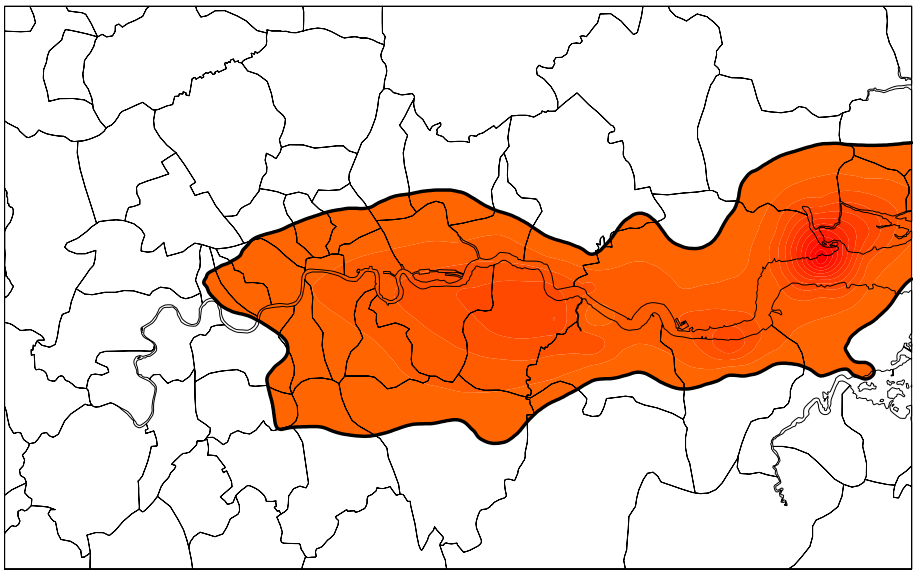



A1.1.5 The consistency of the relationship in Figure A1.13 above indicates that we can use the factor of 2 reasonably confidently in predicting the "worst case" future scenario as all sites lie close to the line of best fit. None of the sites lie significantly away from the line showing that the factor is generally better than those derived previously, the $R^2$ value of 0.89 giving us confidence that when applied, the factor is relevant for the entirety of London. However, with only six sites being used to derive this relationship, a certain degree of caution must be employed in its interpretation.

A1.1.6 Fifteen minute means were calculated by increasing the 99.9th percentile hourly predictions by 10%, based on the relationship between the two statistics from monitoring data in London. The area of exceedence can be seen below, based on "worst-case" meteorology, 1997 emissions data and monitoring data.

A1.1.7 Account has been taken of background concentrations within this assessment and a contribution of 7 ppb has been added to the model predictions. This is the highest annual average $SO_2$ concentration at the monitoring sites within London. This background contribution is associated with road traffic and combustion processes.

**Figure A1.14** Predicted Areas of Exceedence of the $SO_2$ Limit Value ("Worst Case Scenario")



with the addition of a high annual average background concentration of 7 ppb.

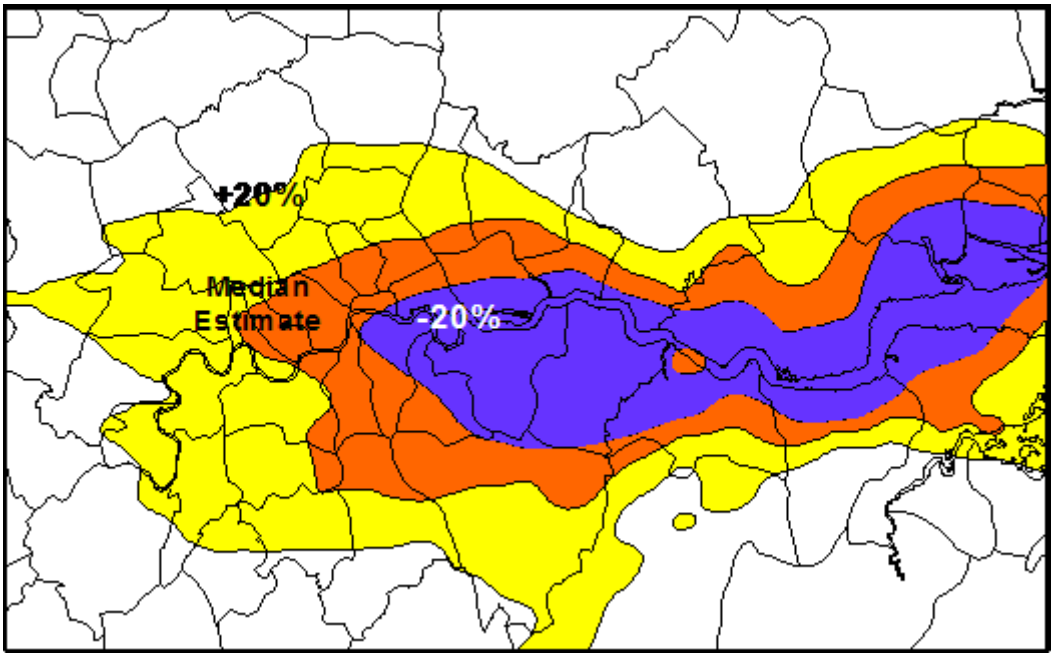
A1.1.8 This area of exceedence could be observed if the meteorology of 1995 is replicated before the end of 2005.

A1.1.9 The London Boroughs expected to exceed the NAQS objective for $SO_2$ are: Bexley, Greenwich, Havering, Barking and Dagenham, Redbridge, Newham, Waltham Forest, Tower Hamlets, Bromley, Lambeth, Lewisham, Southwark, Wandsworth, Kensington and Chelsea, Hammersmith and Fulham, Westminster, Camden, Islington, Merton, Sutton, Hackney and Croydon.

A1.1.10 **Uncertainty in Model Predictions**

A1.1.11 Uncertainty in these predictions is difficult to assess, although an uncertainty of +/- 20% would not be unreasonable. A map showing this uncertainty can be seen below.

**Figure A1.15** Areas of Exceedence in Relation to Reasonable Uncertainties in $SO_2$ Predictions




A1.1.12 Several of the processes modelled in this assessment are gas fired, using only oil as a stand-by fuel. It is probable that many of the models under predictions are due to lack of information on the start-up operation of these oil-fired boilers. Due to the short-term nature of the NAQS objective for $SO_2$, a high concentration could be encountered within a fifteen-minute period, due solely to the start-up process of an oil-fired boiler. $SO_2$ emissions from these processes tend to be averaged out and given as annual means, but when modelling such short-term objectives,

appropriately detailed information on this operation is needed if the objective is to be predicted effectively.

### A1.1.13 **Comparison of AERMOD and ADMS Model Outputs**

A model run using 1997 emissions data and 1995 meteorology was undertaken using the ADMS dispersion model in order to identify any significant differences with the AERMOD system. The 99.9$^{th}$ percentile of hourly concentrations were predicted at the specific receptor locations used in the AERMOD comparison. The outputs were compared with measured data and the results can be seen below.

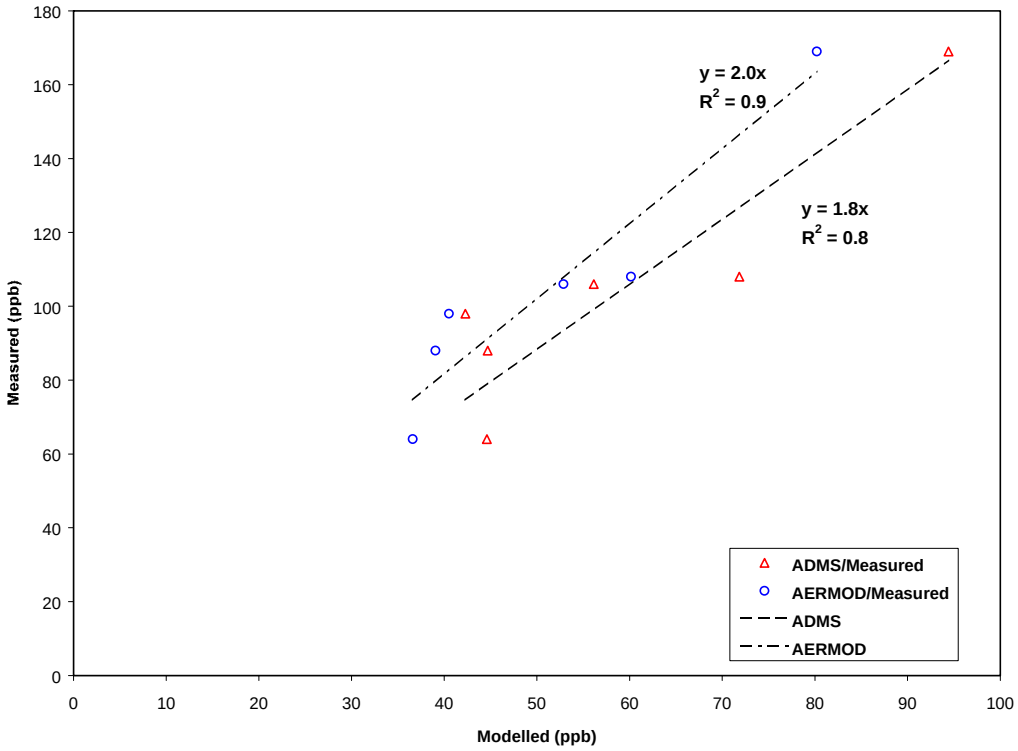
Table A1.5, along with those predicted by the AERMOD model.

| 1995 99.9$^{th}$ Percentile of Hourly Mean Concentrations of $SO_2$ | | | |
|---|---|---|---|
| **Site** | **Modelled Value AERMOD** | **Measured Value ADMS** | **Measured Value** |
| Bexley 1 | 80 | 94 | 169 |
| Ealing | 41 | 42 | 98 |
| Greenwich 4 | 39 | 45 | 88 |
| Kensington and Chelsea | 37 | 45 | 64 |
| Sutton 1 | 60 | 72 | 108 |
| Tower Hamlets | 53 | 56 | 106 |

**Table A1.5** Comparison between Modelled and Measured 99.9$^{th}$ Hourly Values in 1995 using 1995 Meteorology and 1997 emissions data using the ADMS and AERMOD dispersion models

A1.1.1 The outputs from both models were plotted against the measured data and can be seen in Figure A1.16 below.

**Figure A1.16** Relationship between ADMS and AERMOD Modelled and Measured 99.9th Hourly Values in 1995 using 1995 Meteorology and 1997 emissions data




A1.1.2 Initial findings suggest that both models significantly under predicted against the measured values for 1995 using 1997 emissions data. At each of the six sites, ADMS predicted closer to the measured values than AERMOD, although was less consistent as can be seen from the $R^2$ values from AERMOD and ADMS of 0.9 and 0.8 respectively.

A1.1.3 This increased consistency using AERMOD, led the SEIPH-ERG to use this model in preference to the ADMS model for this assessment of $SO_2$. The faster run times of AERMOD were also a deciding factor in which model to use for this large-scale assessment. However, more detailed comparisons between these dispersion models needs to be undertaken in the future in order to ascertain which models perform best under different conditions, although the scope of these Stage 3 assessments did not allow this.

## A1.2.Prediction of PM10 Concentrations From Industrial Processes

**A1.2.1** PM10 concentrations from industrial processes have been predicted using the ADMS Urban model. A selection of the sources in Appendix 2 has been modelled, with only those sources having an emission rate of 1 g/s or greater being chosen.

### A1.2.2 Comparison of Model Results with Measurements

**A1.2.3** Modelling was carried out for base year 1997 at a selection of locations across London. Hourly sequential meteorological data were used from the London Weather Centre. Valid data were available for 94% of values in 1997.

**A1.2.4** It has been assumed that the emissions from each process are released continuously (assumption of operational hours = 8760/annum) except where data on operational times were available.

**A1.2.5** Table A1.6 shows that the contribution of industrial emission sources of PM10 to the Daughter Directive can be regarded as negligible. Even taking into account the likelihood that the model under predicts pollutant concentrations by a considerable margin, the main focus of concern for PM10 concentrations should be road traffic, transboundary sources of secondary particles and the contribution of coarse fraction particles.

**Table A1.6** Contribution of Part A Industrial Sources to PM10 concentrations in 1997

| Site | Contribution of Industrial Sources to PM10 Concentrations on Days over 50 $\mu gm^{-3}$ |
|---|---|
| Bexley 1 | 0.03 % |
| Greenwich 4 | 0.02 % |
| Brent 1 | 0.02 % |
| Tower Hamlets 1 | 0.05 % |
| Kens. & Chel. | 0.05 % |

## A1.1. PM10 Predictions

A1.1.1 SEIPH has adopted and adapted the receptor modelling technique described in Airborne Particles Expert Group (APEG, 1999). The model predicts daily average PM10 concentrations for 1995 to 1997 in the particle fractions, primary, secondary and coarse.

A1.1.2 The model was developed using measurements from the London AURN, from sites within the London Network, rural measurements from the EMEP acid rain monitoring network and black smoke measurement from London.

A1.1.3 The model is consistent with that described in APEG and takes the form described below. It differs in number of respects however, not least of which is its treatment of the coarse particle fraction, which is essential for the correct prediction of the NAQS PM10 objectives and particularly for the prediction of future PM10 concentrations.

*PM10 Concentration = A (Black Smoke Concentrations) + B (Rural Sulphate Concentrations) + C (Total PM10 Concentrations)*

A = Constant derived from regression analysis

B = Relationship between Rural Sulphate Measurements with TEOM – BS

C = Factor relating the proportion of coarse particles with Total PM10 concentration.

### A1.1.4 Estimating the Secondary Particle Contribution

A1.1.5 In common with work by APEG, rural sulphate measurements were plotted against the network average TEOM – black smoke measurements made at background locations throughout London. Rural sulphate concentrations have a gradient east–west and north–south in the UK and so the sites most likely to represent London were chosen. These sites were Barcombe Mills (South Coast) and Stoke Ferry (East Anglia). The period chosen was the year 1996 and separate relationships were included for summer and winter.

### A1.1.6 Estimating the Coarse Particle Contribution

A1.1.7 The coarse fraction particles are an important contributor to the overall PM10 concentration and whilst previous models had used a constant figure throughout the year it was considered important to vary this fraction of PM10 to improve the predictive capability of the model. This was undertaken by relating the fraction of coarse particles, defined in this case as PM10–PM2.5, to the total particle concentration. The data availability of co-located TEOM monitors is not as comprehensive as many other measurements, but it was possible to relate those measurements from the Bexley site for the first and second quarter of 1998. This also allowed factors to be produced for a summer and winter period.

A1.1.8 The assumption that the coarse fraction is the same at every location may not be correct as there are local sources of coarse particles from tyre and brake wear from vehicles and also from the re-suspension of road dust in turbulent vehicle wakes.

A1.1.9 The assumption in the model is that 27.6 % of total PM10 relates to the coarse fraction. This compares well with the assumption for Ealing, 29.5 % and Bloomsbury, 32.5 % and is therefore a reasonable one, although an underestimate is likely towards the central London area.

A1.1.10 Through the above analysis the process of predicting daily average PM10 concentrations was performed using measurement data from the following monitoring sites:

- The network average black smoke measurements from the London sites;
- The average daily sulphate concentration from Stoke Ferry and Barcombe Mills;
- The network average TEOM concentration from the sites Greenwich, Kensington and Chelsea, Tower Hamlets 1, Bexley, Thurrock and Bloomsbury.

The assumptions for the prediction of individual locations are as follows:

- The concentration of coarse and secondary particles vary daily and by separate relationships for summer and winter;
- The primary particles vary daily and are calculated using a relationship with the London network average black smoke measurements;
- The annual average secondary particle contribution is uniform across London;
- The annual average coarse particle contribution is also uniform across London;
- The difference in average concentration between sites is dominated by locally generated primary particles and therefore relates directly to local particle emissions, mainly from motor vehicles.

### A1.1.11 Comparison of Modelled and Measured PM10 Concentrations

A1.1.12 The results from the model, using the variable coarse concentration and a summer and winter secondary particle relationship provided the most robust predictions. An example of a scatter plot of the results is given below:

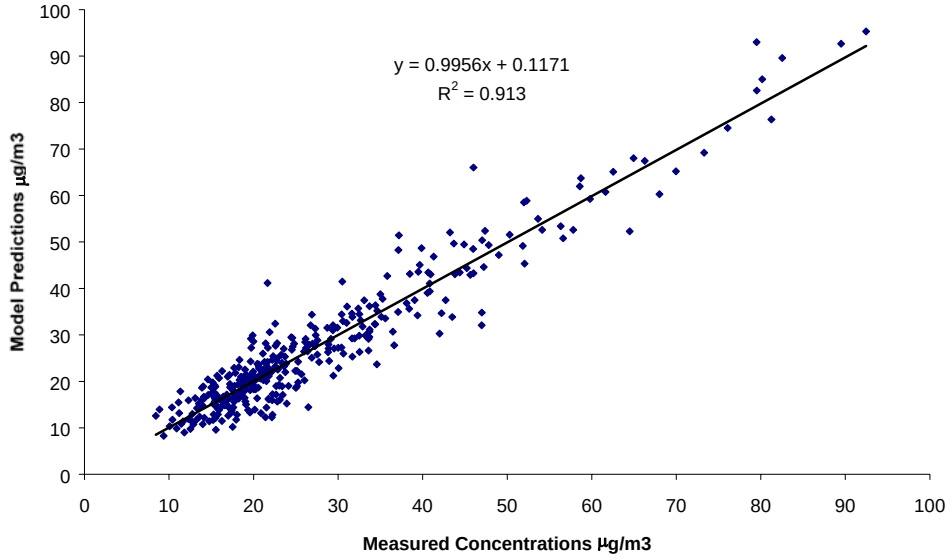



**Figure A1.17** Tower Hamlets PM10 Concentrations vs. Model Predictions (Daily Averages 1996)

A1.1.13 Figure A1.17 shows that predictions made for 1996 at the Tower Hamlets site are very good. Further tests were also undertaken for the year 1997 and again the model provided very good agreement with measurements, in this case at the roadside site in Greenwich. It should be noted however that the daily peak concentrations of PM10 become increasingly difficult to estimate at busy roadside sites in central London, for example Marylebone road. This is due to sensitivity of the model to very high emissions of locally generated particles close to major roads.

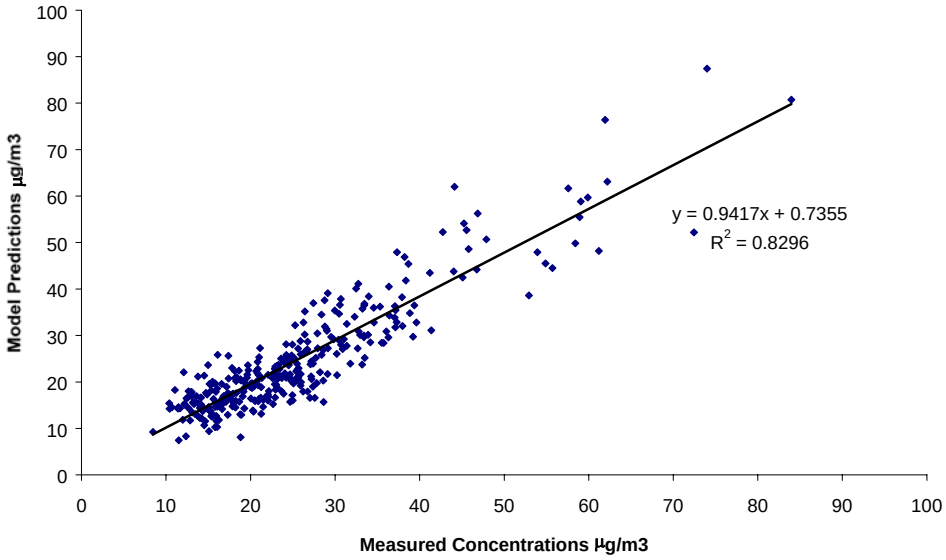



**Figure A1.18** Greenwich Roadside PM10 Concentrations vs. Model Predictions (Daily Averages 1997)

### A1.1.14 Comparison with the NAQS PM10 Objectives

A1.1.15 Predictions have been made of the NAQS objectives and Daughter Directive for 1996 and 1997. Table A1.7 summarises the predictions at background sites in London, for the current NAQS objective. The model provides very good agreement with the measurements with the largest error being a 7 % under prediction at Greenwich.

**Table A1.7** Comparison of Modelled and Measured NAQS PM10 concentrations $\mu g/m^3$ (1996/7)

| Site | TEOM Measurement | Model Prediction | % Difference |
|---|---|---|---|
| **1996** | | | |
| Kensington | 78 | 81 | + 4 |
| Tower Hamlets | 80 | 85 | + 6 |
| **1997** | | | |
| Bexley | 76 | 77 | + 1 |
| Greenwich | 71 | 66 | - 7 |
| Kensington | 84 | 82 | - 3 |
| Tower Hamlets | 84 | 89 | + 6 |

A1.1.1 Table A1.8 summarises the model predictions for background and roadside sites in London. Comparisons are made between modelled and measured data, for the proposed NAQS objective and Stage 1 EU Daughter Directive for PM10. The 1997 results also show very good agreement, with the largest error being an over prediction of 4 days at roadside site in Sutton.

**Table A1.8** Comparison of Modelled and Measured Daughter Directive PM10 concentrations $\mu g/m^3$ (1997) for Roadside and Background

| Location | days > 50 $\mu g/m^3$ (measured) | days > 50 $\mu g/m^3$ (modelled) | days difference between measured and modelled |
|---|---|---|---|
| **Roadside** | | | |
| Camden | 86 | 86 | 0 |
| Sutton 1 | 35 | 39 | + 4 |
| Haringey | 50 | 47 | - 3 |
| Kingston | 47 | 50 | + 3 |
| Greenwich 5 * | 32 | 34 | + 2 |
| **Background** | | | |
| Bexley | 33 | 33 | 0 |
| Greenwich 4 | 25 | 24 | - 1 |
| Kensington | 34 | 35 | + 1 |
| Tower Hamlets | 37 | 38 | + 1 |

Note: A full year's data was unavailable for Greenwich 5

A1.1.1 In summary, the background predictions for both the NAQS objective and the background and roadside predictions for the Daughter Directive are in very good agreement with measured data in London. This, in combination with the improved prediction of daily coarse fraction, provides a robust model for the prediction of PM10 in future years. It should be emphasised however that there remain many uncertainties concerning the sources of particles in urban air. In particular, the proportion of coarse particles which can be attributed to road vehicles as a result of re-suspension is uncertain. An analysis of particle concentrations at the Marylebone Road and Bloomsbury sites suggests that 50 % of the coarse particle concentration may also be attributable to road traffic sources. It should be noted that this work only considers vehicle exhaust emissions of particles and does not attribute any of

the coarse fraction to them. This assumption may lead to an underestimate of the proportion of PM10 that is attributable to road vehicles.

## A1.13 References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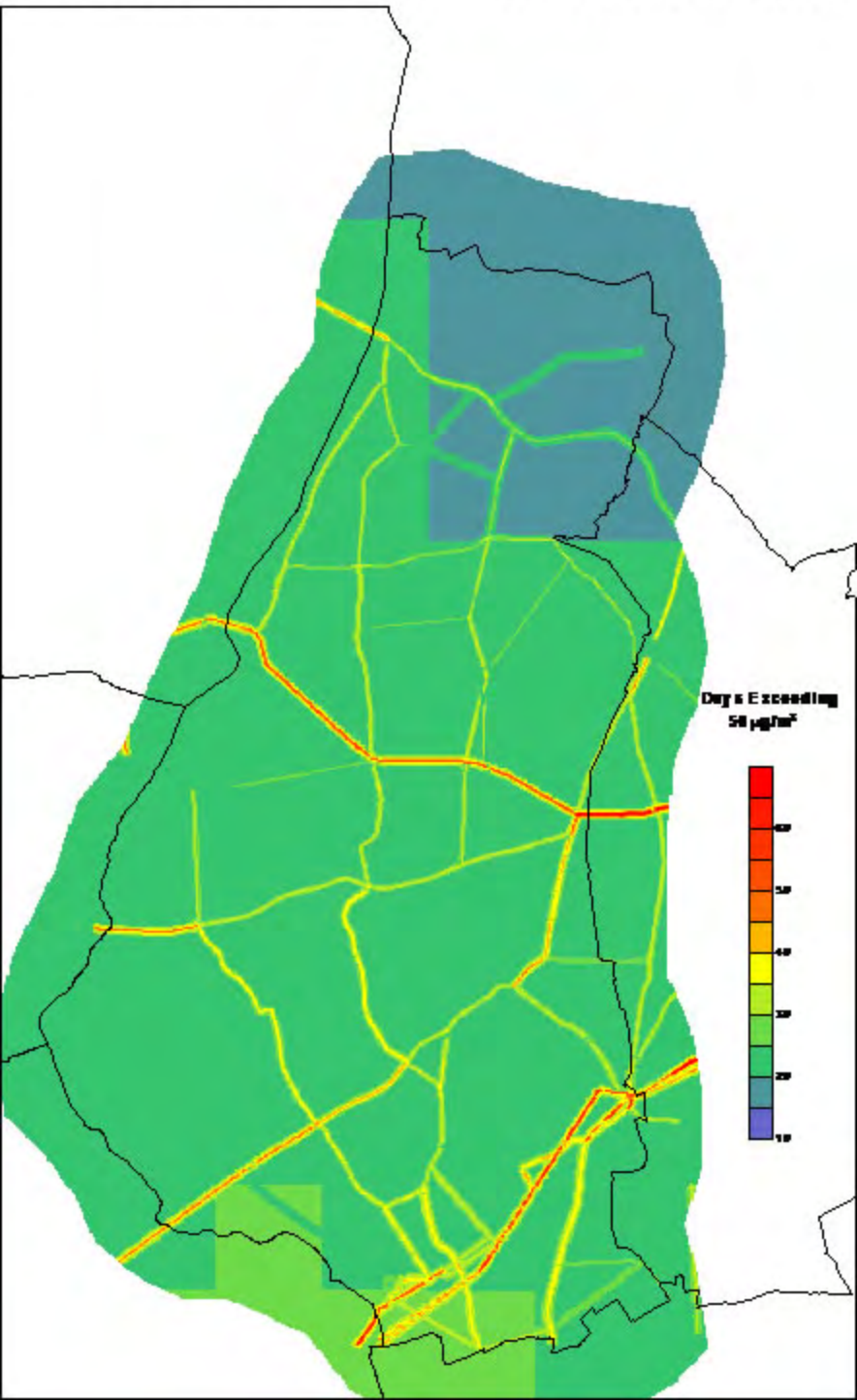
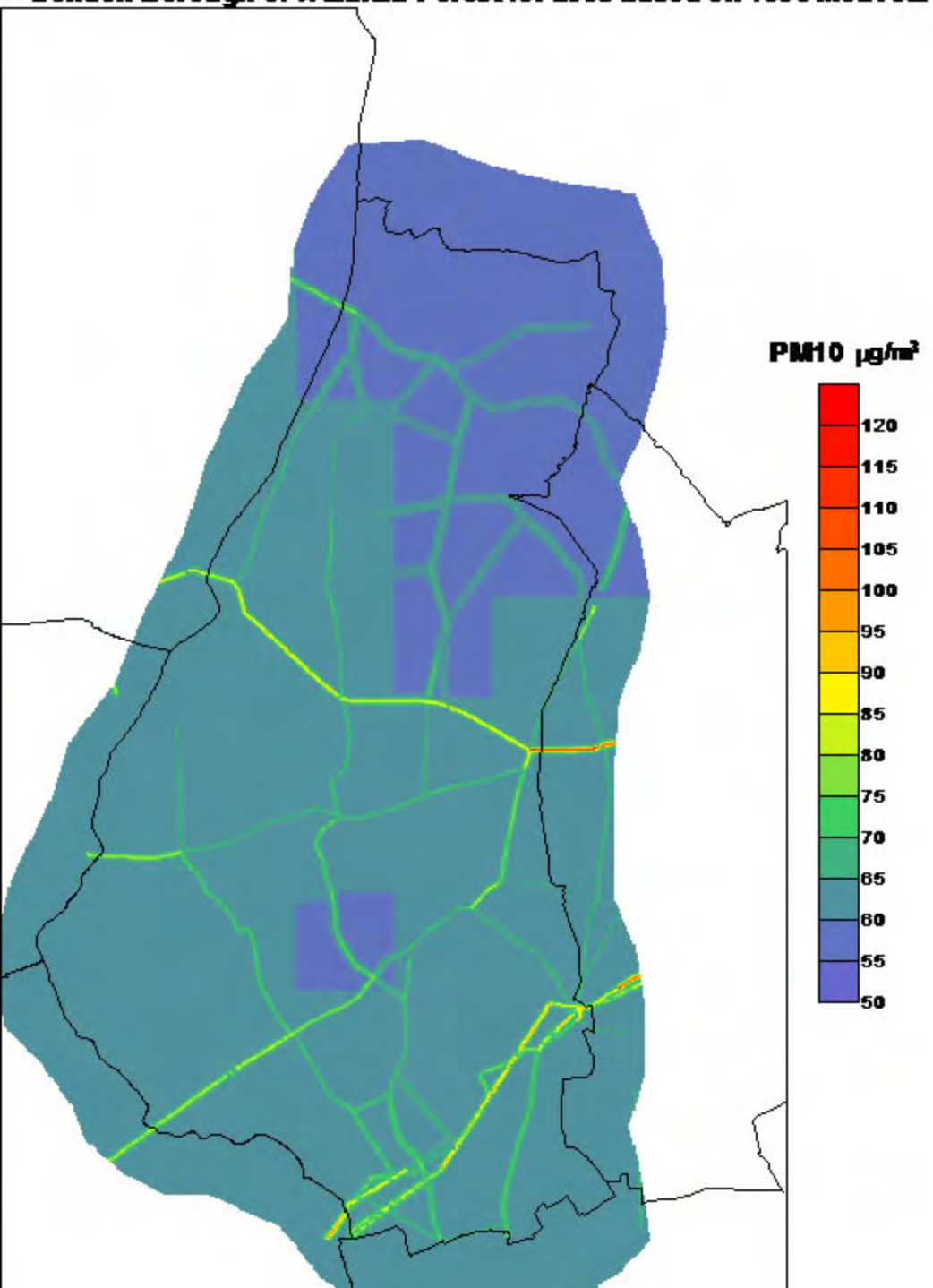
## Acknowledgements

SEIPH gratefully acknowledge the support of the DETR for funding some of this research.

**Map 1 Predictions of the Daughter Directive PM10 Objective for the London Borough of Waltham Forest for 2004 based on 1996 Met.Year**



**Map 2 Predictions of the Existing NAQS PM10 Objective for the London Borough of Waltham Forest for 2005 based on 1996 Met.Year**



Map 3 Predictions of the Nitrogen Dioxide $NO_2$ Objective for the London Borough of Waltham Forest for 2005 based on 1997 Met.Year