Further Assessment (Stage 4) of Air Quality within Two Air Quality Management Areas in Reigate & Banstead

Air Quality Consultants

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Report by
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On Behalf of

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Contents

This report makes use of the dispersion modelling carried out by netcen on behalf of BAA. Following the production of the report, netcen identified a minor error in their modelling, affecting the distribution of emissions during aircraft take-off. The modelling team at netcen has given assurances that this error will make no material difference to the concentrations predicted for the Horley area.

1 Introduction and Background

1.1 On 30th April 2002, Reigate and Banstead Borough Council declared five Air Quality Management Areas (AQMAs). One of these areas has two sections and so there are effectively six separate AQMAs. These are all areas of the Borough where concentrations of nitrogen dioxide have been deemed likely to exceed the Government's air quality objective in 2005. Four of these areas are located in the more northern part of the Borough, close to busy roads. Two are close to Gatwick Airport, where the exceedences are influenced by emissions from the airport. An earlier report (Laxen and Marner, 2003) provided the Stage 4 further assessment for the four AQMAs in the north of the borough. This report provides the further assessment for the remaining two areas.

Policy Context

1.2 The Government's Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Defra, 2000) sets out a framework for air quality improvements, which includes a series of air quality objectives. These are ambient air pollutant concentrations averaged over a defined time period, occasionally with a set number of exceedences allowed. They are based on an assessment of health effects and of the practicality of improving ambient air quality. Only one air quality objective is relevant to this report and this is shown in Table 1.

Table 1 The Air Quality Objective Relevant to This Report

Pollutant	Time Period	Objective	To be achieved by[1]
Nitrogen Dioxide	Annual mean	40 μg/m^3	2005

[1] The end of the specified year.

1.3 National and international measures are likely to achieve the Governments objectives in most locations, but it is recognised that management at a local level will be necessary in some areas. Part IV of the Environment Act 1995 requires local authorities to periodically review and assess the current, and likely future, air quality in their area. The role of this process is to identify areas where it is unlikely that the air quality objectives will be achieved.

1.4 Air Quality Review and Assessment is a multi-stage process, with each stage requiring progressively more complex assessment. This negates the need for very detailed assessments in areas where air quality is unlikely to be a problem. If the possibility that an air quality objective will be exceeded cannot be discounted during Stage 1 and 2 of Review and Assessment, a Stage 3 assessment becomes necessary. Following this more detailed

assessment, if there still appears to be a risk of an objective exceedence, an Air Quality Management Area (AQMA) must be designated. Following this, Sections 84(1) and 84(2)a of the Environment Act 1995 require the local authority to carry out a Stage 4 Review and Assessment of existing and likely future air quality within the AQMA.

Scope

1.5 This report represents the second part of the Stage 4 further assessment for the borough of Reigate and Banstead. It covers the two AQMAs that are near to Gatwick Airport. The AQMAs considered in this report are shown in Appendix 1 and are identified as Reigate and Banstead AQMA 2b, and 5. The other AQMAs have been assessed separately (Laxen and Marner, 2003). This assessment draws on the results of recent monitoring, and of modelling work performed by netcen on behalf of BAA Gatwick.

1.6 The Stage 4 guidance note presented on Defra's Review and Assessment website (Defra 2004a) states that the main purpose of this further assessment is to allow local authorities to supplement the information they have already gathered from their earlier Review and Assessment work. The assessment should provide the technical justification for the measures to be included in the action plan. It allows authorities:

- to confirm their original assessment of air quality against the prescribed objectives, and thus to ensure that they were right to designate the AQMA;
- to calculate more accurately how much of an improvement in air quality would be needed to deliver the air quality objectives within the AQMA;
- to refine their knowledge of the sources of pollution so that air quality action plans can be properly targeted;
- to take account of national policy developments which may come to light after the AQMA declaration;
- to take account as far as possible of any local policy developments which are likely to affect air quality by the relevant date, and which were not fully factored into earlier calculations;
- to carry out real-time monitoring where this has not been done as part of the Stage 1-3 Reviews and Assessments;
- to carry out further monitoring in problem areas to check earlier findings;
- to corroborate other assumptions on which the designation of the AQMA has been based, and to check that the original designation is still valid, and does not need amending in any way;

- to respond to any comments made by statutory consultees in respect of authorities' Stage 1-3 reports, particularly where these have highlighted that insufficient attention has been paid to, e.g., the validation of modelled data.

Key Findings of Previous Review and Assessments Conducted by this Authority

1.7 The second stage of Review and Assessment for Reigate and Banstead indicated a risk of exceeding the annual mean NO_2 objective at a number of major roads in the area, as well as a risk of exceeding the 24-hour PM_{10} objective along certain stretches of road.

1.8 Stage 3 of Review and Assessment involved detailed modelling work focusing on the potential exceedence areas highlighted in the Stage 2 report. Results indicated a likely exceedence of the annual average NO_2 objective in 2005 at a number of residential properties that were within 30 m of the M25, A217 or M23, and for an area of Horley alongside Gatwick Airport.

1.9 Following the Stage 3 assessment, a number of AQMAs were declared within the borough. Those relevant to this report are shown in Appendix 1.

1.10 The previous stage 4 report identified that objective exceedences were unlikely in AQMAs, 2a, 3 and 4. Exceedences were only expected at 4 properties close to the M25 in AQMA 1. At the worst-case receptor, a 21% reduction in nitrogen oxides emissions from the M25 in 2005 would be required for the objective not to be exceeded.

Report Structure and Issues Addressed

1.11 Section 2 of this report assesses the impact of new developments since the Stage 3 report was produced. Section 3 provides responses to the comments of consultees on the Stage 3 report. Section 4 comprises a review of new monitoring and modelled data. Section 5 estimates the relative contribution of the most significant pollution sources to the ambient concentrations at locations within each AQMA. Section 6 states the reduction in concentrations that will be necessary to achieve the Government's annual mean nitrogen dioxide objective in 2005. Section 7 appraises a range of nominal measures for their ability to bring about the necessary changes. An appraisal of the costs and feasibility of these measures is not included in this report and will instead form a part of the action plan.

2 Developments since Declaration of the AQMAs

National Developments

2.1 The road vehicle emission factors provided by Defra have been revised since the AQMAs were designated. The new factors have been used in this report.

2.2 The Government published an addendum to its Air Quality Strategy Document in February 2003 (Defra 2003a). This sets out new air quality objectives for certain pollutants. No new objectives are relevant to this report.

Local Developments

2.3 Since the AQMAs were designated, there has been a new development of 94 residential units approximately 125 m north of AQMA 5. There are a large number of existing properties between the new development and the AQMA and there is no reason that emissions associated with the new development should have any impact on the designation.

2.4 Since the AQMAs were designated, the construction of 2280 new houses in Horley has been proposed. The houses would all be located north of Horley, and over 1 km from AQMA 5. There is no reason why these proposals should have a substantial impact on the AQMA.

2.5 The stage 3 assessment made use of an emissions inventory for London Gatwick Airport for 1996/1997. This assessment uses a revised inventory prepared by netcen for BAA Gatwick for a 12-month period running from 1st June 2002 to 31st May 2003.

2.6 The dispersion model used for the stage 3 work was Breeze Roads. This assessment makes use of ADMS 3.1, which exploits recent advances in understanding the transport-diffusion of pollutants in the lower levels of the atmosphere.

2.7 As is shown in Figure A2.1 in Appendix 2, Gatwick airport continues to grow and passenger numbers are now comparable to those prior to the events of September 11th 2001.

3 Response to Consultees Comments

3.1 The Stage 3 Review and Assessment Appraisal Report accepted the conclusions reached for all pollutants, but did offer a series of comments. These comments, along with the responses offered, are set out below.

3.2 Comment 1

The section on continuous monitoring is brief. A more substantial discussion and analysis of the data from Horley could be provided. Data from this site could also be used to predict 2004/5 concentrations.

The site had not been operating for a long period when the report was prepared. The data were used to validate the model. Further analysis of the monitoring data from the Horley site, and other monitoring sites that have been set up in the area is included in this report, but for reasons that are clearly explained in this report, it is not appropriate to scale 2005 concentrations directly from the measured data.

3.3 Comment 2

The discussion of bias in measurements made by analytical laboratories on page 15 is brief. It is not clear how the conclusions reached on page 15 are carried forward into the assessment, nor is it made clear what the implications of an incorrect conclusion may be.

Understanding of the performance of diffusion tubes has improved since the Stage 3 report was prepared. The current assessment includes an adjustment for diffusion tube bias using the results of a year's inter-comparison with the two automatic monitors.

3.4 Comment 3

In the case of traffic information, it is not clear if any of the assumptions have been validated by traffic counting. Page 18 refers to 'assumptions' that are used to generate traffic flow and speed information. These assumptions should be made explicit.

The current assessment uses traffic data from an assessment conducted by Mott MacDonald for an investigation of access at London Gatwick Airport, commissioned by BAA Gatwick. In that work, a traffic model was built within the CONTRAM model framework, supported by a network of automatic traffic counters. The model was validated with traffic count data. In addition, some links have been added to the network, using data from the Surrey Traffic Model. This assessment also makes use of traffic count data included in the National Atmospheric Emissions Inventory.

3.5 Comment 4

In the case of PM_{10} modelling validation, it is not clear what approach has been taken. On page 5, section 2.2, it states that monitored data from the TEOM is used in model validation. However, on page 32, section 4.1, it states that no validation could be undertaken for PM_{10} due to a lack of roadside monitoring. This is potentially confusing and it should be made clear what validation has been attempted for PM_{10}.

There was no direct validation of the PM_{10} model output due to the absence of monitoring data for roadside locations. Background is an important component of PM_{10}. The national maps used at that time gave higher background concentrations than the measured value in Horley. This suggests that the model results will have over-predicted concentrations, reinforcing the decision not to declare any AQMAs for PM_{10}. Monitoring carried out at the Reigate South site alongside the NO_x monitor (see section 4), 13 m from the edge of the M25, during the winter period November 2002 – February 2003, gave a period mean of 19 $\mu g/m^3$ (gravimetric equivalent), with no exceedences of the 24-hour objective of 50 $\mu g/m^3$. This is considerably lower than the modelled values for this location, further supporting the decision not to declare any AQMAs for PM_{10}.

4 Corroboration of Previous Findings

Important Local Factors

4.1 In most locations across the country, future nitrogen dioxide concentrations can be predicted, with reasonable confidence, using default factors supplied by Defra. These factors are based on national trends and projections, predominantly related to road traffic emissions, and do not take into account specific local sources. The areas addressed in this report are significantly influenced by airport-related emissions. Estimates of future concentrations must thus take into account future increases in airport-related activity. Because activity at the airport will grow at a different rate to that on the roads, knowledge of the importance of different emission sources is a prerequisite for estimating future concentrations. For this reason, the monitoring data are not used directly to estimate future concentrations. They are, however, used to verify the model.

New Automatic Monitoring Data

4.2 Real-time chemiluminesence NO_2 monitors have been operated at 2 locations close to Gatwick Airport. These monitors, known as RG1 and RG2, are representative of residential exposure within AQMA 5. The location of each monitor is shown in Figure A1.3. RG1 is 15m from a quite residential road. RG2 is approximately 3m from a very quite residential cul-de-sac. RG1 is operated by Reigate and Banstead BC with data ratification and verification by the Environmental Research Group of Kings College London (ERG). It is calibrated automatically every 24 hours and manually every 2 weeks. In addition there is a 6-monthly QA/QC system audit by the national physical laboratory (NPL). RG2 is operated by AEA Technology on behalf of Reigate and Banstead BC and BAA. Data are downloaded every 24-hours and the instrument is calibrated monthly.

4.3 Data were collected for the year running from 00:00 hrs on 1/6/02 until 23:00 hrs 31/5/03 (inclusive). One-hour mean concentrations at both locations are plotted in Appendix 3. Annual mean concentrations are set out in Table 1. The data shown in Appendix 3 appear to follow very similar patterns, reaching a maximum in March 2003, with generally lower results for the preceding months. This corresponds with the view that levels in winter tend to be generally higher than summer values; due mainly to the inhibition of dispersion and dilution during winter. It might also reflect a nation-wide trend of generally higher nitrogen dioxide concentrations during 2003 than were experienced during 2002. There were no exceedences of 200 $\mu g/m^3$ as a 1-hour mean concentration in these data. The annual mean concentrations at both sites were remarkably similar and well below the level of the 2005 objective. For the

reasons set out above, it is not appropriate to apply a simple scaling of future concentrations at these sites to predict 2005 concentrations.

Table 1 Annual Mean Chemiluminescence Monitor Data (μg/m^3)

Site	Data Capture (%)	Annual mean 2002-2003	2005 Annual Mean Objective
RG1	99	31.4	40
RG2	88	31.6	40

RG1 = Horley Automatic Monitoring Station; RG2 = Outside 74 The Crescent Horley.

New Diffusion Tube Data

4.4 Monthly average nitrogen dioxide concentrations have been measured at a range of sites within AQMA 5 for an 11-month period from 29/5/02 using passive diffusion tubes. A problem with the analysis of tubes has meant that data from the 12th month had to be discarded. Tubes were exposed on a monthly basis, except during August and September 2002 and December 2002 and January 2003, when a 2 month exposure was used. The location of each site is shown in Figure A1.4. In addition, triplicate diffusion tubes have been co-located with automatic analysers at RG1 and RG2. Because of the varying exposure intervals, and because only 11 months of data were available, separate bias adjustment factors have been calculated for each diffusion tube exposure period and applied to the data for that period. The adjustment factors were calculated from the two sets of co-location data (from RG1 and RG2) using orthogonal regression as recommended by Defra (2004a)[1]. During December 2002 and January 2003 data capture at RG2 was poor, and so only the factor from RG1 was used for this period. Table 2 sets out the correction factors used.

4.5 Table 3 sets out the measured annual mean concentration at each site. These data are shown spatially in Figure A1.5. There is no clear spatial pattern to the data. Values ranged from 28 to 44 μg/m^3 (in 2002-2003) and exceedences of 40 μg/m^3 as an annual mean were only measured at 3 of the sites. For the reasons set out above, it is not appropriate to apply a simple scaling of future concentrations at these sites to predict 2005 concentrations.

[1] Orthogonal regression was used here as an alternative to averaging the bias from the 2 separate co-location studies. A separate regression was thus performed for each month in order to derive a factor. The method takes account of the relative uncertainty in both measurement techniques and forces the regression line through zero. The factors thus obtained are only very slightly different to those which would have been derived by averaging the biases. Further details are available from Defra (2004a).

Table 2 Co-located Diffusion Tube (DT) and Automatic Monitor Data (μg/m^3) Used to Calculate the Diffusion Tube Bias Adjustment Factors.

	RG1	RG1	RG1	RG2	RG2	RG2	
Measurement Period	**DT mean**	**Auto mean**	**Auto data capture**	**DT mean**	**Auto mean**	**Auto data capture**	**Adjustment Factor[a]**
29/5/02 - 3/7/02	19	26	100%	19	25	99%	**1.348**
4/7/02 - 29/7/02	26	26	100%	22	29	94%	**1.134**
30/7/02 - 30/9/02	7	27	100%	10	23	97%	**2.838**
1/10/02 - 28/10/02	19	31	100%	40	34	100%	**1.171**
29/10/02 - 2/12/02	42	38	94%	21	34	98%	**1.191**
3/12/02 - 3/2/03	29	35	99%	*30*[b]	*32*[b]	*40%*	*1.182*
4/2/03 - 3/3/03	39	42	100%	43	45	98%	**1.061**
4/3/03 - 31/3/03	21	39	100%	30	43	100%	**1.630**
1/4/03 - 28/4/03	17	30	100%	33	33	99%	**1.301**

[a] Calculated using orthogonal regression as advised by Defra's Review and Assessment Website. Following this advice, the uncertainty of the diffusion tubes has been assumed to be double that of the automatic monitors.
[b] Not used as data capture poor.

New Modelling

4.6 The modelling methodology used is given in detail by Underwood *et al.*, (2003a) and is summarised in Appendix 4. Appendix 5 describes how the model has been verified and its results adjusted to provide the best estimates of future concentrations. Appendix 6 explains how uncertainty in the adjusted model results has been estimated. The base-year for modelling corresponds with the monitoring period described above (i.e. May 2002 to June 2003). Appendix 7 describes how the modelled concentrations have been used to predict concentrations in 2005. Following established methodology (NSCA, 2000) the value of one standard deviation of the model (SDM, = 5 μg/m^3) has been used to estimate the uncertainty inherent in the modelled data. Some of the uncertainty will be because the model does not explicitly include minor roads. The model results can be assessed directly against the 40 μg/m^3 level of the objective, because each modelled concentration is the best estimate of the true concentration. The results can also, however, be assessed against a value of 35 μg/m^3, which is the objective level minus the SDM. This will minimise the likelihood of possible objective exceedences being overlooked, but represents a cautious approach.

4.7 The modelled nitrogen dioxide concentrations at each of the monitoring sites, as well as at a range of worst-case residential receptors, during 2002/2003 and during 2005, are set out in Table 4. For the 2005 data, exceedences of the 40 μg/m^3 objective are shaded. Values above 35 μg/m^3 (i.e. the objective – the SDM) are shown in bold type. The data for 2005 are shown spatially in Figure A1.6 for AQMA 5 and Figure A1.7 for AQMA 2b.

Table 3 Measured Annual Mean Concentrations (May 2002 – June 2003) at Each Diffusion Tube Monitoring Site (μg/m^3). Values in bold are > 40 μg/m^3.

Site Name	Code	Data Capture (months)	NO_2 Concentration (μg/m^3)[a]
Outside 38, Riverside, Horley	RB11	11	35
Horley Police Station, Massetts Road, Horley	RB12	11	**44**
Public Car Park, off Massetts Road, Horley	RB13	11	28
Outside 17 Wolverton Gardens, Horley	RB51	11	33
Outside 20 Wolverton Gardens, Horley	RB52	11	37
Outside 66/68 Cheyne Walk, Horley	RB53	11	30
Outside 7/9 Crescent Way, Horley	RB54	11	**43**
Outside 40a Crescent Way, Horley	RB55	8	32
Outside 8/10 The Crescent, Horley	RB56	11	32
Outside 29/31 The Crescent, Horley	RB57	11	38
Outside 39/41 The Crescent, Horley	RB58	11	34
Outside 92/94 The Crescent, Horley	RB59	11	**41**
Outside 120/122 The Crescent, Horley	RB60	11	32
Outside 79/81 The Crescent, Horley	RB61	11	33
Outside 16/22 The Drive, Horley	RB64	10	32
Outside 4/6 The Drive, Horley	RB65	11	39
Outside 3a/3b Fairfield Avenue, Horley	RB66	11	23
Outside 30/32 Fairfield Avenue, Horley	RB67	11	29
Outside 57 Fairfield Avenue, Horley	RB68	11	29
Outside 61 Upfield, Horley	RB69	8	33
Outside 58/60 Upfield, Horley	RB70	11	33
On Large Roundabout, Upfield, Horley	RB71	10	35
Outside 25/27 Upfield, Horley	RB72	11	29
Outside 9/11 Upfield, Horley	RB73	11	37
On Green, 30a/30b Meadowcroft Close, Horley	RB74	11	37
On Roundabout, The Coronet, Horley	RB75	9	35
33 Limes Avenue, Horley	RB76	11	40
Layby at Entrance to Staffords Place, Horley	RB77	10	37
Horley Air Monitoring Station	RB24, 25 and 26[b]	11	30
Outside 74 The Crescent Horley (BAA Site)	RB78, 79 and 80[b]	11	35

[a]The data have been adjusted for bias using the factors given in Table 2.
[b]The value given is the mean of 3 collocated tubes (averaged first by month, and then over the year).

4.8 There are inevitable site by site differences between the monitoring and modelling due to uncertainties in both sets of data. These differences do not appear to be systematic (Appendix 5), thus they cannot be adjusted for. At some sites there is good agreement. For instance, at RG1 the automatic monitoring gave 31 μg/m^3 for 2002/2003, while the diffusion tube was 30 μg/m^3 and the model 32 μg/m^3. At RG2 the differences were greater: 32, 35 and 40 μg/m^3 respectively. The overall uncertainty in the model results have been calculated to be ± 5μg/m^3 (1 standard deviation). The scaled-modelled results, nevertheless, represent the best available approximation of conditions in 2005.

Table 4 Predicted Annual Mean Nitrogen Dioxide Concentrations 2005 (μg/m^3)
Predicted Exceedences of the Objective are shaded. Values greater than 35 μg/m^3 are shown in bold.

Site code	Site Description	NO_2 in 2002/2003 (adjusted modelled)	NO_2 in 2005 (μg/m^3) (adjusted modelled)
AQMA 5			
RB11	Outside 38, Riverside, Horley	34.6	33.0
RB13	Public Car Park, off Massetts Road, Horley	27.6	26.0
RB51	Outside 17 Wolverton Gardens, Horley	30.4	28.7
RB52	Outside 20 Wolverton Gardens, Horley	31.7	30.0
RB53	Outside 66/68 Cheyne Walk, Horley	32.2	30.7
RB54	Outside 7/9 Crescent Way, Horley	32.7	31.1
RB55	Outside 40a Crescent Way, Horley	34.5	33.0
RB56	Outside 8/10 The Crescent, Horley	36.1	34.7
RB57	Outside 29/31 The Crescent, Horley	37.7	**36.3**
RB58	Outside 39/41 The Crescent, Horley	38.9	**37.5**
RB59	Outside 92/94 The Crescent, Horley	42.4	**41.0**
RB60	Outside 120/122 The Crescent, Horley	37.8	**36.4**
RB61	Outside 79/81 The Crescent, Horley	36.0	34.6
RB64	Outside 16/22 The Drive, Horley	29.5	28.0
RB65	Outside 4/6 The Drive, Horley	29.0	27.5
RB66	Outside 3a/3b Fairfield Avenue, Horley	29.9	28.4
RB67	Outside 30/32 Fairfield Avenue, Horley	31.2	29.7
RB68	Outside 57 Fairfield Avenue, Horley	32.4	31.0
RB69	Outside 61 Upfield, Horley	33.4	31.9
RB70	Outside 58/60 Upfield, Horley	31.2	29.7
RB72	Outside 25/27 Upfield, Horley	29.7	28.1
RB73	Outside 9/11 Upfield, Horley	29.1	27.5
RB74	On Green, 30a/30b Meadowcroft Close, Horley	34.8	33.2
RB75	On Roundabout, The Coronet, Horley	35.3	33.3
RB76	33 Limes Avenue, Horley	30.4	28.8
RB77	Layby at Entrace to Staffords Place, Horley	29.4	27.9
RG1	Horley Air Monitoring Station	32.2	30.7
RG2	Outside 74 The Crescent Horley (BAA Site)	40.2	**38.8**
ER1	Brighton Road, Near The Ave	37.5	34.8
ER2	Brighton Road, opposite j. with Massetts Road	36.4	33.9
ER3	Longbridge Road	36.9	34.7
ER4	SW end of Cheyne Walk	39.4	**37.3**
ER5	SW end of Woodroyd Gardens	38.9	**37.0**
AQMA 2b			
ER6	Near Perrylands Lane, Just west of M23	40.5	**37.4**
ER7	Trentham	47.3	**43.6**
ER8	Just East of M23	38.7	**35.7**
Objective			**40**
Objective – 1SDM[a]			*35*

[a] As explained in the text, assessing against this value allows for predicted uncertainty in the model.

Assessment of the data for AQMA 5

4.9 An exceedence of the objective is only predicted at one of the receptors in AQMA 5. The predicted exceedence is at receptor RB59, which is outside 92/94 The Crescent, Horley and is the furthest south of all of the modelled receptors. It is thus the receptor most influenced by emissions (in general) from Gatwick Airport and also from the southern stretches of the A23. Annual mean concentrations greater than 35 $\mu g/m^3$ are predicted at a further 6 receptors, which are those closest to Gatwick Airport. Concentrations tend to fall with distance from the airport, with some slight elevations adjacent to the major roads. The smallest annual mean nitrogen dioxide concentration at any of the modelled receptors (26 $\mu g/m^3$) is therefore at site RB13, which is the site furthest from the airport and is also some distance from any major roads. The monitored value for this site in 2002/3 was 28 $\mu g/m^3$.

4.10 The predicted concentrations are very similar to those determined in the stage 3 review and assessment, especially close to the airport. The main difference is that the new predictions show concentrations falling off slightly more rapidly with distance from the airport, i.e. to lower values than previously identified.

4.11 Even though these new predictions indicate that there will be very few objective exceedences in 2005 it would not be appropriate at this stage to reduce the area of the AQMA[2], because of the uncertainty associated with the modelled data, and because Gatwick airport is expected to continue growing beyond 2005.

Assessment of the data for AQMA 2b

4.12 An exceedence of the objective is only anticipated at one of the receptors in AQMA 2b. This is a residential property approximately 25m from the edge of the M23, which was also identified in the stage 3 report as likely to experience an objective exceedence. The other worst-case receptors in AQMA 2b are both expected to experience annual mean concentrations greater than 35 $\mu g/m^3$ in 2005.

4.13 These concentrations are based on the dispersion model results, which have only been verified using monitoring data from AQMA 5. They are therefore less certain than those predicted for AQMA 5. In order to highlight this uncertainty, the nitrogen dioxide concentration in 2005 at site ER7 has been estimated using a simple screening model (Design Manual for Roads and Bridges (DMRB), Highways Agency, 2003). This model showed good agreement with the monitoring carried out for the AQMA alongside the M25 (Laxen and Marner, 2003). The concentration predicted using the DMRB is 36.5 $\mu g/m^3$. This is considerably lower than the 43.6 $\mu g/m^3$ predicted by the dispersion model, but is still too high to justify revocation of the

[2] Government guidance allows LAs to define AQMAs as being larger than the area of likely exceedence.

AQMA. It is therefore recommended that the AQMA should be retained but that monitoring is conducted at this receptor. In subsequent chapters, the predicted 2005 nitrogen dioxide concentration at ER7 is taken to be 43.6 μg/m^3 but it is acknowledged that this value is uncertain.

Summary

4.13 Overall, these data confirm the likely exceedences of the annual mean nitrogen dioxide objective in both AQMAs that were previously identified during the Stage 3 assessment. The AQMAs should therefore be retained. The predictions for AQMA 2b are uncertain and further monitoring is advised.

5 Source Apportionment

5.1 In order to develop an appropriate action plan it is necessary to identify the sources contributing to the exceedences of the annual mean nitrogen dioxide objective at the worst-case locations within each AQMA. The principal local sources will be emissions from engines, related to both the airport activities and road vehicles. These emissions will be primarily nitric oxide (NO) with a small component of NO_2, jointly being termed nitrogen oxides (NOx). The NO emission is important, because it is converted in the atmosphere to NO_2, mainly by reaction with ozone. Close to the source there is usually insufficient ozone to convert more than a small proportion of the NO to NO_2. The relationship between NO_2 and NOx is not linear, the proportion decreasing as NOx concentrations increase. In order to calculate the contributions of the various sources, and how changes in emissions will affect NO_2 concentrations, it is necessary to consider NOx concentrations[3].

5.2 The source apportionment for NOx has been carried out for 4 representative worst-case locations (receptors RB59, RG1, ER4 and ER7). The total predicted NOx concentration at each location has been divided according to the source of that NOx, following the method described in Appendix 8. The results are presented in Table 5 and in Figure 1. An explanation of the categories listed is given below:

- Background: All sources not included explicitly in the dispersion model; including non-specific local sources and long-range transport (for example from London).
- Non-airport road vehicles: Emissions from any road vehicle making a journey that is not related to Gatwick Airport on the specified road network.
- Airport-related road vehicles: Emissions from any road vehicle making a journey that is related to Gatwick Airport on the specified road network.
- Aircraft: Emissions from aircraft during landing and take-off
- APUs: Emissions from Auxiliary Power Units used to service stationary aircraft.
- Airside vehicles: Emissions from land-bound non-road vehicles operating within the airport.

[3] The modelling methodology (Appendix 4) explains that concentrations are initially modelled as NOx, and this is used to estimate NO_2. These NOx concentrations have not been subjected to any verification-adjustment as employed for nitrogen dioxide in Chapter 4.

- Misc. airport: Emissions from sources within the airport that have been explicitly included in the dispersion model, but that are not listed above, including boiler plant.

5.3 At the worst-case receptor in AQMA 5 (site RB59), background sources account for 43 % of total ambient NOx (Table 5). 24% of NOx at this site comes from road vehicles (split equally between airport-related and non-airport journeys); 12 % from aircraft; and a further 21% from other airport sources. The airport therefore accounts for 45% of NOx at this receptor.

5.4 At the worst-case receptor in AQMA 2b (site ER 7) background sources account for only 29% of total ambient NOx. This is because other sources are greater, not because the background is significantly lower. Road vehicles making non-airport-related journeys account for over one half of total NOx, while road vehicles associated with the airport account for a further 14%. Only 4% of ambient NOx at this site comes from aircraft and the airport. Because road-vehicle emissions account for such a large proportion of total NOx at this site, these emissions have been apportioned further, as shown in Table 6 and Figure 2. Goods vehicles (the sum of both Light Goods Vehicles (LGVs) and Heavy Goods Vehicles (HGVs)) account for just over one half of all NOx from road vehicles. Most of this is from articulated HGVs. Cars account for 42% of all NOx from road vehicles.

Table 5 The Total Modelled[a] NOx Concentration at Representative Receptors and the Relative Contribution from Different Sources.

AQMA	Site code	Total NOx	Background	Non-airport road vehicles	Airport-related road vehicles	Aircraft	APUs	Airside vehicles	Misc. airport
		$\mu g/m^3$	%	%	%	%	%	%	%
5	RB59	81	43	12	12	12	9	9	3
5	RG1	56	63	10	6	9	5	5	2
5	ER4	78	45	25	11	6	5	4	4
2b	ER7	112	29	54	14	2	1	1	0

[a] This does not take into account the adjustment applied to the validated model data but this will not affect any of the percentage contributions shown.

Table 6 Total NOx from Road Traffic at site ER7 and the Relative Contribution from Different Sources.

Total Road-Related NOx	Cars	Bus/Coach	LGV	Rigid HGV	Articulated HGV
75.3 $\mu g/m^3$[a]	42%	5%	10%	16%	27%

[a] This is the sum of NOx from airport-related and non-airport road vehicles.

Figure 1 The Total Modelled[a] NOx Concentration at Representative Receptors as the Sum of Source-Specific Contributions.

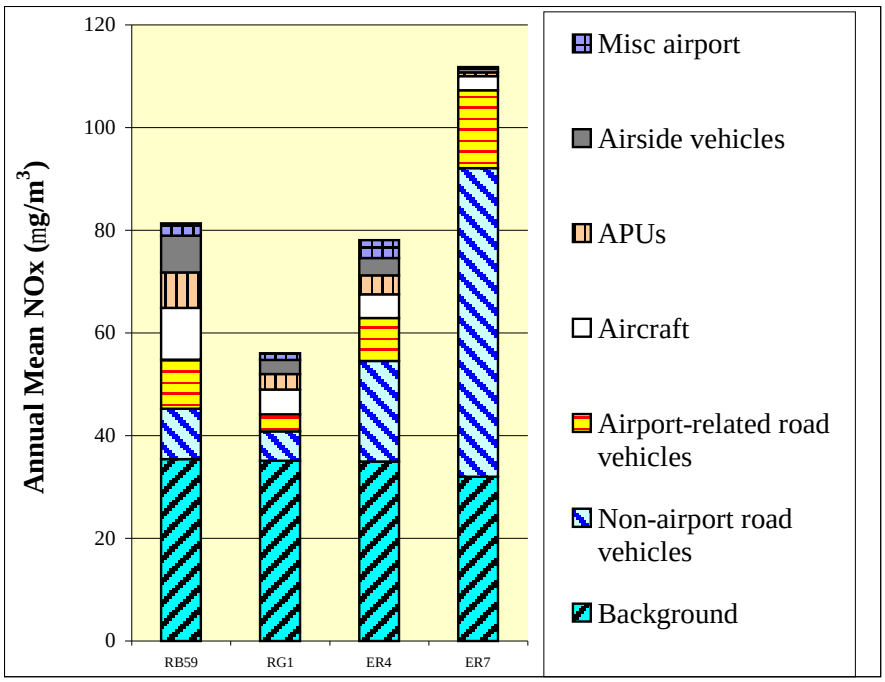
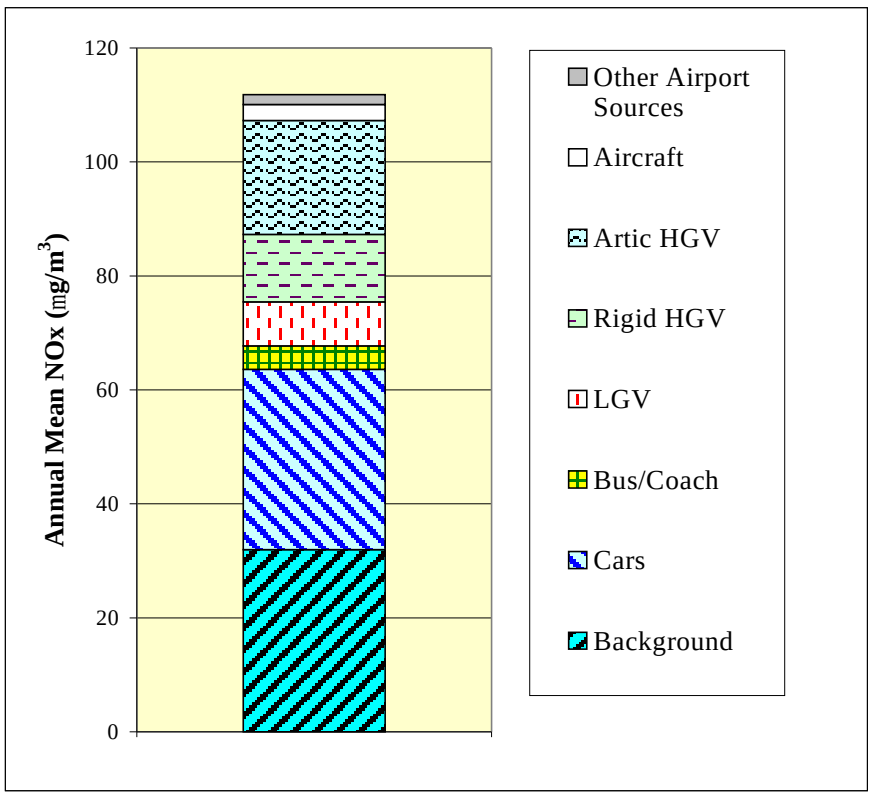


Figure 2 The Total Modelled[a] NOx Concentration at Site ER7 as the Sum of Source-Specific Contributions.



[a] This does not take into account the adjustment applied to the validated model data but this will not affect the relative contributions shown.

6 Statement of Air Quality Improvements Needed

6.1 Section 4 shows that the maximum improvements in air quality necessary to achieve the objective in 2005 are defined by the predicted concentrations at site RB59 in AQMA 5 and at site ER7 in AQMA 2b. The predicted annual mean nitrogen dioxide concentrations in 2005 at these sites are 41.0 $\mu g/m^3$ and 43.6 $\mu g/m^3$ respectively. The concentration at RB59 is estimated with more certainty than the concentration at ER7. In order to achieve the 40 $\mu g/m^3$ objective, an improvement of 1 $\mu g/m^3$ nitrogen dioxide is required at site RB59 and an improvement of 3.6 $\mu g/m^3$ nitrogen dioxide is required at site ER7. This improvement is not presented in terms of NOx, because the adjustment to the model (Appendix 5) was applied to the final nitrogen dioxide concentrations, not to the NOx.

7 Management Planning

7.1 To help with the preparation of the action plan, the effectiveness of a number of possible mitigation scenarios has been explored. The method used to assess these is presented in Appendix 9. They are presented for the worst-case receptor in each AQMA (i.e. sites RB59 and ER7).

AQMA 5

7.2 The nitrogen dioxide concentrations that could be expected at site RB59 in 2005, if different scenarios were to take place, are presented in Table 7. It is clear that if management was focussed on individual sources, then even very drastic options would have relatively little influence on ambient concentrations. The objective could though be achieved by more realistic combinations of measures. The options will be explored further during preparation of the Action Plan.

Table 7 The Likely Effect of Different Scenarios on the Nitrogen Dioxide Concentration at Site RB59 in 2005

Concentrations below the objective level are shown in bold

Scenario	Predicted Concentration ($\mu g/m^3$)
Base Case	41.0
Halving airport growth between the model year and 2005	40.4
Halving all emissions from aircraft	**39.0**
Halving all emissions from APUs	**39.6**
Halving all emissions from Airside vehicles	**39.6**
20% reduction in airport-related road traffic	40.3
20% reduction in non-airport-related road traffic	40.3
20% reduction in all road traffic	**39.5**
10% reduction in all airport-related emissions (including those from roads)	**39.6**

AQMA 2b

7.3 The nitrogen dioxide concentrations that could be expected at site ER7 in 2005, if different scenarios were to take place, are presented in Table 8. Halting all NOx emissions at Gatwick Airport would not cause the objective to be achieved. The most effective measure investigated is that of controlling vehicle speeds on the M23. It is important to note, however, that the speeds used do not necessarily represent those expected on the road in 2005. What this analysis shows, as explained in Appendix 9, is the scale of reductions that would be possible when changing from a situation in which vehicles travelled at sub-optimum speeds in terms of emissions per kilometre to a scenario where this efficiency was optimised.

7.4 The optimum speed in terms of minimising emissions of NO_x is in the range 50-80 kph (31-50 mph), with higher emissions at both lower and higher speeds. If an average speed of 80 kph (50 mph) is made up of periods of flow at 30 kph (19 mph) (daytime congestion) and at 120 kph (75 mph) (night-time free flow), then the emissions will be greater than if a constant average of 80 kph (50 mph) were assumed. Imposition of a speed limit of 80 kph (50 mph) should be an effective way to minimise emissions, as it would avoid the high speeds with their greater emissions and reduce the incidence of flow breakdown, with slower speeds and stop-start driving.

Table 8 The Likely Effect of Different Scenarios on the Nitrogen Dioxide Concentration at Site ER7 in 2005

Concentrations below the objective level are shown in bold

Scenario	**Predicted Concentration (µg/m^3)**
Base Case	43.6
Removing all airport and aircraft emissions	41.7
Halving all emissions from airport-related traffic	41.7
Halving emissions from non-airport goods vehicles	**39.6**
Halving emissions from non-airport cars	40.4
10 % reduction in emissions from all road traffic	41.7
20 % reduction in emissions from all road traffic	**39.8**
Reducing the average speed of all road vehicles from 110 kph (68 mph) to 80 kph (50 mph)[a]	**39.4**

[a] This does not mean that the emissions were estimated based on these speeds, but signifies the effect that traffic calming measures are likely to have.

8 Conclusions

8.1 Nitrogen Dioxide concentrations have been measured and modelled at a large number of locations. The results have been used to reassess air quality in two AQMAs, known as Reigate and Banstead AQMA 5 and AQMA 2b. The conclusions are presented following the list of Stage 4 requirements given in paragraph 1.6.

AQMA 5

8.2 In collaboration with BAA Gatwick, extensive new monitoring has been carried out across the AQMA. This has been combined with a new updated emission inventory and modelling study carried out by BAA Gatwick for 2002/3. This Stage 4 study has used the monitoring and modelling data to project forward concentrations to 2005, the reference year for the assessment. The results of the monitoring and modelling have confirmed that exceedences of the annual mean nitrogen dioxide objective are still likely in 2005. The exceedence area is similar to that identified during the Stage 3 assessment, and includes properties on the southern end of The Crescent, Horley, close to the airport. There is no requirement to amend the AQMA.

8.3 The maximum nitrogen dioxide concentration expected at any relevant location in the AQMA is 41 $\mu g/m^3$ and therefore an improvement of at least 1 $\mu g/m^3$ would be required to deliver the air quality objectives. Source apportionment studies have been carried out, which show that approximately 43% of the nitrogen dioxide at the worst-case receptor will come from background sources. 24% will come from road vehicles (split equally between airport-related and non-airport journeys); 12% from aircraft; and the remaining 21% from other airport sources. In total, the airport will be responsible for around 45% of the total at this location.

8.4 Indicative scenarios to reduce concentrations have been modelled. These show that it would be difficult to bring about large reductions in ambient concentrations by targeting just one of the emission sources.

8.5 There have been no new policy developments that are likely to have a significant impact on the declared AQMA, although this assessment has accounted for revised assessment methodologies, new housing developments and the growth of Gatwick Airport.

AQMA 2b

8.6 The same extensive modelling package developed and verified for AQMA 5 has been applied to the nearby AQMA 2b alongside the M23. The results suggest that the annual mean nitrogen dioxide objective is likely to be exceeded in 2005; although there is significant uncertainty associated with the data. The exceedence area is similar to that predicted in the Stage 3 assessment. There is no requirement to amend the AQMA. It is noted though that the exceedence at this location has not been confirmed by monitoring and not supported by use of the DMRB model. It would therefore be appropriate to install nitrogen dioxide diffusion tubes at several locations within this AQMA to confirm the findings.

8.7 The maximum concentration expected at any receptor is 43.6 $\mu g/m^3$ and therefore an improvement of at least 3.6 $\mu g/m^3$ would be required to deliver the air quality objectives. Approximately 29% of the ambient nitrogen dioxide concentration at the worst-case receptor is expected to come from background sources, with the majority, 68%, coming from road traffic.

8.8 Indicative scenarios to reduce concentrations have been modelled. These show the objective might be achieved by reducing peak speeds and the incidences flow breakdown on the M23 running through the AQMA.

8.9 There have been no new policy developments that are likely to have a significant impact on the declared AQMA, although this assessment has accounted for revised assessment methodologies, new housing developments and the growth of Gatwick Airport.

References

Cambridge Environmental Research Consultants (2004) www.cerc.co.uk

Casella Stanger (2003) www.casellastanger,com

Competitions Commission (2004) www.competition-commission.org.uk

Defra (2000) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland.

Defra (2003a) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland: Addendum.

Defra (2003b) Local Air Quality Management Technical Guidance (TGO3).

Defra (2004a) Review and Assessment Website. www.uwe.ac.uk/aqm/review

Defra (2004b) Air Quality website: www.airquality.co.uk

Highways Agency (2003) Design Manual for Roads & Bridges, spreadsheet version 1.02, November 2003. Available from Defra (2004b).

Laxen and Marner (2003) Further Assessment (Stage 4) of Air Quality within Four Air Quality Management Areas in Reigate & Banstead. www.reigate-banstead.gov.uk

Laxen and Wilson (2002) A New Approach to Deriving NO_2 from NOx for Air Quality Assessment of Roads. www.aqconsultants.co.uk.

National Atmospheric Emissions Inventory. www.naei.org.uk

NSCA (2000) Air Quality Management Areas. Turning Reviews into Action. www.nsca.org.uk

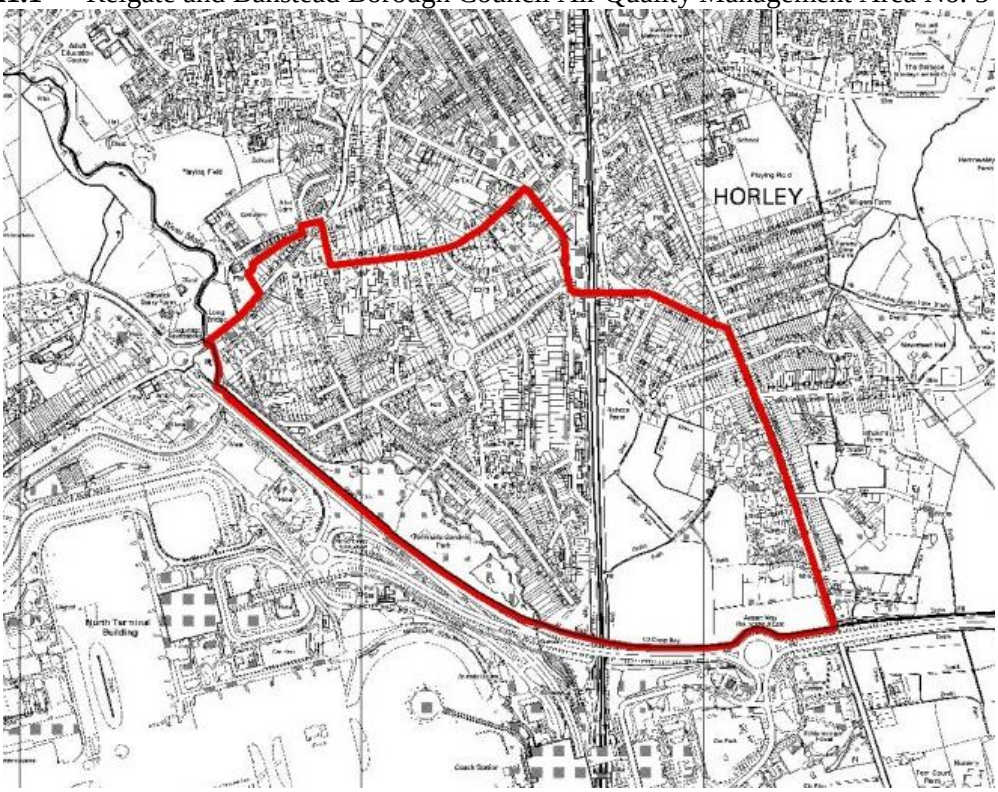
Underwood, B.Y., Walker, C.T. and Peirce, M.J. (2003a) Air Quality Modelling for Gatwick Airport 2002/3. A report produced for BAA Gatwick. netcen/AEAT/ENV/R/1625/Issue 1

Underwood, B.Y., Walker, C.T. and Peirce, M.J. (2003b) Gatwick Emission Inventory 2002/3 netcen/AEAT/ENV/R/1569/Issue 1

Wayson R L, Fleming G G and Kim B (2002) Preliminary report: the use of LIDAR to characterise aircraft initial plume characteristics. FAA-AEE-02-04. DTS-34-FA34T-LR1

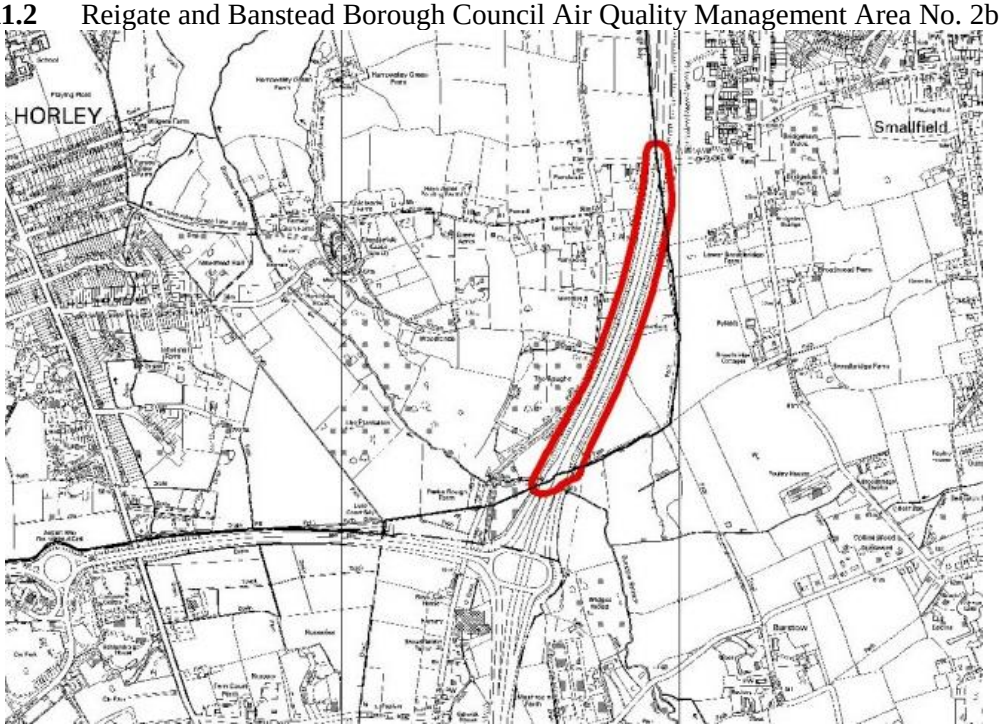
Appendix 1 Maps

Figure A1.1 Reigate and Banstead Borough Council Air Quality Management Area No. 5



Reigate & Banstead BC: OS Licence No. LA 079065 (2002)

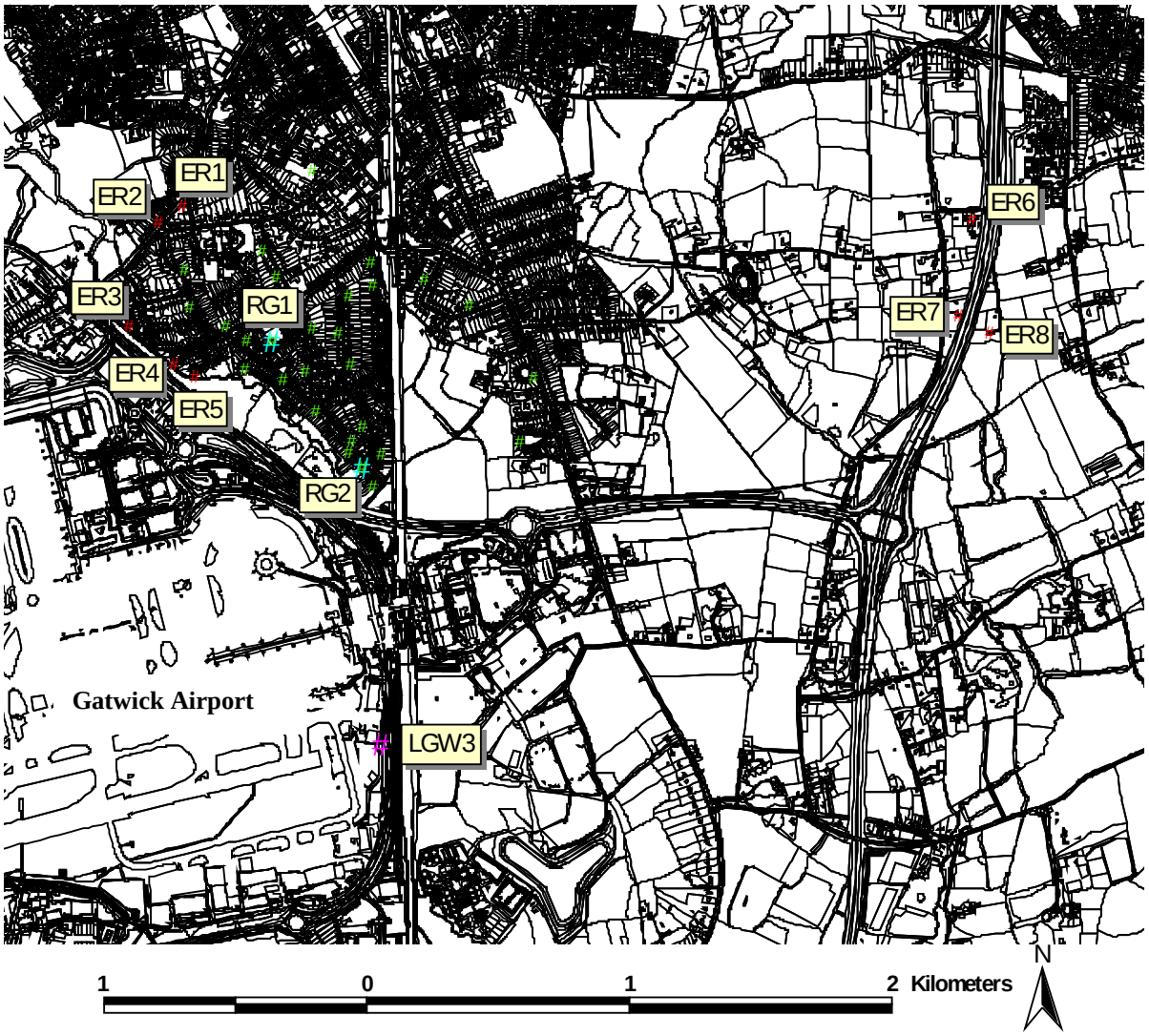
Figure A1.2 Reigate and Banstead Borough Council Air Quality Management Area No. 2b



Reigate & Banstead BC: OS Licence No. LA 079065 (2002)

Figure A1.3 Air Quality Monitoring Sites and Additional Receptors for Modelling

(Diffusion Tube sites are not individually labelled)



Automatic Monitors in AQMA 5
BAA Automatic Monitor (outside of AQMA)
Extra Receptors for Modelling
Diffusion Tube Sites

Figure A1.4 Diffusion Tube Sites

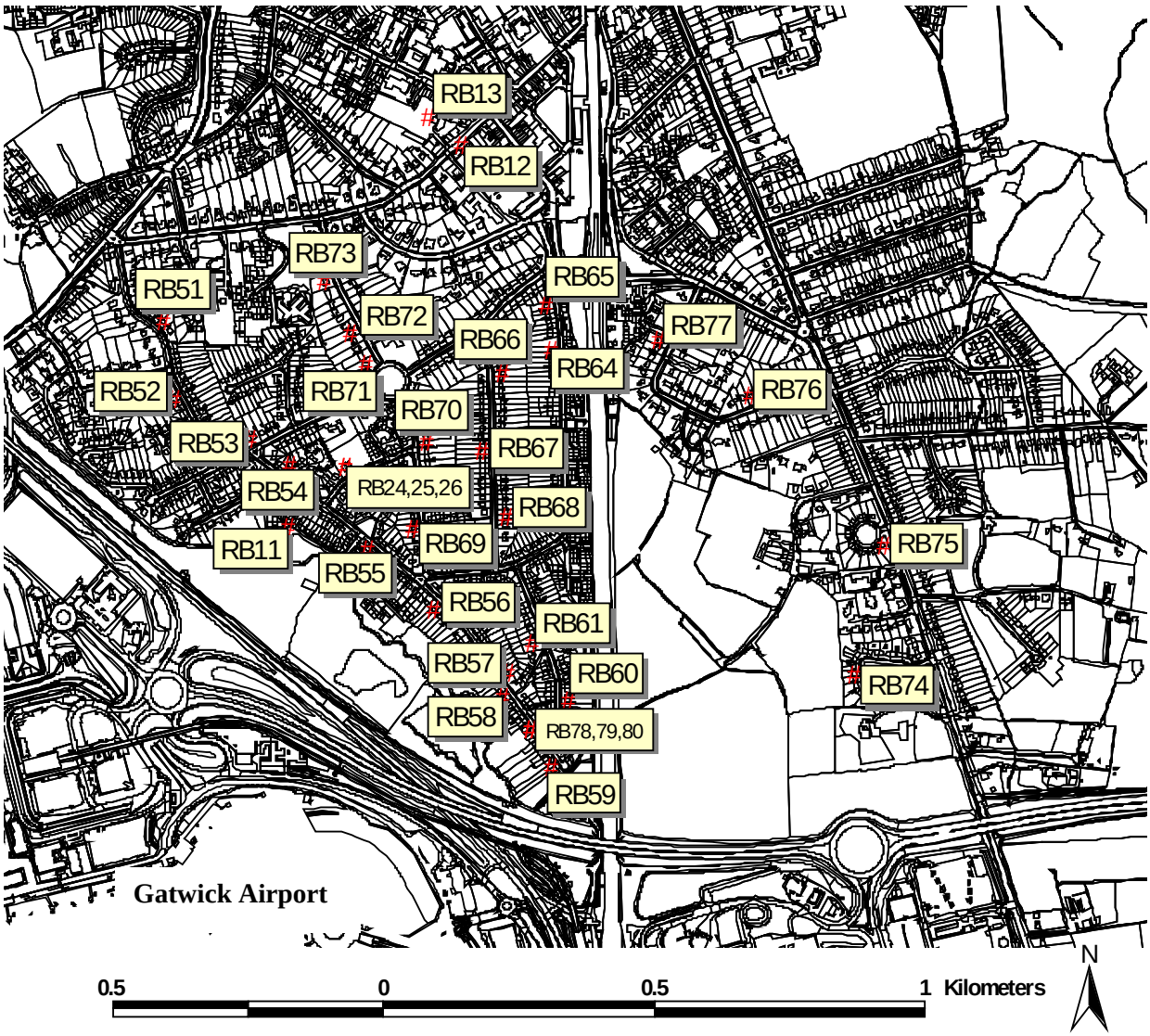
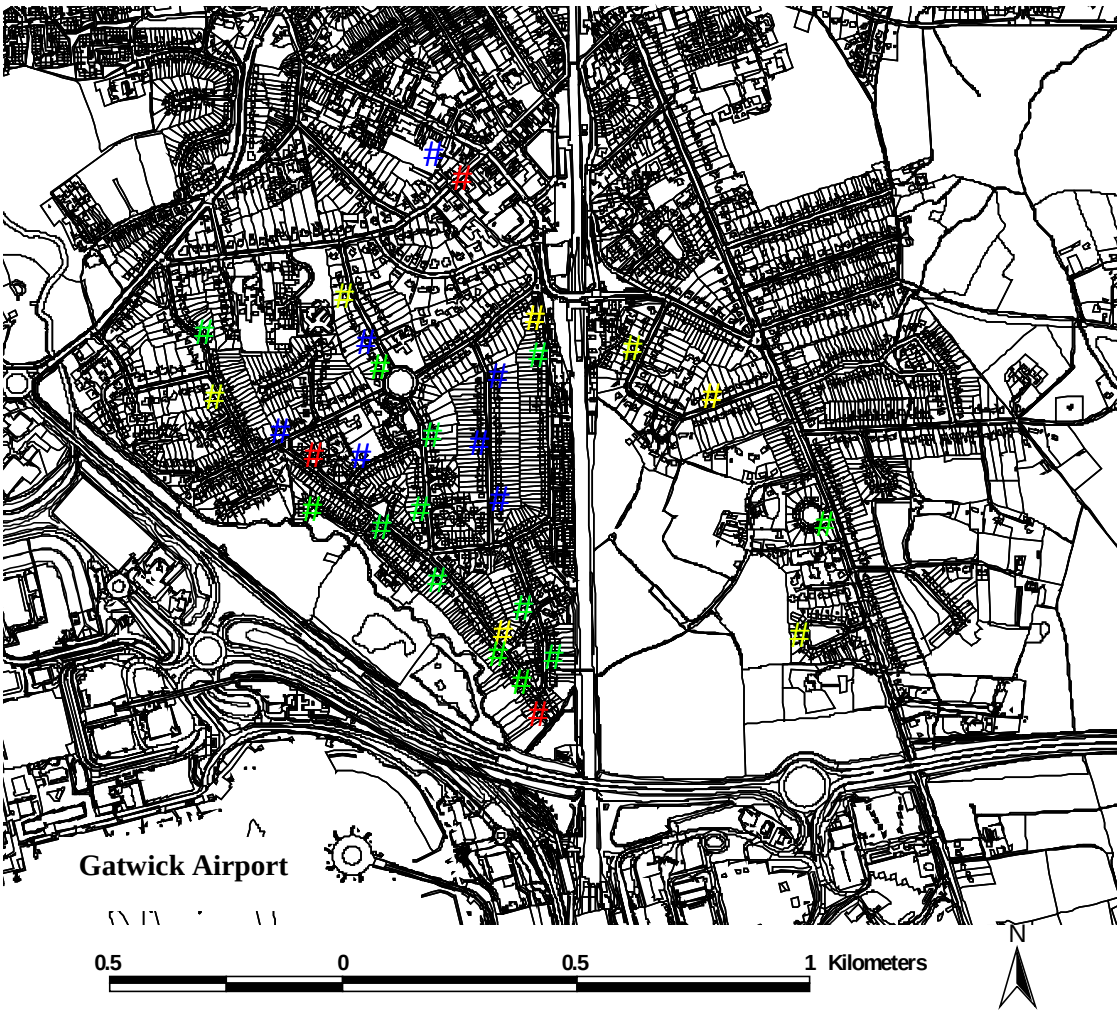


Figure A1.5 The Spatial Pattern Of Nitrogen Dioxide Concentrations Measured by Diffusion Tubes (2002/2003)



Key : Measured Annual Mean Nitrogen Dioxide Concentrations (2002/2003) $\mu g/m^3$

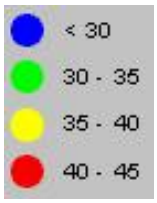
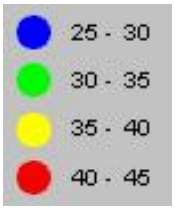


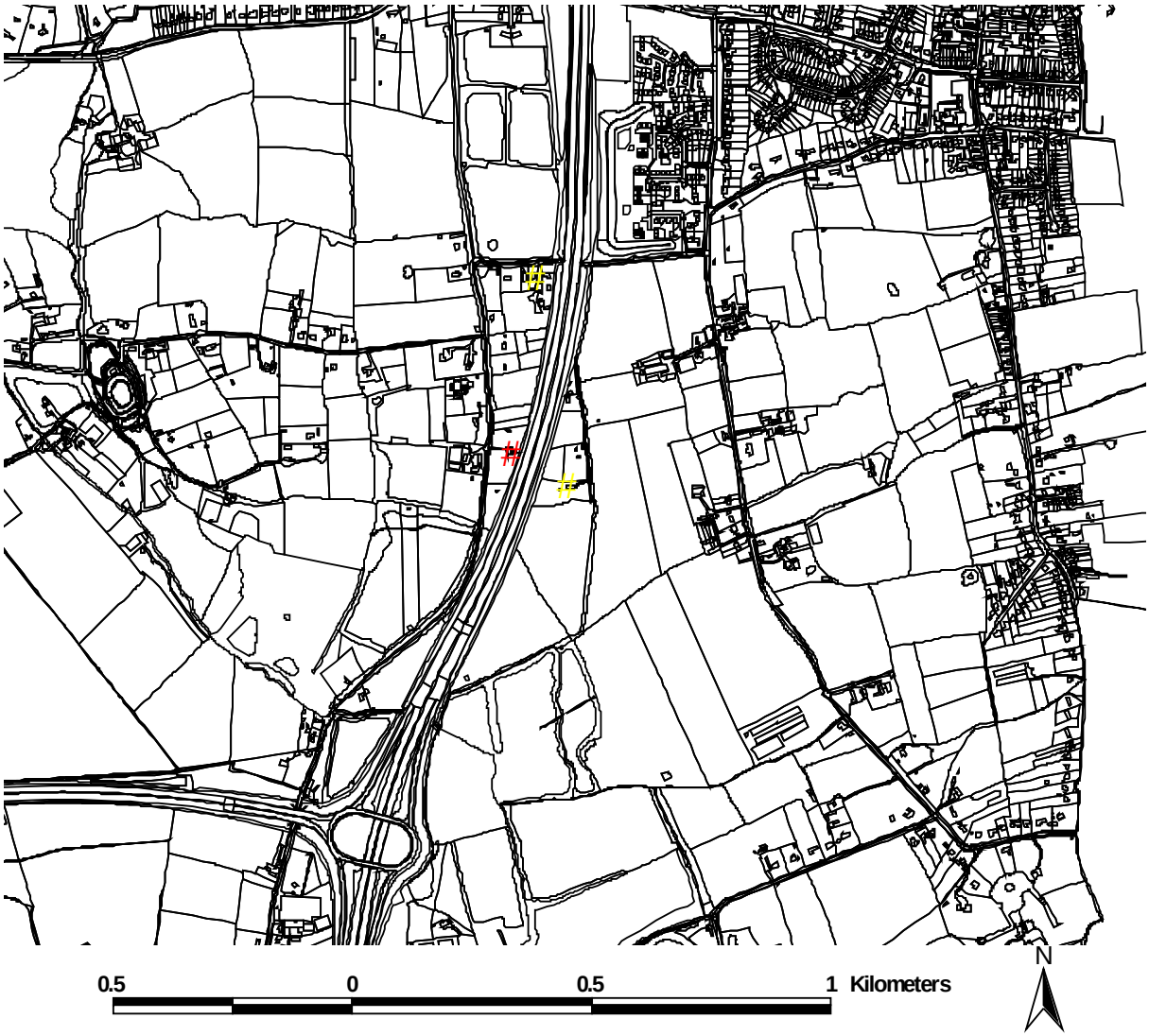
Figure A1.6 Estimated Annual Mean Nitrogen Dioxide Concentrations in 2005 in AQMA 5

Key : Estimated Annual Mean Nitrogen Dioxide Concentrations in 2005 mg/m^3

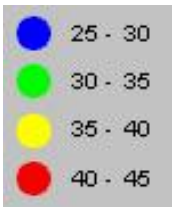


NB. 40 µg/m^3 is the objective level. 35 µg/m^3 is the objective level minus 1 standard deviation of the model.

Figure A1.7 Estimated Annual Mean Nitrogen Dioxide Concentrations in 2005 in AQMA 2b



Key : Estimated Annual Mean Nitrogen Dioxide Concentrations in 2005 mg/m^3

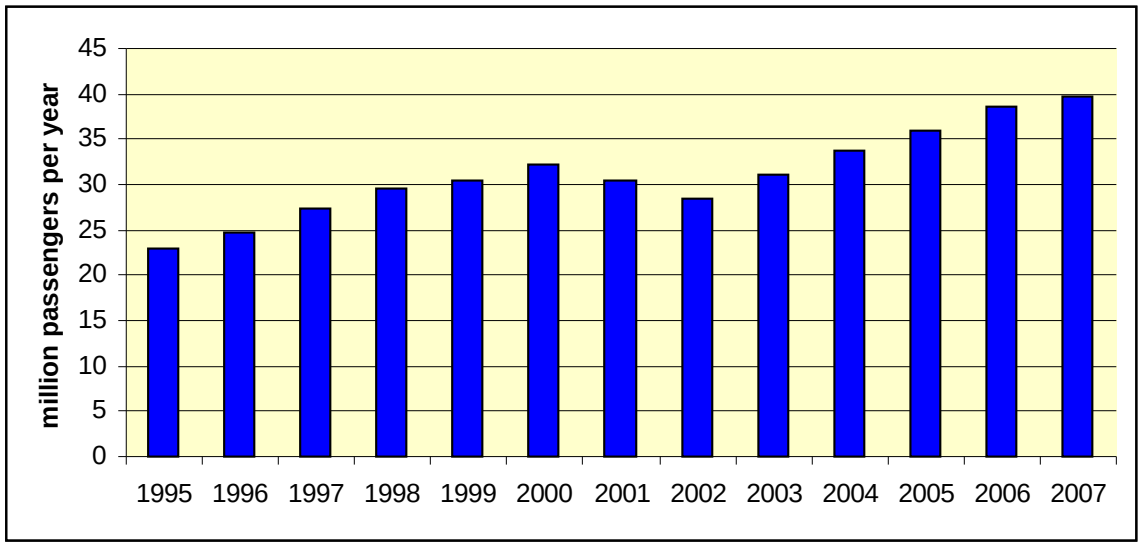


NB. 40 µg/m^3 is the objective level. 35 µg/m^3 is the objective level minus 1 standard deviation of the model.

Appendix 2 Growth of Gatwick Airport

The growth in passenger numbers gives a good indication of growth in overall activity at the airport. Figure A2.1 shows approximate growth in the number of passengers over 13 years. These data are taken from Competition Commission (2004). Elsewhere in this report, the growth in passenger numbers has been used as part of the calculation of future air quality. The data used in these calculations came directly from BAA, and are not the same as those shown in the Figure. We are unable to publish the information provided by BAA. Figure A2.1 represents general historical trends, and future projections in growth of the airport, but the data are less current than those used to assess air quality.

Figure A2.1 Approximate Passenger Numbers at Gatwick Airport Over 13 Years.



NB. The dip in Figure A2.2 follows the events of September 11th 2001.

Appendix 3 Measured 1-hour Mean Nitrogen Dioxide Concentrations

Figure A3.1 1-hour Mean Nitrogen Dioxide Concentrations During the Study Period at Site RG1

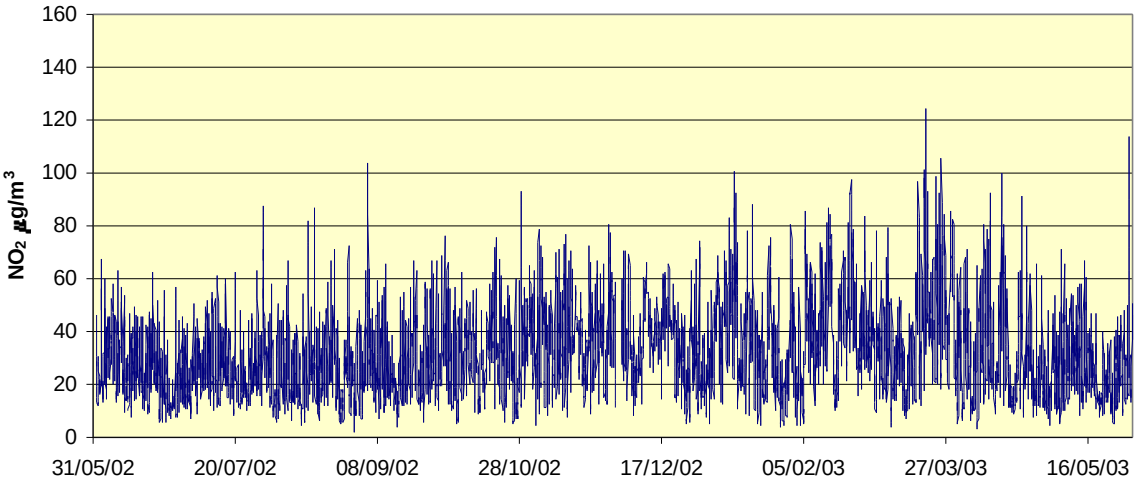
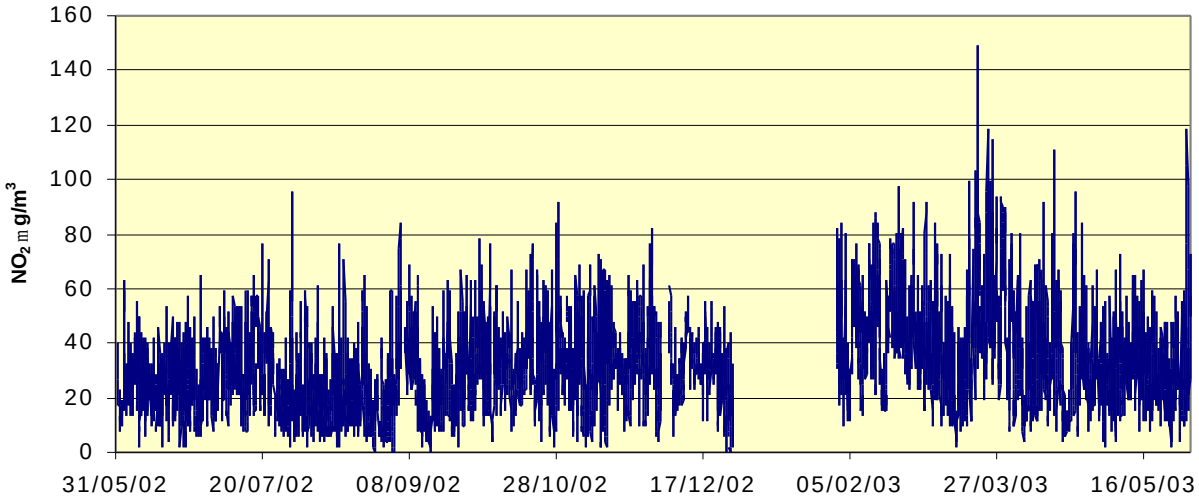


Figure A3.2 1-hour Mean Nitrogen Dioxide Concentrations During the Study Period at Site RG2



Appendix 4 Modelling Methodology

Overview

Annual mean NO_2 concentrations at the worst-case receptors were modelled by netcen on behalf of BAA Gatwick. The method was discussed in advance with Reigate and Banstead BC and Air Quality Consultants Ltd. The methodology is reported fully in Underwood *et al*. (2003a) and summarised below.

The total annual mean NOx concentration was assumed to have 2 contributions. The first contribution was from those sources explicitly identified in the Gatwick Emissions Inventory (Underwood *et al*., 2003b) and the second was the background contribution from all sources not explicitly identified. The explicit sources included were:

- aircraft in the landing-take-off cycle, including Auxiliary Power Unit (APU) emissions and emissions from engine testing;
- airside vehicles/plant;
- road vehicles on landside airport roads and on the road network around the airport;
- car parks and taxi queues;
- heating plant;
- fire-training ground.

Dispersion Modelling

The contribution from the explicit emissions data were calculated using the ADMS 3.1 dispersion model. ADMS has been compared against experimental data in a wide variety of situations, sufficient to justify its applicability to sources on the airport, provided adequate consideration is given to near-source effects that are not automatically dealt with by the model. Information on ADMS validation can be found on the Cambridge Environmental Research Consultants website (CERC, 2004).

Emissions were represented using combinations of three basic configurations in plan view – point, line, or area. For points, the source was specified in terms of the co-ordinates of the point and the total annual emissions. Where the point was actually representative of emissions over a small area (as, for example, in the case of airside vehicle emissions), a specification was given for the horizontal extent represented by the 'point'. Line sources were specified in terms of the ends of the line, a width and the total emissions for the line element. Emissions were assumed to be uniformly distributed along the

line. Area sources were represented as polygons, defined in terms of the co-ordinates of the vertices, and the total emissions. Emissions were assumed to be uniformly distributed over the area.

The model was run using the following options: no chemistry, no building wakes, no topographical effects on dispersion, and no deposition. A full explanation of the meaning and implications of these options can be found in Underwood *et al.* (2003a) or CERC (2004).

The model parameters defining surface friction and heat-flux, and thus vertical profiles of turbulence and wind speed, were set as follows. These values are thought to be the most suitable for this situation:

- Aerodynamic roughness length = 0.2m
- Lower limit Monin-Obukhov length = 30m
- Priestly-Taylor parameter = 1
- Surface albedo = 0.23

ADMS was applied to the large number of sources on the airport using a "dispersion kernel" technique. This exploits the fact that the annual mean concentration arising from a number of sources is the sum of the annual mean concentrations from each source.

To account for aircraft emissions above ground during take-off and landing, a series of ADMS runs was conducted at 10 separate heights (2m, 4m, 8m, 16m, 32m, 64m, 128m, 256m, 512m and 1024m). Interpolation was used for intermediate heights. A separate ground-level ADMS run was conducted for road-vehicle emissions. The height of aircraft on the ground was taken to be 2.5 m and the height of road-vehicle sources as 1.5 m. The section of Airport Way closest to the RG2 monitoring site has an elevation of 6.5 m and this was represented explicitly.

The emissions data contained information on diurnal variation, which enabled dispersion from each source to be modelled using the appropriate diurnal profile. Aircraft emissions from each phase of the landing-take-off-cycle were calculated separately for the two separate directions of runway operation. Separate model runs were carried out for each direction of runway operation using meteorological data specific to the timing of each set of operations.

Parameters defining initial "near-field" dispersion will have most influence very close to the emission source. For the base ADMS runs the area was defined representing the smallest distance over which variations in emission intensity should be taken into account. This was set at 20m for aircraft sources and 10m for road vehicles. The "volume source depth" was defined to represent the extent of initial vertical dispersion. It is difficult to accurately predict this value for aircraft sources and so the model was run using values of both 10 and 30m in order to gauge its sensitivity to this factor. It was determined that, at the distance of the receptors relevant to this report, sensitivity was negligible. A value of 30m was set, which is thought to be most appropriate. Studies (Wayson *et al.*, 2002) have shown that plume-rise of aircraft exhausts is comparable to the extent of initial vertical dispersion assumed in this modelling. It is thus unnecessary to account for this factor explicitly. For road vehicles, a volume source depth of 3m was used. Boiler house emissions were assigned an initial vertical extent of 20m, which is likely to give a conservative estimate of their contribution to annual mean ground-level concentrations.

The UK Meteorological Office supplied hourly wind-speed and cloud-cover data for the 12-month period of interest. The wind-speed data came from an automatic monitoring station at Redhill; approximately 7 km NNE from Gatwick Airport; the cloud-cover data (which will vary regionally rather than locally) came from Heathrow Airport.

Background contribution

The background contribution was calculated using the methodology that is also used to produce the background maps available from Defra. The basis of this method is described at Defra (2004b). To avoid double counting, relevant airport sources and the major roads within the study area were removed from the emission inventory before calculating the background concentrations. This procedure generated background concentration data for 2001. In order to project background concentrations to the 12 month study period in 2002/2003, an adjustment was made based on measured trends over this period at Lullington Heath automatic monitoring site, which is 47 km away. This gave an adjustment factor of 0.95. Concurrent trends at other national monitoring sites were found to be similar to this.

NOx/NO_2 Relationship

The model generates NOx concentrations, but the objectives refer to NO_2 concentrations. Two separate relationships have been used to derive NO_2 concentrations from the modelled NOx concentration. One was applied to NOx from sources which are very close to the receptor ("fresh

NOx") and the other is applied to NOx from more remote sources ("aged Nox"). The only source of fresh NOx was very local roads; airport sources were too distant to be classed as fresh.

The fresh NOx relationship (Equation A4.1) is taken from Laxen and Wilson (2002) and is recommended by Defra (2003) for use by local authorities in the review and assessment process:

$C_{NO2i} / C_{NOxi} = 0.53 - 0.68 \ln (C_{NOxt})$ Equation A4.1

Where

C_{NO2i} is the NO_2 increment from nearby sources

C_{NOxi} is the NOx increment from nearby sources

C_{NOxt} is the total annual mean NOx concentration

The relationship used for aged NOx is:

$C_{NO2} = 1.9301 \, C_{NOx}^{0.6887}$ Equation A4.2

Where C_{NO2} is the annual mean NO_2 concentration and C_{NOx} is the annual mean NOx concentration.

In order to partition the total modelled NOx concentration between fresh and aged, a separate model run was conducted in which road-vehicle emissions were smeared out into 1 km grid squares. The difference between this approach and the standard method gave the proportion of fresh NOx. The remainder was assumed to be aged NOx.

This report makes use of the dispersion modelling carried out by netcen on behalf of BAA. Following the production of the report, netcen identified a minor error in their modelling, affecting the distribution of emissions during aircraft take-off. The modelling team at netcen has given assurances that this error will make no material difference to the concentrations predicted for the Horley area.

Appendix 5 Model Verification

Table A5.1 sets out the modelled NO_2 concentrations at each of the monitoring sites, along with the measured concentration at that site. The monitoring sites are described in the main text, with the exception of site LGW3, which is an automatic monitor due east of Gatwick airport. This monitor is operated by AEA Technology on behalf of BAA. It is operated following the same regime as at RG2. The site is very close to the runway and to an adjacent road, it is not in a relevant location for annual mean exposure, and is not within any AQMAs covered by this report. Data from diffusion tube sites RB12 and RB71 have been excluded from Table A5.1 and the subsequent figures. These sites have not been used to validate the model because it was felt that they were likely to be significantly influenced by very local traffic emissions not explicitly included in the model.

Table A5.1 shows that averaged across all of these sites, the model under predicts concentrations very slightly (the average ratio is 0.99). The variation between the two sets of data is not constant, but is not expected to be for a number of reasons. One reason is that the monitoring data will be influenced by emissions from local roads that were not explicitly included in the model. Another reason is that both the monitoring and the modelling will be subject to independent uncertainty.

Figure A5.1 shows the modelled data plotted against the measured data. The dotted line shows a 1:1 relationship (which would be expected if the model agreed perfectly with the measurements). The solid line shows the line fitted to the data using Reduced Major Axis (RMA) Regression, weighting the automatic data by a factor of 2[1] to account for the lower uncertainty associated with these data. This line indicates that there is a systematic difference between the 2 sets of data, namely that the model underestimates slightly at higher concentrations. One interpretation of this is that the background contribution is overestimated, while contributions from road and/or airport sources are underestimated. In order to examine whether this interpretation is valid, the ratios of the modelled : measured values (from Table A5.1) have been plotted against various site-specific data. These plots are shown in Figures A5.2 to A5.6.

[1] By entering the automatic data points into the regression analysis twice.

Table A5.1 Modelled and Measured Annual Mean Nitrogen Dioxide Concentrations (µg/m^3) at the Monitoring Sites

Site	Modelled	Measured	Ratio
RB11[a]	34.1	35.3	0.97
RB13[a]	28.3	27.8	1.01
RB51[a]	30.6	33.0	0.93
RB52[a]	31.7	36.5	0.87
RB53[a]	32.2	29.8	1.08
RB54[a]	32.5	42.9	0.76
RB55[a]	34.1	32.2	1.06
RB56[a]	35.5	32.0	1.11
RB57[a]	36.8	38.4	0.96
RB58[a]	37.9	34.0	1.12
RB59[a]	40.9	40.9	1.00
RB60[a]	36.9	31.6	1.17
RB61[a]	35.4	33.1	1.07
RB64[a]	29.9	31.6	0.95
RB65[a]	29.5	38.8	0.76
RB66[a]	30.2	23.4	1.29
RB67[a]	31.3	28.8	1.09
RB68[a]	32.4	28.7	1.13
RB69[a]	33.1	33.3	0.99
RB70[a]	31.3	32.9	0.95
RB72[a]	30.0	28.7	1.04
RB73[a]	29.5	37.0	0.80
RB74[a]	34.4	36.6	0.94
RB75[a]	34.8	35.2	0.99
RB76[a]	30.6	39.8	0.77
RB77[a]	29.8	36.9	0.81
RG1[b]	32.2	31.4	1.02
RG2[b]	38.9	31.6	1.23
LGW3[b]	50.1	51.9	0.96
Average			**0.99**

[a] Diffusion Tube
[b] Automatic Monitor

Figure A5.1 Relationship Between the Modelled and Measured Annual Mean NO_2 Data

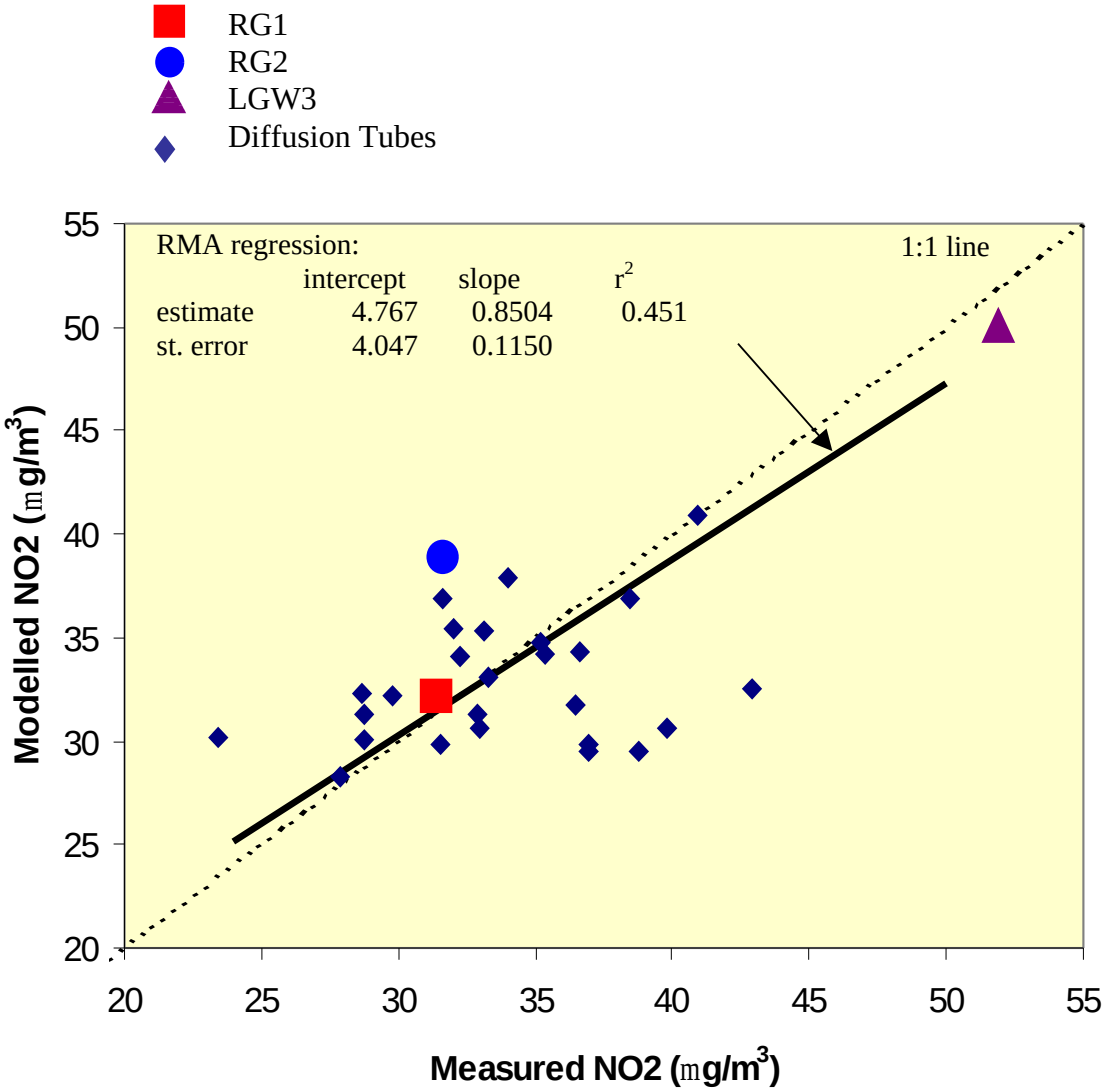


Figure A5.2 Modelled : Measured NO_2 Ratio vs Distance from the Each Monitoring Site to the Closest Main Road (m)

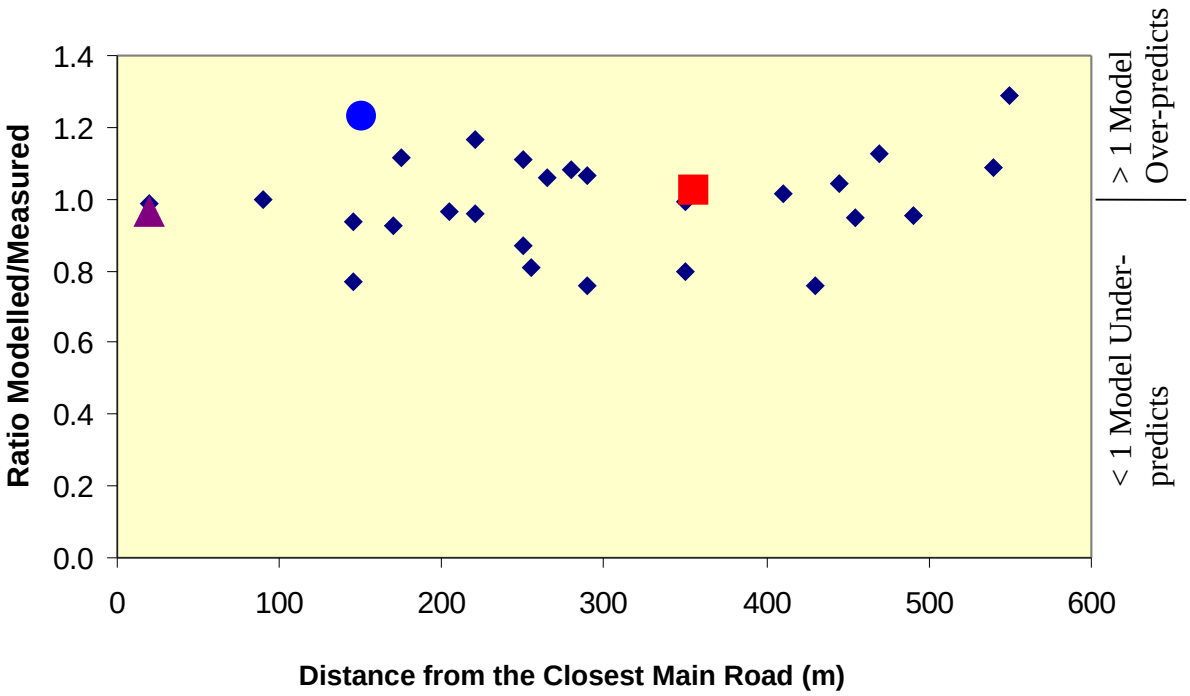


Figure A5.3 Modelled : Measured NO_2 Ratio vs Distance from the Each Monitoring Site to the Airport* (m)

*to a specific central point in the Apron (west end of South Terminal pier)

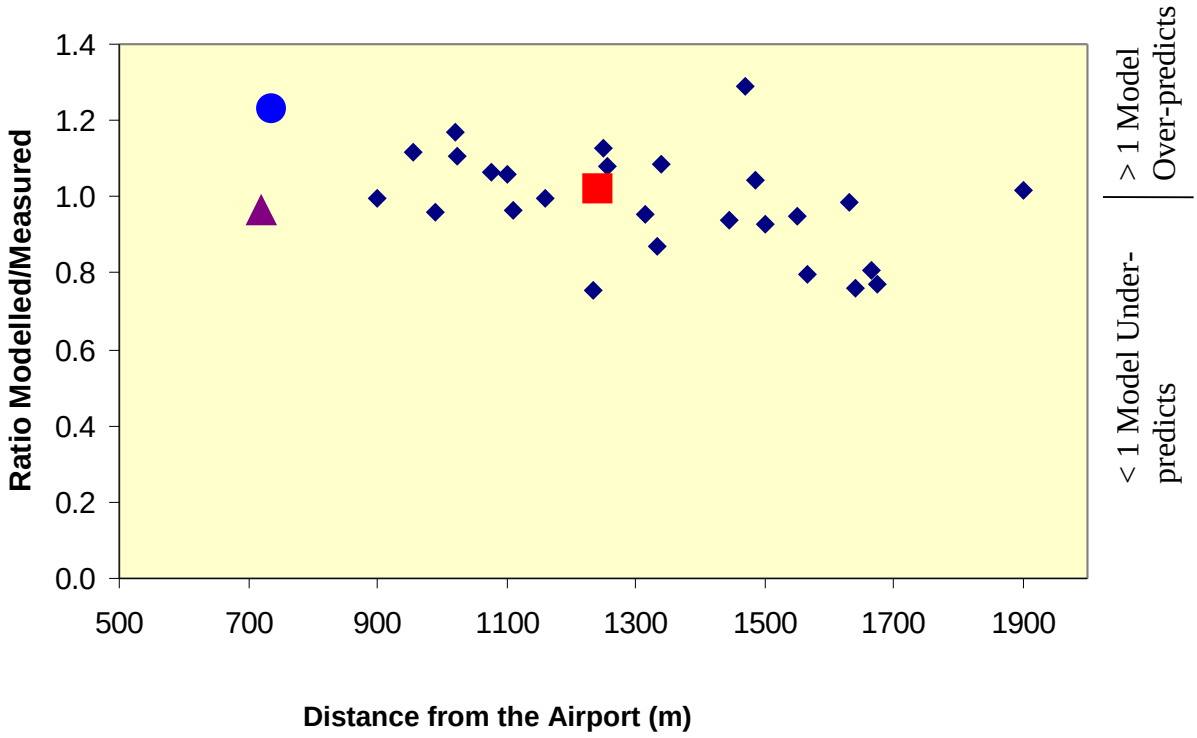


Figure A5.4 Modelled : Measured NO_2 Ratio vs NOx from Aircraft (not including APUs) (µg/m^3)

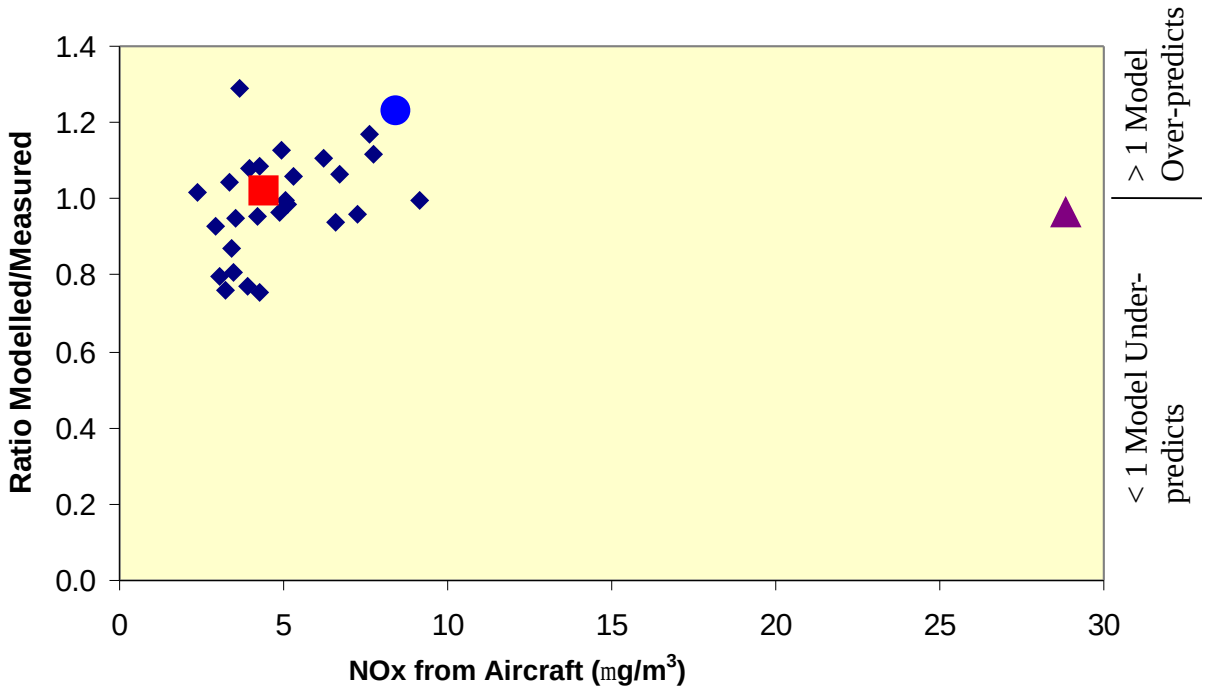


Figure A5.5 Modelled : Measured NO_2 Ratio vs NOx from All Sources except Aircraft (µg/m^3)
(All sources include APUs and airside vehicles)

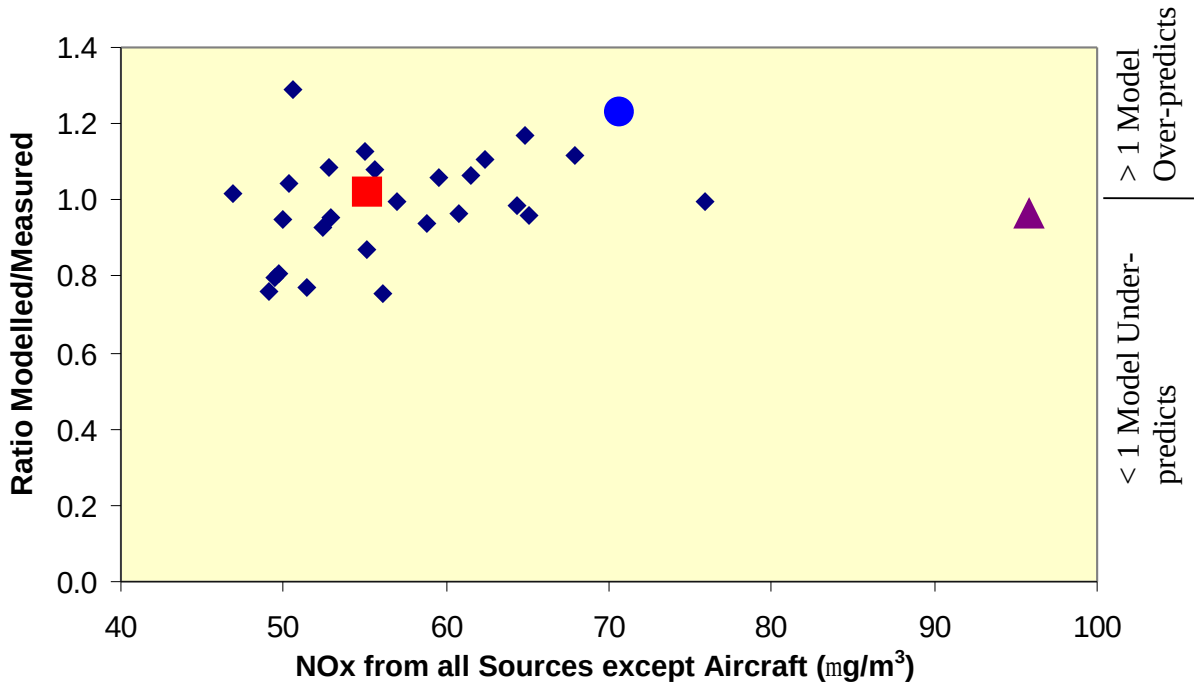
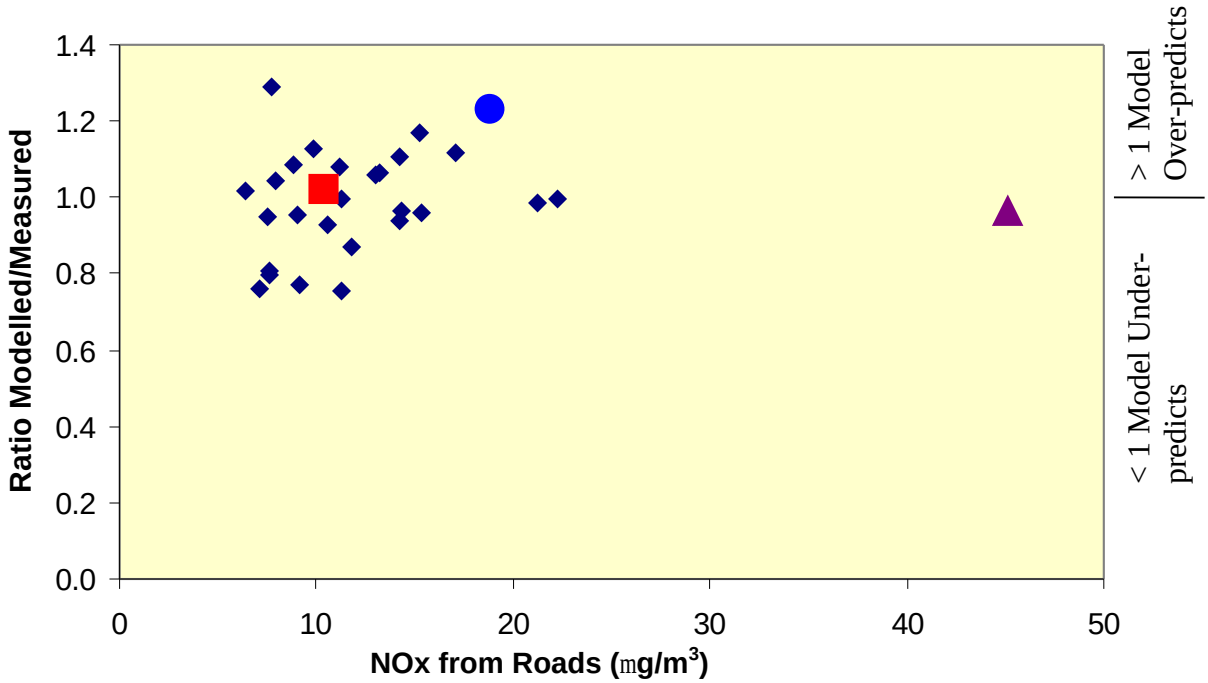


Figure A5.6 Modelled : Measured NO_2 Ratio vs NOx from Roads ($\mu g/m^3$) (both airport-related and non-airport roads)



Because many of the main local roads are close to the airport, it is very difficult to disentangle the influence of distance from roads, from distance from the airport. Despite this limitation, Figure A5.2 indicates that there is no clear relationship between model performance (i.e. ratio) and distance from the nearest main road. This suggests that these road-vehicle sources are adequately represented in the model. Similarly, Figure A5.3 shows no clear relationship between model performance and distance from the airport.

It is suggested above that the model might overestimate background NOx and underestimate other sources. If NOx from aircraft was underestimated, then Figure A5.4 would show that values were under-predicted at higher NOx concentrations. This is not the case, implying that NOx from aircraft is not under-represented. If NOx from non-aircraft airport sources was underestimated, then Figure A5.5 would show that values were under-predicted at higher NOx concentrations. Again, this is not the case, implying that NOx from non-aircraft airport sources is not under-represented. Finally, if NOx from roads was underestimated, then Figure A5.6 would show that values were under-predicted at higher NOx concentrations. Again, this is not the case, implying that NOx from roads is not under-

represented. It is therefore concluded that none of these individual sources are significantly underestimated. Because the model does not systematically produce results that are higher than the measurements, it can also be inferred that the background contribution is not overestimated.

In general, the model will predict falling concentrations with distance from the emission source; because, in very simple terms, this is an assumption on which the model is based. The patterns shown in Figures A5.4 to A5.6 will therefore have some relationship with distance from emission sources. Each of the Figures (A5.4 to A5.6) shows is a very slight pattern that the model under-predicts when the modelled NOx concentrations are low; i.e. further from the emission source. This is apparently contradictory to the pattern shown in Figure A5.1, which suggests that the model over-predicted at lower concentrations.

The explanation for this apparent contradiction is that in Figure A5.1, the "lower concentrations" at which the model over-predicts are the measured concentrations. In the subsequent Figures, the "lower concentrations" at which the model under-predicts are the modelled concentrations. This is exemplified by comparing Figures A5.7 and A5.8, which show the model ratio plotted against first, modelled NO_2, and second, measured NO_2. On each of the plots, the best-fit line from Figure A5.1 has been drawn. Clearly, the two figures show very different patterns and raise questions about how the data should be treated.

Given the contradicting nature of the uncertainty analysis, a pragmatic approach has been adopted to adjust the model outputs for systematic errors. The reasoning behind correcting the model at all is that the measured data are known with more confidence than the modelled data. The modelled data have therefore been adjusted based on the overall relationship between the measurements and the model. This is the relationship plotted as a line on Figures A5.1, A5.7 and A5.8. And can be described thus:

Final NO_2 = 1.176 x Modelled NO_2 –5.606 **Equation A5.1**

(the relationship is derived from RMA regression, assigning double weight to each automatic monitoring site[1]; it is the same relationship shown in Figure A5.1, but the equation is rearranged to make x the subject).

Table A5.2 sets out the adjusted-modelled concentrations and their ratio to the measured data. The unadjusted-modelled concentrations and their ratios to the measurements (from Table A5.1) are also

shown for ease of comparison. The overall under-prediction noted for Table A5.1 has been removed by adjusting the data, and the overall average ratio is now 1.00.

Figure A5.7 Modelled : Measured NO_2 Ratio vs Modelled NO_2 ($\mu g/m^3$)

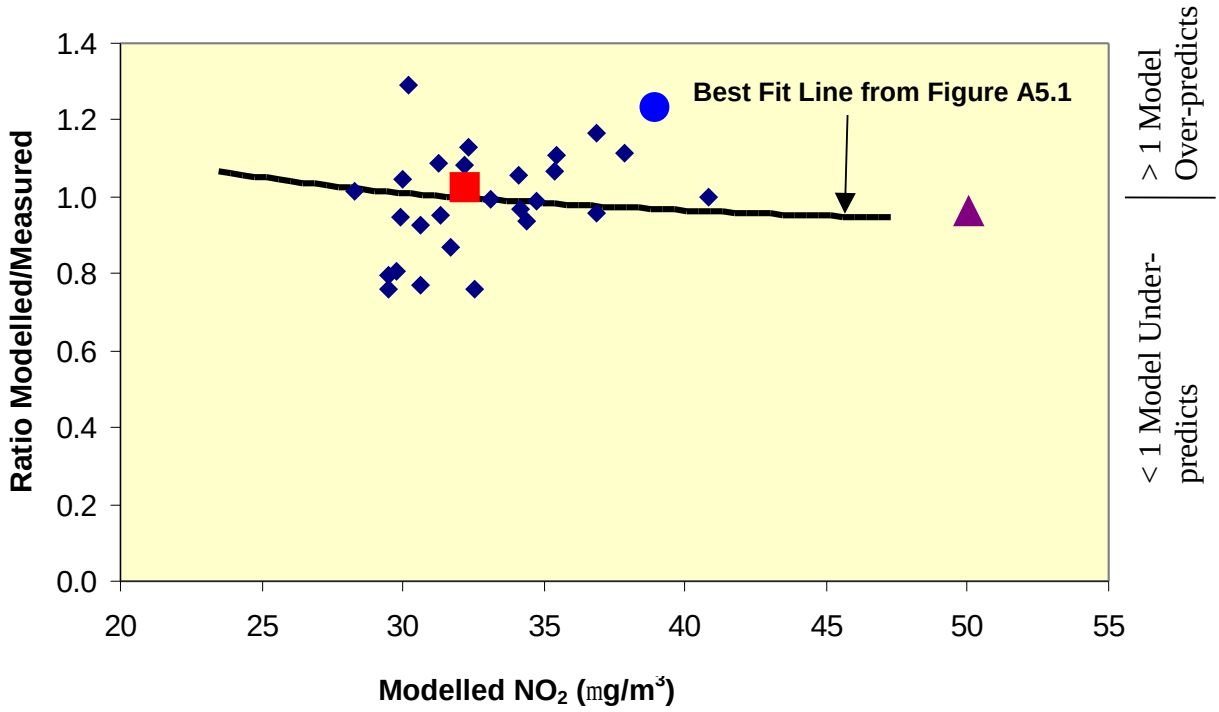


Figure A5.8 Modelled : Measured NO_2 Ratio vs Measured NO_2 ($\mu g/m^3$)

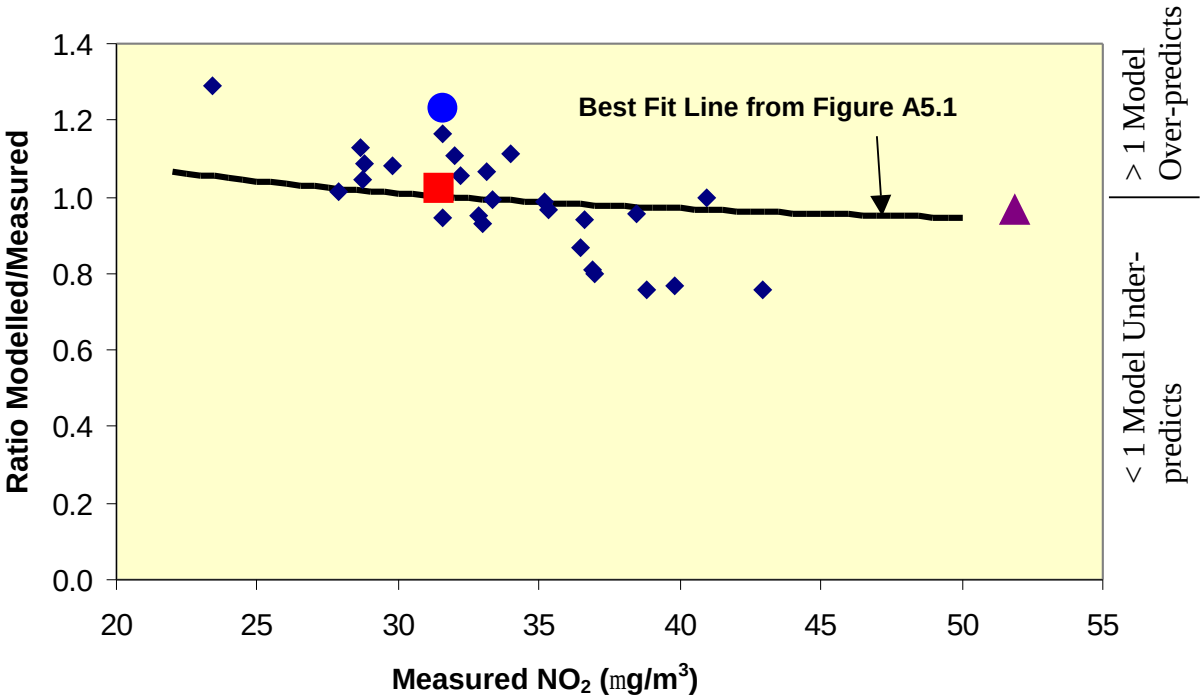


Table A5.2 Adjusted Modelled and Measured Annual Mean Nitrogen Dioxide Concentrations ($\mu g/m^3$) at the Monitoring Sites

Site	Raw Model	Adjusted Model	Measured	Raw Model Ratio	Adjusted Model Ratio
RB11[a]	34.1	34.6	35.3	0.97	0.98
RB13[a]	28.3	27.6	27.8	1.01	0.99
RB51[a]	30.6	30.4	33.0	0.93	0.92
RB52[a]	31.7	31.7	36.5	0.87	0.87
RB53[a]	32.2	32.2	29.8	1.08	1.08
RB54[a]	32.5	32.7	42.9	0.76	0.76
RB55[a]	34.1	34.5	32.2	1.06	1.07
RB56[a]	35.5	36.1	32.0	1.11	1.13
RB57[a]	36.8	37.7	38.4	0.96	0.98
RB58[a]	37.9	38.9	34.0	1.12	1.15
RB59[a]	40.9	42.4	40.9	1.00	1.04
RB60[a]	36.9	37.8	31.6	1.17	1.20
RB61[a]	35.4	36.0	33.1	1.07	1.09
RB64[a]	29.9	29.5	31.6	0.95	0.94
RB65[a]	29.5	29.0	38.8	0.76	0.75
RB66[a]	30.2	29.9	23.4	1.29	1.28
RB67[a]	31.3	31.2	28.8	1.09	1.08
RB68[a]	32.4	32.4	28.7	1.13	1.13
RB69[a]	33.1	33.4	33.3	0.99	1.00
RB70[a]	31.3	31.2	32.9	0.95	0.95
RB72[a]	30.0	29.7	28.7	1.04	1.03
RB73[a]	29.5	29.1	37.0	0.80	0.79
RB74[a]	34.4	34.8	36.6	0.94	0.95
RB75[a]	34.8	35.3	35.2	0.99	1.00
RB76[a]	30.6	30.4	39.8	0.77	0.76
RB77[a]	29.8	29.4	36.9	0.81	0.80
RG1[b]	32.2	32.2	31.4	1.02	1.03
RG2[b]	38.9	40.2	31.6	1.23	1.27
LGW3[b]	50.1	53.3	51.9	0.96	1.03
Average				**0.99**	**1.00**

[a] Diffusion Tube
[b] Automatic Monitor

Appendix 6 Estimating Uncertainty in the Modelled Data

The methodology set out in NSCA (2000) has been used to estimate the uncertainty associated with the model results. This is summarised below and in Table A6.1:

Step 1:

The line of best fit (by standard linear regression) of y (adjusted modelled NO_2) on x (measured NO_2) was found for the data. This is:

$y = 0.5484x + 15.115$ **Equation A6.1**

Step 2:

The deviation of each adjusted modelled datum from this line of best fit was calculated:

Modelling deviation = $(0.5484x + 15.115) – y$ **Equation A6.2**

The results are shown in Table A6.1

Step 3:

A value of U was calculated by:

U = SD / mean of observed data **Equation A6.3**

(Where SD is the standard deviation of the modelling deviations from Step 2)

Therefore:

U= 4.28 / 34.3 = 0.12 **Equation A6.4**

Step 4

The Standard Deviation of the Model (SDM) was then calculated:

SDM = U x Co **Equation A6.4**

Where Co is the concentration of the objective in question.

Therefore

SDM = 0.12 x 40 = 4.99 **Equation A6.5**

Table A6.1 Data Used to Assess Uncertainty in the Model ($\mu g/m^3$)

Site	Adjusted Modelled	Measured	Modelling Deviation
RB11	34.6	35.3	-0.07
RB13	27.6	27.8	2.75
RB51	30.4	33.0	2.83
RB52	31.7	36.5	3.46
RB53	32.2	29.8	-0.79
RB54	32.7	42.9	6.01
RB55	34.5	32.2	-1.67
RB56	36.1	32.0	-3.44
RB57	37.7	38.4	-1.51
RB58	38.9	34.0	-5.19
RB59	42.4	40.9	-4.88
RB60	37.8	31.6	-5.32
RB61	36.0	33.1	-2.68
RB64	29.5	31.6	2.88
RB65	29.0	38.8	7.34
RB66	29.9	23.4	-1.94
RB67	31.2	28.8	-0.29
RB68	32.4	28.7	-1.60
RB69	33.4	33.3	0.03
RB70	31.2	32.9	1.92
RB72	29.7	28.7	1.19
RB73	29.1	37.0	6.29
RB74	34.8	36.6	0.41
RB75	35.3	35.2	-0.84
RB76	30.4	39.8	6.55
RB77	29.4	36.9	5.92
RG1	32.2	31.4	0.09
RG2	40.2	31.6	-7.73
LGW3	53.3	51.9	-9.67
Standard Deviation	-	-	4.28
Mean	-	34.3	-
U	-	-	**0.12**
SDM	-	-	**4.99**

Step 5

1 Standard deviation of the model is therefore essentially 5 μg/m^3. This value is specific to the 2002/2003 data and does not account for the extra uncertainty generated by projecting the data into the future. It is, however, not possible to quantify this "future" uncertainty, and so it has been assumed that the margin of likely error surrounding the 2005 adjusted modelling data is 5 μg/m^3.

Appendix 7 Predicting Future Concentrations

The ADMS 3.1 dispersion model was used to estimate the annual mean NO_2 concentration at each receptor during the year June 2002 – June 2003 (see Appendix 4). The annual mean nitrogen dioxide objective applies in 2005. It is not appropriate to scale the model outputs forward using the default factors provided by Defra, because these do not take account of increases in emissions due to greater activity at Gatwick Airport. The 2002-2003 data have been scaled forward to 2005 using a range of information, and making use of the source apportionment results presented in Chapter 5 of the main report. The methodology used is described for each source category.

Airport Sources:

The number of passengers using Gatwick Airport during the modelling period has been provided by BAA. BAA has also provided budgeted passenger numbers for each subsequent financial year, which have been used to interpolate the number of passengers during 2005. From this information, airport growth between the model year and the 2005 calendar year has been estimated. NOx from each of the following sources (as defined by the modelling) has been increased by 9.4 % in order to account for this growth:

- Aircraft
- APUs
- Airside Vehicles
- Miscellaneous airport

Airport-Related Road Vehicles:

Step 1

The average vehicle speed and traffic composition for all airport-related road vehicles across all of the motorway links explicitly included in the dispersion model was calculated from the model input data (regardless of link length).

Step 2

This information was used in the road vehicle emissions spreadsheet produced by Casella Stanger (2003) (assuming no cold-starts) to estimate emissions per vehicle kilometre during 2002 and 2003 and 2005.

Step 3

The same was done for all non-motorway links included in the dispersion model.

Step 4

Using the emissions factors for the 2002 and 2003 calendar years, a weighted-average for the study period was calculated.

Step 5

An average factor across both road types, weighted by the relative number of links, was then calculated.

Step 6

The ratio between this value for 2002/2003 and for 2005 was calculated. These calculations are shown in Table A7.1

Table A7.1 NOx Emission Factors for the Airport-Related Road Vehicles.

	Number of Links[a]	Relative proportion of vehicles on the links included (%)[b]				Mean Speed (kph)	Emission factor (g/veh.km)[c]				Ratio (2005 / Modelling Period)
		Cars	LGV	HGV	PSV		2002	2003	Modelling Period	2005	
Motorways	23	95	2	1	1	58	0.665	0.583	0.631	0.468	
Other Roads	378	89	4	1	6	40	0.953	0.864	0.916	0.735	
Overall	401								0.900[d]	0.720[d]	**0.800**

[a] Each link explicitly included is counted, regardless of its length.
[b] Only vehicles on airport-related journeys are included
[c] This factor takes account of the average vehicle composition and speed on each link.
[d] See "Step 5".

Step 6

It is assumed that the number of airport-related vehicle movements will increase by 9.4%, in line with passenger numbers at the airport. The overall adjustment factor used to estimate NOx concentrations in 2005 from model outputs in 2002-2003 is therefore 1.094 x 0.800 = 0.876.

Non-Airport-Related Road Vehicles:

Step 1

The method followed that described in steps 1-5 of "Airport-Related Road Vehicles". The values obtained are shown in Table A7.2.

Table A7.2 NOx Emission Factors for the Non-Airport-Related Road Vehicles.

	Number of Links[a]	Relative proportion of vehicles on the links included (%)[b]		Mean Speed (kph)	Emission factor (g/veh.km)[c]				Ratio (2005 / modelling period)
		LDV	HDV		2002	2003	Modelling Period	2005	
Motorways	23	89	11	58	1.545	1.412	1.490	1.221	
Other Roads	378	90	10	40	1.211	1.109	1.168	0.964	
Overall	401						1.187	0.979	**0.825**

[a] Each link explicitly included is counted, regardless of its length.
[b] Only vehicles on airport-related journeys are included
[c] This factor takes account of the average vehicle composition and speed on each link.

Step 2

Growth in the number of non-airport-related vehicles has been predicted following the method described on Defra's Review and Assessment Website (Defra, 2004a). This is summarised in Equations A7.1 and A7.2.

(Horley TEMPRO factor / GB TEMPRO factor) x NRTF factor*. **Equation A7.1**

(*for total traffic and central growth. This therefore assumes that the numbers of different types of vehicle will increase at the same rate. A separate calculation, described in the source apportionment methodology (Appendix 8) shows that this assumption is valid.)

Because TEMPRO gives data for specific calendar years, the raw data (as opposed to the growth factors) for 2002, 2003, and 2005 was extracted from TEMPRO. Data for the modelling period were interpolated from the 2002 and 2003 data and the relevant growth factors to 2005 were thus calculated.

NRTF factors also refer to calendar years, and so factors for growth between the precise modelling period and 2005 were interpolated.

The data used in the calculation described in Equation A7.1 was:

(1.037 / 1.029) x 1.046 = 1.055 **Equation A7.2**

Step 3

The overall adjustment factor used to estimate NOx concentrations in 2005 from model outputs in 2002-2003 was therefore 1.055 x 0.825 = 0.870.

Background:

The background NOx concentration was adjusted forward using the factors provided by Defra (Defra 2004). As with the traffic projections, factors for the modelling period were interpolated from those for 2002 and 2003.

Estimating Future Year NO_2 from Future Year NOx

The method described in the Appendix 4 was followed. This involved partitioning the total NOx concentration into "fresh" and "aged" contributions.

Step 1

As explained in Appendix 4, separate model runs were conducted in order to determine the increment of fresh NOx. The value of fresh NOx for each receptor during the model year was provided by the modelling team at netcen.

Step 2

The average of the adjustment factors used to estimate 2005 NOx emissions from airport-related and non-airport-related roads was calculated (The mean of 0.876 and 0.870 = 0.873).

Step 3

The fresh NOx increment for each receptor was multiplied by this factor to give the concentration of fresh NOx in 2005. This is justified because by definition, all fresh NOx must come from road vehicles and the two factors averaged in step 2 are so very similar that any error introduced will be negligible.

Step 4

The contribution of fresh NOx to the annual mean NO_2 concentration was calculated using Equation A4.1. The contribution of aged NOx to the annual mean NO_2 concentration was calculated using Equation A4.2. The total NO_2 concentration at each receptor was then the sum of these 2 contributions.

Step 5

This total NO_2 concentration was then adjusted to account for model bias using equation A5.1.

Appendix 8 Source Apportionment Methodology

Because the model used a dispersion kernel technique (see Appendix 4) each major source of NOx was modelled individually. Source apportionment of the NOx was therefore very straightforward. The model outputs did not, however, differentiate between the different types of vehicles on the roads. For the receptors beside the M23 in AQMA 2b, emissions from road vehicles are expected to account for a large proportion of total ambient NOx, and it was thus necessary apportion this between different vehicle categories. The receptor in AQMA 2b where an objective exceedence is likely is receptor ER7. It has been assumed that because of its close proximity to the M23, all road-vehicle NOx at this receptor will come from the M23. This will introduce only a very slight error.

Step 1

In order to obtain more detailed vehicle composition data than was available for the dispersion modelling, traffic count data for the section of the M23 running through AQMA 2b was taken from the national atmospheric emissions inventory. These data came from a traffic count conducted in 2000. The vehicle composition on this section of the M23 is shown in Table A8.1.

Step 2

The method described on Defra's Review and Assessment Website (Defra 2004a) was followed to predict growth in the number of each type of vehicle between 2000 and 2005. Although the numbers of vehicles increased, the % contribution of each type of vehicle to the total traffic volume remained unchanged. This supports the assumptions made in predicting total emissions in 2005 (Appendix 7).

Table A8.1 Vehicle Composition (% of total number of vehicles) on the Section of M23 Passing Through AQMA 2b During 2000 and 2005.

	Cars	Bus/Coach	LGV	Rigid HGV	Artic HGV
2000	83	1	10	3	3
2005	83	1	10	3	3

Step 3

Because the worst-case receptor in AQMA 2b is adjacent to an open stretch of the M23, an annual average speed of 110 kph has been assumed. This is different to the overall average motorway speed assumed in Appendix 7, but because this analysis simply apportions a fixed value of NOx, this should introduce little error.

Step 4

Using the road vehicle emissions spreadsheet produced by Casella Stanger (2003) (assuming no cold-starts), emissions factors for each different type of vehicle have been calculated. These have been multiplied by the percentage values given in Table A81. The relative contribution of emissions from each vehicle to the total emissions from all vehicles has then been calculated. This calculation is set out in Table A8.2.

Step 5

The total predicted ambient NOx concentration at receptor ER7 that is due to road vehicles (75.3 $\mu g/m^3$) has been apportioned by the relative contribution of each vehicle type from Table A8.2.

Table A8.2 Percentage Contribution of Each Vehicle Class to Emissions From the M23

	Notes	**Cars**	**Bus / Coach**	**LGV**	**Rigid HGV**	**Artic HGV**	**Total**
Vehicle Composition	(from step 2) %	82.8	1.0	10.3	3.2	2.6	
Emission Factor	g/veh.km	0.5604	5.9628	1.0911	5.4033	11.1154	
Vehicle Composition x Emission Factor		46.4	6.0	11.3	17.4	29.3	110.4
Overall Contribution to Emissions	e.g. 46.4 as % of 110.4	42	5	10	16	27	

Appendix 9 Methodology Used for Management Planning

It has been assumed that any reductions in NOx emissions will result in a directly proportional reduction in source-specific ambient NOx concentrations. The effect of each planning measure was assessed by simply adjusting the source-specific NOx concentration and then following the calculations described in the preceding appendices (i.e. converting total NOx to NO_2 based on a scaled increment of fresh NOx and then adjusting total NO_2 to account for bias in the model). In addition to this simple method, the effect of altering vehicle speeds on the M23 adjacent to receptor ER7 was assessed based on the proportional reduction in emissions factors associated with different speeds. This is described below.

Step 1

It is assumed that all road-vehicle NOx at ER7 comes from the adjacent motorway and that the vehicle composition data given in Table A8.1 represents this traffic. The total predicted NOx emissions from road vehicles in 2005 have been apportioned by these composition data.

Step 2

Using the road vehicle emissions spreadsheet produced by Casella Stanger (2003) (assuming no cold-starts), emissions factors for each different type of vehicle have been calculated for the speeds of 110 kph (68 mph) and 80 kph (50 mph). The percentage reduction associated with slowing vehicles from one speed to the other was then calculated.

Step 3

This percentage reduction was applied to the source apportioned NOx data to give a revised prediction of road-related NOx. This calculation is set out in Table A9.1.

It is important to note that the dispersion model did **not** assume a speed of 110 kph. This analysis therefore shows the general effect that reducing average vehicle speeds could have, rather than a definitive value that could be achieved. In practice, this qualification is not quite as important as it appears. This is because the emission factors are based on average speeds. The optimum speed in terms of minimising emissions of NOx is in the range 50-80 kph (31-50 mph), with higher emissions at both lower and higher speeds. If an average speed of 80 kph (50 mph) is made up of periods of flow at 30 kph (19 mph) (daytime congestion) and at 120 kph (75 mph) (night-time free flow), then

the emissions will be greater than if a constant average of 80 kph (50 mph) were assumed. Imposition of a speed limit of 80 kph (50 mph) should be an effective way to minimise emissions, as it would avoid the high speeds with their greater emissions and reduce the incidence of flow breakdown, with slower speeds and stop-start driving. In real terms, this analysis therefore indicates the possible effect of reducing flow breakdown and general traffic-calming measures.

Table A9.1 Data Used to Predict the Influence of Altering Vehicle Speeds on the M23

	Cars	**Bus**	**LGV**	**HGVr**	**HGVa**	**Sum**
Total NOx from all Road Vehicles Apportioned between the vehicle classes ($\mu g/m^3$)[a]	31.6	4.1	7.7	11.8	20.0	75.2
Emission Factor at 110kph	0.5604	5.9628	1.0911	5.4033	11.1154	
Emission Factor at 80kph	0.3878	5.2277	0.7292	4.7169	9.8174	
80 kph factor / 110 kph factor	0.69	0.88	0.67	0.87	0.88	
Total NOx per vehicle class after speed reduction	21.90	2.97	3.86	8.09	13.82	50.6

[a] Using the data from Table A5.2 (which is also shown in Figure 2 of the main report).