Further Assessment of Nitrogen Dioxide for the Thurrock Council

(as required by s.84(1) of the Environment Act 1995)

April 2007

ERG, King's College London
4th Floor Franklin Wilkins Building
150 Stamford Street, London
SE1 9NH

This page has been left blank intentionally.

Executive Summary

Section 84(1) of the Environment Act 1995 requires the Council to undertake a Further Assessment of air quality following the designation of its air quality management areas (AQMAs). This Further Assessment of nitrogen dioxide report for the Thurrock Borough Council ("the Council") follows the Council's Detailed Assessment and Air Quality Progress reports and thus fulfils this next step of the Local Air Quality Management (LAQM) process.

The earlier Detailed Assessment report produced by the Council identified two new areas within the Council's area where the annual mean nitrogen dioxide concentrations were predicted to exceed government objectives. Public exposure was identified in these areas and the Council consequently designated two AQMAs (in Purfleet (AQMA 21) and West Thurrock (AQMA 23)).

This report follows the guidance produced by the Department of Environment, Food and Rural Affairs (DEFRA) and this allows the Council to refine the knowledge of the sources of pollution so that air quality action plans can be properly targeted. This has been undertaken using further modelling predictions.

The new modelling predictions incorporate a series of improvements over and above those made previously. These improvements include both improved modelling methods and treatment of emissions. This report also incorporates further monitoring undertaken in the Council's area.

The updated monitoring results confirm that the annual mean nitrogen dioxide objective was exceeded at sites in Purfleet and West Thurrock. The revised modelling predictions confirm the earlier findings that the annual mean nitrogen dioxide objective will be exceeded in both areas and therefore that AQMAs 21 and 23 were correctly designated and do need any amendment.

The report investigates the sources of pollution where the AQS objective within these two AQMAs. To do this a number of locations were chosen to help understand the source contribution of oxides of nitrogen, (NO_x). This assessment is for NO_x rather than nitrogen dioxide because the latter is mostly a secondary pollutant formed as a result of complicated atmospheric chemistry from oxides of nitrogen.

The results confirm the importance of road traffic to air quality and based on the results at the roadside locations investigated, about 26% to 38% of the total contribution is derived from background sources of NO_x in AQMA 21 and the nearby AQMA 10, with 45% from background in AQMA 23. In both cases the remainder is from road transport sources. For AQMAs 21 and 10 the contribution from HGVs is approximately 90% of the total from road traffic sources, whereas in AQMA 23 this proportion is almost 80%. Other vehicles categories including cars, LGVs and buses constitute only a small amount (10% or less)

Additional modelling was undertaken of roads in the AQMAs for a 2010 base case scenario. This scenario incorporated changes to vehicle flow and stock characteristics (as well changes to future background levels). For both AQMAs this prediction showed that concentrations of NO_2 decreased. For AQMA 23 only small areas were predicted to exceed the annual mean objective close to the centre line of roads and junctions in the area. No relevant public exposure arises in the areas predicted to exceed for this 2010 scenario.

For AQMAs 21 and 10, despite reduced concentrations the predictions indicated that the annual mean objective was exceeded along roads and where there are areas of relevant public exposure.

Additional scenarios were tested to aid understanding of possible changes that might be required to achieve the objective. These scenarios (which are hypothetical) included reductions in the overall numbers of HGVs along the A1090 and a low emission type scenario based on bringing forward future changes in vehicle stock. The latter is typically based on the inclusion of newer vehicles, which have improved emission abatement and are therefore less polluting. The scenario tested assumed that the 2010 HGVs stock was replaced by a stock completely based on that predicted for 2015. These additional scenarios also indicate reductions beyond those for the 2010 base scenario, with both a 30% reduction in HGVs and the low emission scenario indicating (at relevant facades) that the objective could be achieved. It is however considered that these scenarios may be over optimistic. This view is based on the results of the monitored concentrations over recent years at the Thurrock 2 site. These indicate that concentrations may not be reducing in line with national expectations. A possible reason for this may be the direct NO_2 emissions from HGVs, although further investigation is required to fully determine this.

The Council is recommended to undertake the following actions, in respect of the findings for the statutory objectives relating to annual mean nitrogen dioxide:

Retain AQMAs 21 and 23 and undertake consultation on the findings arising from this report with the statutory and other consultees as required.

Use the results of the source apportionment work in this report to identify potential actions that will enable the Council to work towards improving air quality.

Continue to operate its high quality continuous NO_2 analysers and other monitoring in the borough to improve its current understanding and to confirm the findings of this report.

Table of Contents

List of Figures

List of Tables

1 Introduction to the further assessment of air quality

1.1 Overview

Formatted: Bullets and Numbering

This report provides the further assessment of air quality for the Thurrock Council ("the Council"). This forms part of the Council's duties under Local Air Quality Management (LAQM) process of the Environment Act 1995.

The report includes revised modelling studies of the Council's two additional Air Quality Management Areas (AQMAs) for nitrogen dioxide (NO_2), in Purfleet (AQMA 21) and West Thurrock (AQMA 23). Source apportionment of the pollution sources has also been undertaken. Thus the report fulfils this step of the Local Air Quality Management (LAQM) process.

The Council has also retained other AQMAs within its area (see section 1.3 and Table 2).

1.2 Background

Local air quality management forms a key part of the Government's strategies to achieve the air quality objectives under the Air Quality (England) Regulations 2000 and 2002. As part of its duties the Council completed its second round Updating and Screening Assessment of the seven LAQM pollutants and concluded that a Detailed Assessment was necessary for parts of Purfleet and West Thurrock for NO_2.

The results of the Detailed Assessment identified a risk of the annual mean objective (see Table 1) being exceeded after 2005 in the Council's area, encompassing parts of Purfleet, along Stonehouse Lane near the Concord Hotel and London Road in West Thurrock. As a result the Council designated two additional AQMAs.

Table 1 Air quality objective relevant to this Further Assessment

	Concentration	Measured as	Date to be achieved by
Nitrogen dioxide (NO_2)	40 $\mu g\ m^{-3}$	Annual mean	31-Dec-05

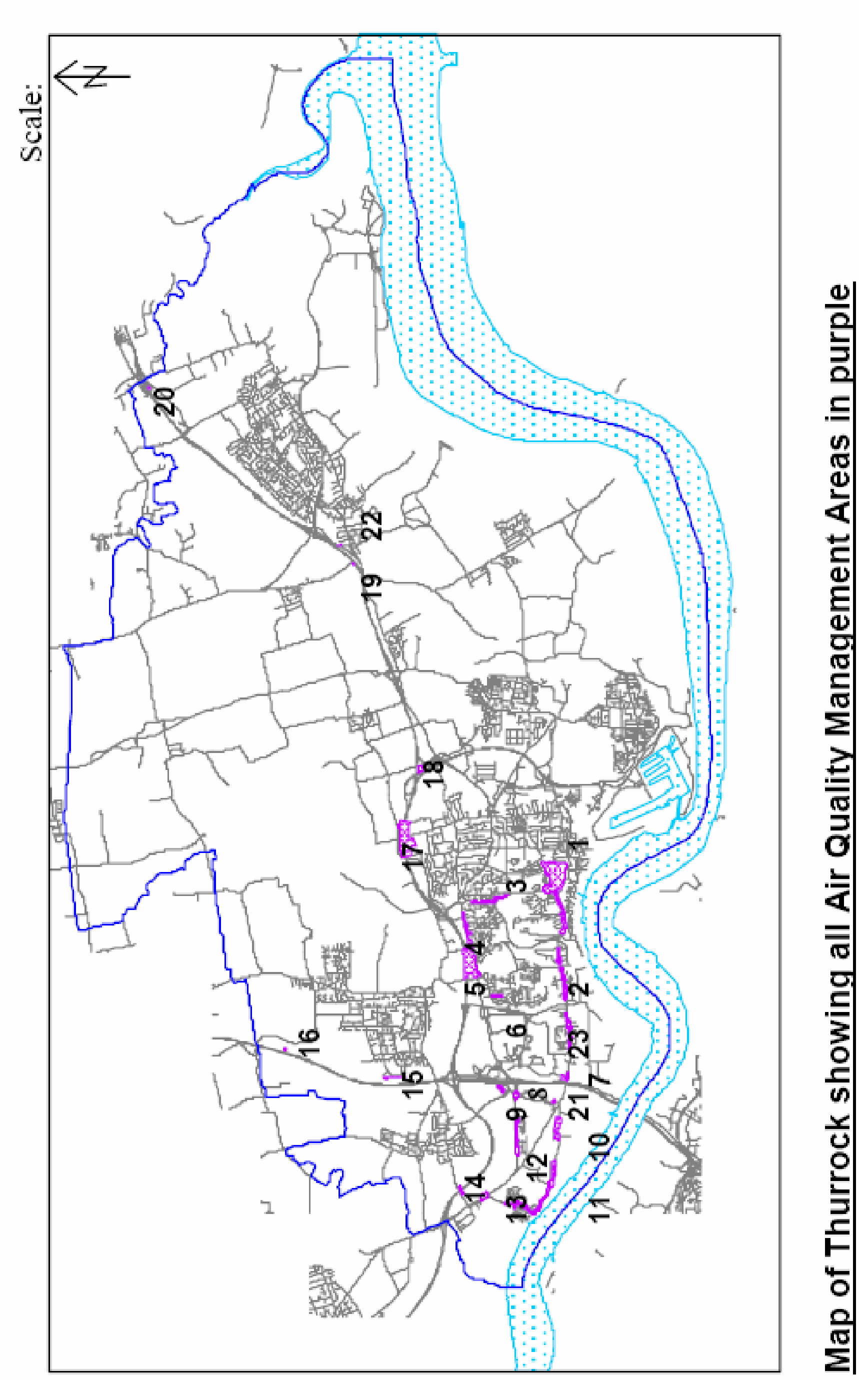
1.3 Other AQMAs in the Thurrock area

The Council initially declared 19 separate AQMAs in its area, however subsequent rounds of review and assessment have changed this position. Currently there are 15 AQMAs in the Council's area. Those AQMAs that are currently in operation are described in Table 2 and shown in Figure 1.

Table 2 Summary of current status of Thurrock's AQMAs

AQMA No.	Status
1	Retained
2	Retained
3	Retained
4	Retained
5	Retained
6	*Revoked*
7	Retained
8	Retained
9	Retained
10	Retained
11	*Revoked*
12	Retained
13	Retained
14	*Revoked*
15	Retained
16	Retained
17	*Revoked*
18	*Revoked*
19	*Revoked*
20	*Revoked*
21	Retained
22	Not declared
23	Retained

Figure 1 Map showing AQMAs in Thurrock (from Detailed Assessment 2004)



This page is left blank intentionally.

2 Air Pollution Measurements in the Thurrock area

2.1 Air pollution measurements in Thurrock

The Council undertakes monitoring of NO_2 both within its AQMAs and outside of the AQMAs.

Continuous monitoring of NO_2 is undertaken at all three of its automatic sites:

1) Thurrock 1 - AURN background site, in Grays (outside of AQMAs)
2) Thurrock 2 - LAQN roadside site in Purfleet (within AQMA 10)
3) Thurrock 3 – LAQN roadside site in Stanford Le Hope (outside of AQMAs)

The Thurrock 2 site is sited in AQMA 10 and is approximately 500m west of the AQMA 21 and Thurrock 1 is approximately 3km east of the AQMA 23. All of the sites are operated to AURN/ LAQN standards of QA/QC. Regular calibrations are carried out, with subsequent data ratification undertaken by the ERG at King's College London.

The results of the monitoring at the sites are given in Table 3. The data capture exceeded 85% for all years other than 2003 for both Thurrock 2 and 3, when the sites were set up.

Table 3 NO_2 and NO_x continuous monitoring in Thurrock (2002 – 2006) (µg m^{-3})

		2002	2003	2004	2005	2006*
Thurrock 1	Annual mean NO_2	35.6	38.3	*35.5*	*34.5*	32.8
	Data capture %	94.2	93.5	*89.8*	*85.2*	95
	Max 1 hour	122	267	*146*	*140*	141
	Exceeds 200 µg m^{-3}	0	1	*0*	*0*	0
	Annual mean NO_x	66.1	68.4	*62.4*	*65.3*	56.6
Thurrock 2	Annual mean NO_2		*74.0*	**70.1**	**73.9**	**74.9**
	Data capture %		*56.0*	95.0	94.0	94
	Max 1 hour		*383*	223	307	264
	Exceeds 200 µg m^{-3}		*4*	3	14	**26**
	Annual mean NO_x		*201.8*	189.1	200.6	192.4
Thurrock 3	Annual mean NO_2		*42.0*	39.0	36.0	35.5
	Data capture %		*35.0*	99.0	99.0	97
	Max 1 hour		*146*	157	161	143
	Exceeds 200 µg m^{-3}		*0*	0	0	0
	Annual mean NO_x		*116.8*	89.6	82.9	83.1

(Note – * includes provisional data; bold exceeds objective; italics < 90% data capture)

The results indicate that the annual mean objective was not exceeded over this time period at the Thurrock 1 and 3 sites, although annual mean concentrations approached the objective in 2004 at the Thurrock 3 site. This site was set up to measure concentrations along the A1014, prior to the development of the proposed shipping terminal at Thameshaven.

The measurements from the Thurrock 2 site (in AQMA 10) however easily exceeded the annual mean for the period 2004 to 2006 inclusive.

The Thurrock 2 site has also recorded periods where the 200 µg m^{-3} standard has been exceeded during each year of operation. The hourly objective of more than 18 such periods was however only exceeded in the most recent year i.e. 2006. To date in 2007 there have been 9 hours that exceed this standard, suggesting that the objective will be exceeded or approached again this year (based on provisional data to date).

The maximum hourly mean has not exceeded the hourly standard at the Thurrock 1 and 3 sites, apart from one occasion in 2003 at Thurrock 1. Consequently the objective of more than 18 hours exceeding the hourly standard has not been exceeded at these sites.

The Council also uses diffusion tubes to measure NO_2 at 26 locations across its area. The diffusion tubes used are supplied and analysed by Gradko using a preparation method of 50% TEA in water.

Locally derived correction factors have been derived from the diffusion tubes exposed adjacent to the Thurrock 1 background and Thurrock 3 roadside monitoring sites. The Thurrock 1 correction factors are for 2002 to 2006 and the Thurrock 3 site for 2004 and 2006; as follows:

Table 4 Locally derived bias factors

Thurrock 1			
	Cm	Dm	Bias factor
2002	35.6	31.4	1.13
2003	38.3	34.2	1.12
2004	35.5	34.9	1.02
2005	34.5	30.5	1.13
2006	32.8	32.0	1.03
Thurrock 3			
	Cm	Dm	Bias factor
2004	39.0	43.6	0.89
2005	36.0	38.3	0.94
2006	35.5	37.9	0.94

The factors indicate that for the urban background site the diffusion tube measurements are under reading the continuous results. The factors for the roadside site however indicate that the diffusion tube measurements are over reading the continuous results.

The results presented in Table 5 are the bias adjusted results for 2002 to 2006 for those sites within AQMAs only and Table 6 for those in revoked AQMAs. Estimated 2010 predictions for the sites based on the 2006 results are also presented in Table 5. Estimates based on the predicted reductions in the LAQM TG03 technical guidance are also included for 2010. This date is when the EU Limit value for NO_2 should be met.

Table 5 Diffusion tube monitoring in all Thurrock's AQMAs (2002 to 2006) (μg m^{-3})

Site	2002	2003	2004	2005	2006	Estimated 2010	AQMA No.
Cromwell Road Grays (I)	38.3	**43.3**	32.3	34.4	37.1	33.2	1
London Road Grays (R)	**47.4**	**45.9**	36.9	38.5	**41.5**	37.2	1
Stanley Road Grays (R)				33.9	35.7	32.0	1
Queensgate Centre Grays (R)	**67.0**	**62.8**	**44.1**	**45.2**	**49.9**	**44.7**	1
London Road South Stifford (R)	**45.9**	**49.6**	**43.4**	**43.7**	**48.7**	**43.6**	2
Elizabeth Road (R)	**40.9**	**50.6**	**44.3**	**50.3**	**51.3**	**46.0**	3
Hogg Lane (R)	**40.9**	**41.9**	34.8	37.8	38.5	34.5	3
A1306 (R)	**70.1**	**74.1**	**59.2**	**61.0**	**64.3**	**57.6**	5
Ibis Hotel (UB)		**59.8**	**57.8**	**65.0**	**54.3**	**48.7**	7
Jarrah Cottages (R)	**53.9**	**57.1**	**56.3**	**53.1**	**57.1**	**51.2**	10
Watts Crescent (R)	**49.6**	**47.8**	**45.6**	**44.6**	**43.6**	39.0	12
London Road Arterial Road (R)	**43.0**	**43.2**	**49.9**	**49.1**	**55.1**	**49.4**	13
Gatehope Drive (UB)		37.4	**44.4**	**45.6**	38.7	34.7	15
Kemps Cottage (UB)		38.8	**47.3**	**47.6**	39.5	35.3	16
Stonehouse Lane (R)				**47.5**	**46.3**	**41.5**	21
London Road W Thurrock (R)	**48.2**	**49.5**	**49.8**	**45.0**	**44.9**	**40.3**	23

(Note - bold indicates > AQS objective)

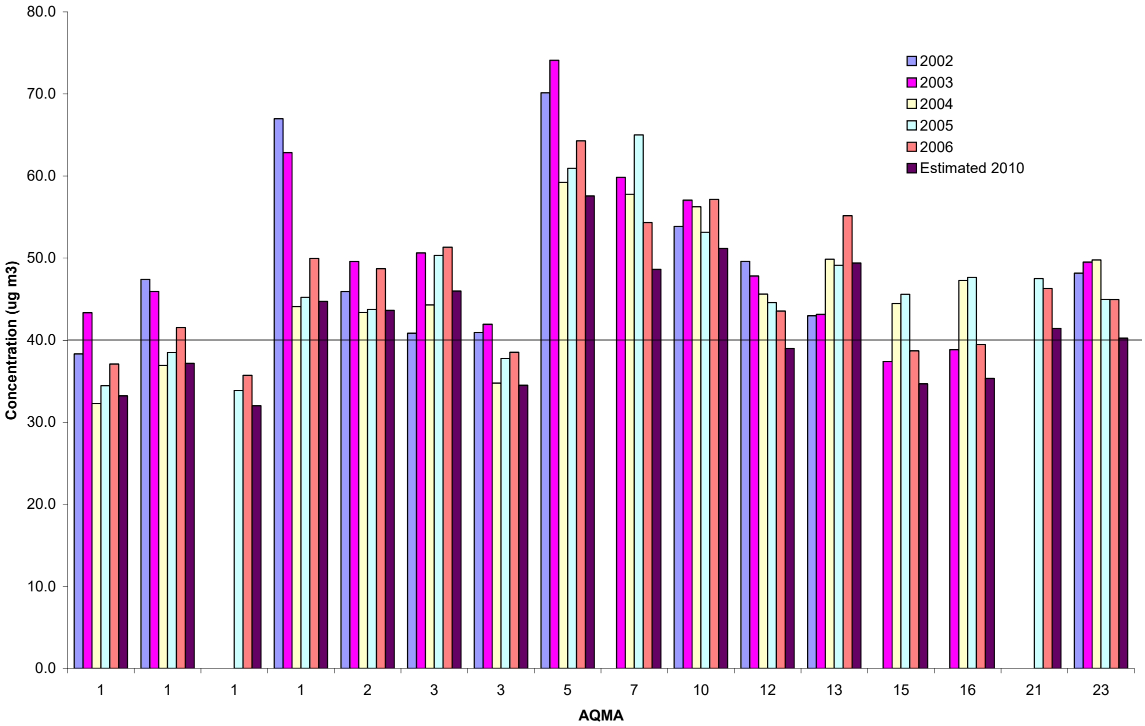
Table 6 Diffusion tube monitoring in Thurrock's revoked AQMAs (2002 to 2006) (μg m^{-3})

Site	2002	2003	2004	2005	2006	AQMA No.
Purfleet Rail Station (R)	37.2	**40.4**	36.7	34.9	38.2	11
William Edwards School (R)	**41.6**	39.3	37.7	36.1	37.8	17
Park Road (R)		35.3	32.3	32.2	33.7	22

The results indicate that concentrations within AQMAs 21 and 23 exceed the annual mean objective. Using the year adjustment factors, the 2010 predictions indicate that there will be a reduction in concentrations at all sites, based on reductions in background and roadside concentrations arising from predicted increased emission abatement nationally. This reduction however will be sufficient for sites in AQMAs 12, 15 and 16 to meet the 40 μg m^{-3} annual mean standard. For the other AQMAs the estimated reduction at all sites is not sufficient to meet this standard.

The measurements in the AQMAs are also shown in Figure 2.

Figure 2 Bias corrected diffusion tube monitoring results in Thurrock AQMAs (µg m^{-3})



The inter annual variation in concentrations does not highlight any reduction in over the period shown. For 2006, concentrations increased at 10 of the 16 sites shown (it also increased slightly at the three former AQMA sites shown in Table 6). This increase at these sites was not however reflected at two of three automatic sites (see Table 3), where there were slight reductions between 2005 and 2006.

3 Predictions of Nitrogen Dioxide (NO_2) for the Thurrock AQMAs

3.1 Outline of modelling developments

Formatted: Bullets and Numbering

The Further Assessment incorporates:

Major roads on an exact geographic basis Ordnance Survey (OS), to allow an improved assessment of exposure;
Predictions plotted on OS base maps;
Incorporation of a direct NO_2 component;
A best estimate of model uncertainty, using Monte Carlo techniques;

Formatted: Bullets and Numbering

Formatted: Bullets and Numbering

A detailed explanation of the methods used, including the developments undertaken is given in the appendices.

The model has been empirically developed for urban areas and has been widely validated against a range of continuous monitoring sites in London and the southeast. Details of the model validation are given in Appendix C.

Revised traffic data are used for the modelling; these were based upon Department for Transport Rotating Census using recent traffic count sites for the road links. Traffic information details are given in Appendix D. Road traffic data were not available for all roads and in those cases data were obtained from previous Council reports.

3.2 Annual mean NO_2 ($\mu g\ m^{-3}$) in 2005 in AQMAs 21 (and 10)

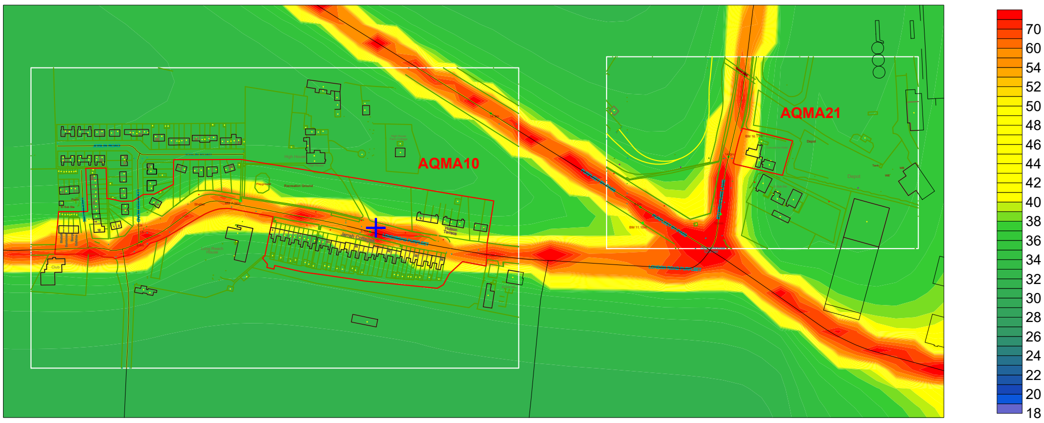
The predicted concentrations of the annual mean NO_2 for the corrected 2005 base case for Purfleet including AQMAs 21 and 10 are shown in Figure 3. Only areas coloured yellow to red exceed the air quality objective.

The locations of the major roads are modelled to a high degree of accuracy and in this case it is within 1m. This enables the concentration contours to be plotted with OS Landline data[1], which gives details of individual houses and allows easy estimation of the exposure of the local population to concentrations above the AQS objective. The pollution contours also show the rapid fall off in concentration to the background from the road.

The predictions confirm that the air quality objective is exceeded in the AQMAs, in areas close to the centre of roads and close to junctions.

[1] Note – Reproduction from/based upon the Ordnance Survey Mapping with the permission of the Controller of Her Majesty's Stationery Office © Crown Copyright. Unauthorised reproduction infringes Crown Copyright and may lead to prosecution or civil proceedings. Thurrock Borough Council Licence No. LA079766.

Figure 3 Modelled 2005 annual mean NO_2 in the Purfleet AQMAs 10 and 21 ($\mu g\ m^{-3}$)



(Notes – the blue cross marks Thurrock 2 site monitoring site; red lines indicates the AQMAs)

3.3 Comparison with monitored results

The monitored results for the Thurrock 2 site in AQMA 10 were given in the previous chapter. The 2003 and 2005 results are compared below to the predicted results at the same sites using the 2003 and 2005 base model.

Table 7 Comparison of monitored and modelled concentrations at Thurrock 2 ($\mu g\ m^{-3}$)

	NO_2	NOx
2003 monitored	*74.0*	*201.8*
2003 modelled	75.0	215.1
2005 monitored	73.9	200.6
2005 modelled	68.7	192.7

(Note – italics indicates 56% data capture for the year)

This comparison indicates an overall reasonable agreement, whilst recognising the limitations of both the monitoring and modelling. For the 2003 the model slightly over predicted both NO_x and NO_2 monitored results (6.5% and 1% respectively), although it should be noted there was low data capture for 2003 (the site opened in May 2003).

For 2005 the modelling slightly under predicted NO_x and NO_2 concentrations (4% and 7.5% respectively). Since monitoring started at this site in 2003 both annual mean NO_x and NO_2 concentrations have shown very little change over time (see Table 3). This is contrary to national (and model) expectations and may be as a result of specific emission characteristics for the site, rather than inter annual variations due to meteorology.

3.4 Annual mean NO_2 ($\mu g\ m^{-3}$) in 2005 in AQMA 23

Modelling was also undertaken for AQMA 23 in West Thurrock and the results are shown in Figure 4 and Table 8. These indicate that the objective is exceeded close to junctions and road centre in this area.

Figure 4 Modelled 2005 annual mean NO_2 in the West Thurrock AQMA 23 ($\mu g\ m^{-3}$)

(Note – the blue cross marks diffusion tube monitoring site)

3.5 Comparison with monitored results

Continuous monitoring is not undertaken at the roadside in this area, although monitoring is undertaken using diffusion tubes. A comparison of the results for 2003 and 2005 is given in Table 8.

Table 8 Bias adjusted monitored and modelled annual mean NO_2 concentrations in AQMA 23 ($\mu g\ m^{-3}$)

	NO_2
2003 monitored	49.5
2003 modelled	44.0
2005 monitored	45.0
2005 modelled	42.7

These show that the modelling provides a reasonable agreement, with the modelled results slightly under predicting the bias adjusted diffusion tube results (12.5% in 2003 and 5% in 2005).

3.6 AQMA modelling

As a result of the reasonable agreement between the modelling and monitoring in both AQMAs further verification has not been undertaken. The 2005 modelling also indicates that there is relevant public exposure; as a result the AQMAs do not need amendment.

4 Source Apportionment for NO_X in the Thurrock AQMAs

4.1 Methodology

To better understand the air quality improvement needed to achieve the AQS objectives, it is necessary to determine the individual source emissions that contribute to the overall predicted pollution concentration. Both pollutant emissions, location and atmospheric processes, including meteorology, determine the pollution concentration in any given area.

The pollutant under investigation in this stage of the LAQM process, i.e. NO_2, further complicates the understanding of source apportionment. For NO_2, the contribution that the different sources make to the predicted concentrations can only be fully understood by examining the contribution of NO_x sources as the primary emission. This reflects the fact that the relationship between NO_2 and NO_x is non-linear and mostly determined by photochemistry that is highly location dependent. The modelling undertaken to derive the predictions of NO_2 reflect this aspect and this is explored more fully in the model description given in Appendix A. The uncertainty associated with the modelling undertaken is explained in Appendix E.

The source apportionment methodology used here is based on determining the source apportionment for individual categories of the vehicle fleet, which of course recognises the major influence of road transport (as the dominant local source). The categories used are Cars (i.e. all diesel and petrol cars, including taxis); Buses (i.e. all buses and coaches); HGVs (i.e. all rigid and articulated vehicles > 3.5 tonnes) and LGVs (including petrol and diesel vans, etc). Each category also includes within it all Euro and pre-Euro classifications.

In all instances the determination of the influences of the different sources is undertaken by modelling sources independently of one another and establishing the predicted concentration at a given point. This is necessary since the influence of the different sources varies between locations due to their proximity to the sources; hence the apportionment is location dependent.

4.2 Source apportionment of NO_x

Specific point locations were selected for investigation to provide a representative understanding within the AQMAs.

A series of model runs for the base case were undertaken for each of the categories described above. The locations chosen include monitoring site locations in the AQMAs. The results of relative contributions of NO_x for the sites for the separate AQMAs are shown below.

Table 9 Predicted relative NO_x contributions (%) for the different sources – AQMAs 21 and 10 in Purfleet

Location	Buses	Cars	HGVs	LGVs	Background
Concord Hotel	0.1	2.4	57.7	2.0	37.8
Thurrock 2	0.1	2.9	69.4	1.7	25.9

The results show the varying contributions between the different sources, which relate to the location itself, especially proximity to kerbside and to the varying traffic activity (types, numbers and speeds of vehicles). The Thurrock 2 site is located approximately 2m from the kerb and the location used for the source apportionment at the Concord Hotel is its front façade, located approximately 13m from the kerb. As a consequence of this, the background contribution varies slightly between the locations examined, with the smallest proportion at the most polluted site, i.e. the Thurrock 2 site on London Road, Purfleet, which is approximately 26%. The Concord Hotel site has a lower measured pollution concentration and hence has the highest background proportion of 38%. The background contribution itself comprises NO_x arising from other non-road vehicle emission sources, including domestic/ commercial (including heating and lighting) and industrial sources, plus other roads in the area and rural sources.

The HGVs category completely dominates the largest individual contribution of the road vehicle categories at the two locations examined. For these sites the contribution is approximately 60% of the total and is greater than background sources. In terms of the total for road vehicles only: HGVs provide 90% of emissions.

The contribution from other road vehicles is approximately 5% of total sources for both sites. Cars and LGVs constitute approximately 2% each, with buses less than 1%.

For AQMA 23 the source apportionment was based on 2005 modelling, rather than 2010. This is because concentrations in 2010 are expected to be less than the annual mean objective (see next section), unlike the above AQMAs. The source apportionment location chosen was the roadside diffusion tube site on London Road (in AQMA23), which is located 7m from the road centre line.

Table 10 Predicted relative NO_x contributions (%) for the different sources – AQMA 23 in West Thurrock

Location	Buses	Cars	HGVs	LGVs	Background
London Road W Thurrock (R)	0.0	4.4	43.6	7.0	45.0

For AQMA 23 the background represented 45% of the total NO_x in 2005, with the contribution from vehicles again dominated by HGVs. In this instance the HGV contribution was slightly less than the background proportion. Both Cars and LGVs provided much smaller contributions, which when combined total just over 11% of the total NO_x. Of these the greater proportion was from LGVs (7%), with Cars contributing just over 4%. There were no buses modelled along this section of road and consequently there is no NO_x contribution from buses.

5 Scenario modelling for AQMAs 21 and 23

5.1 Scenario selection

To test the effectiveness of possible measures to improve air quality within these AQMAs, a series of scenario tests have been considered. These reflect the fact that road transport is the main source of emissions (as discussed above). The tests build upon the modelling undertaken earlier, including the source apportionment work.

The scenarios tested reflect that there are likely to be changes over time; including an increased uptake of newer less polluting vehicles replacing older vehicles.

The scenarios tested are as follows:

1) For AQMAs 21 and 10

- 2010 base case

- 2010 with reduced vehicle flows to indicate the sensitivity of the site to hypothetical changes. The reductions in flows relate to 10%, 20% and 30% less total HGVs only, all other vehicle categories are unchanged from the 2010 base case

- 2010 based on changes to the vehicle fleet reflecting an impact arising from a low emission type scenario. This reflects that the likely aim of any such measure is to reduce vehicle emissions by bringing forward newer technologies that have lower emissions. In this instance the scenario assumes that the 2015 HGV vehicle fleet is brought forward to 2010 (note the 2010 background however remains)

- No traffic growth is included for the modelling, based on recent traffic count information (see Table 14).

2) For AQMA 23

- 2010 base case

For the future 2010 base scenarios, the vehicle stock rollover i.e. the replacement of older vehicles by newer vehicles is assumed to be in line with the changes predicted nationally. The vehicle speeds are also assumed to be unchanged for each scenario.

5.2 Results of scenario testing in AQMAs 21 and 10

The results of the modelling for the scenario tests undertaken are given in the following table. The results provided are the predicted NO_2 concentrations at the selected sites used earlier for the source apportionment, plus an estimate of concentrations at the façade of one of the houses in AQMA 10 (number 23 Jarrah Cottages). The modelled results for the 2005 base year are also included for comparison purposes.

Table 11 Predicted annual mean concentrations of NO_2 ($\mu g\ m^{-3}$) at the identified locations

Location	Easting	Northing	2005 base	2010 base	2010 90%hgv	2010 80%hgv	2010 70%hgv	2010 low emission
Thurrock 2	556738	177928	**68.7**	**51.0**	**48.7**	**46.4**	**44.1**	**42.1**
Jarrah Cottages	556738	177909	**59.3**	**44.7**	**43.0**	**41.2**	39.5	37.9
Concord Hotel	557123	178004	**52.6**	**40.0**	38.7	37.3	36.0	34.7

(Note - bold indicates > AQS objective)

The results indicate that for all locations and scenarios tested, the annual mean concentrations reduce of NO_2 will reduce from the modelled 2005 base case. This reduction reflects both the changes to vehicle stock, plus the predicted reduction in background concentrations in the area to 2010.

The 2010 base scenario indicates that predicted concentrations at the Thurrock 2 site sites exceed the 40 $\mu g\ m^{-3}$ standard for all scenarios examined. The greatest reduction arises with the low emission type scenario for 2010. The reduction at this site is predicted to be almost 40% for the 2005 base case.

The predictions for Jarrah Cottages show that only the low emission scenario and the 30% reduction in HGVs meet the 40 $\mu g\ m^{-3}$ standard, with the latter only just meeting it by 0.5 $\mu g\ m^{-3}$.

For the Concord Hotel site the 40 $\mu g\ m^{-3}$ standard is reached in 2010 for the base case scenario. The other scenarios all indicate that concentrations will be below this level and therefore meet the standard.

5.3 Commentary on the scenarios investigated at AQMAs 21 and 10

The relationship between NO_x and NO_2 is one of a number of critical factors relevant to understanding the outcomes from the scenario test undertaken. This relationship, which is location dependent, provides the understanding between the photochemical processes that lead to the formation of NO_2 from NO_x. This relationship is non linear which means that a reduction of the primary emission (i.e. NO_x) does not lead to a corresponding equivalent reduction in the secondary pollutant. (Appendix A further describes this relationship).

The comparison of modelled and monitored concentrations for 2003 and 2005 was provided earlier and it was noted that there was a reasonable agreement between the sets of results. The 2005 NO_x and NO2 modelled results however both slightly under predicted the monitored concentrations, as compared to very slight over predictions in 2003. It was also noted from the previous section that there has been little change in annual mean concentrations at the Thurrock 2 since monitoring started in 2003. Traffic flows in the area (see Table 14) indicate low levels (typically 7000 AADT), with a high proportion of HGVs (approximately 34%). A possible reason for both the high monitored concentrations and the little change over time is the influence of direct NO_2 from the high proportion of HGVs along the road.

If this is the case it is likely that concentrations of NO_x and NO_2 may not change (i.e. fall) as expected into the future. In this instance the model results may be overly optimistic, with the result that concentrations will not meet the objective as outlined. Further information and investigation is required on the traffic stock and flows are required at the site to better understand this particular location.

The contour plots produced from the scenario tests are shown below, see Figure 5 to Figure 9 inclusive. (Notes – the blue cross marks Thurrock 2 site monitoring site; red lines indicates the AQMAs)

Figure 5 Modelled 2010 annual mean NO_2 in the Purfleet AQMAs 10 and 21 ($\mu g\ m^{-3}$)

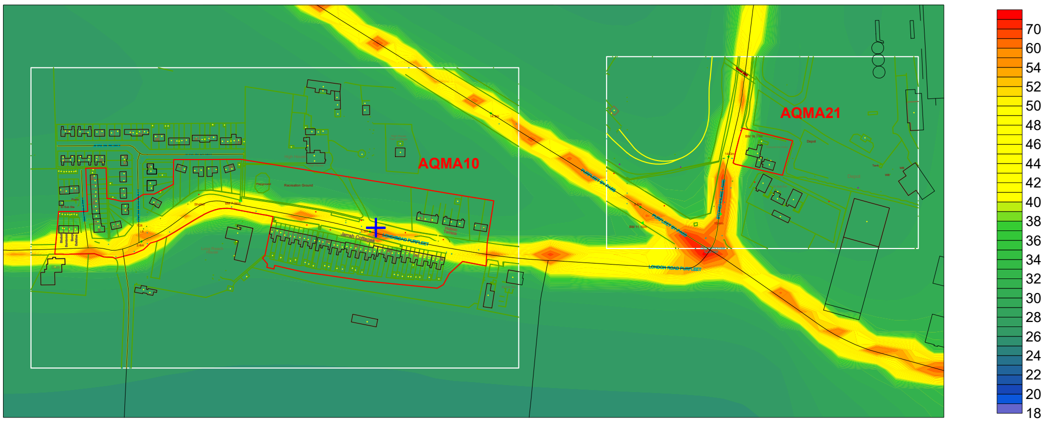


Figure 6 Modelled 2010 annual mean NO_2 in the Purfleet AQMAs 10 and 21 with 90% HGVs ($\mu g\ m^{-3}$)

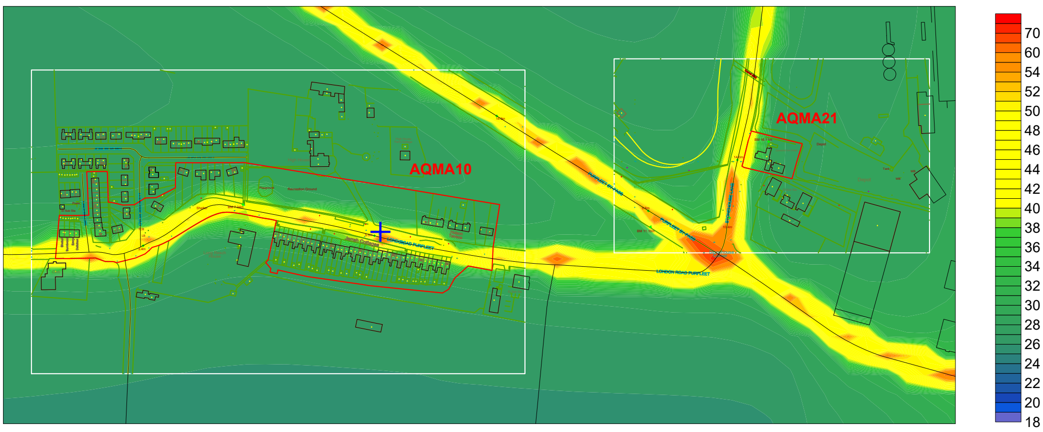


Figure 7 Modelled 2010 annual mean NO_2 in the Purfleet AQMAs 10 and 21 with 80% HGVs (µg m^{-3})

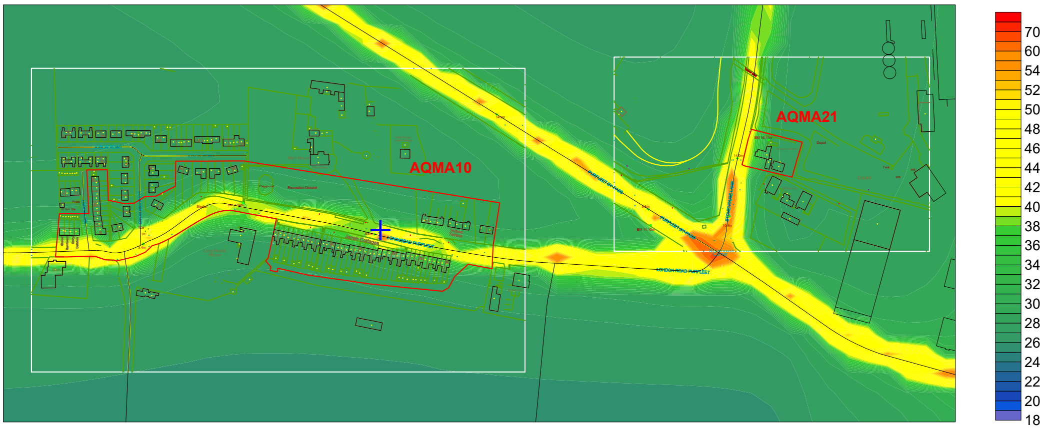


Figure 8 Modelled 2010 annual mean NO_2 in the Purfleet AQMAs 10 and 21 with 70% HGVs (µg m^{-3})

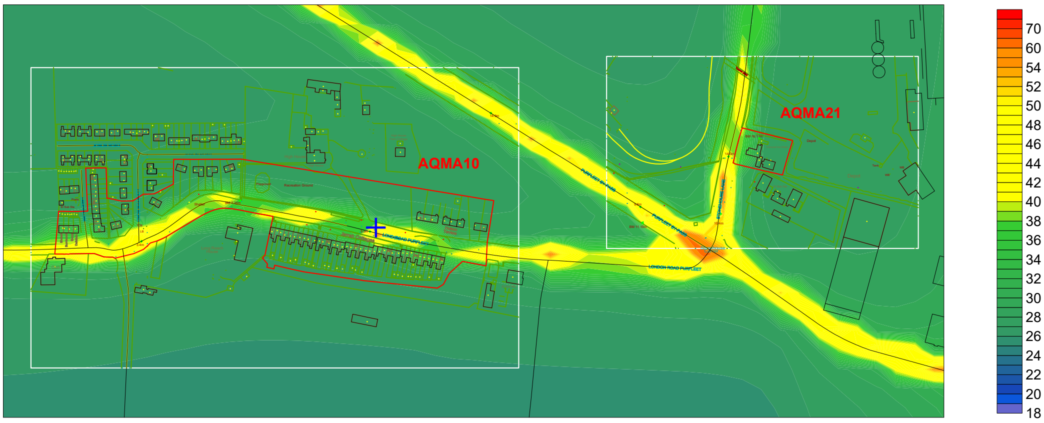
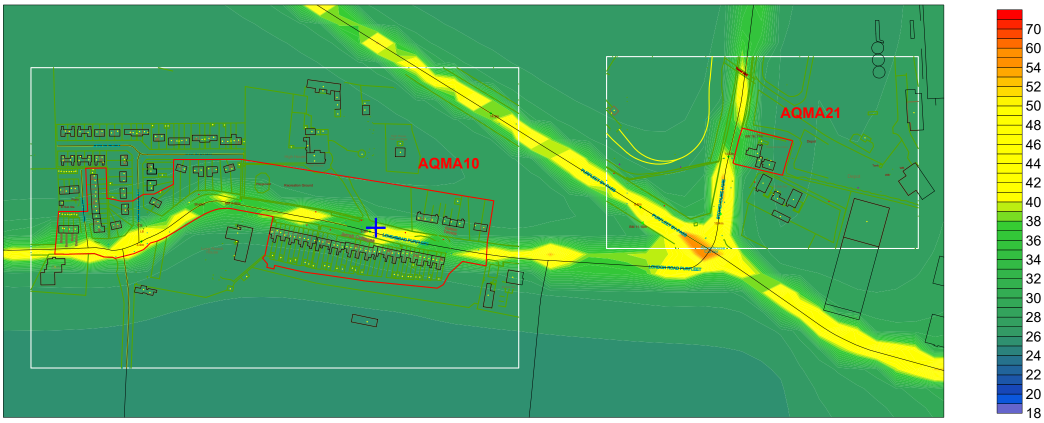


Figure 9 Modelled 2010 annual mean NO_2 in the Purfleet AQMAs 10 and 21 with a low emission type scenario HGVs (µg m^{-3})



5.3 Results of scenario testing in AQMA 23

As shown from both the monitoring and modelling earlier, concentrations at AQMA 23 are lower, despite greater traffic flows in this AQMA compared to AQMAs 10 and 21. The 2010 base case scenario is based on an estimated traffic growth at the site, along with changes to vehicle stock arising from the predicted uptake of less polluting vehicles and also predicted reduced background concentrations. The predicted results from the modelling are based on the diffusion tube monitoring location on London Road (West Thurrock) in this AQMA used previously for source apportionment. The 2005 based case prediction is also shown for comparison purposes.

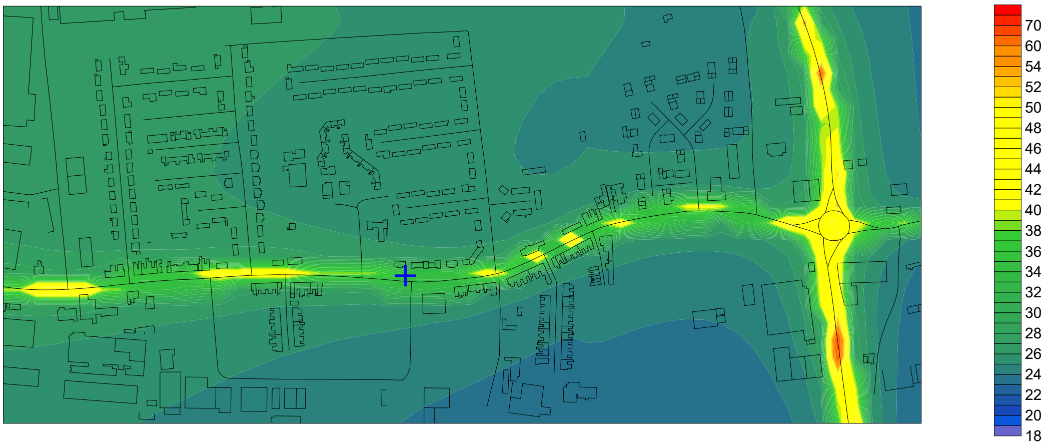
Table 12 Predicted annual mean concentrations of NO_2 (µg m^{-3}) in AQMA 23

Location	Easting	Northing	2005	2010
London Road W Thurrock (R)	558482	177677	**42.7**	34.4

The predicted result indicates that the concentration in 2010 will meet the 40 µg m^{-3} standard, based on the expected changes outlined above. As shown earlier the model slightly under predicted concentrations in comparison with the diffusion tube measurement. However even with a 5% under prediction, 2010 concentrations will still meet the 40 µg m^{-3} standard.

A contour plot for this scenario is given in Figure 10, this indicates that the only areas predicted to exceed are close to the road centre and also junction with the A126. All of these are outside of any area with relevant public exposure.

Figure 10 Modelled 2010 annual mean NO_2 in West Thurrock AQMA 23 ($\mu g\ m^{-3}$)



(Note – the blue cross marks diffusion tube monitoring site)

6 Conclusion

This report fulfils the requirements of the DEFRA guidance for the Further Assessment and addresses relevant issues pertinent to the continuing LAQM process. The Further Assessment incorporates recent monitoring results and improved modelling techniques, plus an improved treatment of emissions using the most recent locally available traffic data.

The monitoring results for the areas investigated in the report indicate that locations within the AQMAs exceed the annual mean objective for 2005.

New modelled predictions have been made for AQMAs 21 (and 10), plus AQMA 23 for the base years of 2003 and 2005. These predictions compare reasonably well to the monitored results. The modelling confirms the extent of the area exceeding the objective and that the AQMAs do not need further amendment.

Based on this model set up, additional model runs were undertaken to understand and apportion the sources of pollution in the area. This was undertaken for specific vehicles groupings (i.e. cars, buses (and coaches), light goods vehicles (LGVs) and heavy goods vehicles (HGVs)). A contribution representing background sources was also incorporated. The source apportionment modelling was based on concentrations of oxides of nitrogen (NO_x) rather than NO_2, as NO_x is predominantly emitted as the primary pollutant. The source apportionment was undertaken for specific sites relating to the monitoring sites in the AQMAs.

The results of the source apportionment indicated that HGVs were the main group of emission sources in all the AQMAs examined. The traffic flows in AQMAs 10 and 23 are relatively low and less than 7000 per day. For these AQMAs, HGVs exceed 30% of the total traffic flow. As a result emissions from HGVs at the two sites examined was approximately 60% of the total emissions and greater than the contribution from background sources. The combined contribution from Cars, LGVs and Buses was less than 5% of the total emissions.

For AQMA 23, HGVs were also the dominant source but to a lesser extent, representing just over 40% of the total, again the background contribution represented the second largest total, with emissions from Cars and LGVs of the order of 11%. (There were no buses that were modelled).

A 2010 scenario was separately modelled to assist in understanding the likely impact of changes over time and in response to changing vehicle flows. The results for this scenario indicate that annual mean NO_2 concentrations reduce from that of the 2005 base case.

For AQMAs 10 and 21 there is still an area predicted to exceed close to roads and junctions. This area includes facades representing relevant exposure along the A1090 London Road in Purfleet within AQMA 10. For AQMA 23 the façade of the Concord Hotel also just exceeds the 40 $\mu g\ m^{-3}$ standard. Further scenario tests were undertaken based on hypothetical changes to traffic on the roads in the area. These included reduced proportions of HGVs and also a low emission type scenario, based on bringing forward expected changes in HGV fleet. For AQMA 10 there were areas predicted to exceed for all scenarios, although the area predicted to exceed reduced with increased reductions in HGV emissions. For areas with relevant exposure, the scenarios based on 70% HGVs only and the low emission type scenario indicate that the 40 µg m^{-3} standard will be met. There is however a note of caution in that the modelling may be too optimistic. This is based on the fact that monitored concentrations have not reduced in AQMA 10 since monitoring began in 2003. This may be due to the effect of direct NO_2 emissions from vehicles along the road. A further investigation at vehicle stock and traffic conditions is required to confirm the latter.

For AQMA 23, the 2010 base case scenario indicates that there is only a small area that exceeds the 40 µg m^{-3} standard close to the centre of roads and the junction with the A126. The modelling also indicates that there are no facades with relevant public exposure within the area that exceeds.

7 Recommendation

The Council is recommended to undertake the following actions, in respect of the findings for the statutory objectives relating to annual mean nitrogen dioxide for these AQMAs:

7.1 Retain AQMAs 21 and 23 and undertake consultation on the findings arising from this report with the statutory and other consultees as required.

7.2 Use the results of the source apportionment work in this report to identify potential actions that will enable the Council to work towards improving air quality.

7.3 Continue to operate its high quality continuous NO_2 analysers and other monitoring in the borough to improve its current understanding and to confirm the findings of this report.

8 References:

Carslaw D, Beevers S 1999. Estimating the Uncertainty of Model Predictions using a Monte Carlo Simulation, Department of the Environment, Transport and the Regions, April 99

Carslaw, D., C., Beevers, S., D., Fuller, G., 2001. An Empirical Approach for the Prediction of Annual Mean Nitrogen Dioxide Concentrations in London. Atmospheric Environment 35-8, 1505-1515.

Derwent, R.G. and Middleton D.R., 1996. An Empirical Function for the Ratio NO_2:NO_X. Clean Air 26, No. ¾, National Society for Clean Air, Brighton.

DEFRA, 2003. Local Air Quality Management Technical Guidance. LAQM.TG3 (03) London: The Stationery Office.

DETR, 2000. Air Quality Strategy for England, Scotland, Wales and Northern Ireland. London: The Stationery Office. ISBN 010 145482 1.

Thurrock Borough Council, 2004. Detailed Assessment of Air Quality.

Thurrock Borough Council, 2006. Third Round Updating and Screening Assessment 2006.

AEAT/ Netcen 2006. NO_2 diffusion tubes for LAQM: guidance note for local authorities. Prepared for Defra. March 2006.

9 Appendix A

Model Development

Formatted: Bullets and Numbering

1.1 Model Overview

The modelling approach adopted in this report is refined from that used by the ERG on behalf of local authorities in the southeast of England; including the Mayor of London, London Boroughs, plus Unitary, Borough and District local authorities in Essex, Surrey, Sussex, Kent, Herts and Beds and Berkshire.

A receptor based approach was first developed by ERG through combining both modelling and measurement further. Separate modelling was undertaken of two categories of sources: 1) the road network close to measurement sites and 2) all sources, including roads further away. These were combined with a constant representing emission sources. A multiple regression analysis was then undertaken with the monitoring results from the London Air Quality Network and other regional networks in the southeast to establish the modelling relationship used.

This approach describes the balance between the local road contribution and the background since it provides a good comprise between the most robust aspects of both modelling and measurements.

Further details on the methodology developed can be found on the GLA website (see http://www.london.gov.uk/mayor/environment/air_quality/docs/modelling.pdf)

1.2 NO_X and NO_2 Relationships

Formatted: Bullets and Numbering

1.2.1 The Adopted Method

Formatted: Bullets and Numbering

To determine the predicted NO_2 the ERG method builds on the approach described by Carslaw et al. (2001). In summary, the relationship between hourly NO_X and NO_2 can be described by plotting NO_2 against NO_X in different NO_X 'bins', for example 0-10 ppb, 10-20 ppb etc, (Derwent and Middleton, 1996). The resulting NO_X to NO_2 relationship describes the main features of NO_X chemistry, first the NO_X -limited regime where NO_2 concentrations increase rapidly with NO_X and second the O_3-limited regime where a change in NO_X concentration has little effect on the concentration of NO_2. A third and final regime also exists where, once again NO_X and NO_2 increase pro-rata, related to extreme wintertime episodes. In all cases, the precise relationship is always both year and site dependent.

1.2.2 Roadside/ Background Concentrations

Formatted: Bullets and Numbering

Of more use than the hourly relationship discussed earlier is the relationship between the annual mean NO_X and NO_2 concentrations. The construction of these curves described in Carslaw et al. (2001) and is both site and year specific. The relationship for a site relates annual mean concentrations of NO_X to NO_2 whilst implicitly including the full distribution of concentrations measured each hour of the year.

When using these relationships it is important to differentiate between those applicable to background locations and those applicable to roadside locations for any given predicted year.

The NO_X and NO_2 relationships described above are year and site dependent. However, analysis shows that the roadside concentration of NO_2 for any NO_X concentration lies within a range of values that can be related to location. The range varies from a central London, busy street canyon, at Marylebone Road to an outer London suburb with an open road location, i.e. the A3 dual carriageway. The contrast between the two locations relates specifically to the background concentration of NO_x and NO_2, with Marylebone Road (70,000 vehicles per day) in a region of very high background concentration and the A3 site (120,000 vehicles per day) in an area with a low background concentration of NO_x and NO_2, and thus it is similar to a rural motorway. For all years Marylebone Road provides the upper limit of NO_2 concentrations and A3, the lower limit for any given concentration of NO_X. The hierarchy of NO_x and NO_2 relationships is summarised in Figure 11.

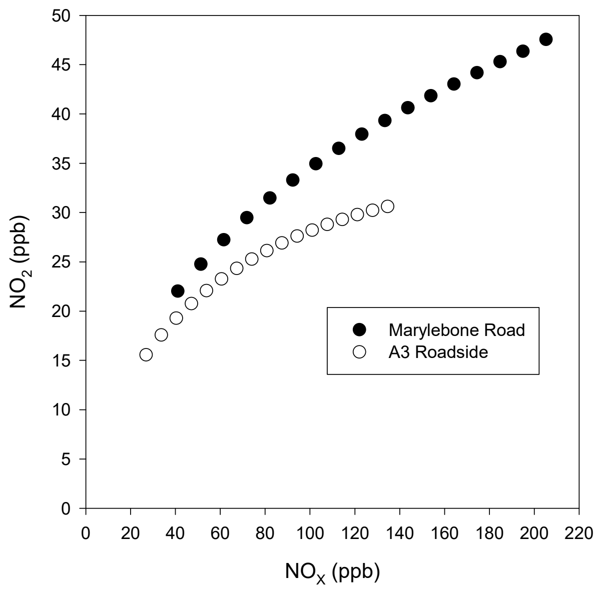


Figure 11 NO_x and NO_2 Relationships at Roadside Sites across London

The range of NO_2 concentrations, for a given NO_x concentration at the roadside are much larger than for background locations. This is because of a number of factors, including the relative contribution of the road to total NO_X concentrations, the rapid fall-off in concentration away from a road and the rapid reaction between NO and O_3 to form NO_2. The use of the roadside/ background curves is decided within the model itself by examination of the ratio of the other source NO_x contribution and local roadside NO_x contribution made at each prediction point.

10 Appendix B

Modelling Detailed Road Networks

Formatted: Bullets and Numbering

1.1 Geographic Accuracy of Model Predictions

Formatted: Bullets and Numbering

All major roads have been split up into 10 m sections, as shown in Figure 12, below. There are several benefits, which result from this development. First, each 10 m point can act as a source of emissions, thus allowing emissions to be varied along each link. This approach allows, for example, emissions near junctions where vehicle idling is important to be increased. Second, the emissions sources are geographically accurate, enabling roundabout and complex road junctions be modelled thoroughly. Third, maps of concentration will also be geographically accurate allowing more accurate assessments to be made of population exposure.

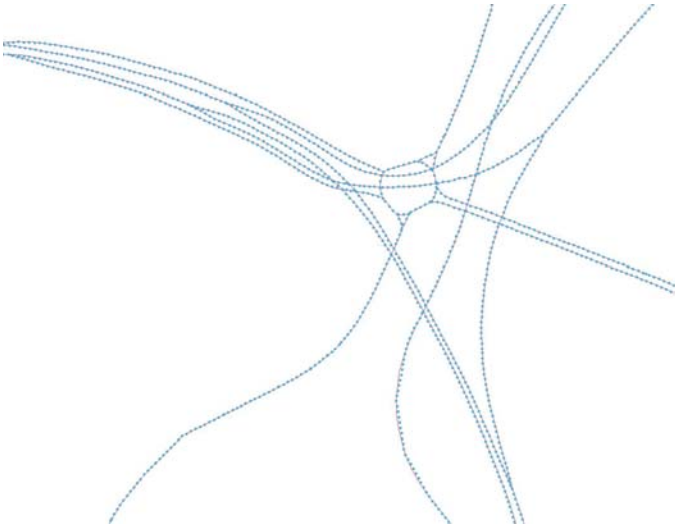


Figure 12 10m sections of road, showing complex junction details

This is further demonstrated in Figure 13 overleaf which shows that features such as roundabouts and curved roads are accurately represented.

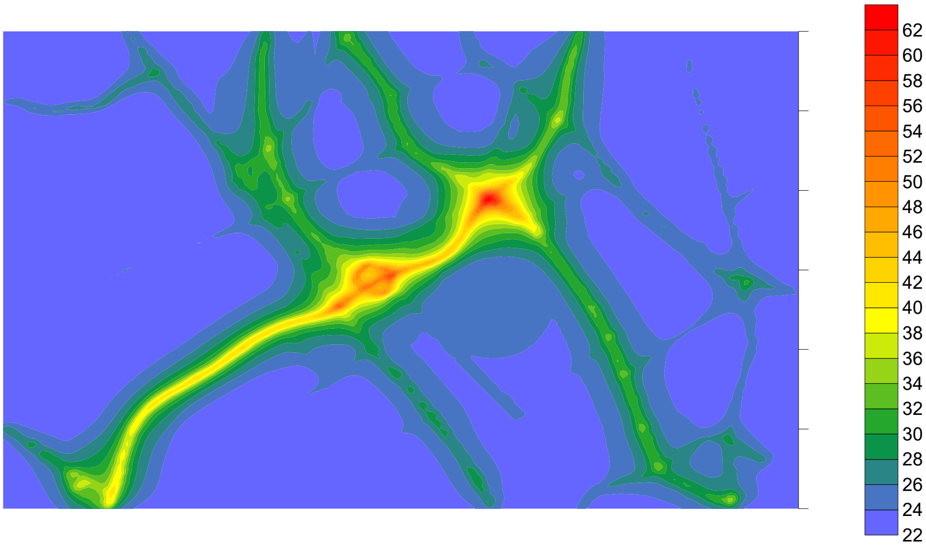


Figure 13 Modelled example showing concentrations near complex road junctions.

1.2 Emissions at Major Road Junctions

Formatted: Bullets and Numbering

The new approach of separating road links into 10 m sections allows emissions near to junctions to be explicitly accounted for. Within a short distance of each junction it is assumed that vehicle idling is increased and the average speed of vehicle is reduced significantly. The assumption used in the model predictions is that 30 m[2] from a major road junction vehicles travel on average at 5 km/hr and that this includes significant periods of idling. Having made significant improvements in the predictions of average link speed, using 'floating car' data, care was taken to keep the link emissions constant, by increasing the emissions at the ends of the links and reducing the emissions elsewhere on the link. In summary the effect of junctions is accounted for through a redistribution of the emissions along each of the road links.

Deleted: s

Deleted: are

A further set of assumptions is required for the application of such a scheme. First, the road junctions are assumed to be congested on one side of the road only and second, that there is a combination of periods of free flowing traffic and traffic travelling at 5 km/hr. The assumption for the proportion of time spent at the average link speed was assumed to be 50 % on the side of the road affected by the queue. The application of the emissions redistribution was taken only on roads that were greater than 150 m in length as it is assumed that the congested nature of such short links would be well reflected in the measured average speed.

The assumptions used in the emission model are a first estimate and it is accepted that individual road links should be treated independently, for example, using detailed traffic models. However, data on delay times and average speeds are not available, for specific road junctions. Furthermore, emission factors of the type used to develop large-scale emissions inventories are not a suitable method by which to represent emissions

[2] 30 m was assumed as being a typical length for queuing traffic. In practice, road traffic activity is more variable and there is a lack of quality data available from which to improve the predictions made here.

for specific driving characteristics (idling, acceleration/deceleration), which are unique to each junction separately.

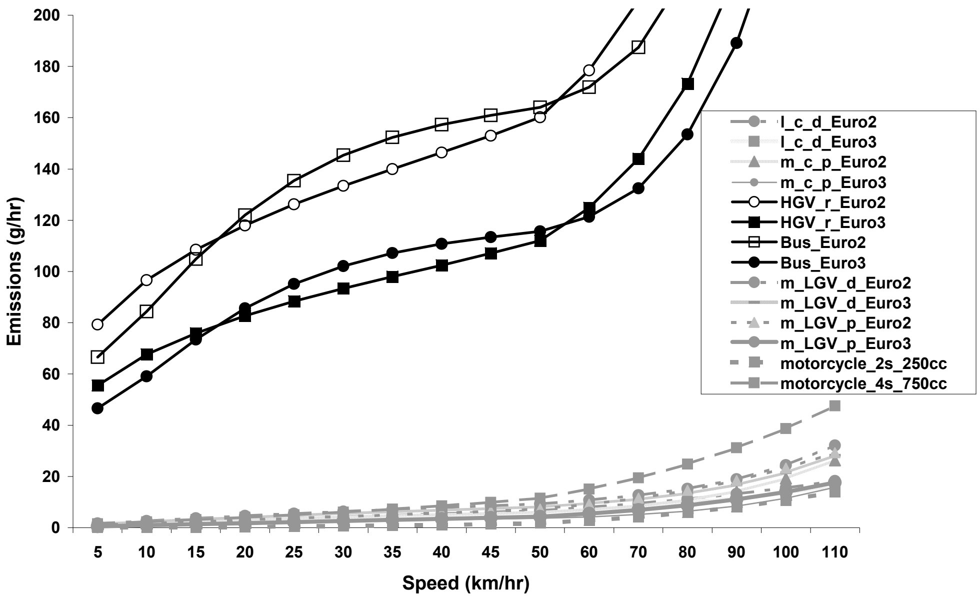


Figure 14 Emissions NO_X (g/hr) for Euro 2 and 3 Vehicles at different Average Speeds (km/hr)

The detailed DMRB emission factors are applicable down to a speed of 5 km/hr, although factors at this speed are highly uncertain. These data were employed in the redistribution of junction emissions described above. It is worth therefore investigating the effect of low speeds on the emissions of, in this case NO_X, from different vehicle types. By multiplying the g/km results for different average speeds by the speed the emissions may be expressed in g/hr. A sample of the g/hr vehicle emissions for Euro 2 and 3 vehicles is summarised in Figure 14 above. It shows that as LGV (petrol and diesel), cars (petrol and diesel) and motorcycles increase their speed so the emissions increase steadily and are at a maximum at 110 km/hr. This increase in emissions is related to the additional work, which is being done by the engine. It is important to note however, that for these vehicle types the g/hr emissions approaches zero at 5 km/hr. Also plotted in black are rigid HGVs, and buses in the Euro 2 and 3 technology categories. These vehicles contrast significantly with the cars, LGVs and motorcycles by showing emissions up to a factor 40 times greater than for smaller vehicles at very slow speeds. It is therefore these specific vehicle types, which provide the majority of the emissions close to road junctions. Since comparatively little work has been carried out on emissions from heavy vehicles, the emission factors derived at such slow speeds should be treated with considerable caution. It is important to considered these effects when considering the results from the modelling.

Deleted:

11 Appendix C

Model Validation

Formatted: Bullets and Numbering

1.1 Model validation

A comprehensive validation exercise was undertaken for the ERG NO_X-NO_2 model at measurement sites in London. A very extensive data set exists for the years 1996, 1997, 1998 and 1999 and these were used in the exercise. Comparisons were made with sites located at roadside and kerbside in both open locations and street canyons, as well as in background locations. All sites were not available for every year and for NO_x and NO_2.

To ensure the validity of the exercise care was taken to locate the site locations as accurately as possible, particularly in relation to roadside sites, where a steep concentration gradient exists and poor site locations may lead to significant changes to the model performance.

Overall the model performed very well with the average modelled and measured predictions showing close agreement. The standard deviation of the measured minus the predicted NO_2 concentrations was 12 % (1996), 9 % (1997), 11 % (1998), and 11 % (1999). The percentages were calculated by dividing the standard deviation by the all site average measured NO_2 concentration.

This level of accuracy does not apply to all sites and certain roadside sites are not as well predicted, this might be a result of the very low vehicle speeds at this site (approximately 10 km/hr throughout the day) and the uncertainty in emission factors at this speed, as described in Appendix E.

12 Appendix D

Emissions from Road Transport in Thurrock

Formatted: Bullets and Numbering

1.1 Major Road Flows

Recent AADT traffic counts for 2005 were obtained from the Department for Transport (DfT) for roads in the AQMAs and nearby. These are based traffic counts for 11 vehicle classes for the principal roads in the area. For those roads, not included, LAEI road traffic data and information from the Council's 2004 Detailed Assessment was used.

1.2 Vehicle Classification, Age and Speed

Formatted: Bullets and Numbering

The breakdown of vehicle ages was based on the national model.

Table 13 Roads modelled

Road	AQMA
London Road, Purfleet	10
Stonehouse Lane, Purfleet	21
West Thurrock Way	23
London Road, West Thurrock	21 and 23
London Road A126	23

Vehicle speeds in the AQMA were obtained from the London Atmospheric Emissions Inventory 2003.

1.3 Vehicle growth

Formatted: Bullets and Numbering

For 2010 scenarios in AQMA 23 a 1% per annum traffic growth was used in line with previous modelling in Thurrock.

For 2010 scenarios no growth was assumed from 2005 since counts from Stonehouse Lane and London Road, Purfleet indicate that flows have reduced since 1999.

Table 14 AADTs for roads in AQMA 21 and 10

A) Stonehouse Road						B) London Road, Purfleet					
Year	CAR	BUS	LGV	HGV	All MV	Year	CAR	BUS	LGV	HGV	All MV
1999	4790	28	995	2186	8096	1999	2819	93	455	285	3692
2000	4843	27	1006	2157	8140	2000	2850	89	460	280	3723
2001	4693	28	1013	2000	7846	2001	2232	76	355	168	2856
2002	4768	28	1086	1967	7965	2002	2267	76	381	159	2908
2003	3545	7	690	2129	6486	2003	2183	74	413	156	2861
2004	3591	6	761	2349	6782	2004	2118	46	351	177	2728
2005	3426	5	811	2250	6553	2005	2020	43	375	179	2648

13 Appendix E

Model Uncertainty Assessment

Formatted: Bullets and Numbering

1.1 Introduction

Formatted: Bullets and Numbering

This appendix describes the application of Bayesian Monte Carlo (BMC) analysis to the ERG model developed to predict present and future concentrations of annual average NO_2 in London. Model uncertainties arise because of limited scientific knowledge, limited ability to assess the uncertainty of model inputs, for example, emissions from vehicles, poor understanding of the interaction between model and/or emissions inventory parameters, sampling and measurement error associated with NO_X sites in London and whether the model itself completely describes all the necessary atmospheric processes. The application of the BMC technique here results in the reduction in uncertainties predicted through the additional information provided by the measurements themselves.

1.2 Uncertainty Assumption in Model Input Parameters

Formatted: Bullets and Numbering

Selection of the uncertainty of input variables are obtained through access to published literature, the opinions of experts in the field, and through the assessment of relationships used within the model. A summary of the assumptions made for the model are given in the table below:

Table 15 Uncertainty Assumptions (1 σ) use for the Uncertainty Predictions

	(%)
Road Traffic Emissions	30
Other Emissions	50
London + Rural NO_X Contribution	10
Pollution Climate Mapping (NO_X)	11
NOx-NO2 Relationship	10
Roadside Dispersion	20

Formatted

Formatted

1.3 Bayesian Monte Carlo Analysis

Formatted: Bullets and Numbering

In Monte Carlo analysis, the model is run with the input variables varied simultaneously and independently of each other and a resulting probability distribution of the output information, obtained. Bayes' theorem is then applied to derive a final uncertainty estimate, by assigning a high probability to those predictions that agree with the measurements and a low or zero probability to those, which do not. The application of probabilities to the model prediction uses the likelihood function (Equation 1) and results in the best estimate of overall model uncertainty.

$$L(Y_k \mid O) = \frac{1}{\sqrt{2\pi\sigma_e}} \exp\left(-\frac{1}{2}\left[\frac{O - Y_k}{\sigma_\varepsilon}\right]^2 \right) \qquad (1)$$

A mathematical summary of BMC is given below. From Bayes' theorem the final probability of model output is defined by equation 2 as

$$p(Y_k \mid O) = \frac{L(Y_k \mid O)\,p(Y_k)}{\sum_{j=1}^{N} L(Y_j \mid O)\,p(Y_j)} \qquad (2)$$

1.4 Results at Background

Formatted: Bullets and Numbering

A BMC uncertainty analysis was carried out for annual average NO_2 concentration throughout London. The application of BMC analysis reduces the final uncertainty giving a standard deviations in this case are 2.0 ppb (8.5 %).

The BMC analysis was then applied for 5 sites individually and the results summarised in Table 17. Again BMC analysis results in a significant reduction in σ providing a reduction in uncertainty. The average σ for the 5 sites was 1.8 ppb.

Table 16 Final uncertainty and measured annual mean NO_2 concentrations (ppb) at all sites in London for 1998

Average Model Prediction (ppb)	σ (ppb)	Uncertainty %	Measured Result (ppb)
23.6	2.0	8.5	23.2

Table 17 Final uncertainty and measured annual mean NO_2 Concentrations for separate Sites in London for 1998

Site Location	Final Model Prediction (ppb)		Uncertainty %	Measured Results (ppb)
		σ (ppb)		
Bridge Place	30.6	2.2	7.2	30.2
Bexley 2	19.1	1.5	7.8	18
Tower Hamlets 1	24.1	1.8	7.5	24.6
West London	26.8	2.0	7.5	26.8
Sutton 2	18.6	1.4	7.5	19.8

1.5 Results at Roadside

Formatted: Bullets and Numbering

Predictions of the concentration of NO_2 at roadsides throughout London have shown a high sensitivity to the pass/fail standard. These predictions are crucial to the development of air pollution control, through local authority action plans, and it is therefore essential to completely understand the uncertainty associated with them. Only then will the strengths and weaknesses of the predictive process be understood enough for decision-makers to make informed policy judgements. It is the uncertainties associated with these predictions, which are the subject of this appendix.

Monte Carlo modelling techniques have been used to calculate the uncertainties associated with roadside NO_2 predictions. It also includes a full sensitivity analysis to determine the most important input variables to the model. Specific tests include the uncertainties associated with flows and emissions from LGVs, HGVs and buses, vehicle speed, the dispersion model, and the pollution climate mapping technique, used for calculating background concentrations.

In *Monte Carlo* analysis, the input variables are varied simultaneously and independently of each other, and the effect on important outputs assessed. The model uncertainty, relating to the input parameters, is calculated by treating them as random variables. By studying the resulting probability distribution of the output (i.e. the concentration or emission estimate), information is obtained regarding the model uncertainty.

The original study has focused on Marylebone Road for a base year of 1997 for meteorology and atmospheric chemistry and uses the London Transportation Studies (LTS) traffic model. Further uncertainty assessments have also been undertaken for an "average road' in central and outer London, as well as a 'Motorway' in outer London.

The sensitivity analysis revealed that roadside NO_X predictions are mostly sensitive to the assumptions regarding HGV emissions and flows and the dispersion model used to predict roadside concentrations. For the prediction of NO_2, the NO_X-NO_2 relationship used is the most important factor. Table 18 below shows how each input data or modelling method affects the final concentration, for the Marylebone road example.

Table 18 The Relative Importance of Model Parameters in Predicting NO_2 at Marylebone Road

Model Parameter	Relative Importance 2005 (% of mean at 2σ)	Relative Importance 1997 (% of mean at 2σ)
NO_X-NO_2 relationship	13.9	11.9
HGV emissions	7.9	8.1
Dispersion model	7.3	6.8
HGV flow	5.5	5.5
LGV emissions	4.2	4.7
LGV flow	4.2	4.7
Vehicle speed	3.6	2.1
Background mapping	1.8	1.7
Bus emissions	1.2	0.9
Bus flow	0.6	0.4

For 1997, NO_X was predicted to be 258 +/- 83 ppb and NO_2 47 +/- 10 ppb, at two standard deviations – equivalent to the 95 % confidence interval. These statistics assume that the resultant distribution is normal.

The overall uncertainty of NO_2, which corresponds to 22 %, is less than that for NO_X (32 %). This feature is a result of the non-linear NO_2 relationship, which is quite insensitive to NO_X concentrations, implying that a stated NO_X uncertainty is a better indication of the quality of a prediction.

Measurements for the Marylebone Road site for NO_X and NO_2 are within the uncertainty limits calculated here. NO_X was between 213 and 229 ppb and NO_2 between 44 and 48 ppb for 1997. The range reflects the two different monitoring techniques used at the Marylebone site.

Similarly, for 2005, NO_X is estimated to be 117 +/- 35 ppb and NO_2 33 +/- 7 ppb, at two standard deviations – equivalent to the 95 % confidence interval. It can therefore be concluded that with a probability of 95 % the true value lies within the ranges given above. This would indicate that, despite the calculation of uncertainty associated with the 2005 predictions, the NO_2 concentration always exceeds 21 ppb and therefore Marylebone Road will exceed the AQS objective. This may not always be the case however and with a prediction whose range straddles 21 ppb, a decision must be made concerning the approach to be taken. For example, a prediction of 20 +/- 2 ppb could be considered a pass or a fail.

It is further concluded that the prediction of NO_2 concentrations in London depend most on the NO_X-NO_2 relationship used and the traffic data for HGVs. It is flows of, and emissions from, HGVs and buses that become more important in the future, as emissions from these vehicles will make up a greater proportion of the total.

The results from the analysis of a further three roads is given in Table 19. These represent an average road at a central and outer location and an average motorway in outer London. The flow and percent HGV for the average road was derived from all 10,000 roads in the LTS 91 network.

Table 19 NO_2 Uncertainty Estimates for Typical Roads in London in 2005

Road Type/Location	Total vehicle flow	Percent HGV	Uncertainty (% of mean at 2σ)
Average road (central London)	17,000	9	16
Average road (outer London)	17,000	9	18
Motorway (outer London)	80,000	9	21

Our best estimate of the uncertainty in annual mean NO_2 predictions is therefore +/- 16-21 % at two standard deviations.

14 Appendix F

Table 20 Diffusion tube site information

Site	Easting	Northing	AQMA Number
Gatehope Drive (UB)	557595	181060	15
Ibis Hotel (UB)	557570	177790	7
Kemps Cottage (UB)	558141	183537	16
Cromwell Road Grays (I)	561572	178154	1
Elizabeth Road (R)	560946	179569	3
Hogg Lane (R)	561108	178920	3
Jarrah Cottages (R)	556738	177928	10
London Road Arterial Road (R)	555298	179449	13
London Road Grays (R)	560623	177810	1
London Road South Stifford (R)	559784	177908	2
Park Road (R)	567781	182399	22
Purfleet Rail Station (R)	555388	178145	11
Stanley Road Grays (R)			1
Stonehouse Lane (R)			21
Watts Crescent (R)	556320	178764	12
William Edwards School (R)	561948	180965	17
London Road W Thurrock (R)	558482	177677	23
Queensgate Centre Grays (R)	561467	178064	1
A1306 (R)	559722	179632	5