

**2007 Detailed Assessment of Air Quality  
for the  
Runnymede Borough Council**



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## Executive Summary

This is the Detailed Assessment of air quality for the Runnymede Borough Council (“the Council”). This assessment fulfils the Council’s next step of the Local Air Quality Management (LAQM) process and is required as a result of the findings of the Council’s 2006 Updating and Screening Assessment report.

This earlier screening assessment identified that the government’s annual mean nitrogen dioxide (NO<sub>2</sub>) objective might be exceeded in part of the Council’s area, specifically close to areas with public exposure by the junction of Station Road and High Street in the town centre of Addlestone and in New Haw. The purpose of this report is therefore to provide an accurate assessment of the likelihood of the objective being exceeded at locations with relevant exposure.

New modelling predictions have been made for this report, and these include both improved modelling methods and treatment of emissions. The report also incorporates the most recent monitoring results for the above areas. The report thus meets the requirements of the technical guidance LAQM. TG (03) produced by the Department of Environment, Food and Rural Affairs (DEFRA).

The Council’s bias adjusted diffusion tube monitoring results for its sites at Station Road and New Haw Road indicated that the 2005 annual mean objective for NO<sub>2</sub> was exceeded for 2004 and also approached during 2006.

The modelling predictions, using 2003 meteorology, for roads in this area showed that the annual mean NO<sub>2</sub> objective was exceeded for 2005 close to the centre of the roads. These predictions were also compared against the biased diffusion tube results and these agreed well, indicating that the predictions did not need further verification.

Concentrations near the Station Road and High Street junction in Addlestone had the highest predicted concentrations and these included areas with relevant exposure. As a result an Air Quality Management Area should be designated in the High Street and Station Road, subject to further monitoring in the area.

The predictions for the New Haw area also indicated that the objective was exceeded mainly close to the road centre lines and not at the façade of residential premises in the area.

Modelling of the same area for PM<sub>10</sub> indicates that the daily mean objective was not exceeded where there was relevant exposure.

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

For the High Street and Station Road area in Addlestone, although improvements are anticipated, an AQMA still needs to be designated due to the 2005 objective being exceeded:

1. Undertake consultation on the findings arising from this report with the statutory and other consultees as required.
2. Confirm that there is relevant exposure in the area predicted to exceed and designate an AQMA based on the area predicted to exceed in this report.
3. Consider extending monitoring in the area to confirm the findings of the report.

For the New Haw area:

4. Confirm that there is not relevant exposure in the area predicted to exceed.
5. Undertake consultation on the findings arising from this report with the statutory and other consultees as required.

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## 1 Introduction to Detailed Assessment of Nitrogen Dioxide

### 1.1 Overview to Detailed Assessment

This is the 2007 Detailed Assessment of nitrogen dioxide (NO<sub>2</sub>) for the Runnymede Borough Council. The report fulfils the statutory requirement for this, the Council's next step, of the Local Air Quality Management (LAQM) process. An assessment for the 2004 daily mean PM<sub>10</sub> objective was also included at the request of the Council.

### 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 third round Updating and Screening Assessment (USA) in 2006 for the seven LAQM pollutants. This report identified that there was a risk of the government's annual mean NO<sub>2</sub> objective being exceeded in part of the Borough not previously assessed as such. This assessment was based on results from the Council's diffusion tube monitoring programme. The conclusion of the 2006 USA report was that the Council needed to undertake a Detailed Assessment for NO<sub>2</sub> for Station Road close to Addlestone town centre (see Figure 1) and the A318 New Haw Road from Addlestone to New Haw only (see Figure 2).

The aim of the Council's Detailed Assessment is to determine with reasonable certainty whether or not there is a likelihood of the AQ objectives being achieved. The assumptions in the Detailed Assessment are therefore in depth and the data used are quality assured to a high standard. This allows the Council to have confidence in reaching its air quality management decisions. When carrying out its Detailed Assessment the Council applied its best estimates to all components used in producing estimated future concentrations.

**Table 1** Air quality objectives relevant to this Detailed Assessment report

Pollutant	Concentration	Measured as	Date to be achieved by
Nitrogen dioxide (NO <sub>2</sub> )	40 µg m <sup>-3</sup>	Annual mean	31-Dec-05
Particles (PM <sub>10</sub> )	50µg m <sup>-3</sup>	Daily mean (not to be exceeded more than 35 times in a year)	31-Dec-04

### 1.3 Progress with Local Air Quality Management – Runnymede Borough Council

The Council previously designated an Air Quality Management Area (AQMA) in parts of its area for both NO<sub>2</sub> and PM<sub>10</sub> during earlier review and assessment of air quality rounds. This was in the vicinity of the M25, which runs through the Borough along a north south axis.

## 2 Monitoring results

### 2.1 Updated NO<sub>2</sub> results

This section provides an update of the results of the Council’s monitoring programme for the area under investigation. As reported in the 2006 Updating and Screening Assessment, the Council undertook a programme of monthly diffusion tube monitoring of NO<sub>2</sub>, supplied and analysed by Lambeth Scientific Services. The method of preparation was 50% triethanolamine (TEA) in acetone as absorbent.

The Council did not monitor NO<sub>2</sub> continuously for the period and therefore a locally derived bias adjustment factor was not available, instead default factors obtained from DEFRA helpdesks were used. These factors were obtained from the Review and Assessment website (<http://www.uwe.ac.uk> - September 2007 version). These indicated that the diffusion tubes measurements were less than continuously monitored concentrations at the same location. The figure in brackets was the default factor used in the 2006 USA from a previous version. This factor changed as a result of further data being added to update the spreadsheet.

Year	Bias adjustment factor
2002	1.15
2003	1.05
2004	1.19 (1.21)
2005	1.24
2006	1.33

NO<sub>2</sub> monitoring was undertaken at locations close to the Civic Centre building on Station Road in Addlestone and outside 175 New High Road in New Haw. Station Road is the main route in the Addlestone town centre and the A318 New Haw Road is a main route from Addlestone to Byfleet.

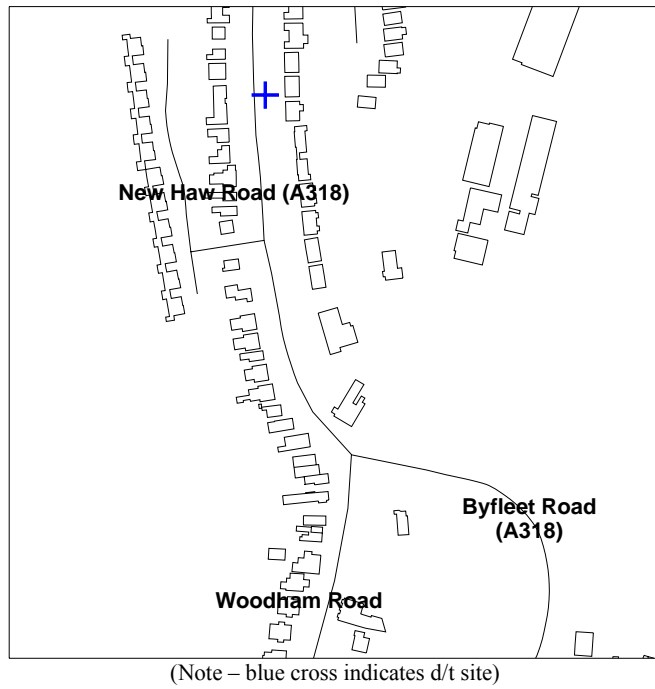
There was one diffusion tube site in each area. The Station Road site is located 4m from the kerbside at a height of 3.5m. The New Haw Road site is located 2m from the kerb and at a height of 2m. (See Figure 1 and Figure 2 for the location of the sites). Both sites were started prior to 2002. The Station Road site is representative of exposure along Station Road, although this road is mainly commercial and retail. It is also close to buildings on the High Street of Addlestone, which front the road. The New Haw Road site, represents kerbside exposure, although the nearest residential buildings are set further back from the diffusion tube site.

Both areas are dominated by slow moving traffic in the area throughout the day, with queuing at the junctions. The crossroads junction, approximately 50m to the west of the Station Road site, is signal controlled. The New Haw junction is configured with a mini roundabout, approximately 300m to the south of the monitoring site. The area includes a small commercial area with several small shops, although there is some accommodation provided over the shops close to the junction with Byfleet Road and Woodham Road in some buildings.

**Figure 1** NO<sub>2</sub> monitoring site close to the Station Road/ High Street, Addlestone junction.



**Figure 2** NO<sub>2</sub> monitoring site in New Haw



The biased adjusted results for the sites are given below and for the years reported, there was more than 75% data capture (unless indicated).

**Table 2** Diffusion tube monitoring at High Street/ Station Road site

Site no.	Location	Type	2002	2003	2004	2005	2006
1	Civic Offices (Front)	R	<b>42.5</b>	37.0	<b>41.8</b>	32.5	38.6
9	175 New Haw Road	R	39.2	38.8	<b>40.2</b>	38.4	38.8

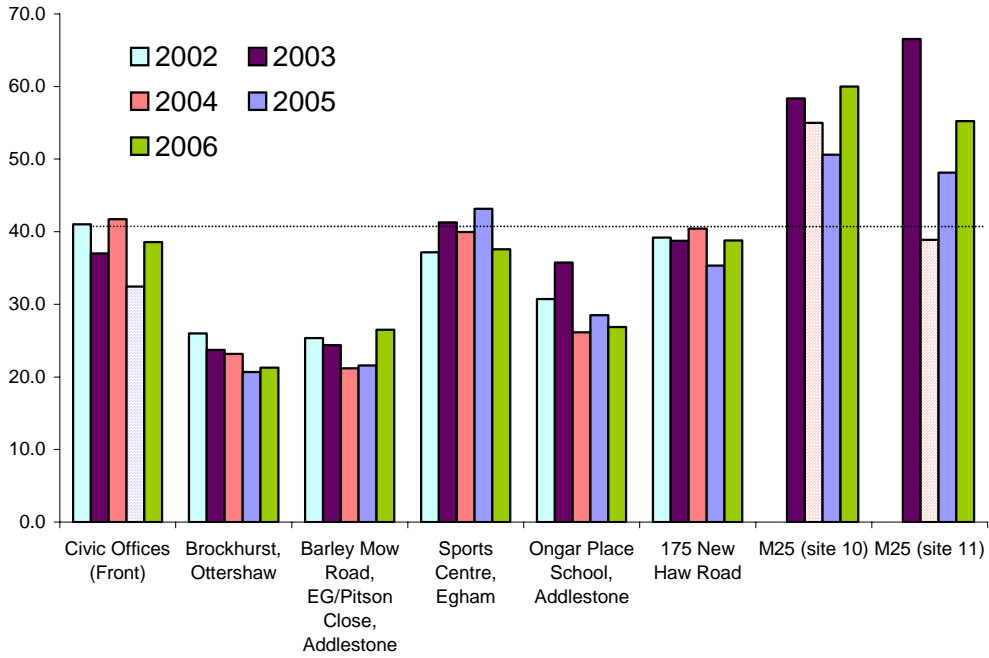
(Note: bold indicates exceeds objective; italics indicate < 75% data capture)

The results indicated that the annual mean objective of 40 µg m<sup>-3</sup> was exceeded at both sites for at least one year during the monitoring period shown. (Note - the unbiased monthly results are given in Appendix F). There was however variation between years, with the annual mean objective not being exceeded for more years than for those that exceeded.

This variation in concentration between years may partly be explained by changes in local emissions of pollutants, variation in meteorology between years or a combination of both. It is slightly surprising however that the 2003 bias adjusted concentrations at the two sites were lower than some of the other years. Elsewhere, for example in nearby London concentrations in 2003 were higher as a result of meteorology during the year which was conducive the formation of NO<sub>2</sub> and other pollutants (ERG, 2003). Results from the other Runnymede sites (see Figure 3) also indicate that 2003 concentrations were mostly higher than other years.

The data capture for the monitoring at the Civic Offices site in 2005 did not exceed 75% (there were 7 months data capture only) and therefore the result was corrected using the method described in TG03. This correction was based on the annual mean to period mean ratio from nearby AURN and LAQN background sites in Teddington, Harlington and Hounslow. The ratio used to factor the monitored result was 1.14. Despite this adjustment the concentration at the site for 2005 was significantly lower (i.e. 90% or less) of other years. In view of the insufficient data capture and uncertainty surrounding the 2005 result for Station Road site these data were considered less representative of the sites.

**Figure 3** Bias adjusted annual mean concentrations for the Runnymede diffusion tube sites (2002 –2006)



### 3 Predictions of NO<sub>2</sub> at Station Road, Addlestone and New Haw

#### 3.1 Outline of modelling developments

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The Detailed Assessment incorporates:

- Major roads on an exact geographic basis to allow an improved assessment of exposure;
- Predictions plotted on OS base maps;
- A best estimate of model uncertainty, using Monte Carlo techniques.

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

The model was empirically developed for urban areas and has been previously used for modelling assessments by the Council as part of its local air quality management responsibilities. Details of the model validation are given in Appendix C.

The traffic data used for the modelling were obtained from the London Atmospheric Emissions Inventory and Department for Transport Rotating Census and are based upon the 2005 traffic counts for the road links. Traffic information details are given in Appendix D.

The area modelled was also extended to include junctions of the High Street with Station Road and also the junction of New Haw Road, Byfleet Road and Woodham Road.

#### 3.2 Annual mean NO<sub>2</sub> (µg m<sup>-3</sup>) in 2005

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The predicted annual mean concentrations for the 2005 base case, assuming that the meteorology of the year 2003 was repeated, are shown in Figure 4. Only areas coloured yellow to orange exceed the air quality objective.

The locations of the 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<sup>1</sup>, which gives details of individual buildings 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.

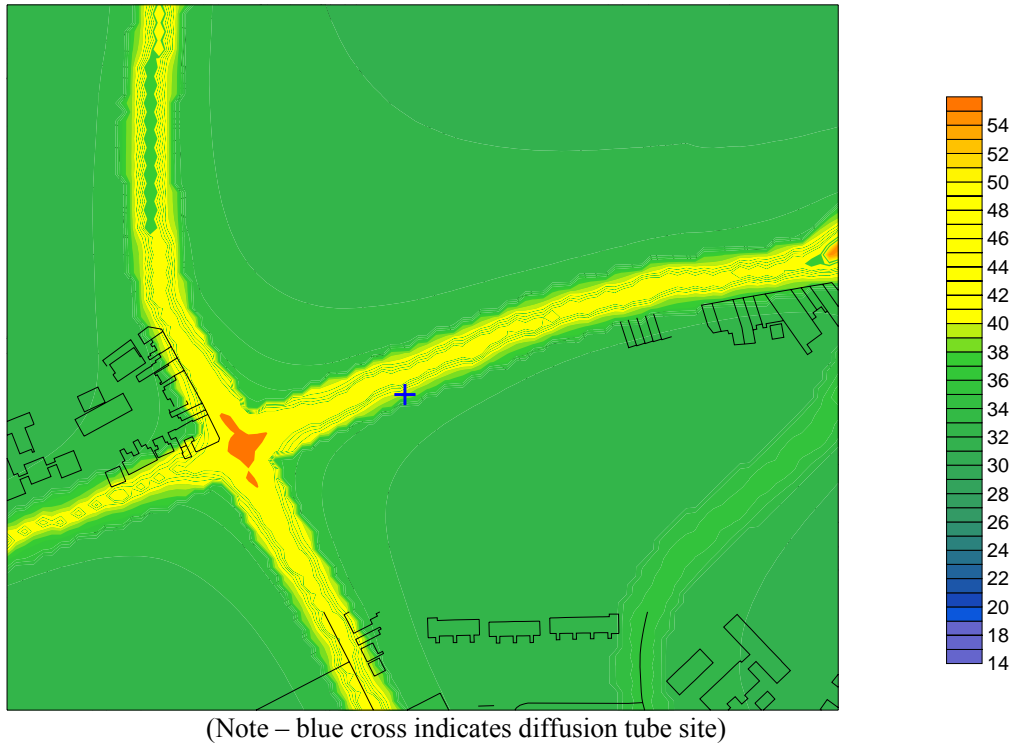
#### 3.3 Predictions of NO<sub>2</sub> for the Addlestone town centre

The base case predictions confirmed that the annual mean air quality objective was exceeded along the roads modelled. The area that exceeded was mostly close to the centre of roads. The area that exceeded however also overlapped the façades of nearby relevant buildings with potential public exposure.

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**Figure 4** Predicted annual mean NO<sub>2</sub> (µg m<sup>-3</sup>) at the Addlestone town centre for 2005 base case (with 2003 meteorology)



### 3.4 Comparison with monitored results

The bias adjusted annual mean NO<sub>2</sub> monitored results for the Civic Centre site on Station Road were given in the previous section. The monitoring results indicated in 2002 and 2004 that the objective was just exceeded. For both 2003 and 2006 the monitoring results approached the objective. Whereas for 2005 there was insufficient data capture. From Figure 4 above, it can be seen that the monitoring site is very close to the area that exceeds.

Table 3 gives a comparison of the modelled and monitored results. These show a broad agreement with both sets of results approaching the objective.

**Table 3** 2005 modelled and biased monitored annual mean NO<sub>2</sub> concentrations for the Station Road site (µg m<sup>-3</sup>)

Easting	Northing	Class	Monitored 2006	Modelled 2005
505090	164615	Roadside	38.6	38.0

Despite this good agreement there were many uncertainties in both monitoring and modelling this section of road. The monitoring was undertaken by diffusion tube, which  
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is more uncertain than continuous monitoring. In accordance with the TG03 guidance and to try to reduce this uncertainty, the diffusion tubes were corrected. In this instance default bias correction factors were used. These indicated that the diffusion tube measurements were less than measurements obtained using a continuous monitoring and therefore the measurements were biased upwards.

The location investigated was near to a busy town centre, close to a signalled traffic junction. The TG03 guidance suggests where there is disparity between predicted and measured results an appropriate adjustment factor should be determined. The guidance also highlights that this is not generally recommended based on solely on diffusion tubes. However in view of the reasonable agreement between modelled and monitored results in this instance verification was not undertaken.

### **3.5 Predictions of NO<sub>2</sub> for New Haw**

The base case predictions confirmed that the annual mean air quality objective was exceeded along the roads modelled. The area that exceeded was mostly close to the centre of roads. The area that exceeded however did not overlap with the façades of nearby relevant buildings with public exposure (see Figure 5).

The modelling also extended further south to include the mini roundabout junction with Byfleet Road and Woodham Road. The area predicted to exceed extended further from the road centre close to the junction and the threshold where the objective is exceeded was therefore much closer to the nearby buildings. Those buildings identified as closest to the objective are marked as building A and B and these are not considered as relevant buildings with public exposure.

**Figure 5** Predicted annual mean NO<sub>2</sub> (µg m<sup>-3</sup>) at New Haw for 2005 base case (with 2003 meteorology)



(Note – blue cross indicates diffusion tube site)

### 3.6 Comparison with monitored results

The annual mean NO<sub>2</sub> monitored results for the New Haw diffusion tube site were given in the previous section. The monitoring results for 2004 indicated that the objective was just exceeded, whereas in 2002, 2003, 2005 and 2006 the objective was approached but not exceeded. From Figure 5, it can be seen that the location of the diffusion tube site was just outside the area that exceeds. The nearest houses to this site were almost 10 m further away and therefore within the area estimated not to exceed the 40 µg m<sup>-3</sup> objective. Table 4 gives a comparison of the modelled and monitored results at the diffusion tube site.

**Table 4** 2005 modelled and biased monitored annual mean NO<sub>2</sub> concentrations for the New Haw Road site (µg m<sup>-3</sup>)

Easting	Northing	Class	Monitored 2005	Modelled 2005
505407	163324	Roadside	38.4	39.9

These show reasonable agreement, with the modelled prediction slightly exceeding the monitored result by about  $1.5 \mu\text{g m}^{-3}$ , indicating that the prediction provides a slight conservative approach for this area.

The modelled predictions at the nearest facades to the nearby New Haw junction are provided in Table 5.

**Table 5** 2005 modelled annual mean  $\text{NO}_2$  concentrations for the identified New Haw facades ( $\mu\text{g m}^{-3}$ )

Façade	Easting	Northing	Modelled 2005
A	505447	163139	40.5
B	505443	163106	40.1

The predictions indicate the objective was only just exceeded at these facades and may be slight overestimates based on the comparison above.

As referred to earlier there were many uncertainties in both monitoring and modelling this section of road. The monitoring was undertaken by diffusion tube, which is more uncertain than continuous monitoring. In accordance with the TG03 guidance and to try to reduce this uncertainty, the diffusion tube results were corrected. In this instance default bias correction factors were used. These indicated that the diffusion tube measurements were less than measurements obtained using a continuous monitoring and therefore the measurements were biased upwards.

The location that exceeds by the greatest amount was close to a mini roundabout traffic junction. The TG03 guidance suggests where there is disparity between predicted and measured results an appropriate adjustment factor should be determined. The guidance also highlights that this is not generally recommended based on solely on diffusion tubes. However due to the reasonable agreement at the New Haw site between modelled and monitored results, no further verification was undertaken.

An estimate of 2010 concentrations was made using the year adjustment calculator provided by DEFRA for the purposes of local air quality management. The estimates for the diffusion tube site in New Haw and the two identified facades are given in Table 6 and these all indicate that the objective will be met by 2010.

**Table 6** Estimated 2010 annual mean concentrations ( $\mu\text{g m}^{-3}$ )

Façade A	505447	163139	35.1
Façade B	505443	163106	34.8
New Haw d/t site	505407	163324	33.6

## 4 Predictions of PM<sub>10</sub> at Station Road, Addlestone and New Haw

### 4.1 Outline of modelling PM<sub>10</sub>

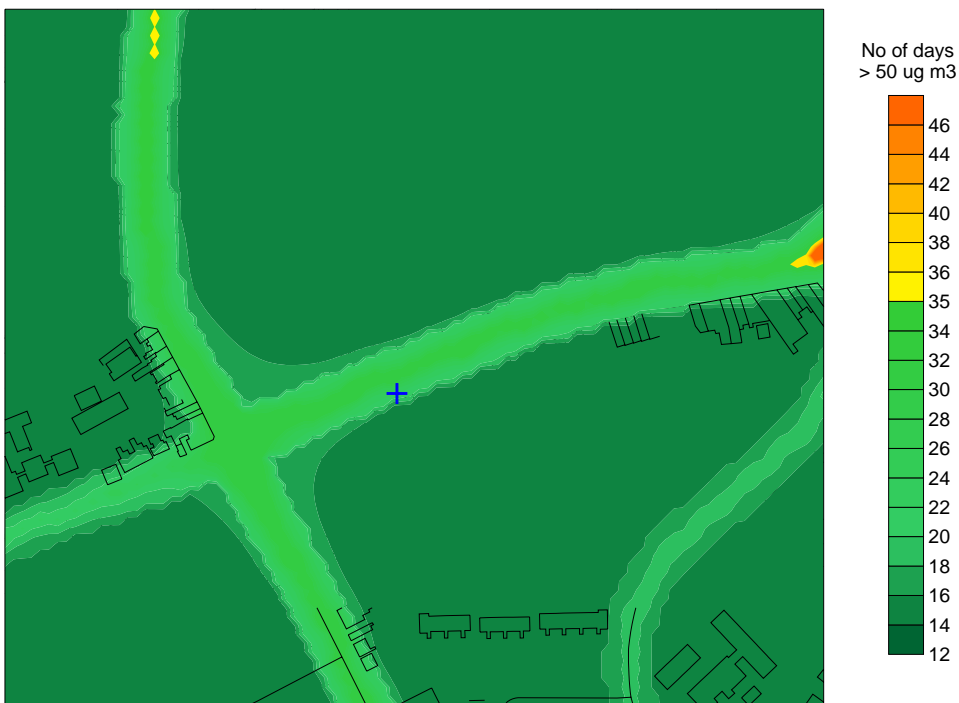
At the request of the Council, PM<sub>10</sub> was also modelled for the Addlestone and New Haw areas investigated for NO<sub>2</sub>. This modelling was based on the 2004 AQS daily mean objective, which was considered the stringent of the Pm10 objectives to achieve in the Council's area. The modelling used the ERG PM<sub>10</sub> model, which has been extensively used by local authorities in the southeast. The traffic data used were as for the NO<sub>2</sub> modelling.

### 4.2 Daily mean PM<sub>10</sub> predictions (exceeding 50 µg m<sup>-3</sup>) in 2005

The number of days predicted to exceed the PM<sub>10</sub> daily standard of 50 µg m<sup>-3</sup> are shown in Figure 6 and Figure 7. This indicates that the objective is just exceeded in parts of the High Street and the junction with Station Road, close to the road centre lines only.

Monitoring is not carried out in the Borough. The results however show reasonable agreement to nearby LAQN sites elsewhere, with the background results similar to those of Mole Valley background site for 2003 and the kerbside results similar to those for Sutton 4 (see Table 7).

**Figure 6** Predicted number of days PM<sub>10</sub> (> 50 µg m<sup>-3</sup>) near High Street/ Station Road junction in Addlestone



**Figure 7** Predicted number of days PM<sub>10</sub> (> 50 µg m<sup>-3</sup>) in New Haw



**Table 7** PM<sub>10</sub> monitoring in neighbouring local authorities (2002 to 2006)

		2002	2003	2004	2005	2006*
Mole Valley 2 background (LAQN)	Annual mean (µg m <sup>-3</sup> )	22	24	20	20	22
	Days > 50 µg m <sup>-3</sup>	4	15	1	1	<i>1</i>
	Data capture %	96	99	99	99	52
Sutton 4 kerbside (LAQN)	Annual mean (µg m <sup>-3</sup> )	32	34	30	31	33
	Days > 50 µg m <sup>-3</sup>	8	<b>37</b>	9	14	21
	Data capture %	<i>43</i>	99	99	95	97

(Note – \* data are provisional; bold indicates objective exceeded; italics < 90% data capture)

## 5 Conclusion

This report fulfils the requirements of the DEFRA guidance for the Detailed Assessment. The Detailed Assessment incorporates recent monitoring results and improved modelling techniques, plus an improved treatment of emissions using the most recent locally available traffic data.

The bias corrected NO<sub>2</sub> monitoring results for the diffusion tube site near the junction of the Station Road and High Street in Addlestone indicated that roadside locations monitored exceeded the annual mean objective for the year 2004 and approached this level in other years.

Similarly at the diffusion tube site in New Haw, annual mean concentrations were monitored as exceeding the objective in 2004 and approaching this level in other years.

Modelled predictions were made to determine concentrations at nearby areas close to the monitoring locations for 2005. Overall these agreed reasonably well with the biased monitored results. In view of this the modelling predictions were not corrected using a verification factor (this was based on TG03 guidance).

The predictions indicated that concentrations exceeded the annual mean objective close to the road centres in the Addlestone town centre. The area predicted to exceed overlapped the front facades of buildings with relevant exposure along the roads modelled.

In New Haw the predictions also exceeded the annual mean objective close to the road centres and just extended beyond the facades of two buildings in New Haw. The predicted concentrations were 0.5 and 0.1 µg m<sup>-3</sup> over the 40µg m<sup>-3</sup> objective. The comparison of modelled and monitored concentrations at New Haw however indicated that the modelling over predicted the monitored result slightly. It is also not considered that these buildings represent relevant facades with public exposure. An estimate of concentrations based on the predictions at the nearest selected facades to the junction confirmed that concentrations will easily meet the objective in 2010.

Based on the above findings, it is considered that the objective was not achieved at facades representing relevant public exposure along the High Street and Station Road. In view of these findings the Council will need to designate an AQMA in this area. Although in view of variation in monitored concentrations over recent years both above and below the government's AQS objective, further monitoring should be considered in the area.

The modelling undertaken for PM<sub>10</sub> indicates that the daily mean objective is exceeded close to the centre line of the roads and junctions in very small parts only. It is not considered that the area that exceeds includes areas of relevant exposure in this instance.

## **6 Recommendations**

The Council is recommended to undertake the following actions, for the statutory objective relating to annual mean nitrogen dioxide:

For the High Street and Station Road areas examined in the report:

1. Undertake consultation on the findings arising from this report with the statutory and other consultees as required.
2. Confirm that there is relevant exposure in the area predicted to exceed and designate an AQMA.
3. Consider extending monitoring in the areas modelled to confirm the findings of the report.

For the New Haw area examined in the report:

4. Confirm that there is not relevant exposure in the area predicted to exceed.
5. Undertake consultation on the findings arising from this report with the statutory and other consultees as required.

## Appendix A

### Model Development

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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 Borough local authorities in Surrey, Herts and Beds, Sussex, Kent, Essex and Berkshire.

#### Annual mean NO<sub>2</sub> vs. NO<sub>x</sub> relationships

The modelling approach adopted in this report uses the approach described by Carslaw et al. (2001) and a summary of the key points is given here. The relationship between hourly NO<sub>x</sub> and NO<sub>2</sub> has in the past been summarised by plotting NO<sub>2</sub> against NO<sub>x</sub> in different NO<sub>x</sub> ‘bins’, for example 0-10 ppb, 10-20 ppb etc, (Derwent and Middleton, 1996). The resulting NO<sub>x</sub> to NO<sub>2</sub> relationship describes the main features of NO<sub>x</sub> chemistry, first the NO<sub>x</sub>-limited regime where NO<sub>2</sub> concentrations increase rapidly with NO<sub>x</sub> and second the O<sub>3</sub>-limited regime where a change in NO<sub>x</sub> concentration has little effect on the concentration of NO<sub>2</sub>. A third and final regime also exists where, once again NO<sub>x</sub> and NO<sub>2</sub> increase pro-rata, related to extreme wintertime episodes.

#### NO<sub>x</sub> and NO<sub>2</sub> Relationships, the Adopted Method

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#### Roadside Concentrations

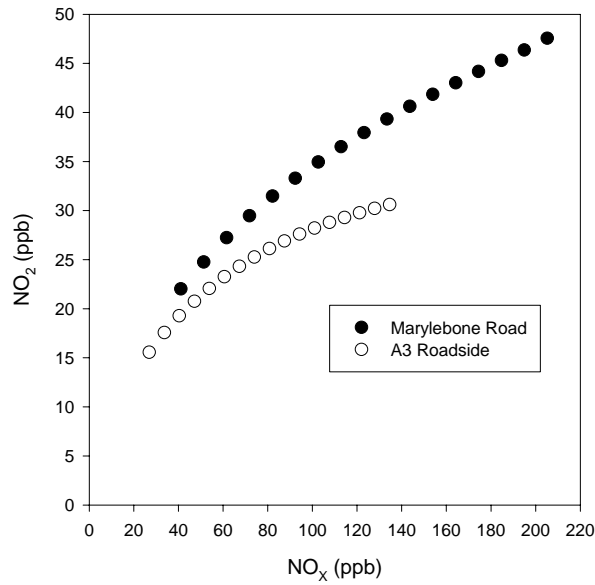
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Of more use than the hourly relationship discussed earlier is the relationship between the annual mean NO<sub>x</sub> and NO<sub>2</sub> concentrations. The construction of these curves is described in Carslaw et al. (2001) and is both site and year specific. The relationship for a site relates annual mean concentrations of NO<sub>x</sub> to NO<sub>2</sub> 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<sub>x</sub> and NO<sub>2</sub> relationships described above are year and site dependent. However, analysis shows that the roadside concentrations of NO<sub>2</sub> for any NO<sub>x</sub> concentration lies within a range of values and that this relates to location. The range is from a central London, busy street canyon, at Marylebone Road to an open road location, e.g. the A3 dual carriageway. The contrast between two such locations relates specifically to the background concentration of NO<sub>x</sub> and NO<sub>2</sub>, 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<sub>x</sub> and NO<sub>2</sub>, and thus it is similar to a rural motorway. For all years Marylebone Road provides the upper limit of NO<sub>2</sub> concentrations and A3, the lower limit for any given concentration of NO<sub>x</sub>. The hierarchy of NO<sub>x</sub> and NO<sub>2</sub> relationships is summarised in Figure 8 below.

**Figure 8** NO<sub>x</sub> and NO<sub>2</sub> Relationships at Roadside Sites across London



The range of NO<sub>2</sub> concentrations, for a given NO<sub>x</sub> 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<sub>x</sub> concentrations, the rapid fall-off in concentration away from a road and the rapid reaction between NO and O<sub>3</sub> to form NO<sub>2</sub>.

**Background Concentrations**

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Background concentrations for the area were modelled from the London Atmospheric Emissions Inventory emission sources for 2005.

## Appendix B

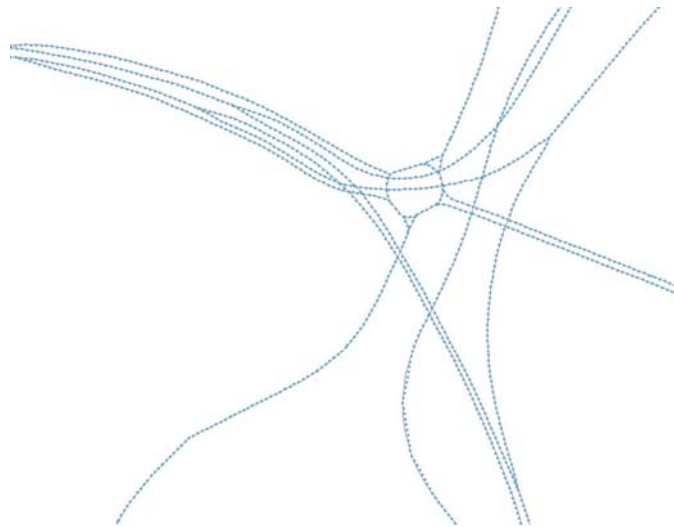
### Modelling Detailed Road Networks

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#### Geographic Accuracy of Model Predictions

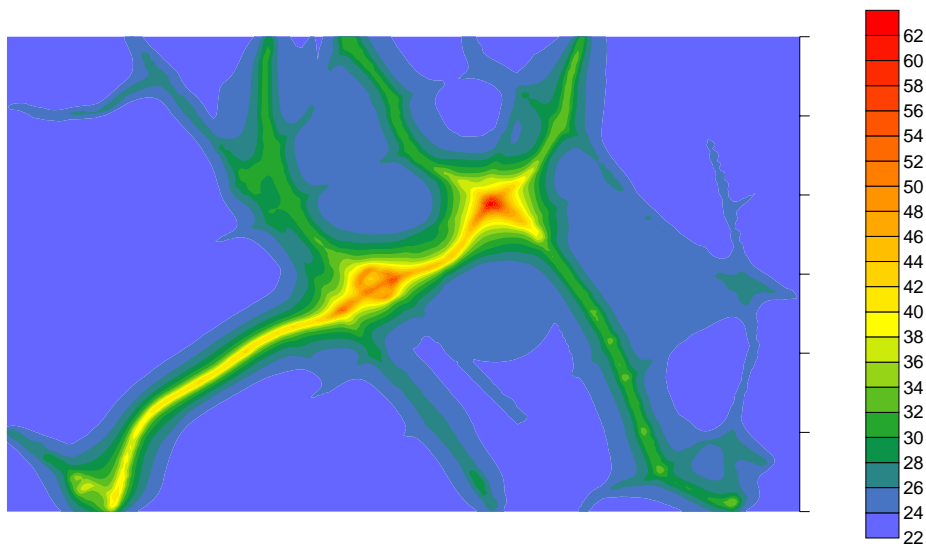
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To improve the geographic accuracy of predictions all roads have been split into 10 m sections, as shown in Figure 9. There are several benefits, which result from this development. First, each 10 m point can act as a source of emissions, thus allowing 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 9** 10m sections of road, showing complex junction details

This is further demonstrated in Figure 10 overleaf which shows that features such as roundabouts and curved roads are accurately represented.



**Figure 10** Modelled example showing concentrations near complex road junctions.

**Treatment of Emissions**

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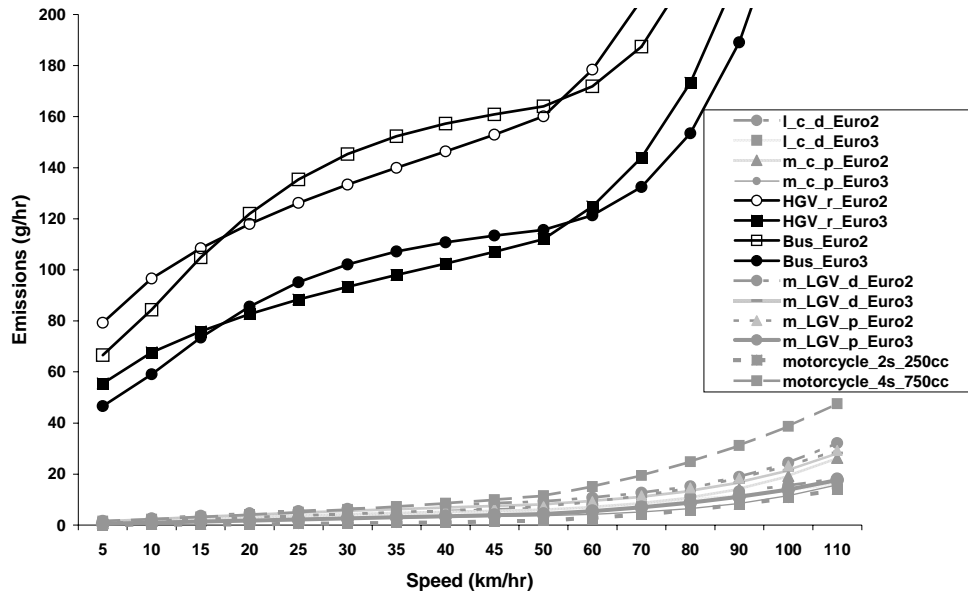
The model has used the latest detailed emission factors released by DEFRA. These are applicable down to a speed of 5 km/hr, although factors at this speed are highly uncertain.

It is therefore worth investigating the effect of low speeds on the emissions of, in this case NO<sub>x</sub>, from different vehicle types. By multiplying the g/km results for different average speeds by 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 11 below. 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.

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**Figure 11** Emissions NO<sub>x</sub> (g/hr) for Euro 2 and 3 Vehicles at different Average Speeds (km/hr)

## Appendix C

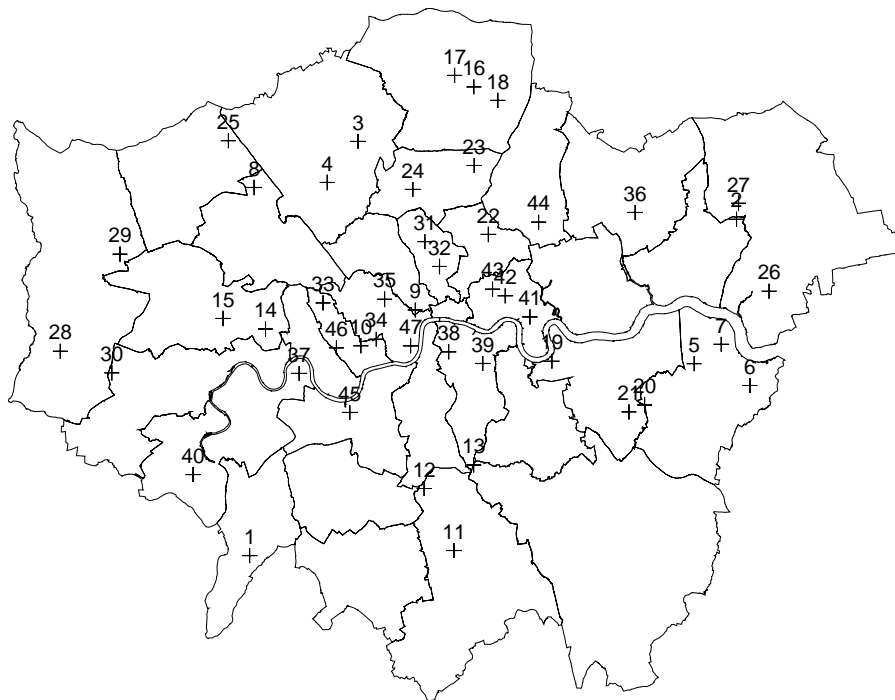
### Model Validation

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A comprehensive validation exercise has been undertaken for the ERG models used at measurement sites in London and the southeast and this is presented below.

#### Sites used for model validation

A very extensive data set exists 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. However, Figure 12 summarises sites used during the validation exercise. The validation exercise encompasses all types of location. This is beneficial since it is only through a comparison with many sites types in different locations can the approaches used in this study be properly tested.



**Figure 12** Sites used to validate model predictions (numbers are site references)

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.

**Predictions of Annual Average NO<sub>x</sub> and NO<sub>2</sub>**

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Table 8 provides the actual results and a summary of the overall model performance. Sites were not included with data capture rate of less than 90%.

Overall the model performed very well with the average modelled and measured predictions showing close agreement. A summary of the overall performance of the model is given in Table 9.

**Table 8** Annual Mean NO<sub>x</sub> and NO<sub>2</sub> (ppb) validation results for 2003

Reference	Site	NO <sub>x</sub>		NO <sub>2</sub>	
		Measured	Prediction	Measured	prediction
1	A3	97	71.6	38	31.4
2	Barking & Dagenham 1 - Rush Green	28	30.3	16	19.1
3	Barnet	98	105.1	39	41.0
4	Barnet 2 - Finchley	37	35.1	20	21.0
5	Bexley 5 - Bedonwell	27	29.2	18	18.7
6	Bexley1	35	31.4	20	19.4
7	Bexley2	33	29.4	19	18.7
8	Brent1	31	31.3	18	19.6
9	Camden 3 - Shaftesbury Avenue	83	106.5	36	42.4
10	Cromwell Road	100	117.0	39.2	45.3
11	Croydon 4 - George Street	64	70.1	29	31.3
12	Croydon 5 - Norbury	121	88.7	39	36.6
13	Crystal Palace 1 - C Palace Parade	60	73.1	26	31.8
14	Ealing 2	89	66.3	32	30.5
15	Ealing1	43	49.3	22	25.5
16	Enfield1	28	31.6	18	19.7
17	Enfield2	49	68.1	24	30.3
18	Enfield3	31	30.8	17	19.4
19	Greenwich 5 - Trafalgar Road	56	68.4	26	30.8
20	Greenwich Bexley 6 - A2 Falconwood	76	62.5	29	28.8
21	Greenwich4	31	32.3	20	19.9
22	Hackney4	56	48.7	26	25.0
23	Haringey	61	70.5	27	31.6
24	Haringey 2 - Priory Park	33	35.6	19	21.1
25	Harrow 1 - Stanmore	28	29.8	16	19.0
26	Havering	48	49.0	23	24.5
27	Havering 3	57	57.6	22	27.3
28	Hillingdon	73	76.8	28	33.3
29	Hillingdon 1 - South Ruislip	73	52.3	26	25.8
30	Hounslow 2 - Cranford	47	35.6	27	21.3
31	Islington 2 - Holloway Road	97	81.6	36	34.7
32	Islington1	42	45.7	25	24.4
33	KC1	39	45.7	23	24.5
34	Kens and Chelsea 3 -	126	135.0	49	50.2

	Knightsbridge				
35	Marylebone Road	164	139.5	56	51.2
36	Redbridge 1 - Perth Terrace	38	35.0	21	20.9
37	Richmond 1 - Castlenau	51	56.9	25	27.5
38	Southwark1	45	53.4	25	26.8
39	Southwark2	83	85.3	35	35.7
40	Teddington	23	30.1	15	19.0
41	Tower Hamlets 1	36	40.4	22	22.6
42	Tower Hamlets 2	95	80.4	35	34.3
43	Tower Hamlets 3 - Bethnal Green	37	42.8	23	23.4
44	WalthamF1	37	38.8	21	22.3
45	Wandsworth4	59	84.6	27	35.1
46	West London	48	44.6	29	24.2
47	Westminster - AURN	43	49.4	26	25.8

**Table 9** All Site Average NO<sub>x</sub> and NO<sub>2</sub> (ppb)

	Predicted Average	Measured Average	Average difference (measured - predicted)	Standard Deviation (measured - predicted)
NO <sub>x</sub>	58.99	58.64	-0.36	12.30
NO <sub>2</sub>	27.93	26.64	-1.29	3.18

## Appendix D

### Emissions from Road Transport

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#### Major Road Flows

Recent traffic counts for 2005 were obtained from the Department for Transport (DfT) and Surrey County Council for the identified roads in Runnymede. The DfT counts were undertaken for 24 hours.

#### Vehicle Classification, Age and Speed

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The vehicle classification used for the roads was based on the vehicle split provided in the traffic counts undertaken. The breakdown of vehicle ages was based on the national model.

The following road links include the A318 High Street and New Haw Road, Station Road, Church Road in Addlestone, plus A318 New Haw Road and Byfleet Road, Woodham Road in New Haw.

**Table 10** 2005 Traffic flows used in this assessment

Street	Road	M/C	CAR	BUS	LGV	HGVR2	HGVR3	HGVR4	HGVA3	HGVA5	HGVA6
New Haw Road/ High Street	A318	209	16254	90	2530	199	25	42	8	8	8
Byfleet Road	A318	185	14359	80	2235	176	22	37	7	7	7
Woodham Road	B385	122	9494	53	1478	116	15	25	5	5	5
Station Road	B3121	173	13432	74	2091	164	21	35	7	7	7
Church Road	B3121	91	4178	65	471	375	40	57	30	43	27
Garfield Rd/ Crockford Rd		62	4850	27	755	59	7	13	2	2	2

(Note: HGVR – rigid HGVs; HGVA – articulated HGVs)

Average vehicle speeds were assessed from previous discussions with the Council, visits to the site and speeds in the LAEI, which are derived from the DfT Moving Car Observer surveys. These were estimated at 30kph in the town centre. For the sections of the links near the High Street and Station Road junction, an average speed of 16kph was assumed.

## Appendix E

### Model Uncertainty Assessment

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**Note:** This appendix contains extracts of a report written on behalf of the former Department of Environment, Transport and the Regions (DETR), entitled: *Estimating the Uncertainty of Model Predictions using a Monte Carlo Simulation*. Please note that although the DETR report addresses modelling in London, the same principles apply to the Council's report, as a similar methodology was used.

Predictions of the concentration of NO<sub>2</sub> at roadsides have shown a high sensitivity to the pass/fail standard of 40 µg m<sup>-3</sup> (21 ppb). 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<sub>2</sub> 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 used 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<sub>x</sub> 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<sub>2</sub>, the NO<sub>x</sub>-NO<sub>2</sub> relationship used is the most important factor. Table 11 below shows how each input data or modelling method affects the final concentration, for the Marylebone Road example.

**Table 11** The Relative Importance of Model Parameters in Predicting NO<sub>2</sub> at Marylebone Road

Model Parameter	Relative Importance 2005 (% of mean at 2σ)	Relative Importance 1997 (% of mean at 2σ)
NO <sub>x</sub> -NO <sub>2</sub> 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<sub>x</sub> was predicted to be 258 +/- 83 ppb and NO<sub>2</sub> 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<sub>2</sub>, which corresponds to 22 %, is less than that for NO<sub>x</sub> (32 %). This feature is a result of the non-linear NO<sub>2</sub> relationship, which is quite insensitive to NO<sub>x</sub> concentrations, implying that a stated NO<sub>x</sub> uncertainty is a better indication of the quality of a prediction.

Measurements for the Marylebone Road site for NO<sub>x</sub> and NO<sub>2</sub> are within the uncertainty limits calculated here. NO<sub>x</sub> was between 213 and 229 ppb and NO<sub>2</sub> between 44 and 48 ppb for 1997. The range reflects the two different monitoring techniques used at the Marylebone site.

Similarly, for 2005, NO<sub>x</sub> is estimated to be 117 +/- 35 ppb and NO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> concentrations depend most on the NO<sub>x</sub>-NO<sub>2</sub> 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 12. 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 12** NO<sub>2</sub> Uncertainty Estimates for Typical Roads 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<sub>2</sub> predictions is therefore +/- 16-21 % at two standard deviations.*

**APPENDIX F****Monthly NO<sub>2</sub> diffusion tube measurements**

All results are unbiased and expressed in  $\mu\text{g m}^{-3}$ .

**Table 13** Monthly monitoring results for Station Road, Addlestone and New Haw Road (2002 to 2006)

Site ref	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1	2002		40.1	28.7	32.5	22.9	24.8	43.9	21.0	42.0	59.2	42.0	49.7
9	2002	24.8	38.2	22.9	51.6	30.6	24.8	34.4	24.8	38.2	42.0	21.0	55.4
1	2003		59.2	36.3	32.5	21.0	28.7	15.3	24.8	53.5	24.8	55.4	36.3
9	2003	49.7	43.9	55.4	32.5	17.2	22.9	34.4	30.6	22.9	17.2	47.8	68.8
1	2004	29.0	23.0	52.0	74.0	30.0	40.0	35.0	23.0	25.0	18.0	32.0	40.0
9	2004	29.0	49.9	38.0		27.0	48.9	27.0		25.0	21.0	44.0	28.0
1	2005				40.0	24.0	24.0	21.0	15.0	11.0	26.0		
9	2005	43.0	35.0	25.0	37.0	29.0	21.0	33.0	20.0		29.0	31.0	38.0
1	2006	27.0	30.0	21.0			24.0	26.0	20.0	33.0	24.0	45.0	40.0
9	2006	22.0	35.0	25.0	23.0		29.0	10.0	24.0	29.0	38.0	57.0	29.0

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