# Detailed Assessment of Air Quality on the A420 in Warmley for South Gloucestershire Council

September 2014

Experts in air quality management & assessment

# Document Control

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## Contents



**South Gloucestershire Council confirms that it accepts the recommendations made in this report.**

# 1 Introduction

1.1 Air Quality Consultants Ltd has been commissioned by South Gloucestershire Council to undertake a Detailed Assessment of air quality along the A420 in Warmley. In 2012, South Gloucestershire Council completed an Updating and Screening Assessment for air quality, which concluded that a Detailed Assessment was required as a result of a measured exceedence of the nitrogen dioxide annual mean objective on Warmley High Street, Warmley. This conclusion was based on annualised data, however, a full year of monitoring in 2012 confirmed the exceedence.

1.2 The aim of this Detailed Assessment is to determine whether the annual mean nitrogen dioxide objective continues to be exceeded at relevant locations and, if so, the extent of exceedences and thus the boundary of the Air Quality Management Area (AQMA) required.

## Background

1.3 The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Defra, 2007) sets out a framework for air quality management, which includes a number of air quality objectives. National and international measures are expected to achieve these objectives in most locations, but where areas of poor air quality remain, air quality management at a local scale has a particularly important role to play. Part IV of the Environment Act 1995 requires local authorities to periodically review and assess air quality in their areas. The role of this process is to identify areas where it is unlikely that the air quality objectives will be achieved. These locations must be designated as AQMAs and a subsequent Air Quality Action Plan (AQAP) developed in order to reduce pollutant emissions in pursuit of the objectives.

1.4 Technical Guidance for Local Air Quality Management (LAQM.TG(09)) (Defra, 2009) sets out a phased approach to the Review and Assessment process. This prescribes an initial Updating and Screening Assessment (USA), which all local authorities must undertake. It is based on a checklist to identify any matters that have changed since the previous round. If the USA identifies any areas where there is a risk that the objectives may be exceeded, which were not identified in the previous round, then the Local Authority should progress to a Detailed Assessment.

1.5 The purpose of the Detailed Assessment is to determine whether an exceedence of an air quality objective is likely and the geographical extent of that exceedence. If the outcome of the Detailed Assessment is that one or more of the air quality objectives are likely to be exceeded, then an Air Quality Management Area (AQMA) must be declared. Following a Detailed Assessment in 2008, South Gloucestershire Council declared AQMAs in Cribbs Causeway, Kingswood and Staple Hill and has subsequently published an Air Quality Action Plan for Kingswood and Staple Hill. The Kingswood AQMA (Figure 1) is adjacent to the study area for this Detailed Assessment. The information gathered from this Detailed Assessment can be used to inform an Air Quality Action Plan, which will identify measures to improve local air quality.

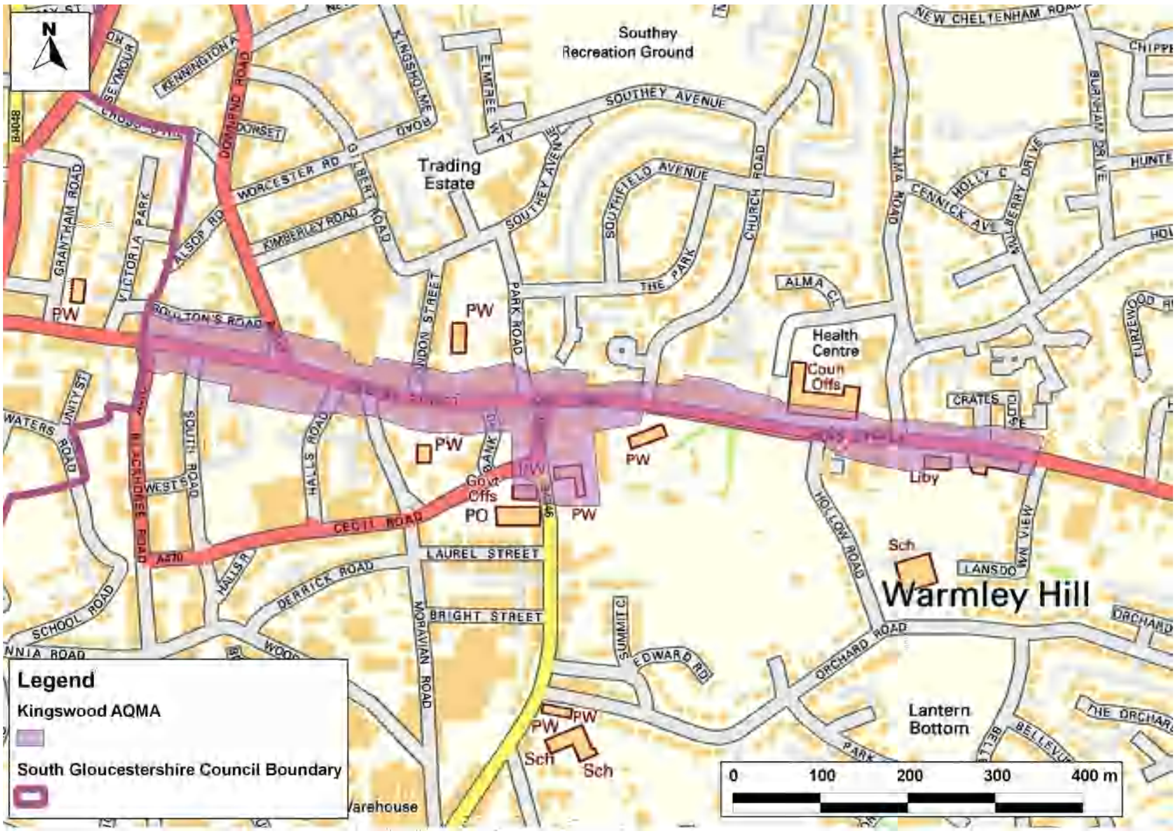


**Figure 1 Kingswood AQMA**



1.6 This report represents a Detailed Assessment following the findings of South Gloucestershire Council's USA published in 2012, which concluded that there was a measured exceedence of the annual mean nitrogen dioxide objective at a location representative of relevant exposure (South Gloucestershire Council, 2012). This conclusion was based on concentrations measured at a diffusion tube monitoring site on High Street, Warmley, where monitoring began in May 2011. South Gloucestershire Council's Progress Report published in 2013 confirmed the findings of the 2012 USA, and the recommendation that a Detailed Assessment be undertaken for the A420 at Warmley (South Gloucestershire Council, 2013). In order to facilitate this, monitoring began at 10 additional diffusion tube locations in 2013.

1.7 South Gloucestershire Council's 2013 Progress Report also identified a proposed biomass boiler at Warmley Park School for which ADMS Screening had indicated potential exceedences of the annual mean and 1 hour mean $NO_2$ objectives. A detailed dispersion modelling assessment was proposed. However, a further ADMS Screen was undertaken by the LAQM Helpdesk as some parameters for the boiler had altered since the initial screening. The outcome of this further screening has confirmed there are no predicted exceedences arising from the boiler operation at locations of worst-impact. The annual mean nitrogen dioxide concentration was estimated as 23.5 µg/m$^3$ (18.48 µg/m$^3$ background plus 5.02 µg/m$^3$ stack contribution) at the worst-case impact location 50m from the stack. With the biomass boiler located over 300m from Warmley High Street, it is not considered that it will have any significant impact on nitrogen dioxide concentrations within the study area so it is not considered further in this Detailed Assessment. Full details of the parameters used in the ADMS Screening are included in the 2014 Progress Report.

## The Air Quality Objectives

1.8 The Government's Air Quality Strategy (Defra, 2007) provides air quality standards and objectives for key air pollutants, which are designed to protect human health and the environment. The 'standards' are set as concentrations below which health effects are unlikely even in sensitive population groups, or below which risks to public health would be exceedingly small. They are based purely upon the scientific and medical evidence of the effects of a particular pollutant. The 'objectives' set out the extent to which the Government expects the standards to be achieved by a certain date. They take account of the costs, benefits, feasibility and practicality of achieving the standards. It also sets out how the different sectors: industry, transport and local government, can contribute to achieving the air quality objectives. The objectives are prescribed within The Air Quality (England) Regulations 2000 (Stationery Office, 2000) and The Air Quality (England) (Amendment) Regulations 2002 (Stationery Office, 2002). Table 1 summarises the objectives which are relevant to this report. Appendix 1 provides a brief summary of the health effects of nitrogen dioxide.

**Table 1: Air Quality Objectives for Nitrogen Dioxide**

| Pollutant | Time Period | Objective |
|---|---|---|
| **Nitrogen Dioxide** | 1-hour mean | 200 µg/m$^3$ not to be exceeded more than 18 times a year |
| | Annual mean | 40 µg/m$^3$ |

1.9 The air quality objectives only apply where members of the public are likely to be regularly present for the averaging time of the objective (i.e. where people will be exposed to pollutants). For annual mean objectives, relevant exposure is limited to residential properties, schools and hospitals. The 1-hour objective applies at these locations as well as at any outdoor location where a member of the public might reasonably be expected to stay for 1 hour or more, such as shopping streets, parks and sports grounds, as well as bus stations and railway stations that are not fully enclosed.

1.10 Measurements across the UK have shown that the 1-hour nitrogen dioxide objective is unlikely to be exceeded unless the annual mean nitrogen dioxide concentration is greater than 60 µg/m$^3$ (Defra, 2009). Thus exceedences of 60 µg/m$^3$ as an annual mean nitrogen dioxide concentration are used as an indicator of potential exceedences of the 1-hour nitrogen dioxide objective.

# 2 Assessment Methodology

## Monitoring

2.1 Monitoring for nitrogen dioxide was carried out by South Gloucestershire Council using one passive diffusion tube site in Warmley in 2011 and 2012 and eleven diffusion tube sites in 2013. The 2013 monitoring sites and study area are shown in Figure 2. Diffusion tubes in 2013 were prepared and analysed by Somerset County Scientific Services using the 20% TEA in water method. It is necessary to adjust diffusion tube data to account for laboratory bias. A national bias adjustment factor for 2013 of 0.90 has been used. This has been taken from the database of national factors provided on the Review and Assessment Helpdesk website (spreadsheet version 03/14). This was based on three studies, one of which was South Gloucestershire Council's study.

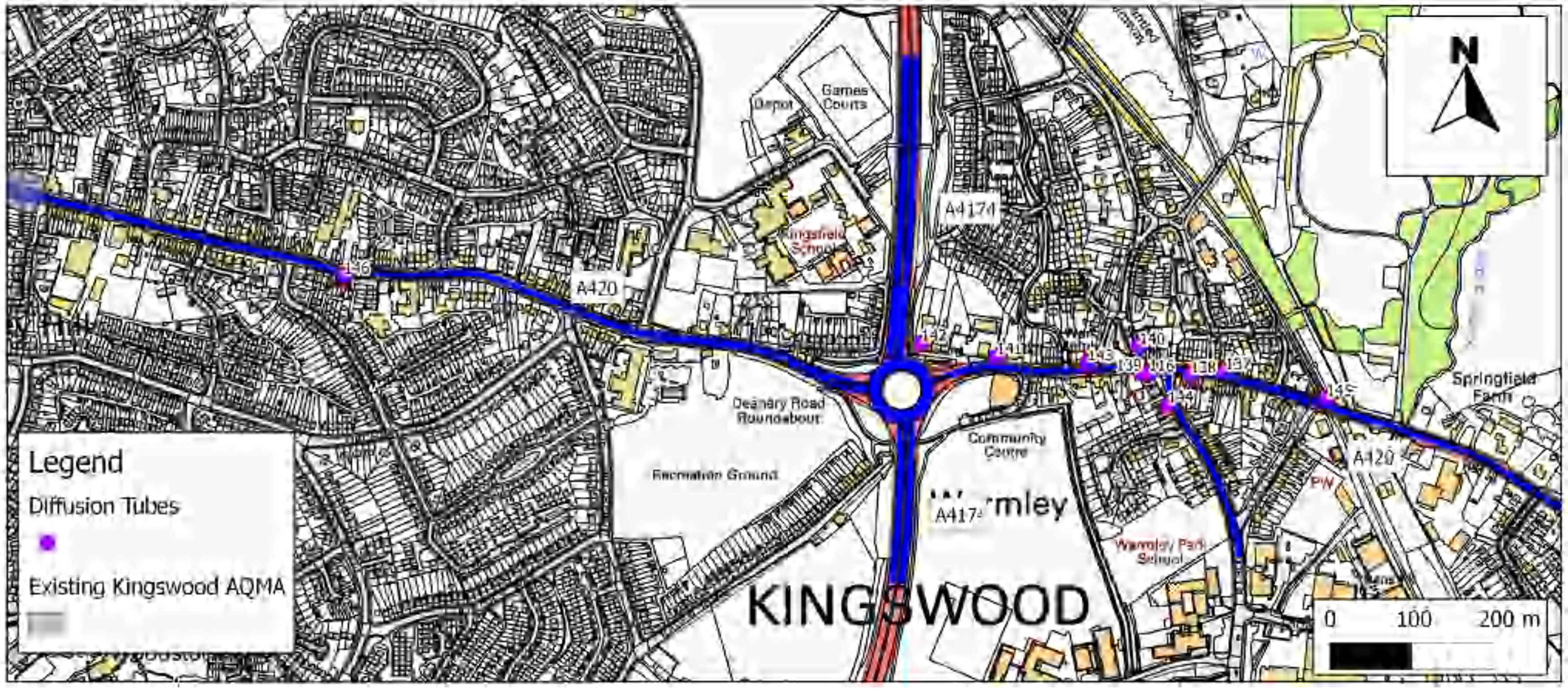


**Figure 2** **Detailed Assessment Study Area, existing AQMA and Monitoring Locations. Roads explicitly included in the model shown in blue.**

## Modelling

2.2 Annual mean nitrogen dioxide concentrations have been predicted using detailed dispersion modelling (ADMS-Roads v3.2). The input data used are described in Appendix 2. The model outputs have been verified against the 2013 monitoring data described in paragraph 2.1. Further details of model verification are also supplied in Appendix 2. Concentrations have been predicted for a grid of receptors across the study area to allow concentration isopleths to be plotted. In addition, concentrations have been predicted at a number of worst-case receptor locations (Figure 3). The worst-case receptors have been modelled at ground floor as this is the worst-case exposure.

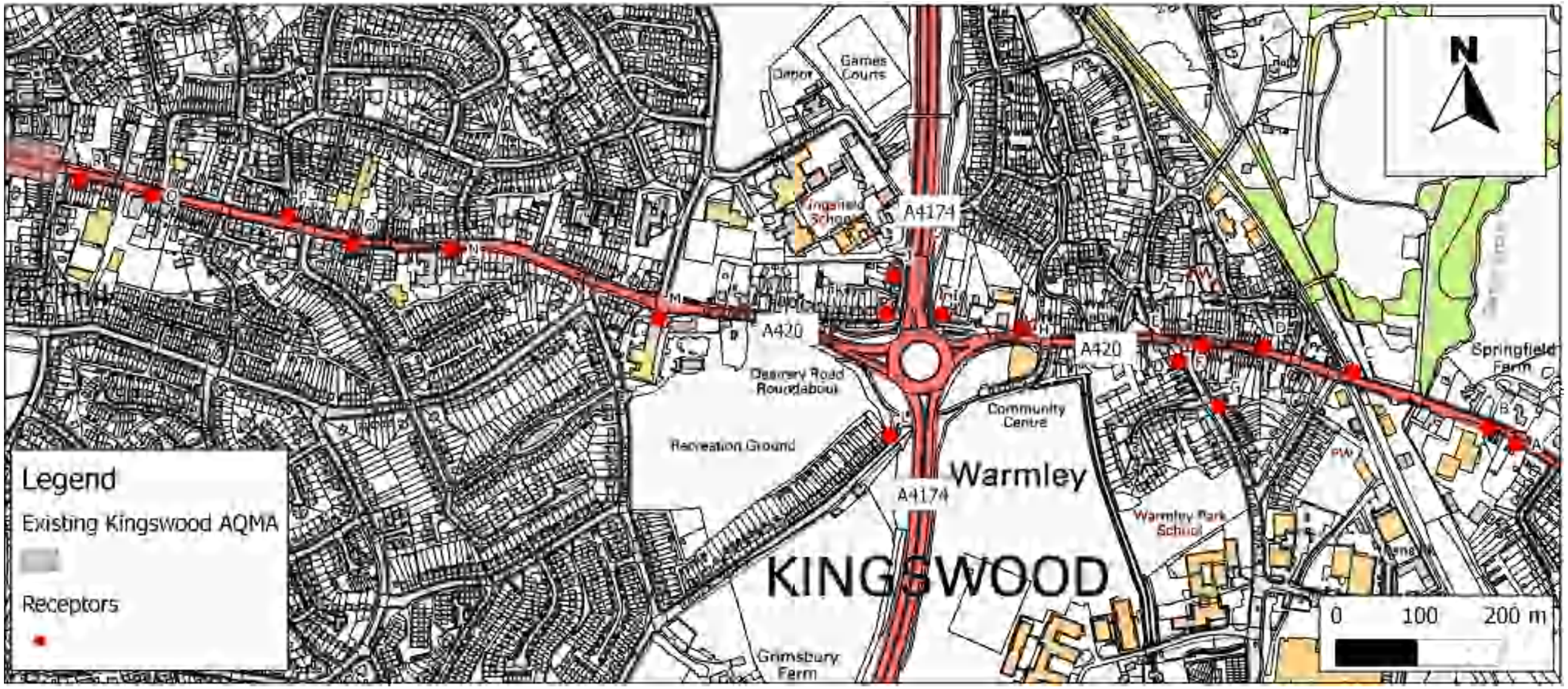


**Figure 3** **Specific Receptor Locations**

## Uncertainty

2.3 Uncertainty is inherent in all measured and modelled data. All values presented in this report are the best possible estimates, but uncertainties in the results might cause over- or under-predictions. All of the measured concentrations presented have an intrinsic margin of error. Defra (2014) suggests that this is of the order of plus or minus 20% for diffusion tube data. The model results rely on traffic data provided by South Gloucestershire Council, and any uncertainties inherent in these data will carry into this assessment. There will be additional uncertainties introduced because the modelling has simplified real-world processes into a series of algorithms. For example: it has been assumed that wind conditions measured at Bristol Airport during 2013 will have occurred throughout the study areas during 2013; and it has been assumed that the dispersion of emitted pollutants will conform to a Gaussian distribution over flat terrain. An important step in the assessment is verifying the dispersion model against the measured data. By comparing the model results with measurements, and correcting for the apparent under-prediction of the model, the uncertainties can be reduced.

2.4 The limitations to the assessment should be borne in mind when considering the results set out in the following sections. While the model should give an overall accurate picture, i.e. one without bias, there will be uncertainties for individual receptors. The results are ‘best estimates’ and have been treated as such in the discussion.

# 3 Results

## Monitoring

3.1 Monitoring data for the sites within the study area (Figure 2) are summarised in Table 2.

**Table 2: Annual Mean Nitrogen Dioxide Concentrations Measured within Warmley (µg/m³)**

| Site | Site Type | Site Description | 2011[a] | 2012[b] | 2013[c] |
|---|---|---|---|---|---|
| **116** | Roadside | Warmley High St Webbs lp | **51.0** | **50.0** | **44.3** |
| **137** | Roadside | Warmley 35 High Street | n/a | n/a | **50.2**[d] |
| **138** | Roadside | Warmley 18 High Street | n/a | n/a | **41.1**[d] |
| **139** | Roadside | Warmley 14 High Street Webbs | n/a | n/a | **43.2**[d] |
| **140** | Roadside | Warmley 2 Stanley Road | n/a | n/a | 26.8[d] |
| **141** | Roadside | Warmley 41 Deanery Rd | n/a | n/a | 37.2[d] |
| **142** | Roadside | Warmley Court façade 33 Deanery Rd | n/a | n/a | 34.2[d] |
| **143** | Roadside | Warmley 1 High St Pharmacy façade | n/a | n/a | 29.3[d] |
| **144** | Roadside | Warmley 8 Tower Road North façade | n/a | n/a | 28.7[d] |
| **145** | Roadside | Warmley 1 London Road/Cycle Path | n/a | n/a | 27.7[e] |
| **146** | Roadside | Kingswood 34 Hill St façade | n/a | n/a | 39.5[f] |
| **Objective** | | | **40** | **40** | **40** |

[a] As reported in South Gloucestershire Council 2012 Updating and Screening Assessment (South Gloucestershire Council, 2012). Data have been bias adjusted by the Council using the Bristol Scientific Services 20% TEA in water national factor (0.83). Monitoring began in May and therefore data have been annualised by the council.

[b] As reported in South Gloucestershire Council's 2013 Progress Report (South Gloucestershire Council, 2013). Data have been bias adjusted by the council using the Somerset Scientific Services, 20% TEA in water national factor (0.95).

[c] Data have been bias adjusted using the Somerset Scientific Services, 20% TEA in water national factor (0.90).

[d] Monitoring began April 2013. The results have been annualised. Details of this annualisation are shown in Appendix 3

[e] Monitoring began June 2013. The results have been annualised. Details of this annualisation are shown in Appendix 3.

[f] Monitoring began Nov 2013. The results have been annualised. Details of this annualisation are shown in Appendix 3.

3.2 The annual mean objective was exceeded at four of the monitoring locations in 2013 (116, 137, 138 and 139) and was close to the objective at an additional two monitoring locations (141 and 146). There are no measured concentrations exceeding 60 µg/m³, and thus exceedences of the 1-hour objective are unlikely.

## Modelling

3.3 Predicted annual mean nitrogen dioxide concentrations in 2013 at each of the receptor locations shown in Figure 3, are set out in Table 3. Predicted concentrations exceed the annual mean objective at Receptors E and I. In addition, concentrations are close to the objective at receptors D, H, K, N, O and Q. The receptors where concentrations are not predicted to exceed or be close to the objective are in locations away from major junctions and where houses are set further from the road.

3.4 The highest modelled annual mean nitrogen dioxide concentration is 44.8 µg/m$^3$, predicted at Receptor I. There are no predicted annual mean concentrations greater than 60 µg/m$^3$, and thus exceedences of the 1-hour objective are unlikely.

**Table 3: Modelled Annual Mean Nitrogen Dioxide Concentrations at Specific Receptors**

| Receptor | Location | 2013 (µg/m$^3$)[a] |
|---|---|---|
| **A** | 22 London Rd, Warmley | 31.5 |
| **B** | 10 London Road, Warmley | 33.0 |
| **C** | 1 London Road, Warmley | 34.2 |
| **D** | 43 High Street, Warmley | 38.6 |
| **E** | 16 High Street, Warmley | **42.5** |
| **F** | 2-4 Tower Road North, Warmley | 31.4 |
| **G** | 11 Tower Road North, Warmley | 29.9 |
| **H** | 43 Deanery Road, Warmley | 40.0 |
| **I** | Warmley Court, 33 Deanery Road, Warmley | **44.8** |
| **J** | 5 Brook Road, Warmley | 33.9 |
| **K** | 31 Deanery Road, Warmley | 36.9 |
| **L** | 99 Baden Road, Kingswood | 30.0 |
| **M** | Springly Court, Kingswood | 30.5 |
| **N** | 50 Hill Street, Kingswood | 39.3 |
| **O** | 30 Hill Street, Kingswood | 36.4 |
| **P** | 49 Hill Street, Kingswood | 34.7 |
| **Q** | 54 High Street, Kingswood | 39.0 |
| **R** | 32 High Street, Kingswood | 31.7 |
| **Objective** | | **40** |

[a] Values in bold are exceedences of the objective.

3.5 Isopleth maps of the modelled annual mean nitrogen dioxide concentrations at ground-floor level are presented in Figures 4, 5 and 6. These show that the annual mean objective is likely to be exceeded alongside the A420 between Station Close in the east and the existing Kingswood AQMA in the west. Although there are parts of this road section where houses are set back from the road and concentrations will not be close to the objective at relevant locations, there are a number of receptors which are located close to the road. The annual mean objective is not likely to be exceeded on Tower Road North close to the junction with the A420.

3.6 The isopleths show the 40 µg/m$^3$ contour in red, as well as the 36 µg/m$^3$ contour in green. There is some uncertainty surrounding both the measured and modelled concentrations. It is therefore recommended that an AQMA is declared to include, as a minimum, those residential properties which lie within the 36 µg/m$^3$ contour, in order to be precautionary.

3.7 No exceedences of 60 µg/m$^3$ as an annual mean nitrogen dioxide concentration have been identified at locations of relevant exposure, and thus exceedences of the 1-hour objective are unlikely.

3.8 The area of exceedence does not extend beyond the study area to the east and receptors to the east of the study area are set further from the road than those within the study area. Therefore there can be confidence that the relevant areas of exceedence have been identified.

### *Population Exposure*

3.9 Objective exceedences are predicted at approximately 40 residential properties. Assuming that each property has on average two occupants, this equates to approximately 80 residents.

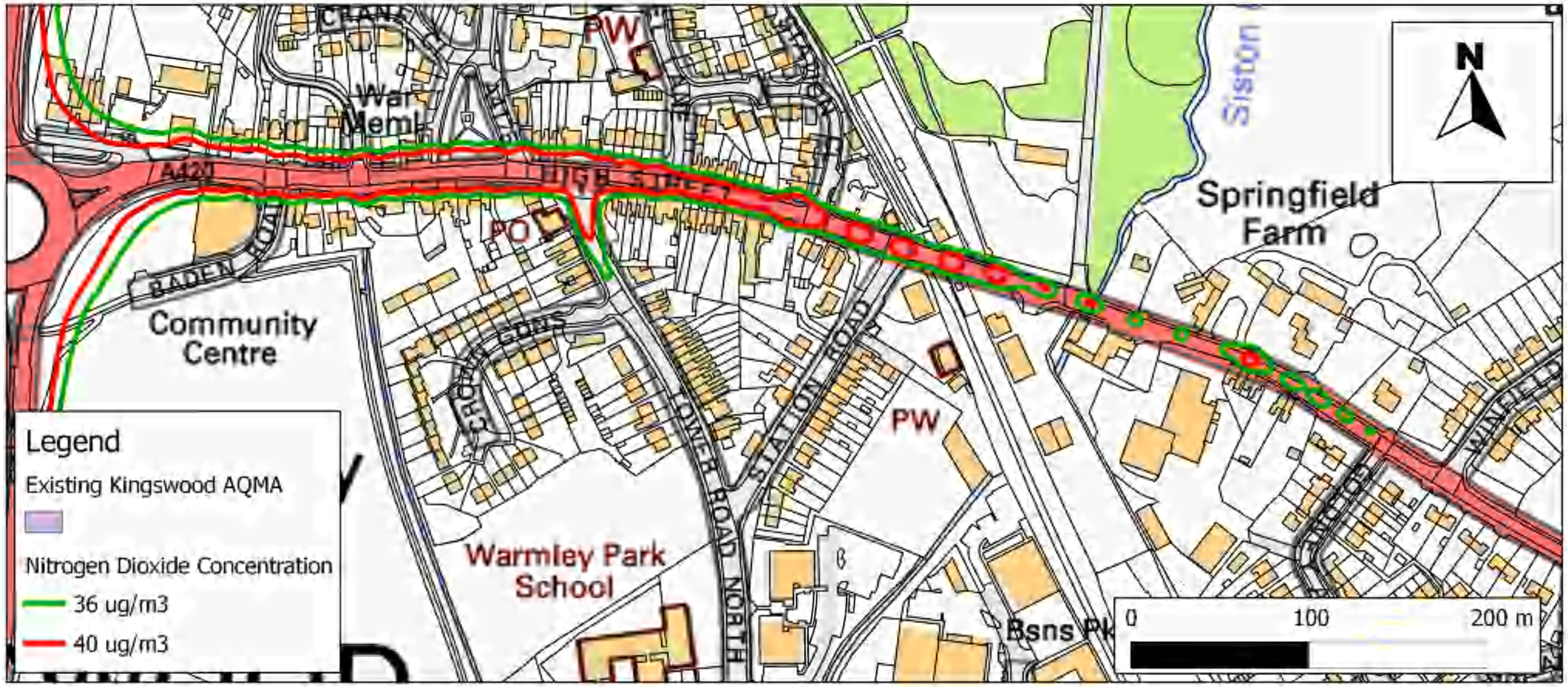


**Figure 4** **Extent of the Modelled 40μg/m³ Contour (red line) and 36 μg/m³ Contour (green line) of Annual Mean Nitrogen Dioxide Concentrations in 2013 (modelled at 1.5 m) on the A420 between the A4174 Ring Road and Goldney Avenue, Warmley**

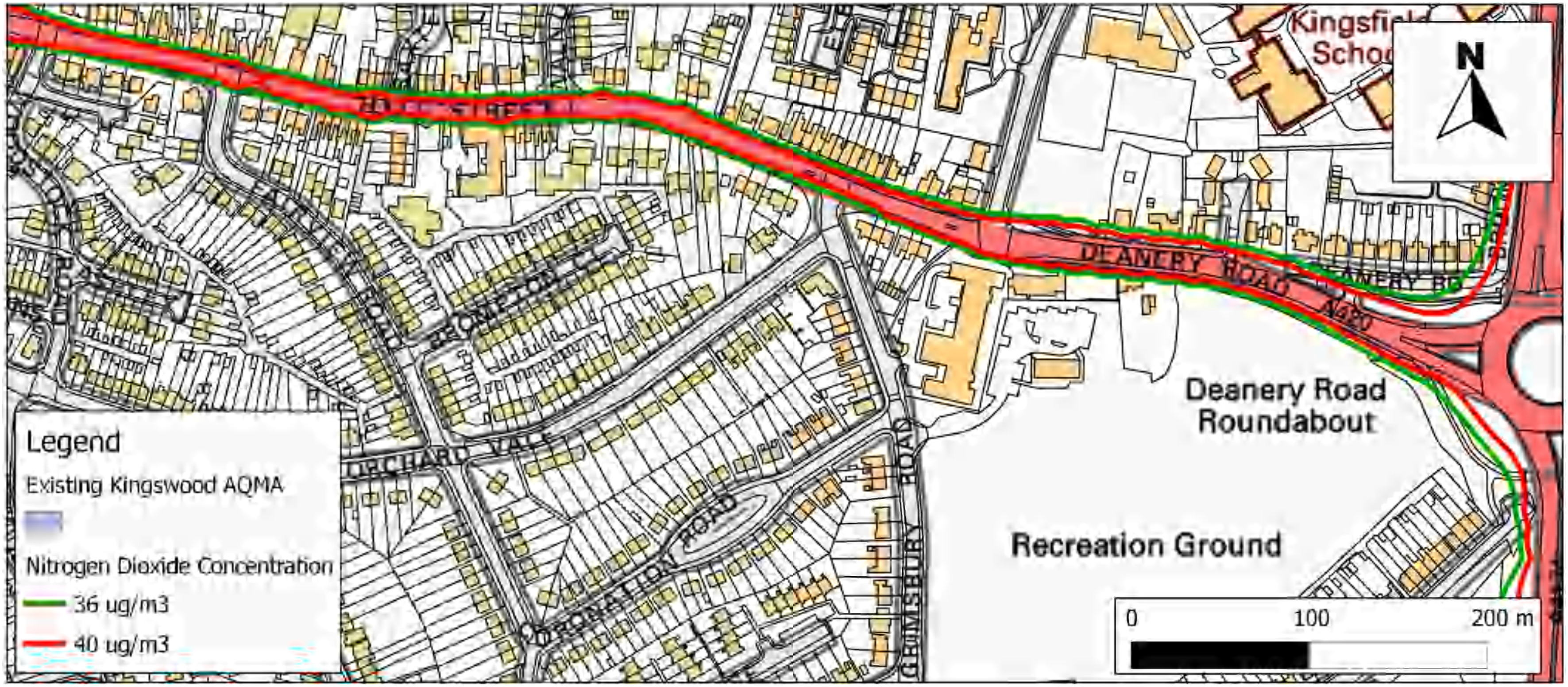


**Figure 5** **Extent of the Modelled 40µg/m³ Contour (red line) and 36 µg/m³ Contour (green line) of Annual Mean Nitrogen Dioxide Concentrations in 2013 (modelled at 1.5 m) on the A420 between the A4174 Ring Road and Walnut Lane, Kingswood**

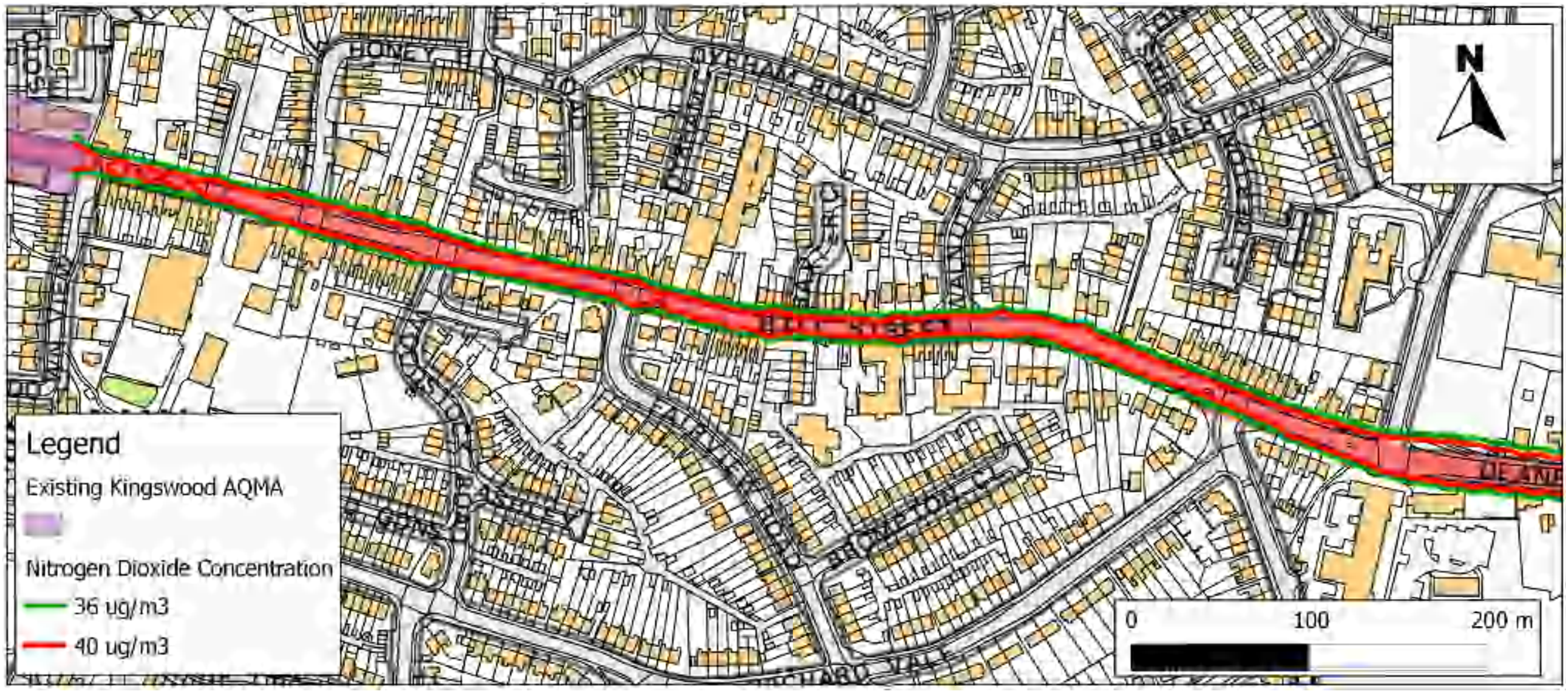


**Figure 6** **Extent of the Modelled 40μg/m³ Contour (red line) and 36 μg/m³ Contour (green line) of Annual Mean Nitrogen Dioxide Concentrations in 2013 (modelled at 1.5 m) on the A420 between Walnut Lane and the existing Kingswood AQMA**

### *Source Apportionment*

3.10 Source apportioned nitrogen dioxide concentrations have been calculated taking account of the different proportions of primary nitrogen dioxide (f-$NO_2$) emitted by different vehicle types. The methodology used is explained in Appendix 2. Table 4 sets out the contributions of different vehicle types to total annual mean nitrogen dioxide concentrations at each receptor, whilst Table 5 sets out the proportion of the total that can be attributed to each vehicle type.

3.11 The largest single contribution to total concentrations at each receptor is the local background, followed by car emissions. The local background concentrations are made up of emissions from a number of sources (such as road traffic, domestic boilers and industrial activities) which are individually either too small or too far from the study area for it to be practical to include in modelling. The background concentrations across the study area have been defined using the national pollution maps published by Defra (2014a). These cover the whole country on a 1x1 km grid and have been used to calculate the relative proportions of regional and local background. Further details of this calculation are provided in Appendix 2.

3.12 In terms of local traffic, cars make the largest contribution, followed by HGVs and then LGVs at most receptors, whilst at receptors G, H and N to R the largest contribution is made by cars followed by LGVs and then HGVs. Figure 7 shows the proportions of nitrogen dioxide from each source.

Table 4: Predicted Annual Mean Nitrogen Dioxide Contributions from Each Source

| Receptor | Annual Mean Concentration (µg/m$^3$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Regional Background | Local Background | Bus | Car | HGV | LGV | Motorbike | Total |
| A | 4.6 | 15.0 | 1.3 | 4.7 | 3.0 | 3.0 | 0.0 | 31.5 |
| **B** | 4.6 | 15.0 | 1.5 | 5.3 | 3.4 | 3.3 | 0.0 | 33.0 |
| **C** | 4.6 | 15.0 | 1.7 | 5.6 | 4.0 | 3.4 | 0.0 | 34.2 |
| **D** | 4.6 | 15.0 | 2.2 | 7.4 | 5.0 | 4.5 | 0.0 | 38.6 |
| **E** | 4.6 | 15.0 | 2.4 | 9.3 | 5.8 | 5.5 | 0.0 | **42.5** |
| **F** | 4.6 | 15.0 | 1.2 | 5.1 | 2.9 | 2.6 | 0.0 | 31.4 |
| **G** | 4.6 | 15.0 | 1.0 | 4.7 | 2.3 | 2.4 | 0.0 | 29.9 |
| **H** | 4.6 | 15.0 | 1.5 | 10.8 | 3.4 | 4.7 | 0.1 | 40.0 |
| **I** | 4.6 | 15.0 | 1.0 | 13.0 | 5.7 | 5.5 | 0.1 | **44.8** |
| **J** | 4.6 | 15.0 | 0.6 | 7.5 | 3.3 | 3.0 | 0.0 | 33.9 |
| **K** | 4.6 | 15.0 | 0.8 | 8.8 | 4.2 | 3.7 | 0.0 | 36.9 |
| **L** | 4.6 | 15.0 | 0.4 | 6.0 | 2.3 | 1.8 | 0.0 | 30.0 |
| **M** | 4.6 | 15.0 | 1.2 | 4.9 | 2.5 | 2.4 | 0.0 | 30.5 |
| **N** | 4.6 | 15.0 | 3.1 | 9.2 | 3.1 | 4.5 | 0.0 | 39.3 |
| **O** | 4.6 | 15.0 | 2.7 | 7.7 | 2.7 | 3.8 | 0.0 | 36.4 |
| **P** | 4.6 | 15.0 | 2.4 | 7.0 | 2.4 | 3.4 | 0.0 | 34.7 |
| **Q** | 4.6 | 15.0 | 3.0 | 9.0 | 3.1 | 4.4 | 0.0 | 39.0 |
| **R** | 4.6 | 15.0 | 1.4 | 6.2 | 1.6 | 3.0 | 0.0 | 31.7 |

**Table 5: Contributions of Each Source as a Percentage of the Total**

| Receptor | % Contribution to Total | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Regional Background | Local Background | Bus | Car | HGV | LGV | Motorbike | Total |
| A | 14.4% | 47.4% | 4.2% | 15.0% | 9.6% | 9.4% | 0.1% | 100% |
| B | 13.8% | 45.3% | 4.4% | 16.2% | 10.2% | 10.1% | 0.0% | 100% |
| C | 13.3% | 43.7% | 5.0% | 16.4% | 11.6% | 10.0% | 0.0% | 100% |
| D | 11.8% | 38.7% | 5.6% | 19.2% | 13.1% | 11.7% | 0.1% | 100% |
| E | 10.7% | 35.1% | 5.7% | 21.9% | 13.6% | 12.9% | 0.1% | 100% |
| F | 14.5% | 47.6% | 3.8% | 16.3% | 9.4% | 8.4% | 0.1% | 100% |
| G | 15.2% | 50.0% | 3.2% | 15.9% | 7.7% | 8.0% | 0.1% | 100% |
| H | 11.4% | 37.4% | 3.6% | 27.1% | 8.6% | 11.8% | 0.1% | 100% |
| I | 10.1% | 33.3% | 2.2% | 29.1% | 12.8% | 12.2% | 0.1% | 100% |
| J | 13.4% | 44.1% | 1.7% | 22.2% | 9.7% | 8.8% | 0.1% | 100% |
| K | 12.3% | 40.5% | 2.1% | 23.7% | 11.3% | 10.0% | 0.1% | 100% |
| L | 15.1% | 49.8% | 1.3% | 20.0% | 7.5% | 6.2% | 0.1% | 100% |
| M | 14.9% | 49.1% | 3.8% | 16.1% | 8.2% | 7.8% | 0.1% | 100% |
| N | 11.6% | 38.0% | 7.8% | 23.3% | 7.9% | 11.4% | 0.1% | 100% |
| O | 12.5% | 41.1% | 7.3% | 21.3% | 7.4% | 10.4% | 0.1% | 100% |
| P | 13.1% | 43.0% | 7.0% | 20.1% | 7.0% | 9.7% | 0.1% | 100% |
| Q | 11.6% | 38.3% | 7.7% | 23.1% | 8.0% | 11.2% | 0.1% | 100% |
| R | 14.3% | 47.1% | 4.6% | 19.5% | 5.0% | 9.4% | 0.1% | 100% |

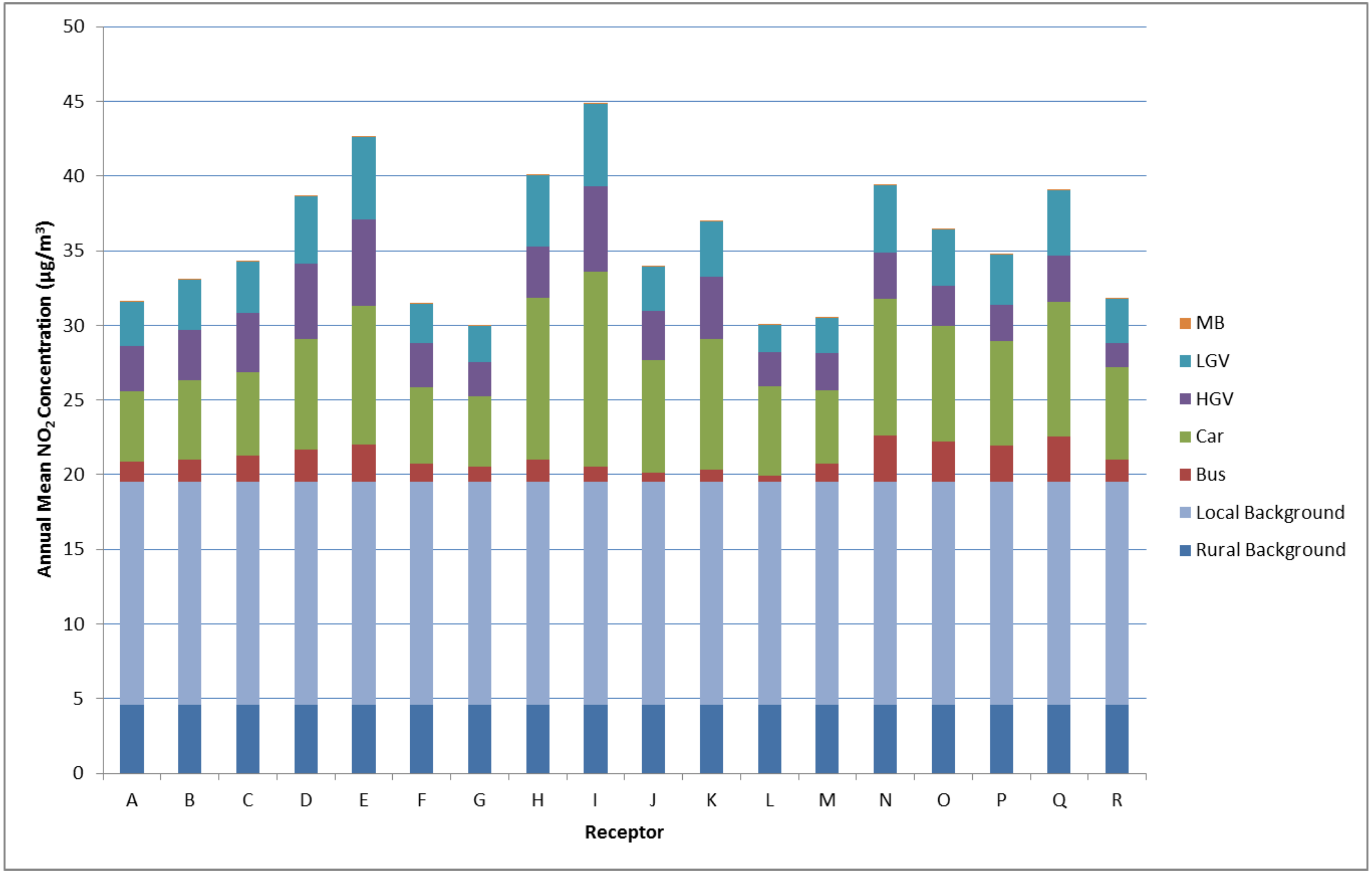


**Figure 7: Contributions of Each Source to the Total Predicted Annual Mean Nitrogen Dioxide Concentration (µg/m$^3$) at each Receptor**

### *Air Quality Improvements Required*

3.13 The degree of improvement needed in order for the annual mean objective for nitrogen dioxide to be achieved is defined by the difference between the highest measured or predicted concentration and the objective level (40 $\mu g/m^3$).

3.14 The highest nitrogen dioxide concentration was predicted at Receptor I (44.8 $\mu g/m^3$), requiring a reduction of 4.8 $\mu g/m^3$ in order for the objective to be achieved. It should be noted that this receptor is located at Warmley Court where annualised diffusion tube monitoring suggests that concentrations are below the objective. This discrepancy is due to the measured results being annualised as well as there being a difference in location between the diffusion tube and modelled receptor which therefore means that they are not directly comparable. The predicted concentration is worst case.

3.15 The highest nitrogen dioxide concentration measured in 2013 was at the 35 High Street diffusion tube monitoring site (Site 137). The concentration measured at this site was 50.2 $\mu g/m^3$, therefore potentially requiring a reduction of 10.2 $\mu g/m^3$ in order for the objective to be achieved. There are, however, uncertainties associated with this measurement which indicates a significantly higher concentration than would be expected in this location. Concentrations measured at 35 High Street are also higher than concentrations measured at other locations that are deemed as representing worst-case exposure. It has not been possible to identify whether this is the result of a fault with the monitoring, an additional local source of nitrogen dioxide (other than road traffic), or a complicating factor such as vehicles idling for long periods of time adjacent to the diffusion tube site. As we have not been able to justify these high concentrations, limited reliance should be placed on the outputs that are based on them which includes the calculation of the reductions in nitrogen dioxide concentrations required to meet the objective at this location.

3.16 In terms of describing the reduction in emissions required, it is more useful to consider nitrogen oxides (NOx). The required reduction in local nitrogen oxides emissions has been calculated in line with guidance presented in LAQM.TG(09) (Defra, 2009). Table 6 sets out the required reduction in local emissions of NOx that would be required at each of the Receptors where an exceedence was predicted in 2013, in order for the annual mean objective to have been achieved. At Receptor I, local emissions would need to have been 22.0% lower in order to meet the objective. At the 35 High Street diffusion tube site, concentrations would need to be 37.8% lower in order to meet the objective.

**Table 6: Improvement in Annual Mean Nitrogen Dioxide Concentrations and in Emissions of Oxides of Nitrogen at Receptors within Warmley in 2013.**

| Receptor | Required reduction in annual mean nitrogen dioxide concentration (µg/m$^3$) | Required Road NOx (µg/m$^3$) [a] | Current Road NOx (µg/m$^3$) [a] | Required reduction in emissions of oxides of nitrogen from local roads (%) |
|---|---|---|---|---|
| **E** | 2.53 | 45.12 | 50.57 | 15.5 |
| **I** | 4.81 | 45.12 | 54.8 | 22.0 |
| **35 HighStreet** | 10.20 | 45.12 | 72.54 | 37.8 |

[a] Calculated using a local background of 19.56 (µg/m$^3$) and NOx to $NO_2$ calculator v3.2.

### *Management Planning*

3.17 In order to inform the focus of any pollution reduction measures, a number of simple and hypothetical measures to deliver reductions at each ground-floor receptor have been explored. The measures that have been examined involve stepped reductions in emissions from each of the vehicle categories. It is not within the remit of this report to speculate on how these reductions might be achieved, and the intention is simply to inform future management decisions. Table 7 sets out the results.

**Table 7: Modelled Annual Mean Nitrogen Dioxide Concentration During 2013 Assuming Hypothetical Emission Reductions from Different Vehicle Classes.**

| Receptor | Predicted Annual Mean Concentration (µg/m³) and Vehicle Type | | | | | | |
|---|---|---|---|---|---|---|---|
| | Bus | Car | HGV | LGV | MB | Total | Do Nothing |
| **10% Emission Reduction** | | | | | | | |
| **A** | 31.4 | 31.1 | 31.3 | 31.2 | 31.5 | 30.4 | 31.5 |
| **B** | 32.9 | 32.5 | 32.7 | 32.7 | 33.0 | 31.7 | 33.0 |
| **C** | 34.0 | 33.7 | 33.8 | 33.9 | 34.2 | 32.8 | 34.2 |
| **D** | 38.4 | 37.9 | 38.2 | 38.2 | 38.6 | 36.9 | 38.6 |
| **E** | **42.3** | **41.7** | **42.0** | **42.0** | **42.5** | **40.5** | **42.5** |
| **F** | 31.3 | 30.9 | 31.1 | 31.2 | 31.4 | 30.3 | 31.4 |
| **G** | 29.8 | 29.4 | 29.7 | 29.7 | 29.9 | 28.9 | 29.9 |
| **H** | 39.9 | 39.0 | 39.7 | 39.6 | 40.0 | 38.1 | 40.0 |
| **I** | **44.7** | **43.7** | **44.3** | **44.3** | **44.8** | **42.6** | **44.8** |
| **J** | 33.9 | 33.2 | 33.6 | 33.6 | 33.9 | 32.6 | 33.9 |
| **K** | 36.9 | 36.1 | 36.6 | 36.6 | 36.9 | 35.3 | 36.9 |
| **L** | 30.0 | 29.4 | 29.8 | 29.8 | 30.0 | 29.0 | 30.0 |
| **M** | 30.4 | 30.0 | 30.2 | 30.2 | 30.5 | 29.4 | 30.5 |
| **N** | 39.1 | 38.5 | 39.0 | 38.9 | 39.3 | 37.5 | 39.3 |
| **O** | 36.1 | 35.7 | 36.1 | 36.0 | 36.4 | 34.8 | 36.4 |
| **P** | 34.5 | 34.1 | 34.5 | 34.4 | 34.7 | 33.3 | 34.7 |
| **Q** | 38.7 | 38.2 | 38.7 | 38.6 | 39.0 | 37.2 | 39.0 |
| **R** | 31.6 | 31.1 | 31.6 | 31.4 | 31.7 | 30.6 | 31.7 |
| **25% Emission Reduction** | | | | | | | |
| **A** | 31.2 | 30.4 | 30.8 | 30.8 | 31.5 | 28.6 | 31.5 |
| **B** | 32.7 | 31.7 | 32.2 | 32.2 | 33.0 | 29.8 | 33.0 |
| **C** | 33.8 | 32.9 | 33.3 | 33.4 | 34.2 | 30.7 | 34.2 |
| **D** | 38.1 | 36.9 | 37.5 | 37.6 | 38.6 | 34.2 | 38.6 |
| **E** | **42.0** | **40.5** | **41.3** | **41.3** | **42.5** | 37.3 | **42.5** |
| **F** | 31.1 | 30.2 | 30.7 | 30.8 | 31.4 | 28.6 | 31.4 |
| **G** | 29.7 | 28.8 | 29.4 | 29.3 | 29.9 | 27.4 | 29.9 |
| **H** | 39.7 | 37.5 | 39.2 | 38.9 | 40.0 | 35.2 | 40.0 |
| **I** | **44.6** | **41.9** | **43.6** | **43.6** | **44.8** | 39.1 | **44.8** |

| Receptor | Predicted Annual Mean Concentration (µg/m$^3$) and Vehicle Type | | | | | | |
|---|---|---|---|---|---|---|---|
| | Bus | Car | HGV | LGV | MB | Total | Do Nothing |
| J | 33.8 | 32.2 | 33.2 | 33.2 | 33.9 | 30.5 | 33.9 |
| K | 36.7 | 34.9 | 36.0 | 36.1 | 36.9 | 32.8 | 36.9 |
| L | 29.9 | 28.6 | 29.5 | 29.6 | 30.0 | 27.5 | 30.0 |
| M | 30.2 | 29.3 | 29.9 | 29.9 | 30.5 | 27.8 | 30.5 |
| N | 38.6 | 37.2 | 38.6 | 38.3 | 39.3 | 34.7 | 39.3 |
| O | 35.8 | 34.6 | 35.8 | 35.5 | 36.4 | 32.4 | 36.4 |
| P | 34.2 | 33.1 | 34.2 | 33.9 | 34.7 | 31.1 | 34.7 |
| Q | 38.3 | 37.0 | 38.3 | 38.0 | 39.0 | 34.5 | 39.0 |
| R | 31.4 | 30.3 | 31.3 | 31.0 | 31.7 | 28.8 | 31.7 |
| **50% Emission Reduction** | | | | | | | |
| A | 30.9 | 29.3 | 30.1 | 30.1 | 31.5 | 25.7 | 31.5 |
| B | 32.3 | 30.5 | 31.4 | 31.4 | 33.0 | 26.5 | 33.0 |
| C | 33.4 | 31.6 | 32.4 | 32.6 | 34.2 | 27.1 | 34.2 |
| D | 37.6 | 35.2 | 36.3 | 36.5 | 38.6 | 29.5 | 38.6 |
| E | **41.4** | 38.4 | 40.0 | 40.0 | **42.5** | 31.7 | **42.5** |
| F | 30.8 | 29.0 | 30.0 | 30.1 | 31.4 | 25.6 | 31.4 |
| G | 29.4 | 27.6 | 28.8 | 28.7 | 29.9 | 24.8 | 29.9 |
| H | 39.3 | 35.0 | 38.4 | 37.8 | 40.0 | 30.2 | 40.0 |
| I | **44.4** | 39.0 | **42.3** | **42.3** | **44.8** | 33.0 | **44.8** |
| J | 33.6 | 30.4 | 32.4 | 32.5 | 33.9 | 26.9 | 33.9 |
| K | 36.6 | 32.8 | 35.0 | 35.2 | 36.9 | 28.6 | 36.9 |
| L | 29.8 | 27.1 | 28.9 | 29.1 | 30.0 | 24.9 | 30.0 |
| M | 29.9 | 28.1 | 29.3 | 29.3 | 30.4 | 25.1 | 30.5 |
| N | 37.9 | 35.1 | 37.9 | 37.2 | 39.3 | 29.9 | 39.3 |
| O | 35.1 | 32.8 | 35.1 | 34.6 | 36.4 | 28.3 | 36.4 |
| P | 33.6 | 31.5 | 33.6 | 33.1 | 34.7 | 27.4 | 34.7 |
| Q | 37.6 | 34.9 | 37.6 | 37.0 | 39.0 | 29.7 | 39.0 |
| R | 31.0 | 28.8 | 31.0 | 30.3 | 31.7 | 25.8 | 31.7 |

# 4 Recommendations

4.1 Based on both the monitoring results and the air quality modelling carried out as part of this Detailed Assessment, it is recommended that the existing Kingswood AQMA be amended to extend eastwards along the A420 through Kingswood and Warmley as far as Goldney Avenue. The additional area to be included in the AQMA is shown in Figure 8.


**Figure 8 Extent of existing Kingswood AQMA and Proposed AQMA**

# 5 Conclusions

5.1 A Detailed Assessment has been carried out for nitrogen dioxide within Warmley. This area was identified as being at risk of exceeding the annual mean air quality objective for nitrogen dioxide in South Gloucestershire Council's 2012 USA.

5.2 The Detailed Assessment has been carried out using a combination of monitoring data and modelled concentrations. Concentrations of nitrogen dioxide have been modelled for 2013 using the ADMS-Roads dispersion model. The model has been verified against measurements made at the ten nitrogen dioxide diffusion tube monitoring locations which lie adjacent to the road network included in the model.

5.3 The assessment has identified that the annual mean nitrogen dioxide objective is being exceeded at a number of relevant locations alongside the A420 in Kingswood (east of the AQMA) and Warmley. No exceedences of 60 $\mu g/m^3$ as an annual mean nitrogen dioxide concentration have been identified at locations of relevant exposure, and thus exceedences of the 1-hour objective are unlikely.

5.4 There is some uncertainty surrounding both the measured and modelled concentrations. It is therefore recommended that the Kingswood AQMA be extended eastwards along the A420 as far as Goldney Avenue, Warmley, and includes, as a minimum, those residential properties that lie within the 36 $\mu g/m^3$ contour to be precautionary.

5.5 It is also recommended that South Gloucestershire Council continues monitoring nitrogen dioxide at the existing monitoring locations.

5.6 Source apportionment of the local traffic emissions has been undertaken. This shows that ambient background concentrations contribute the largest proportion to the overall concentration, followed by emissions from cars on the local roads.

# 6 References

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Stationery Office, 2002. Air Quality (England) (Amendment) Regulations, 2002, Statutory Instrument 3043.

# 7 Glossary

| | |
|---|---|
| **Standards** | A nationally defined set of concentrations for nine pollutants below which health effects do not occur or are minimal. |
| **Objectives** | A nationally defined set of health-based concentrations for nine pollutants, seven of which are incorporated in Regulations, setting out the extent to which the standards should be achieved by a defined date, taking into account costs, benefits, feasibility and practicality. There are also vegetation-based objectives for sulphur dioxide and nitrogen oxides. |
| **Exceedence** | A period of time where the concentration of a pollutant is greater than the appropriate air quality objective. |
| **AQMA** | Air Quality Management Area |
| **ADMS Roads** | Atmospheric Dispersion Modelling System for Roads. |
| **$NO_X$** | Nitrogen oxides (taken as NO + $NO_2$) |
| **NO** | Nitric Oxide |
| **$NO_2$** | Nitrogen dioxide. |
| **$\mu g/m^3$** | Microgrammes per cubic metre. |
| **Roadside** | A site sampling between 1 m of the kerbside of a busy road and the back of the pavement. Typically this will be within 5 m of the road, but could be up to 15 m (Defra, 2009). |
| **HGV** | Heavy Goods Vehicle |
| **LGV** | Light Goods Vehicle |
| **MB** | Motorcycles |
| **AADT** | Annual Average Daily Traffic flows |

# A1 Appendix 1 – Summary of Health Effects of Nitrogen Dioxide

**Table A1.1: Summary of Health Effects of Nitrogen Dioxide**

| Pollutant | Main Health Effects |
|---|---|
| Nitrogen Dioxide | Short-term exposure to high concentrations may cause inflammation of respiratory airways. Long term exposure may affect lung function and enhance responses to allergens in sensitised individuals. Asthmatics will be particularly at risk (Defra, 2007). |

# A2 Appendix 2 – Dispersion Modelling Methodology

**Meteorological Data**

A2.1 The model has been run using a full year of meteorological data for 2013 from the meteorological station near Bristol Airport.

**Background Concentrations:**

A2.2 Background concentrations of nitrogen dioxide have been taken from the national maps of background concentrations published by Defra (Defra, 2014). In addition, the local background concentration has been calculated following the methodology outlined in Box 7.1 of LAQM.TG(09). The background concentrations used in the modelling are presented in Table A2.1.

**Table A2.1: Background Concentrations in 2013 (µg/m$^3$)**

| | NOx | $NO_2$ |
|---|---|---|
| **Total Background** | 29.3 | 19.6 |
| **Regional Background** | 6.8 | 4.6 |
| **Local Background** | 22.5 | 15.0 |

**Traffic Data**

A2.3 The ADMS Roads model requires the user to provide various input data, including the Annual Average Daily Traffic (AADT) flow, the proportion of buses, cars, HGVs, LGVs and motorcycles, the road characteristics (including road width and street canyon height, where applicable), and the vehicle speed.

A2.4 Traffic data including the flows split into a number of vehicle classes were provided by the Council. The traffic flows for the A420 at Alma Road were provided as 24 hour counts for a single day in 2013, these were adjusted to AADT using annual counts for further west on the A420 which were provided by the council. Traffic flows for Deanery Road roundabout were provided as peak hour flows for 2007, these were converted to 24 hour AADT using a ratio calculated from 24 hour traffic data provided by the Council for the A4174 Ring Road, and national statistics and then adjusted to 2013 using Defra data for the A4174 ring road. The traffic data for the A420 at Tower Road North was provided as a twelve hour average flow for a single day in 2012. This was adjusted using traffic data provided by the council for the A420 east of the study area. Traffic speeds have been estimated from local speed restrictions and take account of the proximity to junctions. The traffic data used in this Detailed Assessment are presented in Table A2.2.

**Table A2.2: Summary of AADT Flows (2013)**

| Road Link | Total | Cars | LGV | HGV | Bus | MB |
|---|---|---|---|---|---|---|
| **A420 W of Tower Rd N** | 19,299 | 14,836 | 3,222 | 800 | 268 | 173 |
| **Tower Rd N** | 8,231 | 6,524 | 1,259 | 276 | 91 | 80 |
| **A420 East** | 11,594 | 8,723 | 2,073 | 526 | 179 | 93 |
| **A420 E of rdbt** | 20,956 | 17,110 | 2,877 | 435 | 193 | 341 |
| **Ring Rd S** | 43,064 | 37,840 | 3,500 | 1,298 | 98 | 328 |
| **Ring Rd N** | 38,918 | 31,586 | 5,045 | 1,645 | 142 | 500 |
| **A420 west of rdbt** | 21,593 | 16,907 | 3,265 | 814 | 193 | 414 |
| **A420 east of Alma Rd** | 15,761 | 12,766 | 2,323 | 305 | 211 | 156 |
| **A420 west of Alma Rd** | 16,426 | 13,196 | 2,432 | 305 | 326 | 167 |

### Emissions Calculations

A2.5 Nitrogen dioxide is predominantly a secondary pollutant and emissions are more conveniently quantified in terms of nitrogen oxides (which is the sum of nitrogen dioxide and nitric oxide). Emissions were calculated for each vehicle class included in the traffic model (cars, LGVs, HGVs, Buses/Coaches and motorbikes) separately using emissions factors published by Defra.

### Inputting Emissions into ADMS

A2.6 Annual average hourly emissions were calculated along with a local diurnal emissions profile. The annual average hourly emissions for each link were input into ADMS-Roads V3.2. The local diurnal emissions profiles were also input into ADMS.

### ADMS Source Geometry

A2.7 Each road link in the traffic model was assigned a real-world geometry using Ordnance Survey Mastermap data.

### Primary $NO_2$

A2.8 Nitrogen dioxide ($NO_2$) was calculated from NOx using Defra's NOx to $NO_2$ calculator. This includes year-specific estimates of the proportion of primary $NO_2$ in NOx emissions (f-$NO_2$) within typical vehicle fleets. The fleet-weighted f-$NO_2$ values in the NOx to $NO_2$ calculator were derived from those in the NAEI and relate to national average fleet composition data. This was used to calculate $NO_2$ to produce the contour plots.

A2.9 In order to take account of the influence of the local fleet composition on f-$NO_2$ values, a disaggregated f-$NO_2$ database (which matches the breakdown of vehicle types available to this assessment – i.e. "cars", "LGV", "HGV", "motorbikes" and "buses") was obtained from the NAEI (Tim Murrells, AEA pers. comm.) (Table A2.3). For each receptor, a weighted-average f-$NO_2$ was calculated (with f-$NO_2$ weighted by the relative contribution of each vehicle class to modelled road-NOx - i.e. total-NOx minus background-NOx). Table A2.4 sets out the receptor-specific f-$NO_2$ values used when calculating total $NO_2$ concentrations without any fleet manipulation. f-$NO_2$ values used for source-apportionment and management planning are described subsequently.

**Table A2.3: Values of f-$NO_2$**

| Year | Bus | Car | HGV | LGV | Motorbike |
|---|---|---|---|---|---|
| **2013** | 0.117 | 0.311 | 0.115 | 0.421 | 0.04 |

**Table A2.4: Receptor-Specific f-$NO_2$ Values Used to Calculate Total $NO_2$ Concentrations Without any Emissions Reduction Measures**

| Receptor | Concentration |
|---|---|
| | 2013 |
| **A** | 0.252 |
| **B** | 0.252 |
| **C** | 0.244 |
| **D** | 0.244 |
| **E** | 0.246 |
| **F** | 0.252 |
| **G** | 0.261 |
| **H** | 0.273 |

| | |
|---|---|
| **I** | 0.263 |
| **J** | 0.266 |
| **K** | 0.262 |
| **L** | 0.269 |
| **M** | 0.255 |
| **N** | 0.256 |
| **O** | 0.256 |
| **P** | 0.256 |
| **Q** | 0.256 |
| **R** | 0.275 |

**Source Apportionment**

A2.10 The model was run for each vehicle type separately. The relative contribution from each source to road-NOx concentrations was thus implicit in the model results. The source apportionment calculation has also taken account of the different proportions of primary $NO_2$ (f-$NO_2$) emitted by different vehicle types, following the method developed for a report on Local Measures for $NO_2$ Hotspots in London (AQC/TRL, 2010). The method relies on removing the NOx contribution from each vehicle type in turn and then recalculating the f-$NO_2$ for the remaining vehicle mix (Table A2.5) and using the NOx to $NO_2$ calculator (Defra 2014) to derive a new $NO_2$ concentration. The difference between this $NO_2$ concentration and the total $NO_2$ concentration derived from the calculator is then assigned to the vehicle type.

**Table A2.5: Receptor-Specific f-$NO_2$ Values Used for Source-Apportionment**

| Receptor | All vehicle Types | All Vehicles Except Listed Vehicle Types | | | | |
|---|---|---|---|---|---|---|
| | | Bus | Car | HGV | LGV | MB |
| **A** | 0.252 | 0.272 | 0.217 | 0.308 | 0.207 | 0.252 |
| **B** | 0.252 | 0.272 | 0.217 | 0.308 | 0.207 | 0.252 |
| **C** | 0.244 | 0.264 | 0.207 | 0.302 | 0.201 | 0.244 |
| **D** | 0.244 | 0.264 | 0.207 | 0.303 | 0.201 | 0.244 |
| **E** | 0.246 | 0.266 | 0.209 | 0.304 | 0.204 | 0.246 |
| **F** | 0.252 | 0.270 | 0.213 | 0.307 | 0.212 | 0.253 |
| **G** | 0.261 | 0.278 | 0.223 | 0.312 | 0.221 | 0.262 |
| **H** | 0.273 | 0.288 | 0.235 | 0.315 | 0.236 | 0.274 |
| **I** | 0.263 | 0.272 | 0.220 | 0.323 | 0.229 | 0.264 |
| **J** | 0.266 | 0.274 | 0.222 | 0.323 | 0.232 | 0.267 |

| Receptor | All vehicle Types | All Vehicles Except Listed Vehicle Types | | | | |
|---|---|---|---|---|---|---|
| | | Bus | Car | HGV | LGV | MB |
| **K** | 0.262 | 0.271 | 0.219 | 0.322 | 0.227 | 0.263 |
| **L** | 0.269 | 0.276 | 0.219 | 0.320 | 0.241 | 0.269 |
| **M** | 0.255 | 0.274 | 0.214 | 0.305 | 0.217 | 0.256 |
| **N** | 0.256 | 0.289 | 0.216 | 0.290 | 0.218 | 0.257 |
| **O** | 0.256 | 0.289 | 0.216 | 0.290 | 0.218 | 0.257 |
| **P** | 0.256 | 0.289 | 0.216 | 0.290 | 0.218 | 0.257 |
| **Q** | 0.256 | 0.288 | 0.216 | 0.291 | 0.218 | 0.257 |
| **R** | 0.275 | 0.301 | 0.242 | 0.305 | 0.236 | 0.276 |

## Management Planning

A2.11 In order to calculate the effect of reducing emissions from each vehicle class, it was assumed that there is a direct relationship between NOx emissions from a vehicle category and f-$NO_2$ from that vehicle category[1]. Receptor-specific f-$NO_2$ was thus recalculated for each emission-reduction scenario and used in the NOx to $NO_2$ calculator to determine total $NO_2$ concentrations. The f-$NO_2$ values used are set out in Table A2.6.

[1] i.e. that emissions reduction measures do not affect vehicle class specific f-$NO_2$ values.

Table A2.6: Values of f-$NO_2$ Used to Calculate the Effect of Hypothetical Emission Reduction Measures

| Receptor | f-$NO_2$ | | | | | |
|---|---|---|---|---|---|---|
| | Bus | Car | HGV | LGV | MB | Total |
| **10% Emission Reduction** | | | | | | |
| A | 0.253 | 0.249 | 0.256 | 0.248 | 0.252 | 0.252 |
| B | 0.253 | 0.249 | 0.256 | 0.248 | 0.252 | 0.252 |
| C | 0.245 | 0.241 | 0.248 | 0.240 | 0.244 | 0.244 |
| D | 0.246 | 0.242 | 0.248 | 0.240 | 0.244 | 0.244 |
| E | 0.248 | 0.244 | 0.250 | 0.243 | 0.246 | 0.246 |
| F | 0.254 | 0.250 | 0.256 | 0.249 | 0.252 | 0.252 |
| G | 0.263 | 0.259 | 0.265 | 0.258 | 0.261 | 0.261 |
| H | 0.274 | 0.271 | 0.276 | 0.270 | 0.273 | 0.273 |
| I | 0.264 | 0.261 | 0.268 | 0.260 | 0.263 | 0.263 |
| J | 0.267 | 0.264 | 0.270 | 0.263 | 0.266 | 0.266 |
| K | 0.263 | 0.260 | 0.267 | 0.259 | 0.262 | 0.262 |
| L | 0.269 | 0.266 | 0.273 | 0.266 | 0.269 | 0.269 |
| M | 0.257 | 0.252 | 0.259 | 0.252 | 0.255 | 0.255 |
| N | 0.259 | 0.254 | 0.259 | 0.253 | 0.256 | 0.256 |
| O | 0.259 | 0.254 | 0.259 | 0.253 | 0.256 | 0.256 |
| P | 0.259 | 0.254 | 0.259 | 0.253 | 0.256 | 0.256 |
| Q | 0.259 | 0.254 | 0.259 | 0.253 | 0.256 | 0.256 |
| R | 0.277 | 0.273 | 0.278 | 0.272 | 0.275 | 0.275 |
| **25% Emission Reduction** | | | | | | |
| A | 0.256 | 0.246 | 0.262 | 0.242 | 0.252 | 0.252 |
| B | 0.256 | 0.246 | 0.262 | 0.242 | 0.252 | 0.252 |
| C | 0.248 | 0.237 | 0.255 | 0.235 | 0.244 | 0.244 |
| D | 0.248 | 0.237 | 0.255 | 0.235 | 0.244 | 0.244 |
| E | 0.251 | 0.240 | 0.257 | 0.237 | 0.246 | 0.246 |
| F | 0.256 | 0.246 | 0.263 | 0.244 | 0.252 | 0.252 |
| G | 0.265 | 0.255 | 0.271 | 0.253 | 0.261 | 0.261 |
| H | 0.276 | 0.267 | 0.281 | 0.265 | 0.273 | 0.273 |
| I | 0.265 | 0.257 | 0.275 | 0.256 | 0.264 | 0.263 |
| J | 0.268 | 0.260 | 0.277 | 0.259 | 0.266 | 0.266 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **K** | 0.264 | 0.256 | 0.274 | 0.255 | 0.263 | 0.262 |
| **L** | 0.270 | 0.262 | 0.279 | 0.263 | 0.269 | 0.269 |
| **M** | 0.259 | 0.248 | 0.265 | 0.247 | 0.255 | 0.255 |
| **N** | 0.263 | 0.250 | 0.264 | 0.248 | 0.257 | 0.256 |
| **O** | 0.263 | 0.250 | 0.264 | 0.248 | 0.257 | 0.256 |
| **P** | 0.263 | 0.250 | 0.264 | 0.248 | 0.257 | 0.256 |
| **Q** | 0.263 | 0.250 | 0.264 | 0.248 | 0.256 | 0.256 |
| **R** | 0.281 | 0.270 | 0.282 | 0.267 | 0.275 | 0.275 |
| **50% Emission Reduction** | | | | | | |
| **A** | 0.261 | 0.238 | 0.275 | 0.232 | 0.252 | 0.252 |
| **B** | 0.261 | 0.238 | 0.275 | 0.232 | 0.252 | 0.252 |
| **C** | 0.253 | 0.229 | 0.268 | 0.225 | 0.244 | 0.244 |
| **D** | 0.253 | 0.230 | 0.268 | 0.225 | 0.244 | 0.244 |
| **E** | 0.255 | 0.232 | 0.270 | 0.227 | 0.246 | 0.246 |
| **F** | 0.261 | 0.237 | 0.275 | 0.234 | 0.252 | 0.252 |
| **G** | 0.269 | 0.247 | 0.283 | 0.243 | 0.261 | 0.261 |
| **H** | 0.280 | 0.260 | 0.291 | 0.256 | 0.273 | 0.273 |
| **I** | 0.267 | 0.249 | 0.288 | 0.248 | 0.264 | 0.263 |
| **J** | 0.270 | 0.251 | 0.290 | 0.251 | 0.267 | 0.266 |
| **K** | 0.267 | 0.247 | 0.287 | 0.247 | 0.263 | 0.262 |
| **L** | 0.272 | 0.253 | 0.291 | 0.256 | 0.269 | 0.269 |
| **M** | 0.264 | 0.240 | 0.276 | 0.238 | 0.255 | 0.255 |
| **N** | 0.271 | 0.242 | 0.271 | 0.239 | 0.257 | 0.256 |
| **O** | 0.271 | 0.242 | 0.271 | 0.239 | 0.257 | 0.256 |
| **P** | 0.271 | 0.242 | 0.271 | 0.239 | 0.257 | 0.256 |
| **Q** | 0.271 | 0.241 | 0.272 | 0.239 | 0.257 | 0.256 |
| **R** | 0.287 | 0.264 | 0.289 | 0.258 | 0.276 | 0.275 |

### Model Verification

A2.12 Most nitrogen dioxide ($NO_2$) is produced in the atmosphere by reaction of nitric oxide (NO) with ozone. It is therefore most appropriate to verify the model in terms of primary pollutant emissions of nitrogen oxides ($NO_X = NO + NO_2$). The model has been run to predict the annual mean road-$NO_X$ concentration during 2013 at ten of the diffusion tube monitoring sites described in Table 2, which lie alongside the roads included in the model. As only two months of data are available for diffusion tube 146, this was excluded from use in the verification process.

A2.13 The model output of road-$NO_X$ (i.e. the component of total $NO_X$ coming from road traffic) has been compared with the 'measured' road-$NO_X$. Measured road-$NO_X$ for the diffusion tube sites was calculated from the measured $NO_2$ concentration and the predicted background $NO_2$ concentration using the $NO_X$ from $NO_2$ calculator available on the LAQM Support website (Defra, 2014).

A2.14 A primary adjustment factor was determined as the slope of the best fit line between the 'measured' road contribution and the model derived road contribution, forced through zero (Figure A2.1). This factor was then applied to the modelled road-$NO_X$ concentration for each receptor to provide adjusted modelled road-$NO_X$ concentrations. The total nitrogen dioxide concentrations were then determined by combining the adjusted modelled road-$NO_X$ concentrations with the predicted background $NO_2$ concentration within the $NO_X$ from $NO_2$ calculator. A secondary adjustment factor was finally calculated as the slope of the best fit line applied to the adjusted data and forced through zero (Figure A2.2).

A2.15 The following primary and secondary adjustment factors have been applied to all modelled nitrogen dioxide data:

- Primary adjustment factor : 2.064
- Secondary adjustment factor: 0.997

A2.16 The results imply that the model was under-predicting the road-$NO_X$ contribution. This is a common experience with this and most other models. The final $NO_2$ adjustment is minor.

A2.17 Figure A2.3 compares final adjusted modelled total $NO_2$ at each of the monitoring sites, to measured total $NO_2$, and shows a 1:1 relationship.

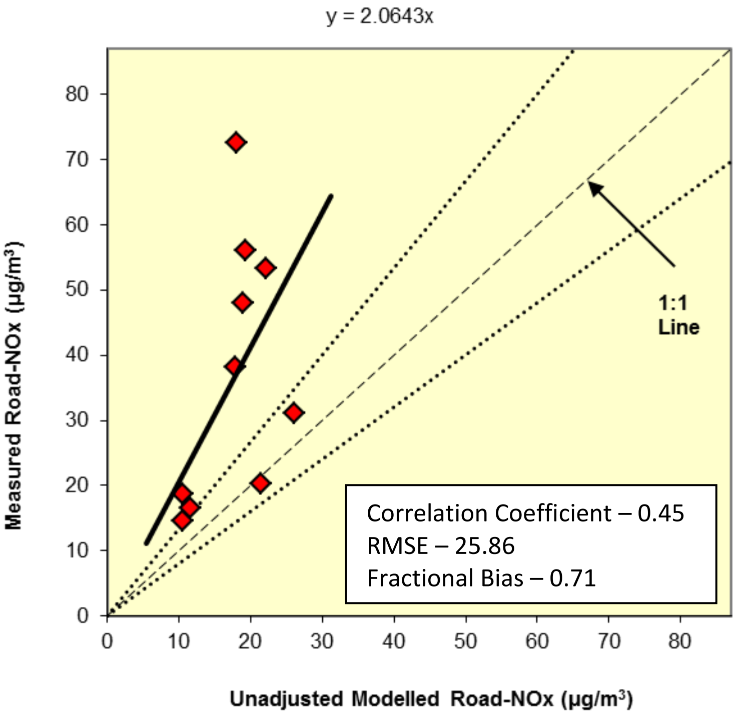


**Figure A2.1: Comparison of Measured Road-$NO_X$ to Unadjusted Modelled Road $NO_X$ Concentrations**

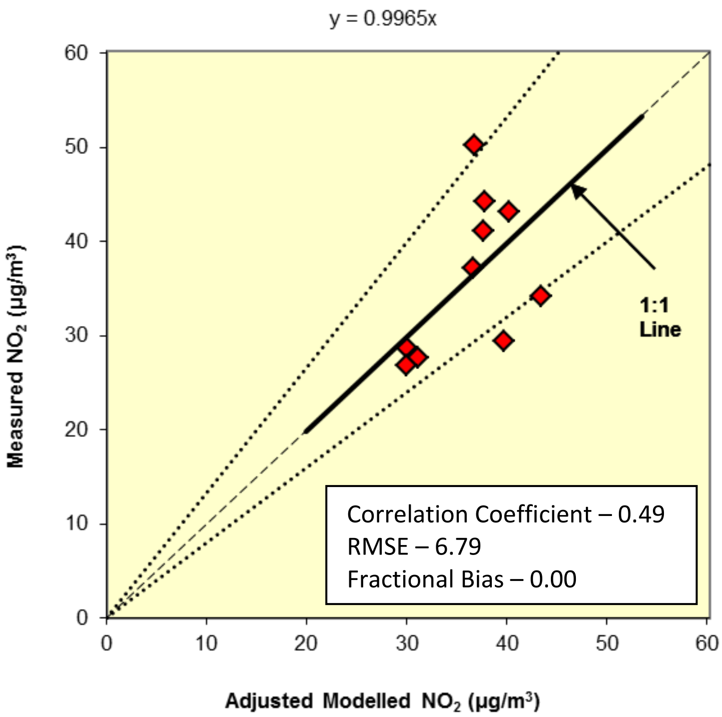


**Figure A2.2: Comparison of Measured Total $NO_2$ to Primary Adjusted Modelled Total $NO_2$ Concentrations**

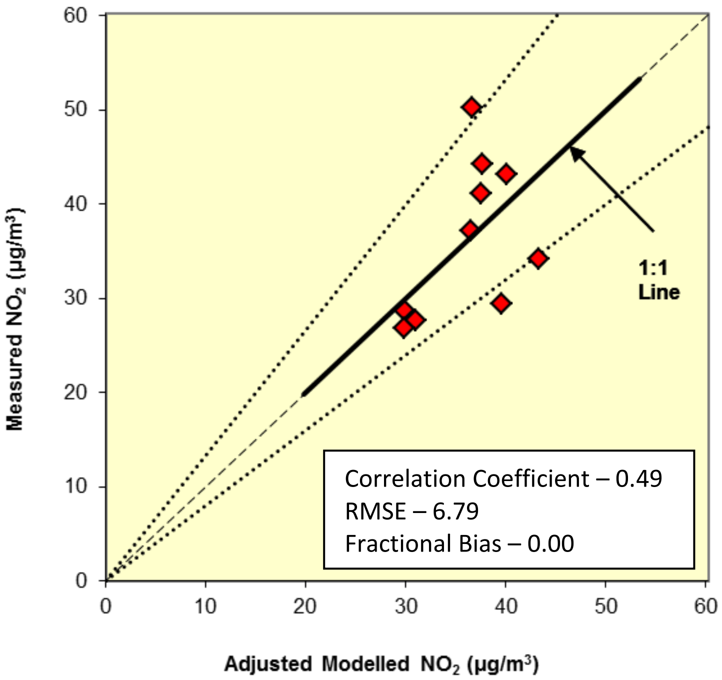


**Figure A2.3: Comparison of Measured Total $NO_2$ to Final Adjusted Modelled Total $NO_2$ Concentrations**

# A3 Adjustment of Short-Term Data to Annual Mean

A3.1 The diffusion tube monitoring site numbered 145 was established on a signpost adjacent to 1 London Road at the end of May 2013 and diffusion tube monitoring site 146 was established on the façade of 34 Hill Street at the end of October 2013. Data for these sites therefore represent less than 75% of a calendar year. Therefore, in accordance with the guidance set out in Box 3.2 of LAQM.TG(09), the data have been adjusted to an annual mean, based on the ratio of concentrations during the short-term monitoring period (7 months; Jun – Dec 2013 and 2 months; Nov-Dec respectively) to those over the 2013 calendar year at four background sites operated as part of the Automatic Urban and Rural Network (AURN) where long-term data are available.

A3.2 In addition, diffusion tube monitoring sites numbered 137 to 144 were established in April 2013. Data for these sites represents 75% of a calendar year. Although therefore borderline, the decision has been made to adjust these monitoring results following the same procedure as for the above sites in order to improve accuracy.

A3.3 The annual mean nitrogen dioxide concentrations and the period means for each of the four monitoring sites from which adjustment factors have been calculated are presented in Table A3.1 to Table A3.3, along with the Overall Factors.

**Table A3.1: Data used to Adjust Short-term Monitoring Data at the 1 London Road diffusion tube monitoring site (145) to 2013 Annual Mean**

| Period Mean Concentration (μg/m$^3$) | Bristol St Pauls | Cardiff Centre | Cwmbran | Newport | Overall Factor |
|---|---|---|---|---|---|
| **2013** | 27.749 | 25.863 | 13.122 | 23.069 | - |
| **Jun – Dec 2013** | 25.081 | 22.567 | 11.230 | 20.926 | - |
| **Adjustment Factor** | **1.106** | **1.146** | **1.169** | **1.102** | **1.131** |

**Table A3.2: Data used to Adjust Short-term Monitoring Data at the 34 Hill Street diffusion tube monitoring site (146) to 2013 Annual Mean**

| Period Mean Concentration (μg/m$^3$) | Bristol St Pauls | Cardiff Centre | Cwmbran | Newport | Overall Factor |
|---|---|---|---|---|---|
| **2013** | 27.749 | 25.863 | 13.122 | 23.069 | - |
| **Nov – Dec 2013** | 37.951 | 35.353 | 18.290 | 27.568 | - |
| **Adjustment Factor** | **0.731** | **0.732** | **0.717** | **0.837** | **0.754** |

**Table A3.3: Data used to Adjust Short-term Monitoring Data at Diffusion Tube Monitoring Sites 137 to 144 to 2013 Annual Mean**

| Period Mean Concentration (μg/m$^3$) | Bristol St Pauls | Cardiff Centre | Cwmbran | Newport | Overall Factor |
|---|---|---|---|---|---|
| **2013** | 27.749 | 25.863 | 13.122 | 23.069 | - |
| **Apr – Dec 2013** | 25.532 | 22.520 | 11.300 | 20.761 | - |
| **Adjustment Factor** | **1.087** | **1.148** | **1.161** | **1.111** | **1.127** |