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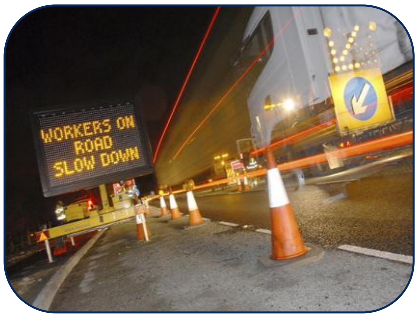


CLIENT PROJECT REPORT CPR2631

Newcastle Under Lyme Air Quality Detailed and Further Assessment

In fulfilment of Newcastle Under Lyme Borough Council's Local Air Quality Management duties

A Savage, K Turpin

Prepared for: Newcastle Under Lyme Borough Council,

Project Ref:

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Executive summary

This report constitutes a combined air quality detailed and further Assessment conducted by the Transport Research Laboratory (TRL Ltd) for Newcastle Under Lyme Borough Council as part of their Local Air Quality Management (LAQM) duties.

The detailed/further assessment focuses on four areas: Madeley Heath close to the M6 motorway, Kidsgrove, Newcastle Under Lyme Town Centre and Porthill/Maybank. Annual mean and hourly mean concentrations of nitrogen dioxide (NO_2) have been modelled using the ADMS-Roads dispersion model for the base year of 2012. The method used for conducting the modelling assessment is in line with Defra's Technical Guidance LAQM.TG(09). The performance of the model was verified against the local authority's monitoring data. Air dispersion modelling uncertainty was conducted and this showed that the model performed within acceptable limits.

The results of the assessment showed that the annual mean NO_2 objective was exceeded at locations of relevant exposure in all four of the study areas. The report provides details of the modelled exceedence areas and provides recommendations and justifications for the boundaries of Air Quality Management Areas (AQMAs) to coincide with the following;

- Madeley – an area encompassing one property, Collingwood, Newcastle Road close to the M6 motorway.
- Kidsgrove – one area along Liverpool Road and Hardingswood Road from the junction with Heathcote Street and Gloucester Road.
- Town centre – one large area to include the entire ring road and area within, namely London Road, Lower Street, Ryecroft and Barracks Road. Also to include King Street up to the borough boundary with neighbouring Stoke on Trent.
- Porthil/May Bank – one area to include relevant receptors adjacent to the southern approach from the Queensway to Porthill Bank and the High Street up to the junction with Basford Park Road.

As part of the requirements for a further assessment, the report includes an assessment of the main sources contributing to exceedences of the NO_2 annual mean objective. In Madeley, the contribution to annual mean NO_2 concentrations is similar from the local background and local traffic emissions, of which the main contribution is from heavy duty vehicles travelling on the M6 motorway. In the other three areas, emissions from local traffic (particularly from cars) made up more than 50 percent of the NO_2 concentrations. The contribution from local background sources was lower than at the more rural site in Madeley.

The report also includes an assessment of the population exposed to concentrations above the objective, the reduction required to achieve the objective and an estimate of when the objective is likely to be exceeded for all study areas. The results showed that annual mean concentrations were highest within the town centre, and it was estimated that a reduction in NO_x emissions from road traffic of 36-39 percent would be required to meet the objective at the worst case receptors. At the worst case receptor, the objective may be achieved by the year 2017 without any additional mitigation.

Given the results of this study and the evidence supporting the prevalence of increased primary NO_2 from road vehicles it is reasonable to suggest that 'doing nothing' is not a viable option. The encouraging result was the modest reductions in road NO_x required to meet the NO_2 annual average objective at Porthill and Madeley. For the latter the modelling was fairly robust (i.e. the traffic situation was represented well in the model). Hence, any emission reducing measures tested here are more likely to have the desired effect at the monitoring site.

The local authority should now consult and declare the AQMAs and prepare an Air Quality Action Plan that focuses on mitigation measures that target the main emissions sources.

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1 Introduction

This report constitutes a combined detailed and further assessment of air quality in Newcastle Under Lyme to determine whether Air Quality Management Areas (AQMAs) need to be declared. The assessment only considers emissions and concentrations of NO_x and NO_2.

In summary, the purposes of air quality detailed and further assessments are to:

1. Determine with reasonable confidence any exceedences of an air quality objective and the boundary of an AQMA.
2. Confirm the findings of previous Detailed Assessments regarding concentrations air quality against the relevant objectives.
3. Assess whether the current AQMA designation is correct and whether any changes are needed.
4. Calculate when the objective is likely to be met at relevant receptor locations.
5. Determine the contribution of key sources (background and different vehicle types) to emissions.

The report is set out as follows:

- Background to air quality in Newcastle Under Lyme (section 2)
- Nitrogen dioxide monitoring results (section 3)
- Dispersion modelling methodology (section 4) and results (section 5)
- AQMA boundary supplementary assessment (section 6)
- Source apportionment (section 7)
- Conclusion and proposed actions (section 8)

2 Background

The Local Air Quality Management (LAQM) process as set out in Part IV of the Environment Act (1995), the Air Quality Strategy for England, Scotland, Wales and Northern Ireland 2007 places an obligation on all local authorities to regularly review and assess air quality in their areas, and to determine whether or not the air quality objectives are likely to be achieved. Where exceedences are considered likely, the local authority must then declare an AQMA. Following a further assessment to confirm the extent of the boundary and emission sources, local authorities are required to prepare an air quality action plan in pursuit of the relevant objectives.

Newcastle Under Lyme Borough Council (NuL) has completed four rounds of the LAQM process and has found that all air quality objectives (see Appendix A) are likely to be met in the borough except for the annual mean nitrogen dioxide (NO_2) objective. Following their 2009 updating and screening assessment (Newcastle Under Lyme, 2009a), they conducted a detailed assessment for NO_2 which determined that AQMAs were required for Kidsgrove and Newcastle Town Centre (Newcastle Under Lyme, 2010). The local authority has begun the fifth round of LAQM and completed an updating and screening assessment (Newcastle Under Lyme, 2013) which found that exceedences have also been recorded in Porthill/Maybank and Madeley. They are therefore required to proceed to a detailed assessment for these two areas.

This report constitutes both a further assessment for Kidsgrove and Newcastle and detailed assessment for Porthill and Madeley. The detailed assessment for the latter two areas also meets the requirements for a further assessment, for example in terms of assessing source contributions.

A summary of the four areas covered in this report and recent monitoring results are given below:

Site 1: Madeley

This is a rural site located to the west of the town centre, close to the M6 motorway (between junctions 15 and 16). There have been marginal exceedences of the annual mean NO_2 objective at one diffusion tube (site 3) on Newcastle Road (A525) in three of the last five years. The detailed assessment aims to determine whether there are any exceedences at relevant locations.

Site 2: Kidsgrove

Liverpool Road (A50) runs through Kidsgrove which is located seven miles to the north of the town centre. The annual mean NO_2 objective has been exceeded at several roadside diffusion tube monitoring sites along the main road and the local authority has concluded that an AQMA is required. The further assessment is required to confirm the extent of the exceedences and boundary of the AQMA.

Site 3: Town centre

Newcastle Under Lyme Town Centre is a busy market town with several major roads (including the A34 and A53) forming an inner ring road round the shopping area. There are widespread exceedences of the annual mean objective at roadside diffusion tube site locations and the local authority had concluded that an AQMA is required. The further assessment is required to confirm the extent of the exceedences and boundary of the AQMA.

Site 4: Porthill

Porthill/Maybank is a residential area located to the north of the town centre, close to the Queensway dual carriageway (A500). Two diffusion tube sites (sites 9 and 24) have recorded concentrations close to the annual mean objective in the last few years (Newcastle Under Lyme, 2013). NuL wishes to proceed to a detailed assessment of the area.

3 Monitoring data

3.1 Continuous monitoring

Continuous monitoring of total oxides of nitrogen (NO_X), nitric oxide (NO) and nitrogen dioxide (NO_2) is conducted at one location within the town centre, at Queens Gardens (see Table 3-1 and Figure 3-3).

Table 3-1: Details of automatic monitoring site.

Site name	Site type	Easting	Northing	Distance to nearest kerb (m)
Queen's Gardens	Urban background/ centre	385046	346147	3

Air pollutant data were ratified as per AURN recommended procedures. The calibration and ratification process for automatic gas analysers corrects the raw dataset for 'drift' in the zero baseline and the upper range of the instrument. The zero reading recorded during the calibration exercise is used to adjust any offset of the baseline. The difference between the span values obtained at two subsequent calibration visits is used to calculate a linear scaling factor, which is applied to data collected between these two visits. Following application of the scaling factor and adjustment of the baseline, data are validated by visual inspection.

A summary of 2012 data for Queen's Gardens is provided in Table 3-2. As the data capture rate was less than 75 percent over the year, the concentrations were adjusted using data from Ladybower and Stoke Centre long term background sites following the recommended methodology in LAQM.TG(09) (Defra, 2009) (see Appendix B). The adjusted annual mean concentration was below the objective and there were no exceedences of the hourly mean objective.

Table 3-2: NO_2 summary statistics – 2012

Statistic	NO_2 concentration (µg/m^3)
Minimum	0.3
Period mean (April-Dec 2012)	28.0
Annual adjusted mean	**30.2**
Maximum	122.8
Data Capture of calendar year (%)	70
Exceedences of the NO_2 hourly mean objective (200 µg/m^3)	0

3.2 Diffusion tube monitoring

Newcastle Under Lyme has an extensive network of over 50 NO_2 diffusion tubes. The location of diffusion tubes relevant to this assessment, i.e. those that are situated in the vicinity of the four modelled areas are shown in Figure 3-1 to Figure 3-4.

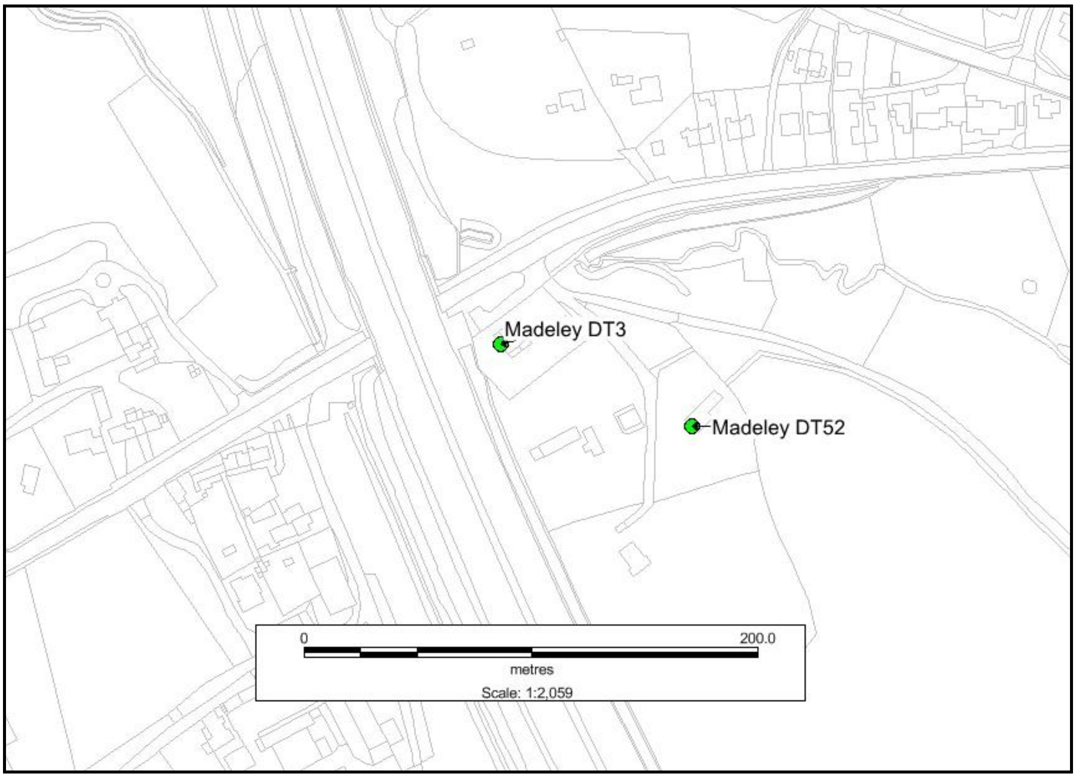

Figure 3-1: Location of diffusion tube monitoring sites, Madeley.

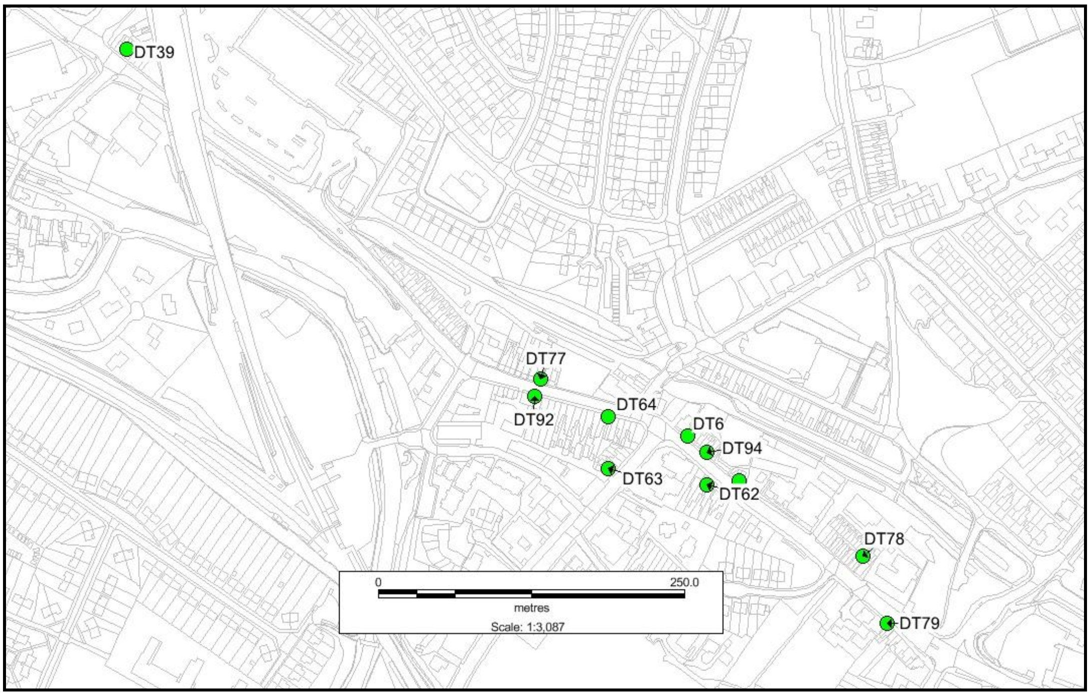

Figure 3-2: Location of diffusion tube monitoring sites, Kidsgrove.

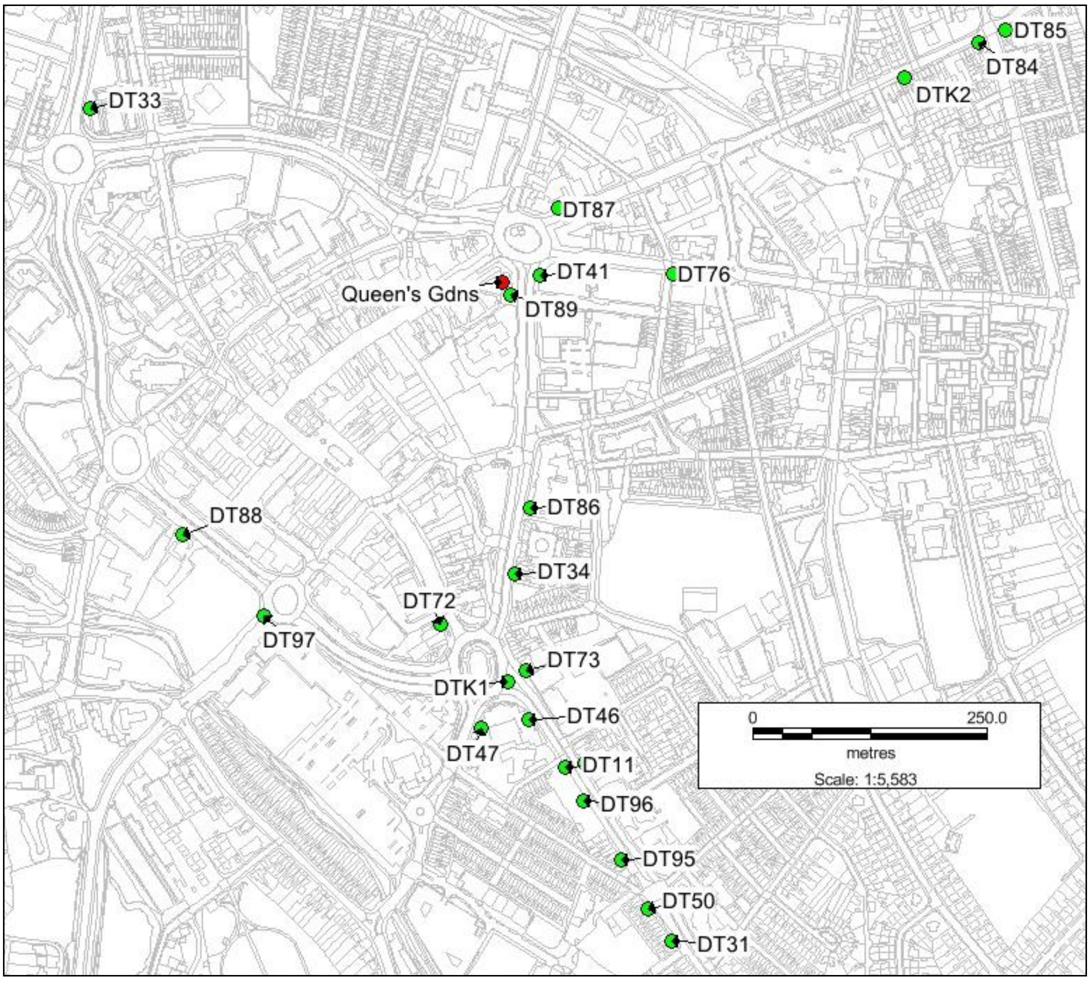

Figure 3-3: Location of diffusion tube and automatic monitoring sites, town centre**.**

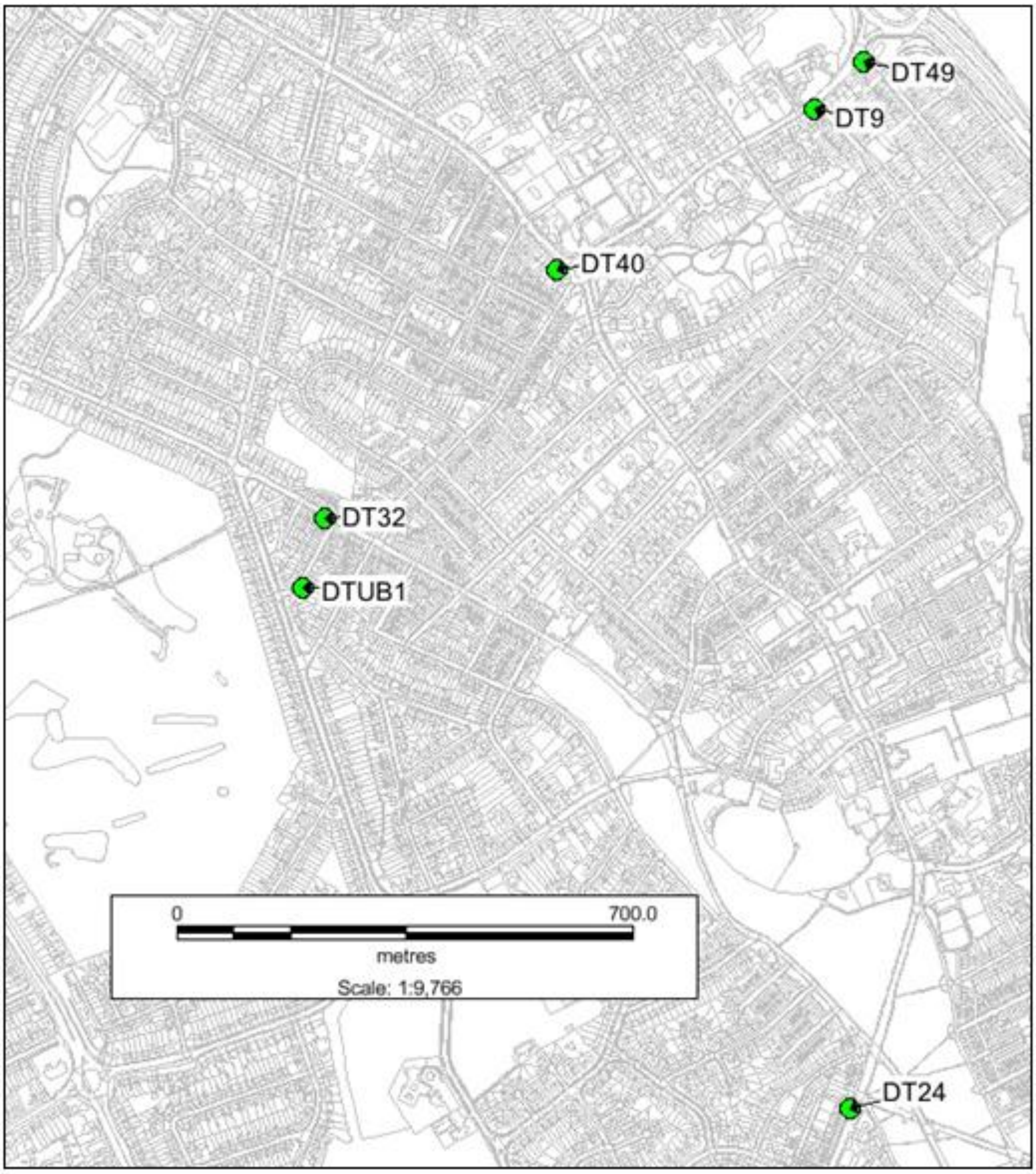

Figure 3-4: Location of diffusion tube monitoring sites, Porthill/

The most recent NO_2 diffusion tube monitoring results are given in Table 3-3. In 2012, there were exceedences of the annual mean NO_2 air quality objective of 40 $\mu g/m^3$ recorded in three of the study areas, at a total of eleven monitoring sites.

Newcastle Under Lyme's nitrogen dioxide (NO_2) diffusion tubes are prepared and analysed by Gradko laboratories using the 20% triethanolamine (TEA) in water method. The bias adjustment factor applied to the 2012 data was taken from Defra's national bias adjustment spreadsheet (version 03/13)[1]. For this laboratory, this value for 2012 was 0.97 (see Appendix B). No local co-location studies were available due to the low data capture rate at Queen's Gardens automatic monitoring site.

[1] http://laqm.defra.gov.uk/bias-adjustment-factors/national-bias.html

Table 3-3: Nitrogen dioxide (NO_2) diffusion tube sites and concentrations, 2012.

Site ID	Site description	Site type	Height (m)	Easting	Northing	Data capture (% of calendar year)	Bias adjusted NO_2 concentration (µg/m^3) (0.97)
			Madeley				
DT3	Collingwood, 3 Newcastle Rd	Rural	2	378116	345488	83	39.6
DT52	Agricon House	Rural	2	378200	345452	100	31.1
			Kidsgrove				
DT6	106 Liverpool Rd)	Suburban	3	384014	354429	100	**45.3**
DT39	4/6 Liverpool Road,	Suburban	3	383560	354739	100	39.9
DT62	79 Liverpool Road	Roadside	3	384030	354390	100	30.1
DT63	9-11 The Avenue	Roadside	3	383958	354403	100	31.9
DT64	Kidsgrove Carpets 57 - 59 Liverpool Road	Roadside	3	383950	354445	100	**41.1**
DT77	68 Liverpool Road	Urban Centre	4	383865	354475	100	28.4
DT78	140 Liverpool Road	Urban Centre	2.5	384156	354333	100	24.3
DT79	89 Liverpool Road	Urban Centre	3	384176	354279	92	33.5
DT92	41/43 Liverpool Road	Urban Centre	3	383890	354461	100	39.0
DT93	118 Liverpool Road	Urban Centre	4	384056	354393	100	37.8
DT94	116 Liverpool Road	Urban Centre	4	384030	354416	100	39.2
			Town centre				
DTK1	A34 Holy Trinity	Kerbside	3	385051	345726	100	**47.1**
DTK2	76 King St	Urban Centre	2	385469	346362	100	34.2
DT11	34 London Road	Suburban	3	385112	345636	100	**44.7**
DT31	102 London Road	Suburban	3	385224	345453	100	33.8
DT33	9 Hart Court	Suburban	3	384611	346330	100	33.6
DT34	15 Barracks Road	Urban Centre	3	385059	345840	100	38.7
DT41	Jubilee Baths,	Urban Centre	3	385086	346155	100	38.9
DT46	1 London Road (Trinity Court)	Urban Centre	3	385073	345686	100	35.3
DT47	1 London Rd (Brook La)	Urban Centre	3	385023	345678	100	34.4
DT50	84 London Road,	Suburban	2	385199	345487	100	30.2
DT72	134 High Street	Roadside	3	384980	345787	92	34.4
DT73	21 London Road	Roadside	3	385070	345738	100	37.6
DT74	39 London Road	Roadside	3	385132	345640	100	38.8
DT76	11 Brunswick Street	Roadside	3	385226	346156	100	37.0
DT84	102 King Street	Urban Centre	3	385548	346400	100	**43.9**
DT85	106 King Street	Urban Centre	2	385575	346413	100	**49.1**
DT86	Hassell C.P. School Barracks Road	Urban Centre	3	385075	345910	100	37.0
DT87	Blue Chilli 1 King Street Newcastle	Urban Centre	2	385105	346225	100	**43.4**
DT88	88 - 27 Lower Street	Urban Centre	3	384709	345881	92	37.7
DT89	Queen's Gardens	Urban Centre	1	385054	346134	100	34.9
DT96	52/54 London Road	Roadside	3	385131	345601	100	**44.9**

Site ID	Site description	Site type	Height (m)	Easting	Northing	Data capture (% of calendar year)	Bias adjusted NO_2 concentration ($\mu g/m^3$) (0.97)
DT97	Blackfriars/ Lower Street	Roadside	2	384795	345796	100	39.6
DT95	76 London Road	Roadside	4	385171	345539	100	**40.8**
			Porthill				
DTUB1	UB1-Wolstanton (Haritngton St)	Kerbside	3	384739	348326	92	23.7
DT32	32-139 Dims Parade West	Suburban	2	384773	348430	100	32.3
DT40	40-Banktop Court, Porthill	Suburban	5	385128	348811	100	33.8
DT9	9-32 Porthill Bank	Suburban	3	385519	349055	92	**40.4**
DT49	49- 2 Vale View, Porthill	Urban Centre	10	385595	349129	92	35.6
DT24	24-26 High St, May Bank	Roadside	3	385574	347530	100	**40.9**

*Exceedences of the objective are shown in bold.

Trends in annual mean NO_2 concentrations are provided for the last three years at selected sites, in relation to the objective (Figure 3-5 to Figure 3-8). Overall the trends in concentrations are relatively stable, with reductions evident at some sites (e.g. in Madeley). 2012 concentrations were found to be typically lower than those recorded in 2010, but higher than in 2011.

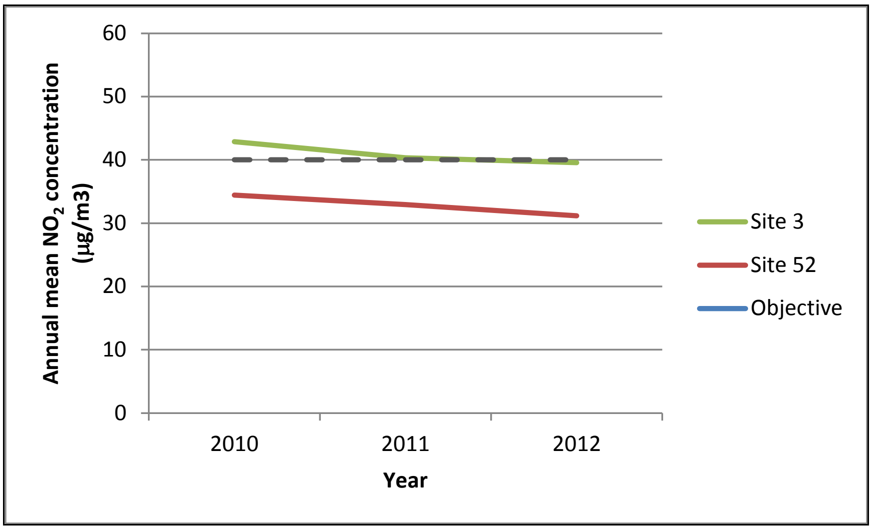

Figure 3-5: Recent trends in annual mean NO_2 concentrations, Madeley.

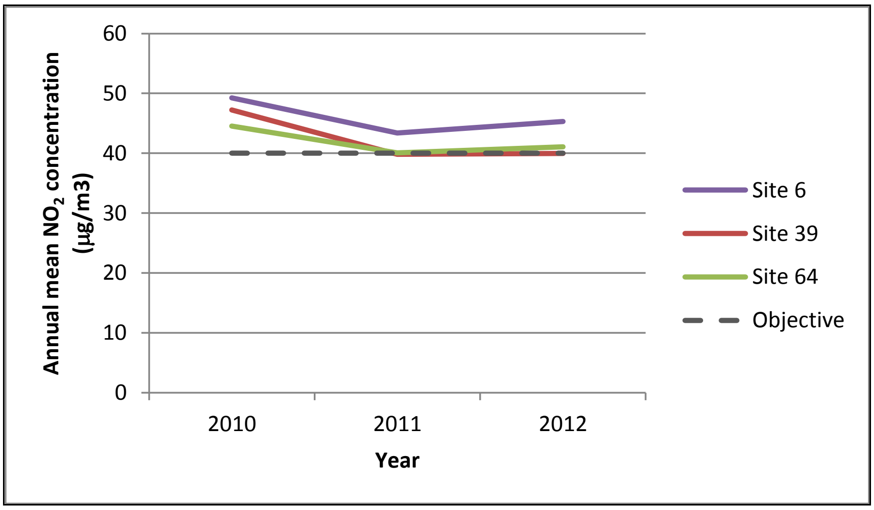

Figure 3-6: Recent trends in annual mean NO_2 concentrations, Kidsgrove.

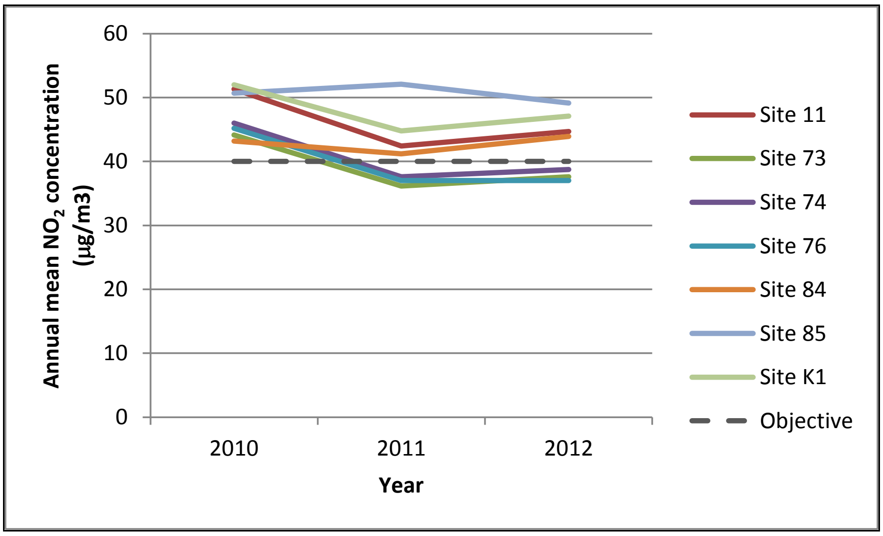

Figure 3-7: Recent trends in annual mean NO_2 concentrations, Town centre.

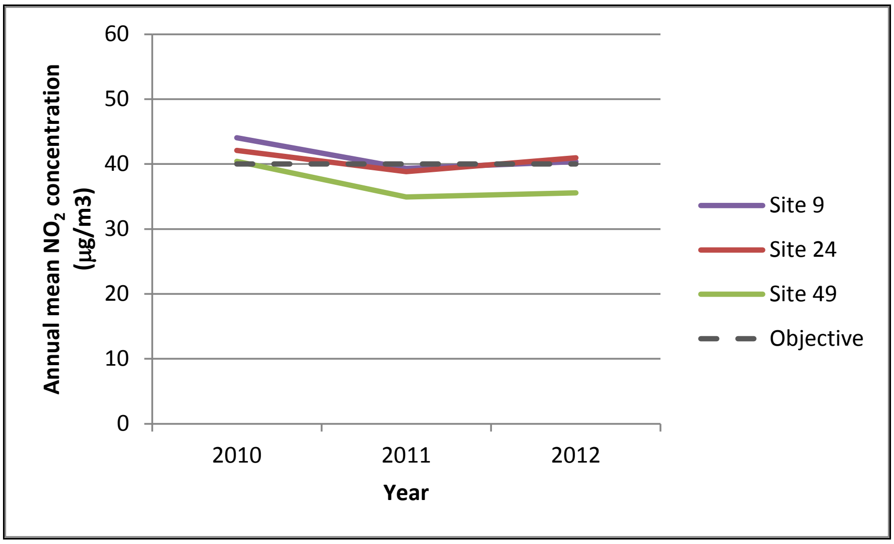

Figure 3-8: Recent trends in annual mean NO_2 concentrations, Porthill.

4 Modelling assessment

Atmospheric dispersion modelling for the base year of 2012 was undertaken using the Gaussian ADMS-Roads (Extra) model (version 3.1), developed by Cambridge Environmental Research Consultants (CERC)[2]. The ADMS-Roads model uses a number of input parameters to simulate the dispersion of pollutant emissions, predicting pollutant concentrations at specified receptors and across a user-defined area. The input parameters include emission source activity data, local meteorological conditions and site specific characteristics including latitude, boundary layer height and surface roughness.

4.1 Maps

Ordnance Survey based Geographical Information System (GIS) data of the model domains and road centrelines were used in the modelling assessment. This enabled accurate road widths to be determined in the MapInfo GIS system.

4.2 Modelled domain and receptors

2012 was selected as the base year for the modelling assessment due to the availability of monitoring data.

For the purpose of this assessment, pollutant concentrations have been modelled at the diffusion tube monitoring sites, as given in Section 3.2 and at address points within 200 metres of modelled roads. All receptors were modelled at two metres in height unless otherwise stated. As well as individual receptors the modelling was undertaken using a grid for each area, at a height of two metres.

4.3 Emissions source activity data

4.3.1 Traffic activity

Traffic activity data were obtained from various sources including Staffordshire County Council and the Department for Transport (DfT)[3]. Traffic data were processed for individual road links and factored to the year 2012 by applying a local factor from the National Trip End Model (NTEM) incorporated into TEMPRO (Trip End Model Presentation Program) 6.2 software[4] (see Appendix C).

For Porthill and Maybank, due to a lack of data, additional traffic counts were conducted at seven locations during May 2013 (see Appendix D). These data included total flow, average speed over 24 hours and vehicle classification into generic vehicle classes. It was assumed that the 2013 data for Porthill applied to 2012.

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[2] Cambridge Environmental Research Consultants http://www.cerc.co.uk/software/admsroads.htm
[3] http://www.dft.gov.uk/traffic-counts/cp.php
[4] http://www.dft.gov.uk/tempro/

Average speeds were obtained from the traffic activity data where available. Where this data were not available, speeds were estimated based on typical journey times using Google maps in preference to the national speed limits.

4.3.2 Emission factor database

The fleet composition was derived from the traffic data provided and entered into version 5.2c of the Emission Factor Toolkit (EFT)[5] to generate NO_x emissions. The EFT requires the following information:

- The year of interest.
- Traffic flow, over a specified time period (for example the annual average daily traffic – AADT flow over 24 hours)
- Average speed.
- The road type (urban, rural, motorway or London urban, rural or motorway)
- The proportions of different generic vehicle categories in the traffic.

4.3.3 Road geometry and gradient

The geometry of each road was determined using GIS mapping data. Road width is defined by the kerb-to-kerb measurement (km). The height of surrounding buildings is accounted for in the model wherever a 'street canyon' effect is observed. For atmospheric dispersion modelling assessments, a street canyon is defined by the building heights being greater than the building-to-building road width (aspect ratio greater than 1.0). No street canyons were included in this assessment.

An assessment of gradient over the study areas was made and it was concluded that there were no roads with a gradient steeper than 1 in 10 (10 percent). As the terrain function of ADMs Roads is only sensitive to gradients in excess of 10 percent, the effect of terrain or gradient was not included as part of the model set up.

4.3.4 Time-varying emissions

Time-varying profiles have been included in the ADMS-Roads model. These consist of a data file which allows the model to take account of the variation in road traffic volumes over a 24-hour period, with the highest volumes in the daytime morning and afternoon peak periods and less traffic during the night. Diurnal profiles for weekdays, Saturdays and Sundays were included in the model for each road link, an example of which is provided in Figure 4-1 .

[5] http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html#eft

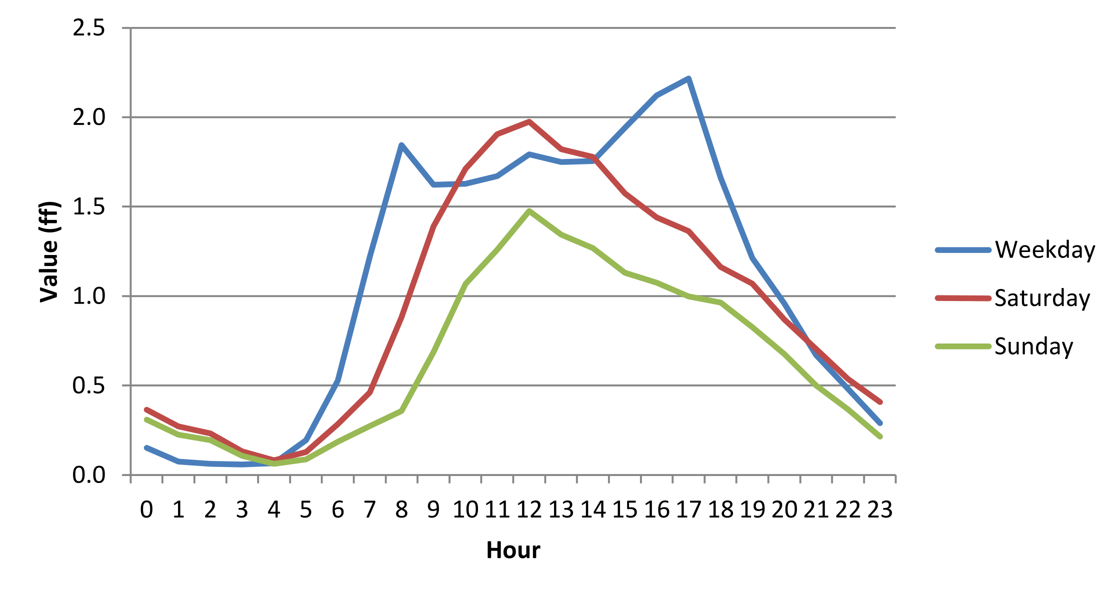

Figure 4-1: Example of traffic flow variation profile (A34 town centre).

4.3.5 Queuing traffic

4.3.5.1 Average speed approach

The characteristic of queuing vehicles at peak times were based on a queue length survey that was conducted over two days (14-15th May 2013). This survey involved estimating the typical length of queues at junctions during both the morning and afternoon peak times. The locations and extent of queues are shown in Figure 4-2 to **Figure 4-5**. The roads selected (yellow lines) are estimated to have journey times greater than 6 minutes per mile or a speed of 10 mph or less. Emissions to represent this level of queuing are analogous to 1,250 vehicles travelling at 5 km/h for 1 hour each weekday (30,000 vehicles in a 24 hourly period). Note that no queues were included in the model set up for the Madeley site. Red queue lines are explained in the following section.

4.3.5.2 Instantaneous emissions approach

In the initial air dispersion modelling run road NO_X emissions were underestimated when using the standard approach to represent queues (as described above), for example within certain areas of the town centre and Kidsgrove (i.e. compared to measured road NO_X). The differences appeared greater on parts of the road network where queuing is prevalent throughout the day. On this basis an alternative technique was developed. This involved the application of 'congested' emission profiles estimated for similar conditions in another area derived from an instantaneous emissions model PHEM[1] (**P**assenger car and **H**eavy-duty **E**mission **M**odel). PHEM calculates the engine power in 1 Hz increments based on profiles of vehicle speed (the "driving cycle") and road gradient, the driving resistances and the losses in the transmission system. The 1 Hz course of engine speed is simulated based on the transmission ratios and a gear-shift model. Alternatively the course of engine load and/or engine speed can also directly be provided to the emission

[1] PHEM = **P**assenger car and **h**eavy-duty **e**mission **m**odel.

model. To take transient influences on the emission levels into consideration, the results from the emission maps are adjusted by means of transient correction functions. The model results then are the 1 Hz courses of engine power, engine speed, fuel consumption and emissions of CO, CO_2, HC, NO_x, NO, particle mass (PM) and particle number (PN).

Various junctions were analysed from the database of instantaneous emissions profiles. Profiles were examined for the approach to and exit of various junctions. Two profiles were selected, one describing the characteristic of driving behaviour of the traffic approaching the junction and another exiting the junction. The interface of the profiles occurred at the approach stop line. The distance applied to the approach and exit queue links were set in accordance with the source data. Application of these newly developed queue links improved emission estimates considerably (compared to measured results) and hence improved the robustness of the overall model. Links using this approach are indicated in red in the figures below.

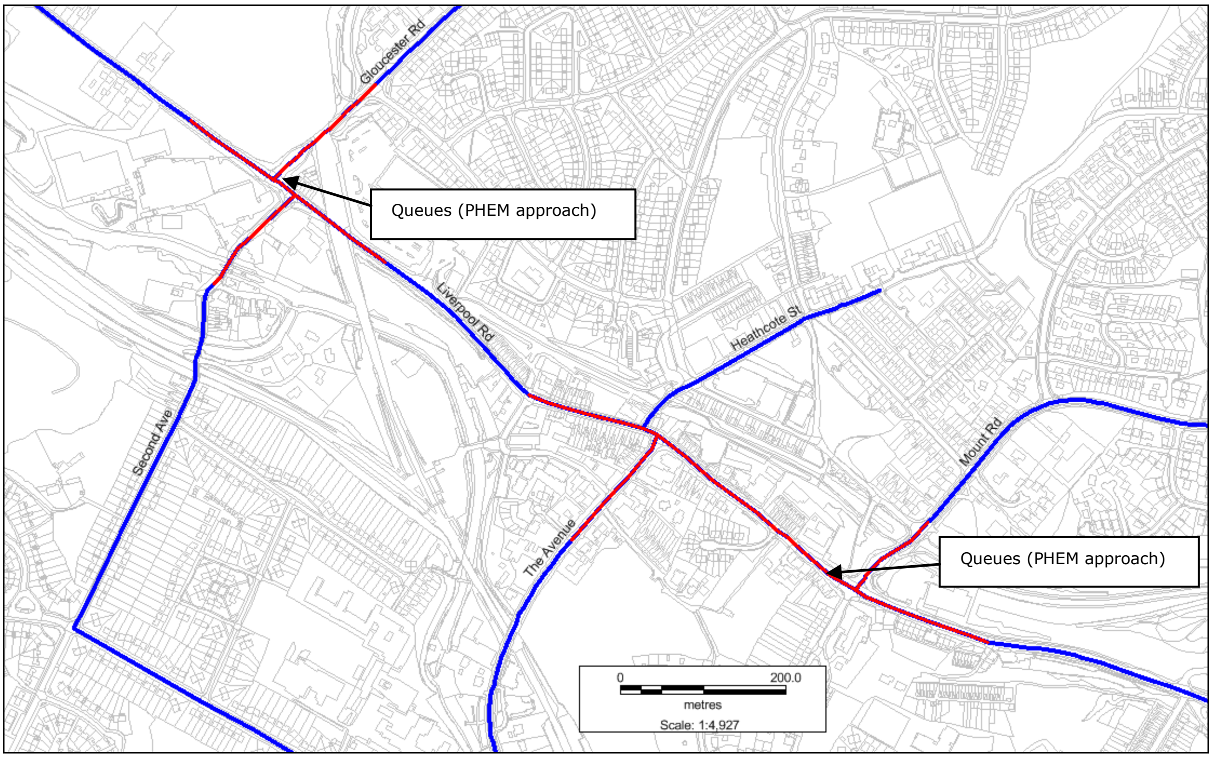

Figure 4-2: Queues represented in Kidsgrove modelled road network.

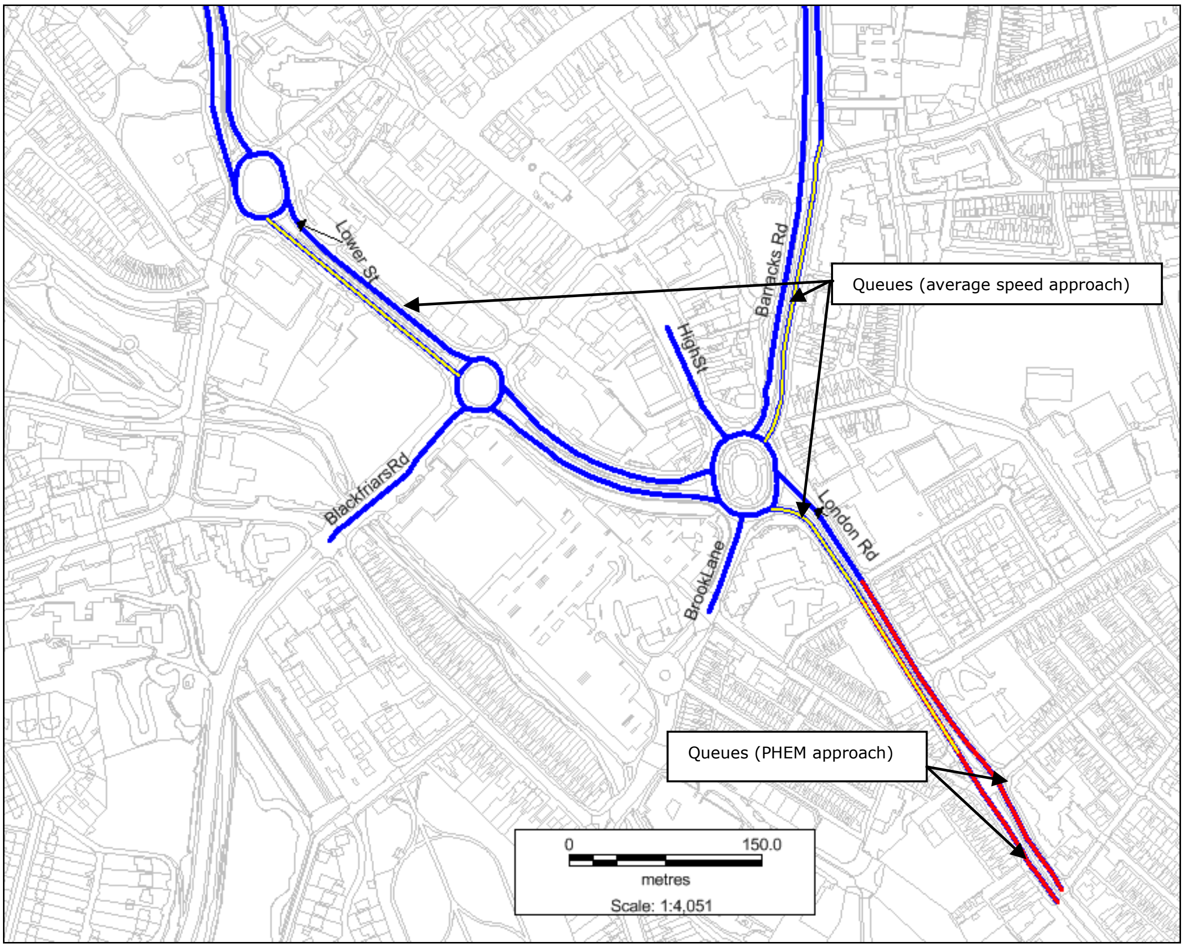

Figure 4-3: Queues represented in town centre modelled road network (1).

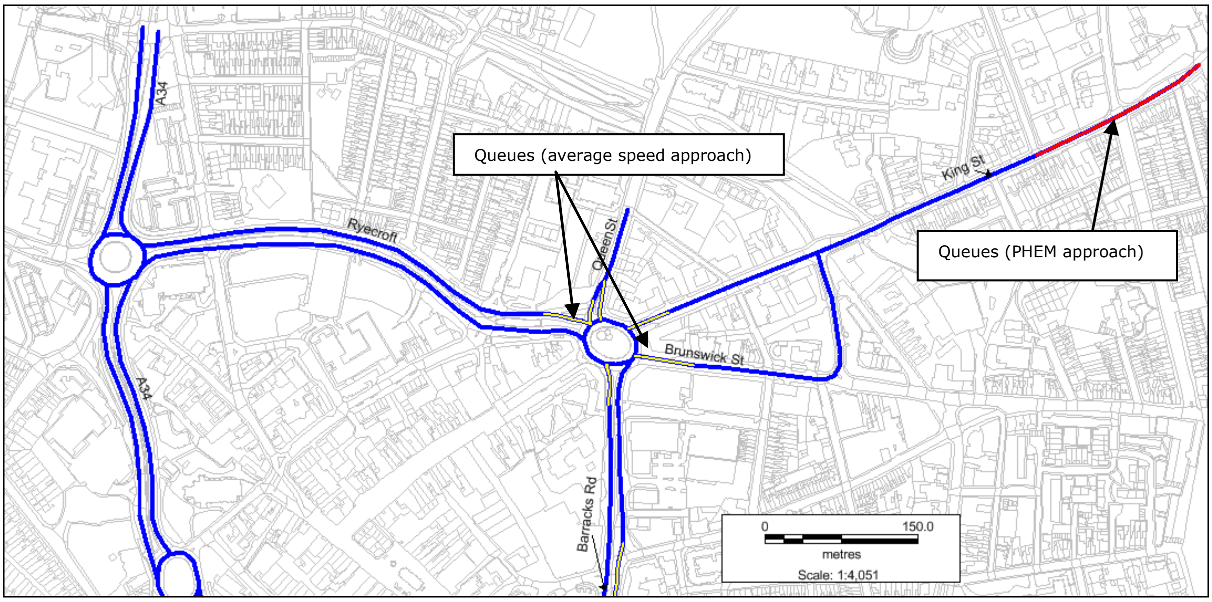

Figure 4-4: Queues represented in town centre modelled road network (2).

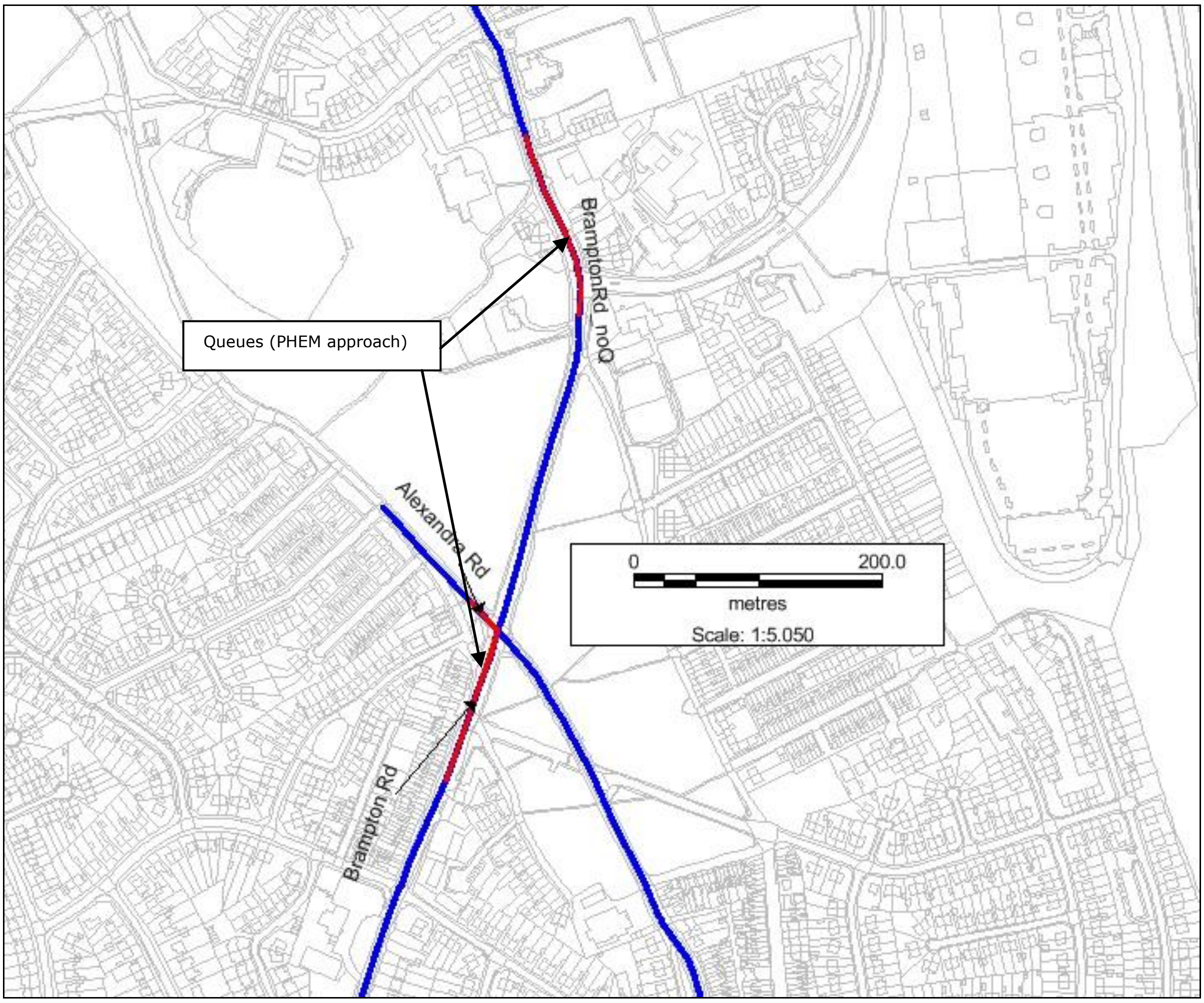

Figure 4-5: Queues represented in Porthill modelled road network, lower section.

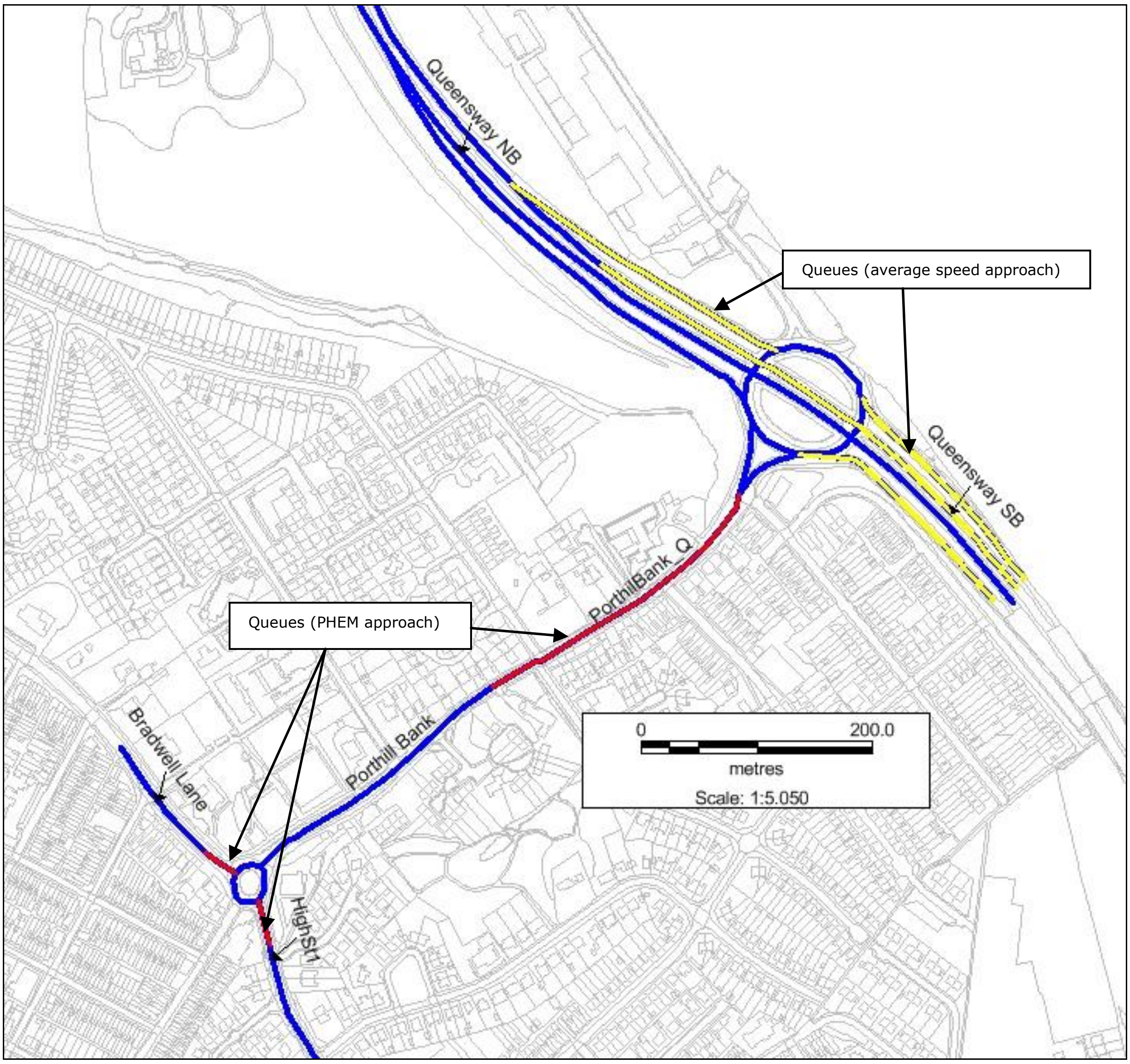

Figure 4-6: Queues represented in Porthill modelled road network, upper section.

4.4 Background concentrations

To represent sources not explicitly included in the modelling, background values of NO_x for 2012 were taken from the Defra background maps based on 2010 data[6]. The concentrations in the relevant 1 km grid squares in each modelled domain are given in Table 4-1. To avoid double counting the source, for Madeley, the NO_x concentration was adjusted by removing the contribution of the M6 motorway within the 1 km square and for Porthill, the contribution of the Trunk Road (A500) was removed. The background applied is shown in brackets in the table. The background NO_x concentration in Kidsgrove (square 383500, 354500) includes a contribution of 13.6 $\mu g/m^3$ from industrial sources. This background source includes emissions from Rockwood Pigment factory, a Part A permitted process located on Liverpool Road, to the west of the junction with Gloucester Road.

[6] http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html

Table 4-1: Background NO_x concentrations from relevant 1 km grid squares, 2012.

X	y	Annual mean NOx concentration (µg/m³)
	Madeley	
378500	345500	45.6 (35.0)
	Kidsgrove	
383500	354500	37.4
384500	354500	25.9
Average		**31.7**
	Town centre	
384500	346500	33.6
384500	345500	28.9
385500	346500	35.8
385500	345500	31.2
Average		**32.4**
	Porthill	
385500	349500	40.8 (32.9)
385500	348500	35.2
385500	347500	33.3
Average		**33.8**

4.5 Atmospheric chemistry

The concentration of NO_2 at a specific location is determined by a combination of emissions, meteorology and atmospheric chemistry. Some NO_2 is emitted directly from vehicle exhaust (this is known as primary NO_2), a high proportion of which is from diesel vehicles. Emissions of NO_X from vehicles are primarily in the form of nitrogen oxide (NO) (AQEG, 2007). Nitrogen oxide undergoes a chemical reaction with oxidants such as ozone (O_3) to produce secondary NO_2. At a roadside location, there is routinely an excess of NO, and thus the limit to the formation of NO_2 is usually determined by the availability of O_3. At heavily trafficked roadside locations, there is not a linear relationship between the transformation of NO_X emissions and NO_2 concentrations.

Nitrogen dioxide concentrations have been derived from the road NO_X concentrations estimated by the ADMS-Roads model using the calculator[7] available on the LAQM tools section of the UK Air Quality Archive website.

[7] http://www.airquality.co.uk/archive/laqm/tools.php

4.6 Meteorological data

The ADMS-Roads model applies hourly sequential meteorological data to calculate atmospheric dispersion. This calculation involves a number of meteorological parameters including wind speed and direction, cloud cover and near surface temperature (the latter two parameters being important for the calculation of atmospheric stability, which affects how pollutants disperse). The meteorological station at Shawbury is the site closest to Newcastle Under Lyme with the highest data capture rate for 2012 and which records the required parameters (with the exception of cloud cover). A wind rose has been produced using 2012 data obtained (see Figure 4-7). The dominant wind speed is from the South West, with maximum speeds of 8-9 ms^{-1}.

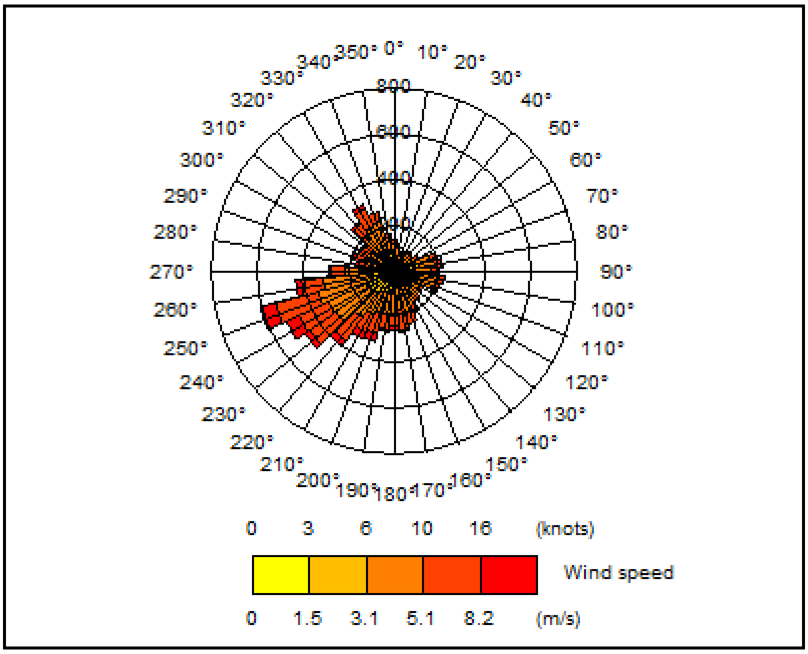

Figure 4-7: Wind rose based on 2012 data from Shawbury meteorological station**.**

4.7 Surface roughness

The interaction of wind flow with the ground generates turbulence, influencing pollutant dispersion. The strength of this turbulence is dependent on the land use, with urban areas generating higher turbulence than open countryside. The ADMS-Roads user guide indicates that a surface roughness length of 1 m is suitable for cities and woodland and 0.5 m is suitable for parkland and open suburbia. This study used a surface roughness that varied from 0.5 m for Madeley to 1 m for the town centre.

The ADMS-Roads model allows the user to specify the surface roughness length of the site where meteorological data has been recorded (used when the surface roughness length at the meteorological site differs from that at the area under assessment). In this way, the ADMS-Roads model modifies the meteorological data to accommodate differences in surface roughness between the modelling domain and the geographical area from which meteorological measurements are obtained. The surface roughness length at the meteorological site used in this study was 0.5 metres.

5 Results

5.1 Modelled NO_2 concentrations

The model was run at selected receptors based on the address point layer provided by NuL (these were fixed receptor points representing each address) and across a grid over each modelled area. Modelled NO_x concentrations were adjusted by a factor specific to each area based on the model verification process (Appendix E) and annual mean NO_2 concentrations were calculated using Defra's NO_x-NO_2 calculator[8] using the background concentrations given in Table 4-1. The uncertainty of results were calculated for each area to take into account the model's performance (see Appendix E).

The modelled annual mean NO_2 concentrations are provided in the sections below for each area in turn. The model was run to calculate both annual and hourly NO_2 concentrations. No exceedences of the hourly objective were predicted at any receptors so figures of these results are not shown. The results show that there are exceedences of the annual mean NO_2 objective at relevant receptors in all four areas, although exceedences were marginal in Madeley. A discussion on appropriate AQMA boundaries for each area is given in Section 6, taking into account the uncertainty of the model performance and practical issues.

In the figures below, the address points of properties were coloured according to their modelled concentration. It is noted that not all of these address points in the figures are residential. In Section 5.4, the address points that are residential have been assessed to estimate the number of properties that are predicted to exceed the annual mean objective.

5.1.1 Madeley

Taking into account the uncertainty of the model (+/- 0.2 $\mu g/m^3$), the results show that the annual mean NO_2 concentration is predicted to be exceeded at one property at the façade of Collingwood, Newcastle Road close to the M6 motorway (as shown in Figure 5-1). The results of this assessment were marginally above the annual mean objective, i.e. the highest concentration was modelled as 40.13 $\mu g/m^3$ at the nearest façade to the motorway. It is considered that the modelling at this location was fairly robust as the model performed well against data from the diffusion tube monitoring sites. Measured concentrations continue to remain around the objective level, so it is recommended that the local authority declare an AQMA at this location.

[8] http://laqm.defra.gov.uk/tools-monitoring-data/no-calculator.html

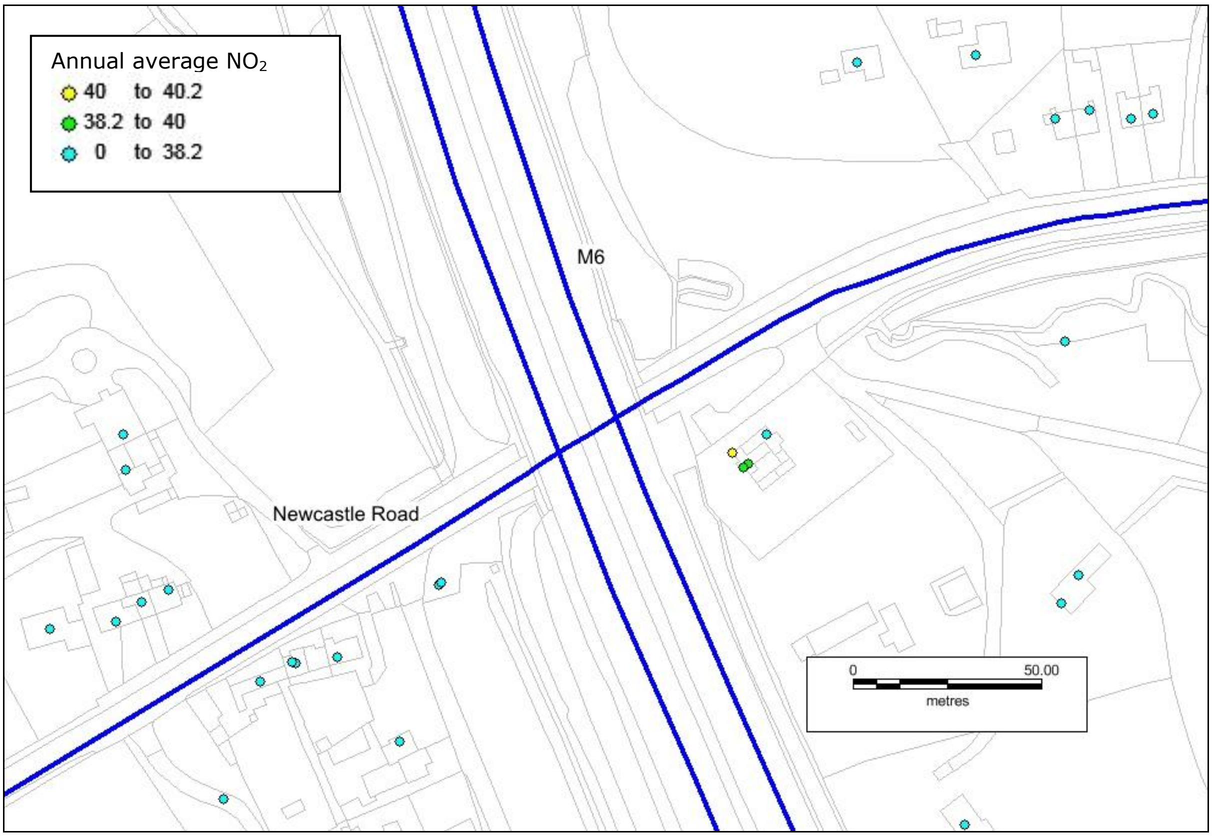

Figure 5-1: Modelled annual mean NO_2 concentration, Madeley. Properties closest to the M6 motorway.

5.1.2 Kidsgrove

Taking into account the uncertainty of the model (40 $\mu g/m^3$ +/- 3.4 $\mu g/m^3$), the results for Kidsgrove are shown in Figure 5-2. The results show that the annual mean NO_2 concentration is predicted to be exceeded at properties around Liverpool Road close to two junctions, one with Heathcote Street and one with Gloucester Road. The exceedences are most likely to be due to higher emissions from slow moving and queuing traffic at peak times at the traffic lights at these junctions.

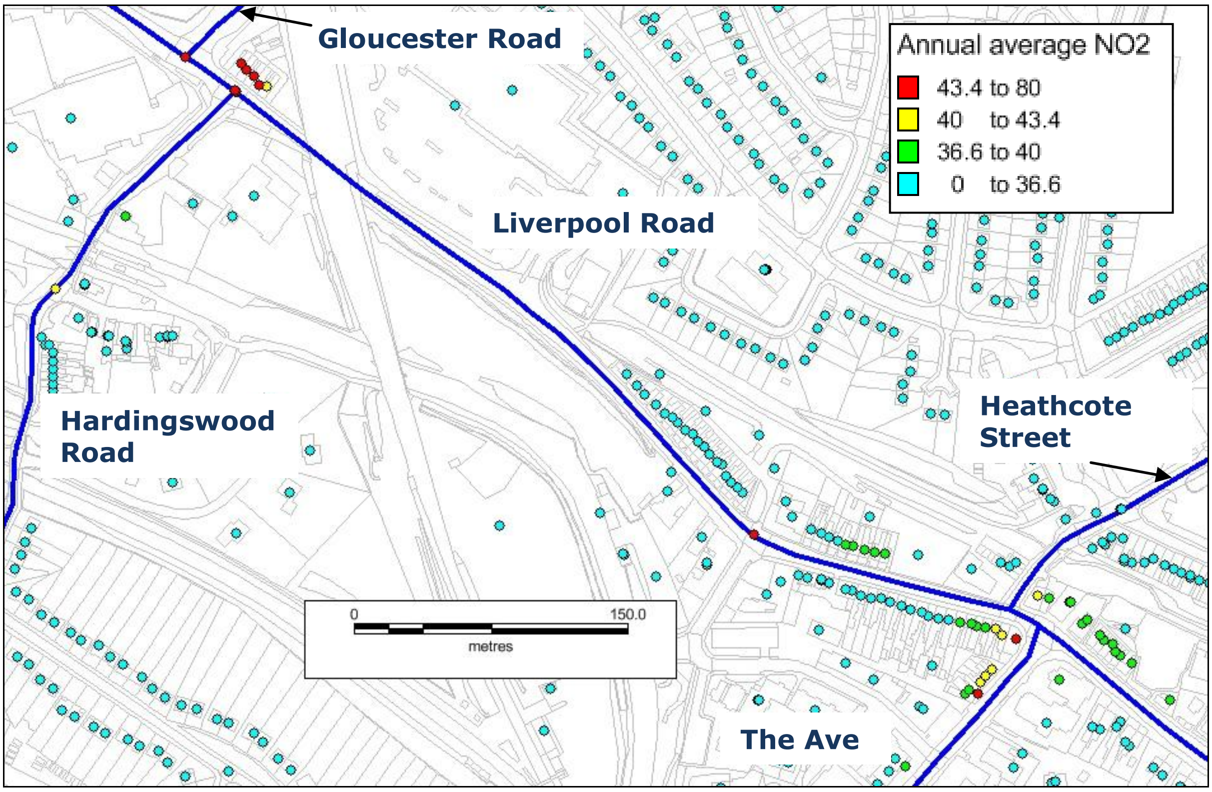

Figure 5-2: Modelled annual mean NO_2 concentration, Liverpool Road, Kidsgrove.

It is noted that there is a modelled exceedence along Hardingswood Road to the south of Liverpool Road. This exceedence is at the Canal Tavern public house. NuL has confirmed that there is relevant exposure at this property.

There is also relevant exposure at the Harecastle Hotel (located on Liverpool Road to the west of Heathcote Street). NuL wished to determine whether there was exceedence at this property. As the address point grid reference was located in the middle of the building, the model was5 run with additional receptors on the façade of the property at ground floor and first floor height. The results show that there is unlikely to be an exceedence at this property at either height (as indicated in Figure 5-3).

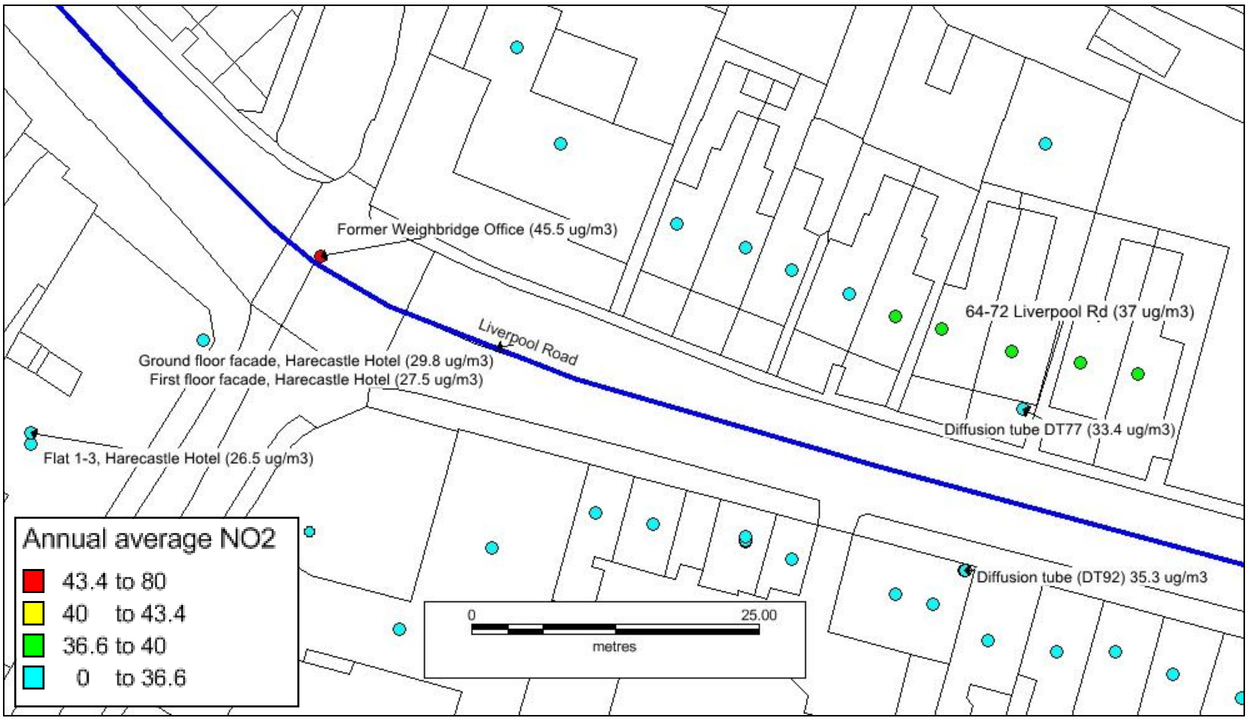

Figure 5-3: Modelled annual mean NO_2 concentrations at the Harecastle Hotel and surrounding properties, Liverpool Road.

5.1.3 Town centre

Annual mean NO_2 concentrations are shown in Figure 5-4 for the whole of the modelled area in the town centre. The contour plots represent the range of concentrations from background level (blue) to highest concentrations (red). The uncertainty of the model results was calculated to be +/- 3.4 $\mu g/m^3$ which suggests that concentrations that are equal to or above 36.6 $\mu g/m^3$ (green, yellow and red) are likely to exceed the objective. The results in Figure 5-4 suggest that there are four discrete areas where the objective is likely to be exceeded where there are relevant receptors, i.e. around both major roundabouts, Barracks Road, King Street and London Road.

The model was run at all address points within 200 metres[9] of the modelled roads (a total of 4903 properties – both residential and commercial). The results showed that the total number of properties identified as being residential with a modelled concentration of 40 $\mu g/m^3$ or higher was 32. These properties are located on London Road and King Street. Taking into account the uncertainty of the model, there would be an additional 65 properties with a modelled concentration of between 36.6 $\mu g/m^3$ to 40 $\mu g/m^3$, on London Road, King Street, Barracks Road and High Street (see Section 5.4). Hassell Community Primary School is outside the exceedence area on Barracks Road.

[9] Region of influence from road emission sources according to the Design Manual for Roads and Bridges (DMRB).

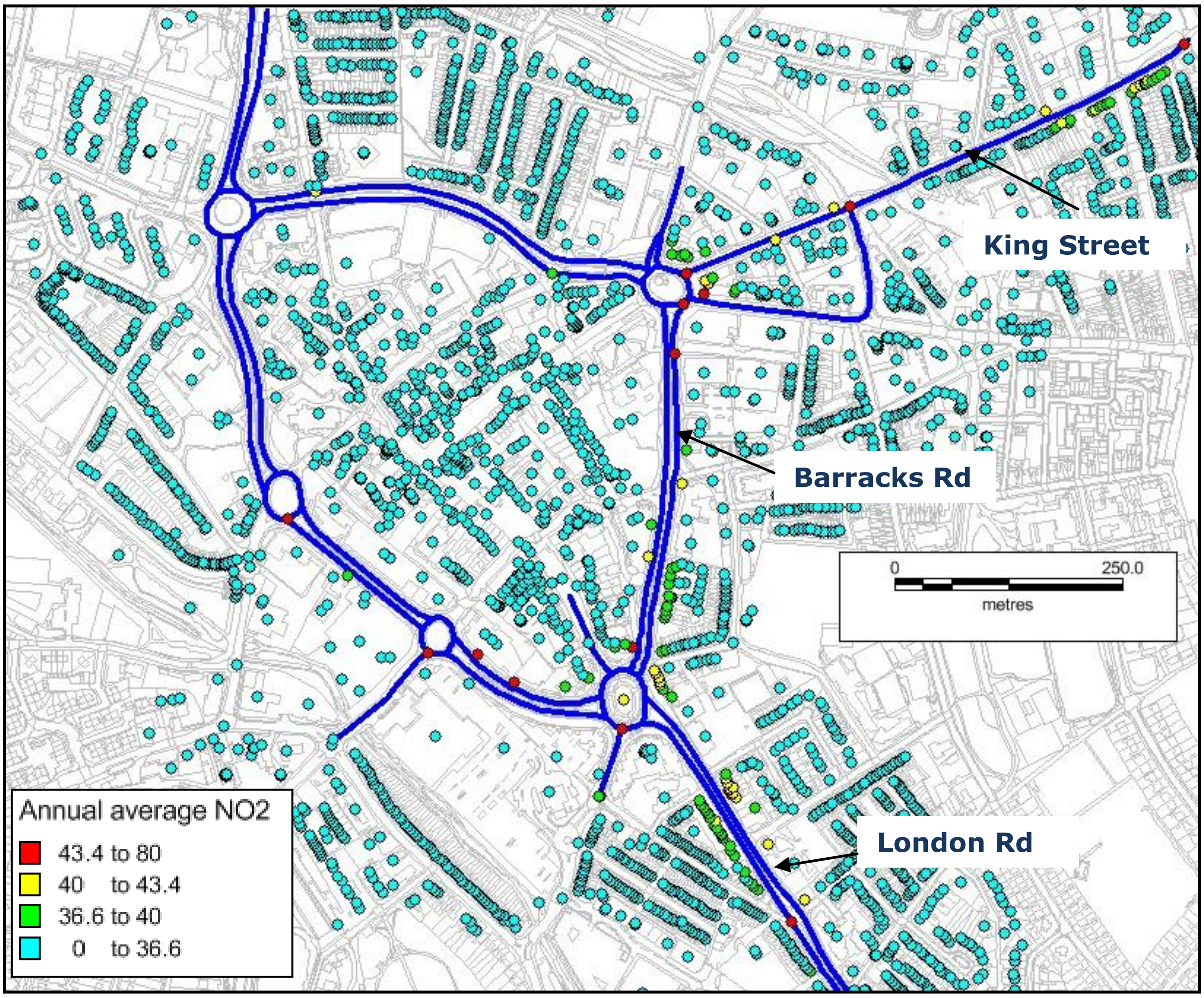

Figure 5-4: Modelled annual mean NO_2 concentration, town centre.

5.1.4 Porthill/May Bank

Annual mean NO_2 concentrations modelled in Porthill are shown in Figure 5-5 and Figure 5-6 for Maybank. The maps show that relevant receptors are exceeding the objective around Porthill Bank/Queensway and a smaller area south of the junction with High Street and Basford Park Road. The uncertainty of the model results was calculated to be +/- 4.5 $\mu g/m^3$ (see Appendix E).

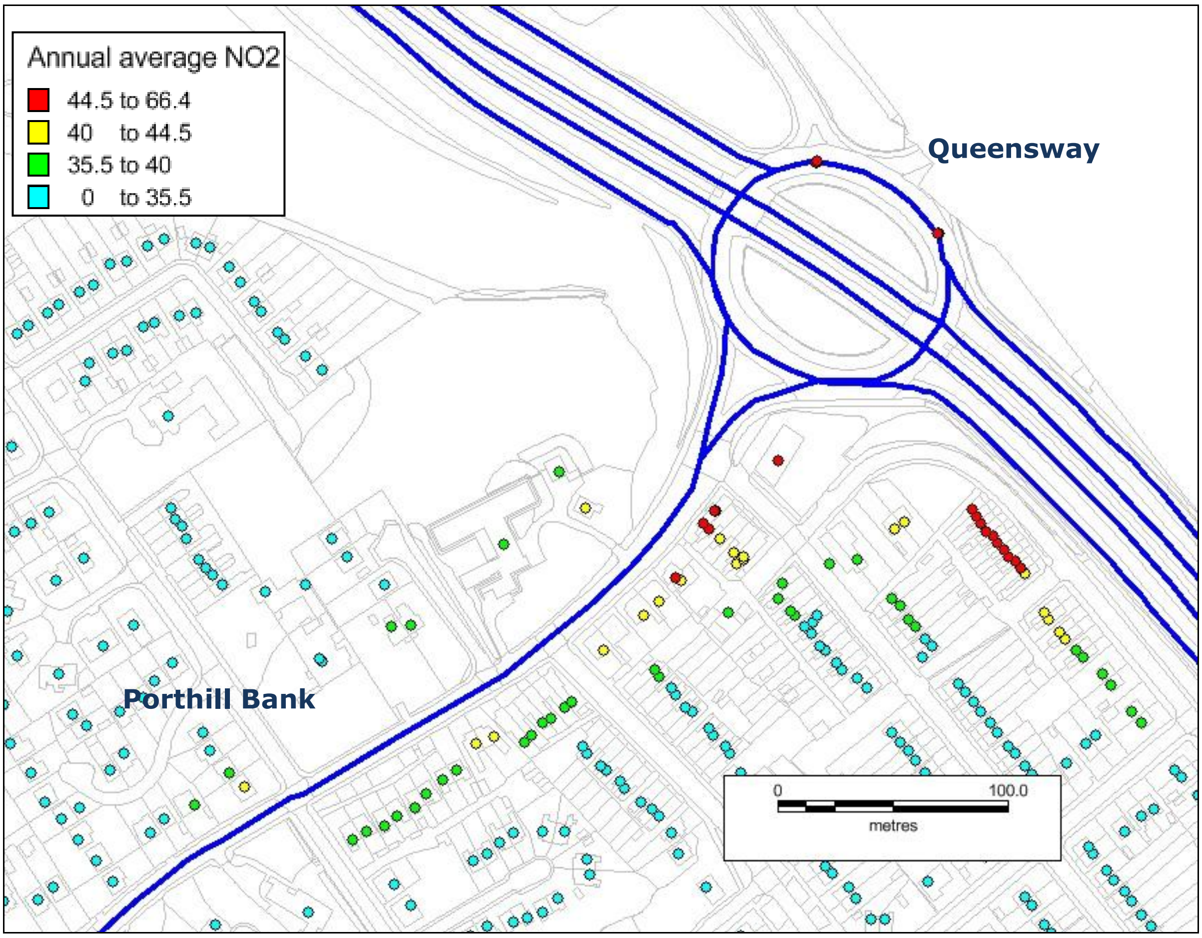

Figure 5-5: Modelled annual mean NO_2 concentration, Porthill Bank.

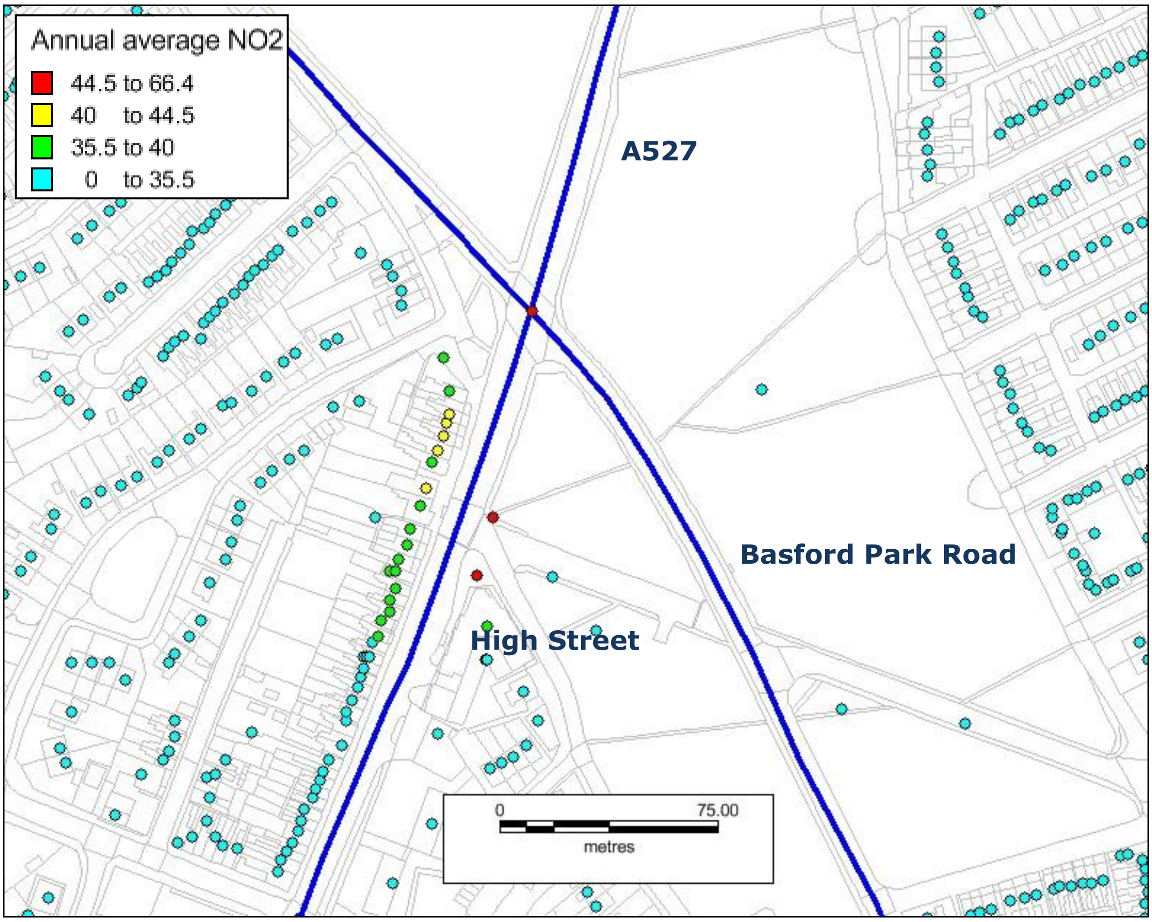

Figure 5-6: Modelled annual mean NO_2 concentration, High Street, May Bank.

5.2 Required reduction to meet the objective

An air quality further assessment requires a determination of the amount of NO_2 reduction required at worst case receptors to meet the objective. This section provides an estimate of the maximum reduction in NO_x and NO_2 concentrations required to achieve the annual mean NO_2 objective at selected worst case locations. The estimate is based on the methodology provided in the Technical Guidance (Defra, 2009) to calculate current and "required" road NO_x concentrations (see Table 5-1). The "required" road-NO_x is the road NO_x concentration required to give a total NO_2 concentration of 40 $\mu g/m^2$ using Defra's NO_x-NO_2 calculator.

The results show that at the worst case site in the town centre (106 King Street), a maximum reduction in road NO_x of 39 percent would be required to achieve the annual mean NO_2 objective. This equates to a NO_2 reduction of 19 percent. In Kidsgrove, the greatest reduction of 12 percent NO_2 is required at DT6 (106 Liverpool Road). The results also indicate the very small reductions required at Madeley and Porthill which is very encouraging with respect to the application of air quality mitigation options.

Table 5-1: Required NOx and NO_2 reduction to achieve the NO_2 annual mean objective.

Site ID	Measured NO_2	Mapped background NO_x	Road NOx	Required road NOx to achieve NO_2 objective	Required reduction in road NO_x (%)	Required reduction in NO_2 to achieve objective (%)
			Concentration ($\mu g/m^3$)			
			Madeley			
Façade of house	**40.1**	35.0	38.8	38.4	0.4 (1%)	0.13 (0.3%)
			Town centre			
DTK1	**47.1**	35.8	55.9	35.6	20.3 (36%)	6.1 (13%)
DT85	**49.1**	35.8	61.3	37.6	23.8 (39%)	9.1 (19%)
			Kidsgrove			
DT6	**45.3**	25.9	62.7	48.8	13.9 (22%)	5.3 (12%)
			Porthill			
DT24	**40.9**	33.3	42.6	40.4	2.2 (5%)	0.9 (2%)

5.3 Expected date of compliance with the objective

An estimate has been provided of a date by which the annual mean NO_2 objective is expected to be met at worst case locations in the study areas. The technical guidance (Defra, 2009) provides a series of adjustment factors to project NO_2 concentrations to future years. These have since been updated[10] and are used to predict the date of predicted compliance at selected diffusion tube monitoring sites or modelled at worst case receptors (see Table 5-2).

Based on these forecasts, the information provided in the table shows that the worst case receptor (DT85) would be expected to meet the objective by 2017. Conversely the receptor at Madeley is expected to comply by the end of 2013. It is noted that these forecasts don't take into account that recent analysis has shown that NO_2 concentrations at roadsides have not declined as expected so these forecasts are considered to be optimistic.

[10] http://laqm.defra.gov.uk/technical-guidance/

Table 5-2: Date of compliance with the NO_2 annual mean objective.

Site ID	Monitored	Annual mean NO_2 concentration ($\mu g/m^3$) Predicted				
	2012	2013	2014	2015	2016	2017
			Madeley			
Façade	**40.13**	38.3	-	-	-	-
			Town centre			
DTK1	**47.1**	**45.0**	**43.0**	**40.9**	38.5	**-**
DT85	**49.1**	**46.9**	**44.8**	**42.7**	**40.2**	37.7
			Kidsgrove			
DT6	**45.3**	**43.3**	**41.3**	39.3	-	-
			Porthill			
DT24	**40.9**	39.1	-	-	-	-

5.4 Population exposure

An estimate of the number of people exposed to pollutant concentrations above the relevant air quality objectives in each area is provided below based on address point data in GIS. This estimate takes into account the uncertainty of the model's performance (i.e. 40 $\mu g/m^3$ +/- RMSE). Based on an average of two people per household, this estimate is provided in Table 5-3.

The number of properties includes multiple flats at the same address (e.g. in the town centre). It is not known from the address point data what floor these flats are on. As the model was set up for receptors at two metres, if relevant receptors are located in flats at first floor level or above, the distance from the road source would be greater than assumed and pollutant concentrations would be slightly lower. Therefore the number of people exposed to concentrations above the objective may be lower than estimated.

Table 5-3: Estimated number of people exposed to modelled annual mean NO_2 concentrations above the objective.

Area	Number of households	Number of people
Madeley	1	2
Town centre	97	194
Kidsgrove	36	72
Porthill	104	208

6 AQMA boundary supplementary assessment

6.1 Methods of determining the AQMA boundary

The air quality modelling results presented in Section 5 have shown that the annual mean NO_2 objective is likely to be exceeded at locations of relevant exposure in all four of the study areas. Therefore Newcastle Under Lyme Borough Council is now required to proceed to designate and declare AQMAs. The method by which to determine the geographical boundary of an AQMA is not explicitly stated in the Technical Guidance (Defra 2009). The final decision on an appropriate boundary can therefore be made by the local authority using the available evidence from the detailed/further assessment. The local authority will need to consult on the proposed AQMA boundaries before declaring official AQMA orders.

One method to determining the extent of an AQMA is for the local authority to take the results from the air quality modelling as the basis of the boundary. In this case the final boundary takes into account the area of exceedence only (including the degree of modelling uncertainty) and is set round geographical features, such as property boundaries. Alternatively, they may wish to take a more pragmatic approach and define a wider AQMA boundary rather than purely the area of exceedence. The advantages of setting a wider AQMA boundary are as follows:

- It can take account of existing wider strategic issues (such as planning guidance and transport plans).
- It could encourage a political will and support for greater change in the area.
- It would take the focus away from designating individual/named properties within an AQMA. This method could potential effect the valuation of the property and lead to issues when selling or buying.
- It would allow areas that are currently non-residential to be included within the AQMA. Therefore if they are subsequently developed as residential at a later stage it would not be necessary to amend the boundary.
- By joining small pockets of exceedence (such as in the town centre), this would allow for a more practical and joined up approach to be taken when implementing an Air Quality Action Plan for the whole area.

The sections below outline the proposed boundary of an AQMA for all four areas. A justification for the proposed boundary and its relevance to developing mitigation measures is given for each area.

6.2 Madeley

The modelling results show that there is only one relevant receptor (Collingwood, Newcastle Road) that is predicted to exceed the annual mean NO_2 objective and that this result is only marginally above the objective. It is unlikely that there would be any future developments that are located closer to the M6 motorway than this property and any developments located further from the motorway would be expected to be below the objective. It is therefore proposed that an AQMA boundary is declared around the land surrounding Collingwood, Newcastle Road (see Figure 6-1). The AQMA should be declared around the wider property area rather than just the existing building in case the owners apply for any extension or development to their property.

There are likely to be few available measures to put in place in an action plan for this site, but the local authority should liaise with the Highways Agency on any plans that they have to improve traffic flow and congestion on this section of the M6 motorway. The local authority will need to maintain their diffusion tube monitoring at the property to determine if the measured annual mean NO_2 concentrations continue to decline.

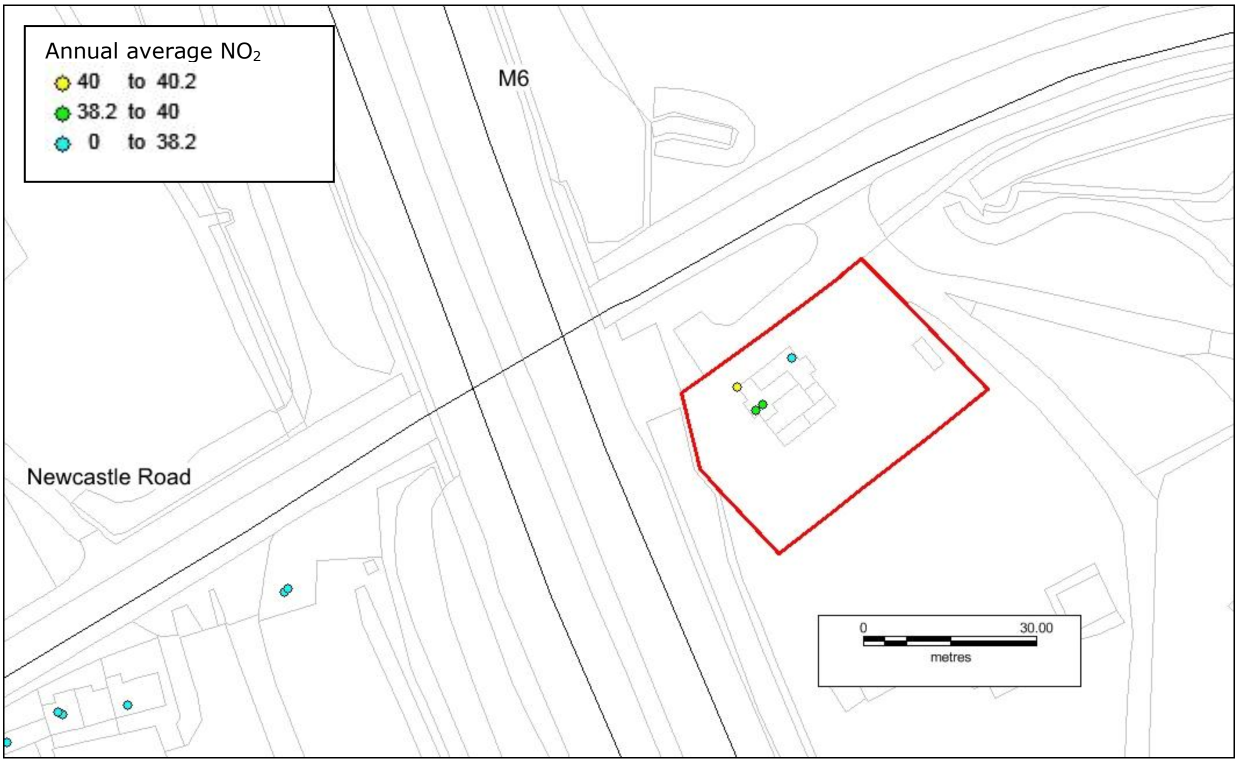

Figure 6-1: Proposed AQMA boundary (in red) for annual mean NO_2 concentrations. Collingwood, Newcastle Road in Madeley.

6.3 Kidsgrove

There are relevant receptors located on Liverpool Road adjacent to two junctions, one with Heathcote Street and one with Gloucester Road (as shown in Figure 5-2). There is a distance of around half a kilometre between these junctions, so it is considered appropriate to join up the areas of exceedence to declare one larger AQMA boundary as proposed in Figure 6-2. This proposed boundary extends to approximately 50 metres either side of Liverpool Road between the two junctions. A section of Hardingswood Road up to the canal is included in the AQMA to encompass the Canal Tavern. It is noted that the green circle to the south of the proposed AQMA (The Avenue) is not a relevant receptor.

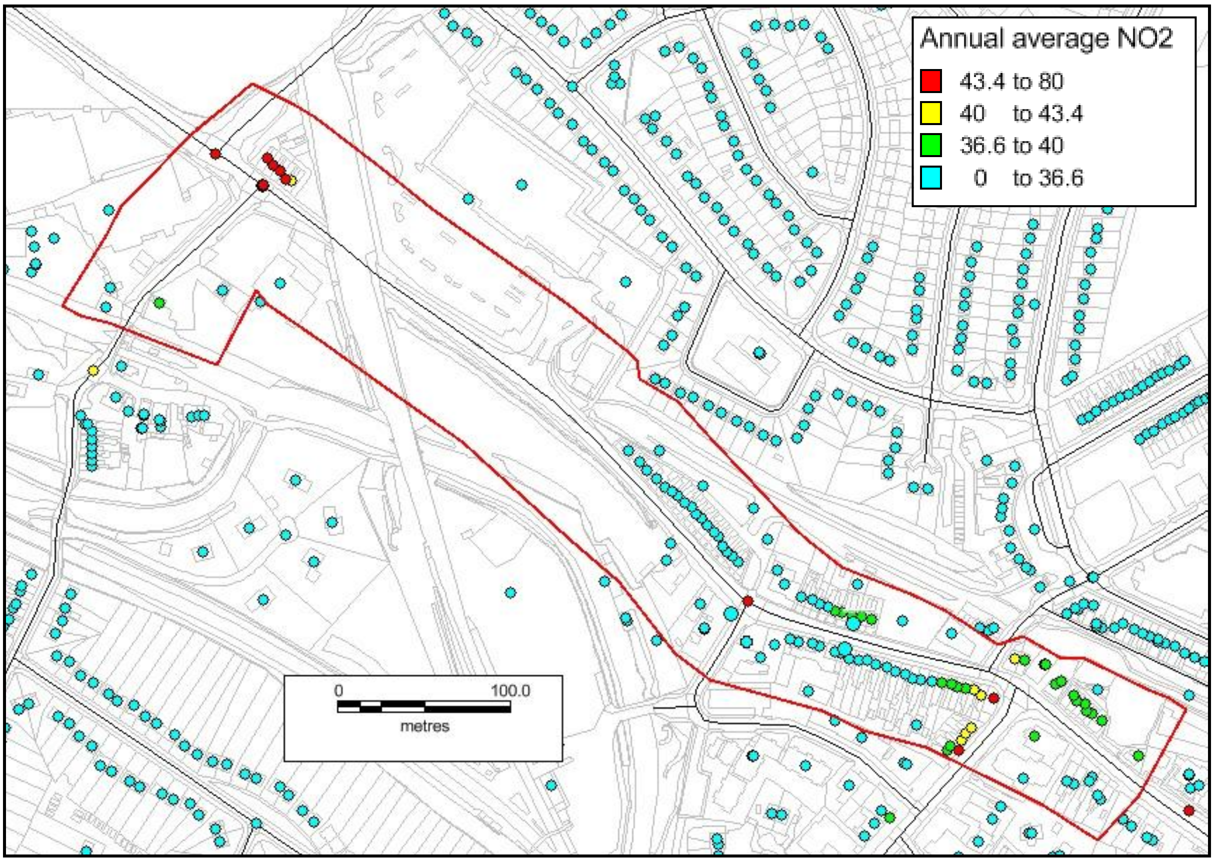

Figure 6-2: Proposed AQMA boundary (in red) for annual mean NO_2 concentrations, Liverpool Road, Kidsgrove.

The County's integrated transport strategy (Staffordshire County Council, 2011) provides a local transport package for Kidsgrove. This includes measures such as developments around the station, which is south of Liverpool Road (including interchange improvements, parking and traffic management), introducing a one way system on Market Square/Heathcote Street and urban traffic control to improve traffic flow and air quality on Liverpool Road.

The local authority's action plan could therefore focus on measures to smooth traffic flow and reduce congestion such as optimisation of traffic signals. There are a few small businesses siding Liverpool Road which would rely on passing trade, hence the need to retain the on road parking although it is noted that there is free parking close by. Being a strategic route it is unlikely that weight restrictions can be applied to the A50, but this should be examined and ruled out.

6.4 Town centre

6.4.1 Strategic planning and transport policies

Under their Local Development Framework the local authority has developed a Core Spatial Strategy (Newcastle Under Lyme and Stoke on Trent, 2009) and supplementary planning document (SPD) for the town centre (Newcastle Under Lyme, 2009b). Spatial Policy ASP4 includes proposals to provide for:

- 25,000m² of additional gross comparison retail floorspace to 2021 and a further 10,000m² to 2026; this will be appropriate in terms of the role of the town centre and capable of meeting the needs of town centre users.
- 60,000m² of additional gross office floorspace within, or on the edge of the town centre, to accommodate new employment of a type in keeping with the role of the town centre.

The town centre is seen as one of the strategic centres in North Staffordshire and the aim of the SPD is to set out guidance for planning and land use issues as a means to promote regeneration and growth of the economy. The document has a vision to attract investment, high quality commercial developments and new residential development to enhance the town's character and features.

In line with these policies, the local authority[11] has provided details of recent development sites (indicated in Figure 6-3). Purple areas are development/redevelopment sites and blue areas are commercial areas that may be permitted residential development in the future.

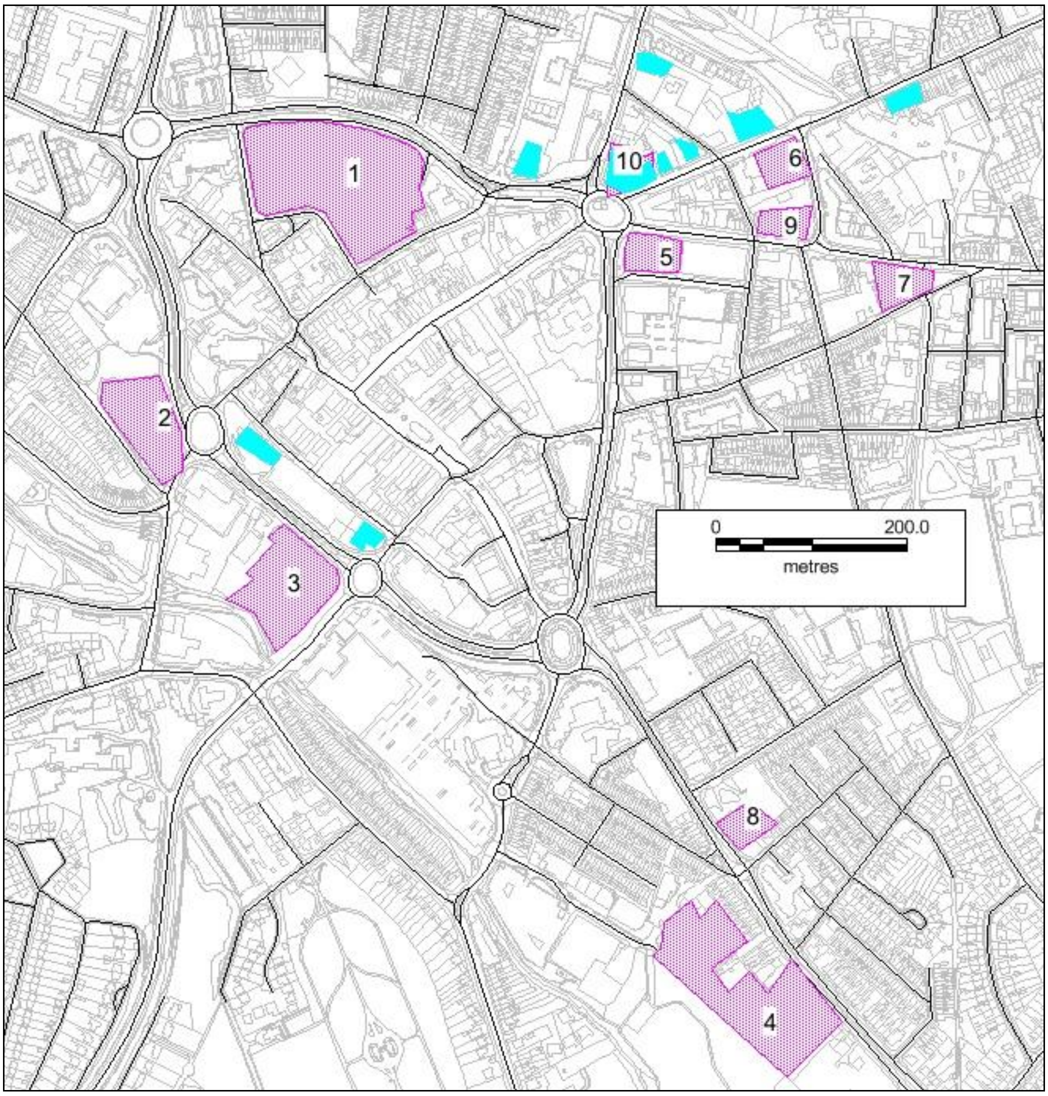

Figure 6-3 : Existing development and redevelopment sites, town centre.

[11] Personal communication (Darren Walters, September 2013).

Details of the existing or proposed development sites (coloured in purple) in Figure 6-3 are given below.

1. Potential civic hub incorporating civic officers or supermarket site
2. Potential offices/student accommodation
3. Potential supermarket or retail site
4. Retail site
5. Jubilee pool- retail ground floor/upper storey flats
6. Existing residential development at first floor
7. Existing redevelopment of site of former nightclub with flats
8. Potential student accommodation
9. Existing residential development at first floor
10. Student accommodation in former offices

Staffordshire County Council developed its Local Transport Plan (LTP) in 2011. The plan has three main objectives – to support growth and regeneration, maintain the highway network and to make transport easier to use and places easier to get to. Within the overall plan, the Council has issued integrated transport strategies for each district. For Newcastle Under Lyme (Staffordshire County Council, 2011), the priority transport measures for the town centre include:

Short term:

- Completing areas of pedestrianisation in the town centre (e.g. Hassell Street) to remove through traffic
- Introducing a bus priority route in Barracks Road
- Installing variable message signs on radial route and car park

Long term:

- Improving the accessibility by all modes of transport to the town centre
- Investigating the use of traffic control measure to reduce peak hour congestion
- Enhancing pedestrian facilities across and within the ring road (e.g. desire lines)
- Implementing further bus priority routes (e.g. George Street) and accessibility improvements (e.g. Queen Street)
- Delivering the Lyme Valley (North) Cycle link
- Introducing speed reduction measures on the ring road

6.4.2 Proposed AQMA boundary

Existing relevant receptors that are located in areas of modelled exceedence of the annual mean NO_2 objective are located adjacent to two major roundabout intersections on the town centre inner ring road namely on Barracks Road, King Street and London Road (as shown previously in Figure 5-4). Based on these existing receptors and the strategic plans for development, it is recommended that the local authority designate the entire area around the ring road as an AQMA. This could include either just those roads within 50 metres of the ring road or the whole town centre area within. They should also extend the AQMA along the A53 King Street to the edge of the local authority boundary with neighbouring Stoke on Trent City Council. Stoke on Trent declared a city wide AQMA for annual mean NO_2 in 2006 and recently amended the order to include the hourly objective for exceedences on the A53 Etruria Road. This road is the main route into Newcastle Under Lyme Town Centre (King Street). The recommended AQMA boundary to include the whole of the town centre is given in Figure 6-4.

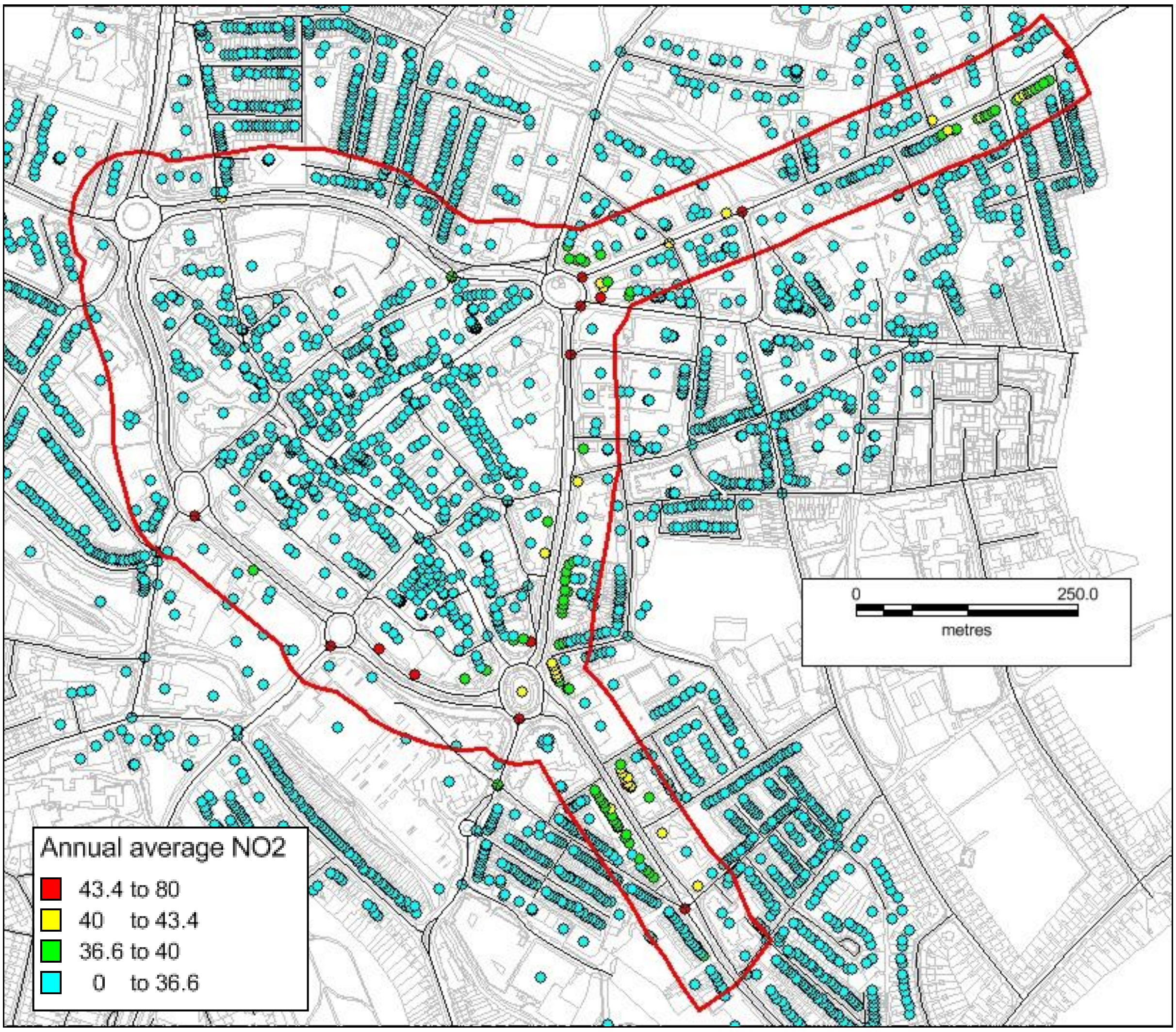

Figure 6-4: Proposed AQMA boundary (in red) for annual mean NO_2 concentrations. Newcastle Under Lyme Town Centre.

This proposed AQMA boundary will take into account the local authority's long term vision to regenerate the town centre and will enable a joined up approach with neighbouring authorities and the County to implement and effectively monitor action plan measures. In addition to those already considered in the integrated transport strategy, other measures to consider could include:

- Promotion of plug-in vehicle technologies with the provision of free recharging facilities and reduced parking tariffs

- Encouraging a modal shift to low emission buses. Operators encouraged to run low emission buses could be given enhanced access on routes in the town centre and key corridors.
- Freight consolidation whereby deliveries to the town centre are switched to electric vehicles.

It is noted that Newcastle under Lyme is going through a transitional phase in terms of planning and development. Regeneration of the town centre will presumably attract more traffic rather than less traffic. This is a conundrum with regards to air quality. It is possible however to decouple environmental degradation and economic growth through the implementation of strategic measures.

6.5 Porthill

In the Porthill/May Bank area there are relevant receptors that exceed the annual mean NO_2 objective adjacent to the approach with the Queensway (A500) and a smaller area at May Bank south of the junction with High Street and Basford Park Road (as shown in Figure 5-5 and Figure 5-6). Following discussions with the local authority it is recommended that these two areas are joined up to declare a wider AQMA boundary to include the A527 High Street from the junction with Basford Park Road to Porthill Bank to the junction with Queensway. The AQMA boundary also includes the approach to Queensway from the south up to the edge of the borough boundary with Stoke on Trent to take into account emissions from queuing traffic (see Figure 6-5). The AQMA extends to no more than 50 metres either side of the road.

One of the reasons for deciding to link these two areas into one AQMA as it is considered to be more practical to implement joined up measures in the air quality action plan. One measure that could ease congestion around both junctions, particularly in peak times could be to improve signage and publicity to drivers advising them of alternative routes from Queensway into May Bank such as by using Grange Lane rather than Porthill Bank.

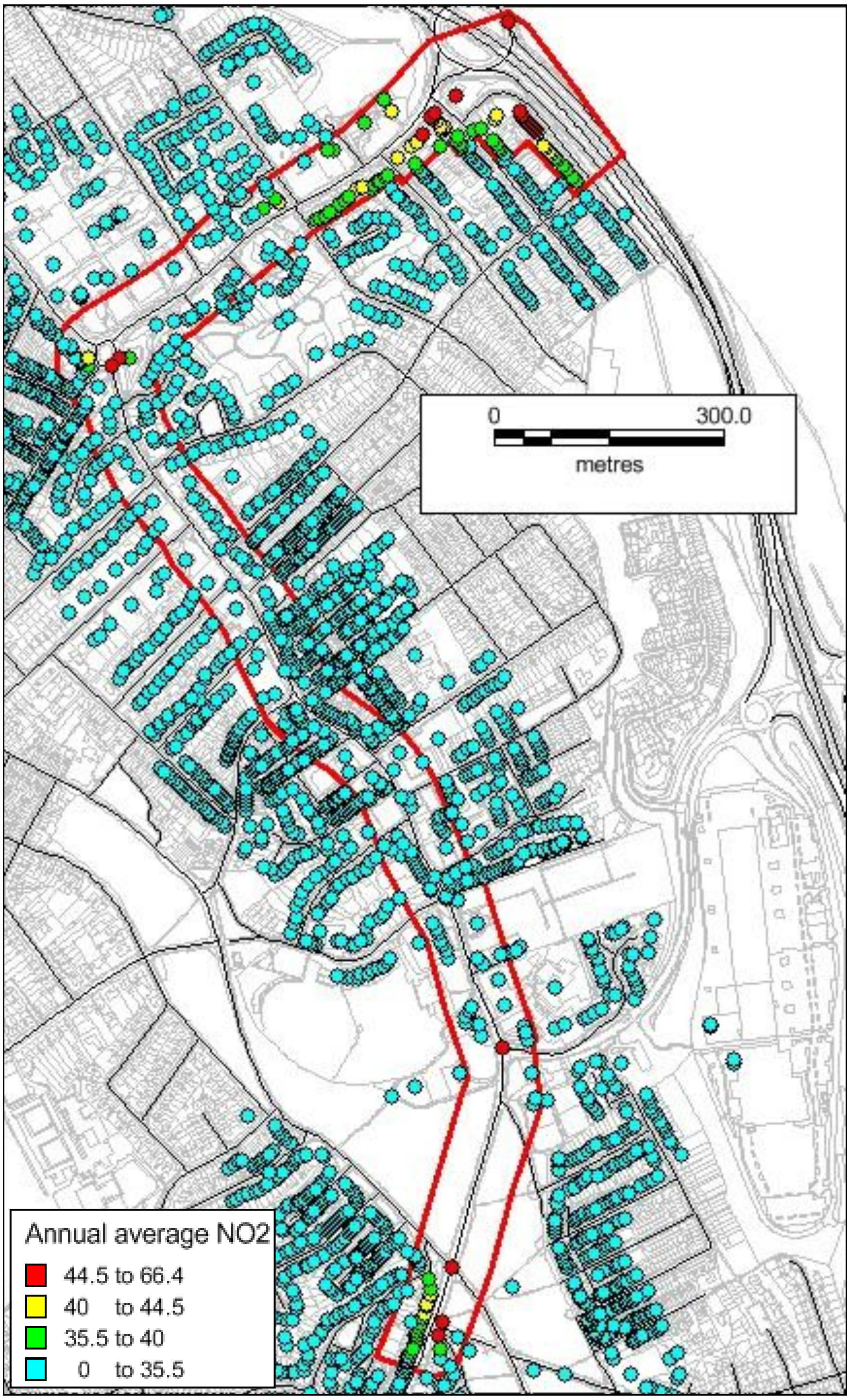

Figure 6-5: Proposed AQMA boundary (in red) for annual mean NO_2 concentrations, Porthill/May Bank.

7 Source Apportionment

The ADMS model was run to calculate the contribution from different vehicle categories to the annual mean NO_2 concentrations at worst case receptors. The contribution of regional background (for which local authorities do not have control over) and local background contribution (which authorities should have some influence over) has also been calculated based on the modelled background maps. The source apportionment exercise was carried out in line with the methodology in the Technical Guidance (Defra, 2009). The results are presented below for each study area in turn.

7.1 Madeley

The contribution to annual mean NO_2 concentrations from the local traffic sources and background are provided in Table 7-1 and Figure 7-1. The results show that the largest contribution (45 percent) is from the local background (i.e. other roads, industry, domestic and railway). The contribution from local traffic is similar, at 43 percent. Of the local traffic emissions, the greatest contribution is from the heavy duty vehicles (HDV (i.e. heavy goods vehicles - HGVs and buses). It is likely that the majority of the HDV emissions are from the M6 motorway as these contribute more than 16 percent to the traffic flow.

Table 7-1: Contribution of sources to modelled annual mean NO_2 concentrations, Madeley.

		Contribution of main sources to total NO_2 concentrations ($\mu g/m^3$)						
Site ID	Total NO_2	Regional background	Local background	Local traffic -				
				Cars	LGV	HGV	Bus	Motorbikes
Façade	40.1	5.0	17.9	6.0	2.1	8.8	0.4	0.0

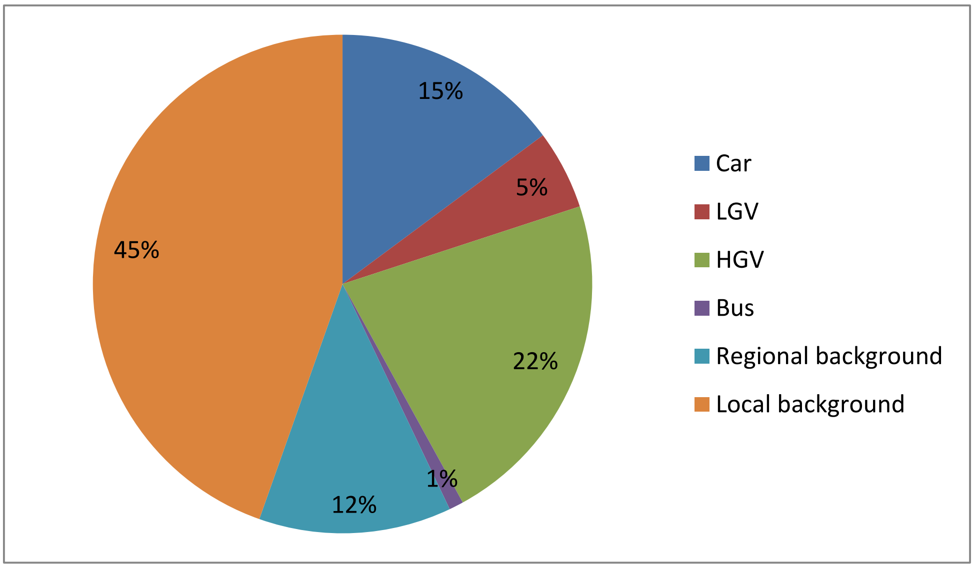

Figure 7-1: Percentage contribution to modelled annual mean NO_2 concentration, façade of Collingwood, Newcastle Road.

7.2 Kidsgrove

The contribution to annual mean NO_2 concentrations from local traffic sources and background was similar at all receptors and are shown in Table 7-2 and Figure 7-2 or a worst case diffusion tube site. The results show that the largest contribution to NO_2 is from local traffic (60 percent), in particular from cars which make up nearly 30 percent. The local background has a lower contribution than at the more rural site in Madeley, making up 28 percent of the NO_2 concentration.

Table 7-2: Contribution of sources to annual mean NO_2 concentrations, Kidsgrove.

		Contribution of main sources to total NO_2 concentrations ($\mu g/m^3$)						
Site ID	Total NO_2	Regional background	Local background	Local traffic - Cars	LGV	HGV	Bus	Motorbikes
DT6	45.3	5.4	12.6	12.8	5.7	4.1	4.8	0.0

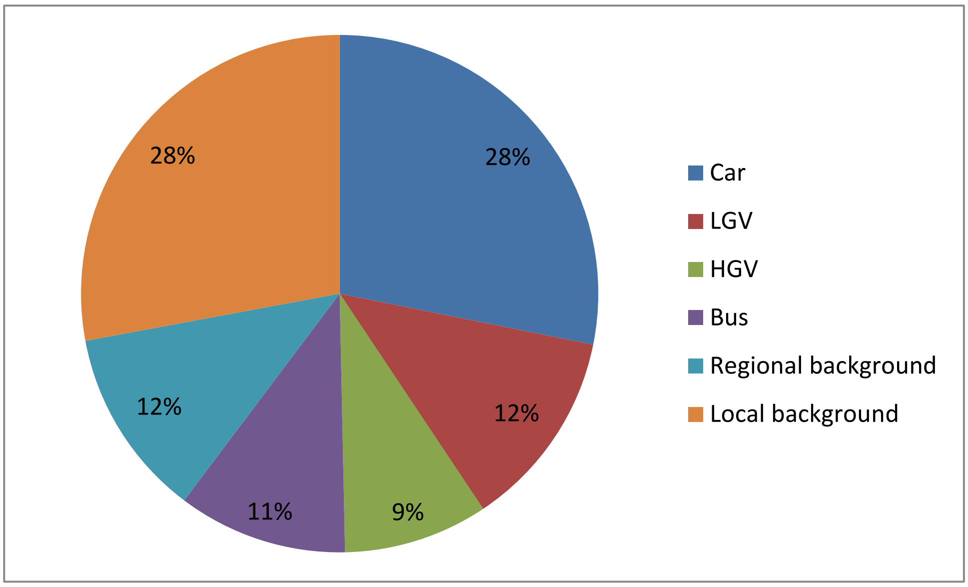

Figure 7-2: Percentage contribution to the annual mean NO_2 concentration, 106 Liverpool Road (DT6), Kidsgrove.

7.3 Town centre

The contribution from local traffic sources and background are provided in Table 7-3, Figure 7-3 and Figure 7-4 for two diffusion tubes at receptors. The results show that the largest contribution is from local traffic (just over 50 percent), in particular from cars. Emissions from buses and HGVs are also significant, particularly on King Street (DT85). The local background does not have as large contribution as at the more rural site in Madeley, making up 35-37 percent of the NO_2 concentration.

Table 7-3: Contribution of sources to annual mean NO_2 concentrations, town centre.

Site ID	Total NO_2	Contribution of main sources to total NO_2 concentrations ($\mu g/m^3$)						
		Regional background	Local background	Local traffic - Cars	LGV	HGV	Bus	Motorbikes
DT85	49.1	5.2	18.3	9.9	2.9	4.9	7.9	0.0
DT96	44.9	5.3	15.7	11.5	3.3	5.9	3.2	0.0

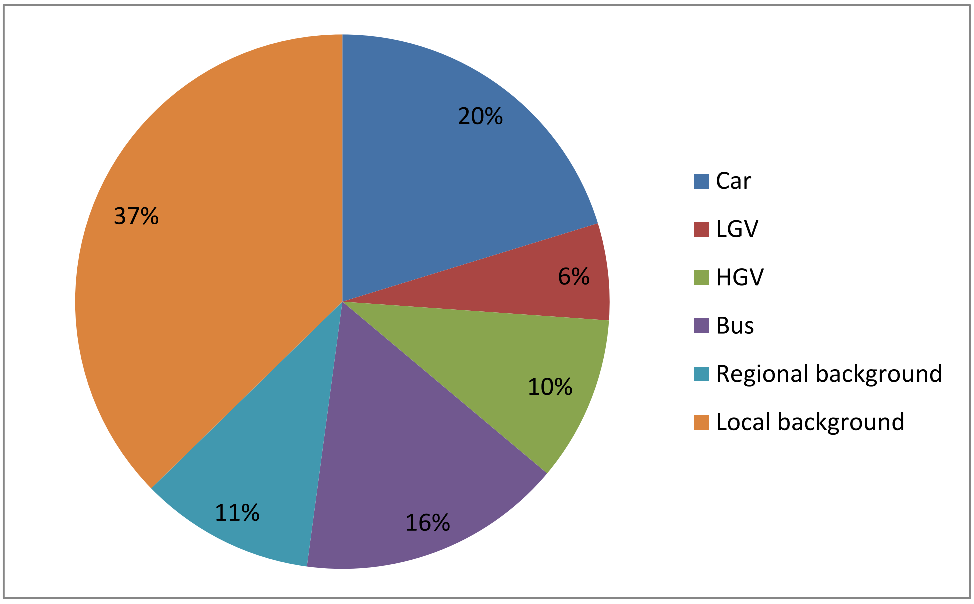

Figure 7-3: Percentage contribution to the annual mean NO_2 concentration, 106 King Street (DT85), town centre.

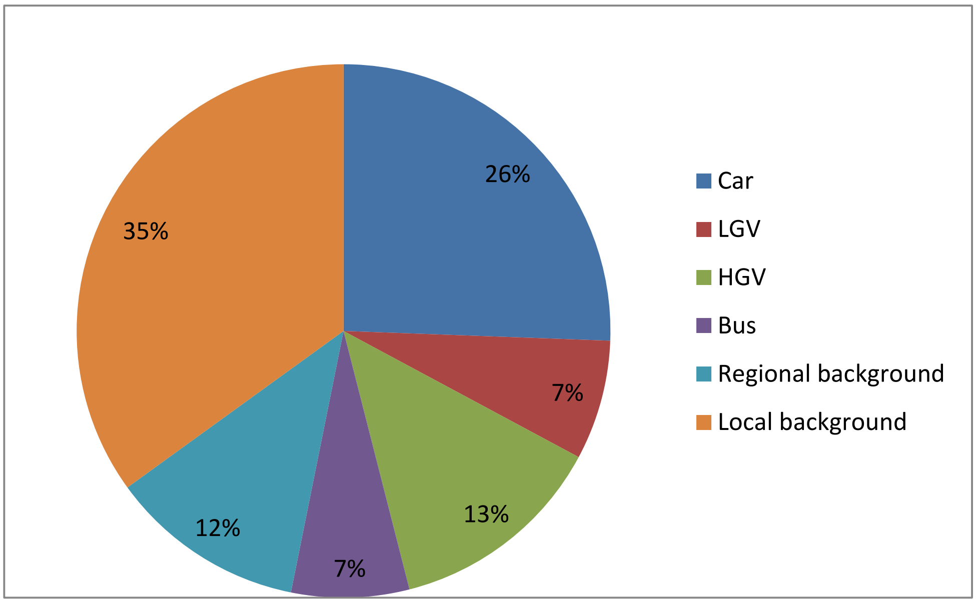

Figure 7-4: Percentage contribution to the annual mean NO_2 concentration, 52-54 London Road (DT96), town centre.

7.4 Porthill

The contribution from local traffic sources and background are provided in Table 7-4, Figure 7-5 and Figure 7-6 for two diffusion tubes located at receptors. The results show that the contribution from local background and all local traffic is similar (at just under half each). Of the local traffic, cars are the greatest contributor at both sites (more than 20 percent). The contribution from LGV and HGVs is marginally higher on Porthill Bank, which is nearest the Queensway dual carriageway, where levels of these vehicles are higher.

Table 7-4: Contribution of sources to annual mean NO_2 concentrations, Porthill.

		Contribution of main sources to total NO_2 concentrations (µg/m^3)						
Site ID	Total NO_2	Regional background	Local background	Local traffic - Cars	LGV	HGV	Bus	Motorbikes
DT9	40.4	5.3	16.6	9.5	2.3	2.6	4.2	0.0
DT24	40.9	5.2	17.9	8.9	2.0	2.4	4.5	0.0

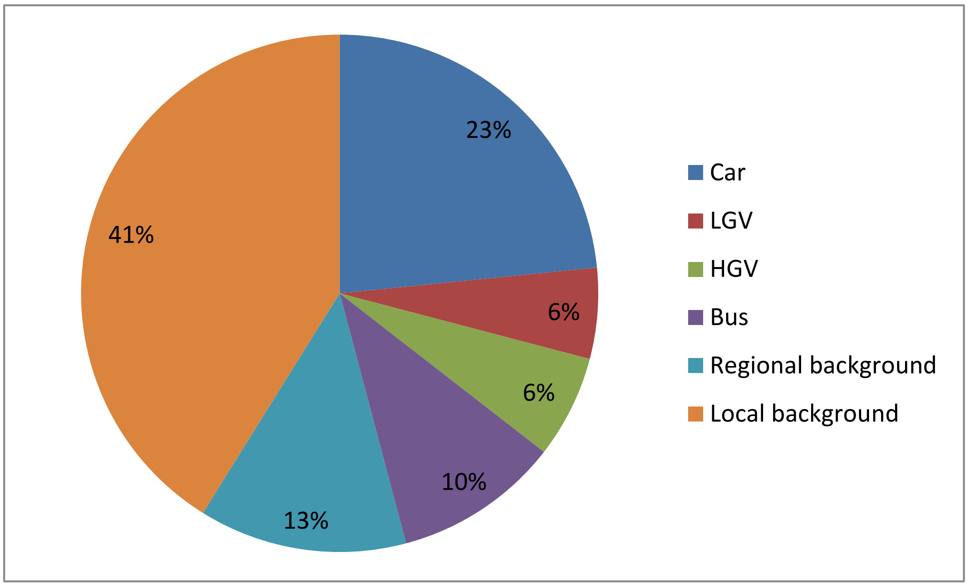

Figure 7-5: Percentage contribution to the annual mean NO_2 concentration, 32 Porthill Bank (DT9), town centre.

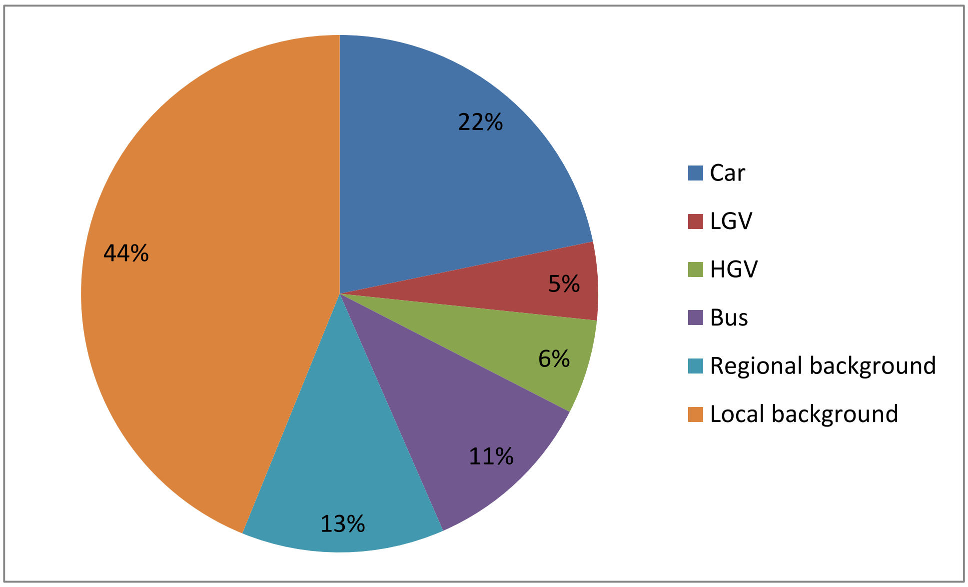

Figure 7-6: Percentage contribution to the annual mean NO_2 concentration, 24-26 High Street (DT24), town centre.

8 Conclusion and proposed actions

The modelling assessment meets the requirements of a detailed and further assessment for four areas of Newcastle Under Lyme – Madeley, Kidsgrove, Newcastle Under Lyme Town Centre and Porthill/May Bank.

Evidence from the measured data and detailed modelling assessment suggests that the annual mean NO_2 objective is likely to be exceeded at relevant locations in all four areas For each study area the following information has been provided; an estimate of the main sources contributing to exceedences of the annual mean objective, an assessment of the population exposed to concentrations above the objective, the required reduction to achieve the objective and an estimate of the year in which the objective is likely to be complied with in the absence of any air quality mitigation strategies. The report provides a section giving the recommendations and justification on the most appropriate AQMA boundaries to declare for each of the four areas.

The next course of action is for the local authority to consult on these proposals and declare the AQMAs. The local authority will then need to develop suitable mitigation measures that target the main emissions sources and develop an Air Quality Action Plan or plans. The plan should consider how best to monitor these measures in order to gauge their effectiveness.

Acknowledgements

The work described in this report was carried out in the Air Quality Team of the Transport Research Laboratory. The authors are grateful to Tim Barlow who carried out the technical review and auditing of this report.

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Glossary of terms and abbreviations

AADT	Annual Average Daily Traffic
ADMS	Atmospheric Dispersion Modelling System
AQEG	Air Quality Expert Group
AQMA	Air Quality Management Area
AQS	Air Quality Strategy
CERC	Cambridge Environmental Research Consultants
Defra	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
EFT	Emission Factor Toolkit
HDV	Heavy Duty Vehicle (includes buses and HGVs)
HGV	Heavy Goods Vehicle (over 7.5 tonnes)
GIS	Geographic Information System
LAQM	Local Air Quality Management
LGV	Light Goods Vehicle (between 3.5 tonnes and 7.5 tonnes)
LDF	Local development framework
LTP	Local Transport Plan
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_X	Total Oxides of Nitrogen
NTEM	National trip end model
NuL	Newcastle Under Lyme
O_3	Ozone
PHEM	Passenger car and Heavy-duty Emission Model
PM_{10}	Particulate matter less than 10 microns in diameter
RMSE	Root Mean Square Error
SPD	Supplementary Planning Document
TEA	Triethanolamine
TEMPRO	Trip End Model Presentation Program
TRL	Transport Research Laboratory

Appendix A Air Quality Objectives

Table A1: Summary of Air Quality Strategy (AQS) Objectives (Defra, 2007).

Pollutant	Objective	Compliance date
NO_2	Hourly mean concentration should not exceed 200 µg/m^3 more than 18 times a year. Annual mean concentration should not exceed 40 µg/m^3.	31 December 2005
Particulate matter, expressed as PM_{10}	24-hour mean concentration should not exceed 50 µg/m^3 more than 35 times a year.	31 December 2004
	Annual mean concentration should not exceed 40 µg/m^3.	31 December 2005
	Scotland: 24-hour mean concentration should not exceed 50 µg/m^3 more than 7 times a year. Annual mean concentration should not exceed 18 µg/m^3.	31 December 2010
Particulate matter, expressed as $PM_{2.5}$	*UK urban areas* Target of 15% reduction in concentrations at urban background.	Between 2010 and 2020
	Annual mean concentration should not exceed 25 µg/m^3. *Scotland:* Annual mean concentration should not exceed 12 µg/m^3.	31 December 2004
Benzene	Running annual mean concentration should not exceed 16.25 µg/m^3.	31 December 2003
	Scotland & Northern Ireland: Running annual mean concentration should not exceed 3.25 µg/m^3.	31 December 2010
	England & Wales: Annual mean concentration should not exceed 5 µg/m^3.	31 December 2010
1,3-butadiene	Running annual mean concentration should not exceed 2.25 µg/m^3.	31 December 2003
CO	Maximum daily running 8-hour mean concentration should not exceed 10 mg/m^3. In Scotland it is expressed as a running 8-hr mean.	31 December 2003
PAHs	Annual mean concentration of B(a)P should not exceed 0.25 ng/m^3	31 December 2010
Lead (Pb)	Annual mean concentration should not exceed 0.5 µg/m/^{3}.	31 December 2004
	Annual mean concentration should not exceed 0.25 µg/m^3.	31 December 2008
SO_2	Hourly mean of 350 µg/m^3 not to be exceeded more than 24 times a year. 24-hour mean of 125 µg/m^3 not to be exceeded more than 3 times a year.	31 December 2004
	15-min mean of 266 µg/m^3 not to be exceeded more than 35 times a year.	31 December 2005
Ozone (O_3)	Running 8-hour concentration of 100 µg/m^3 not to be exceeded more than 10 times a year	31 December 2005

Appendix B Quality assurance of data

B1: Short term adjustment

The data capture rate for Queen's Gardens for 2012 was 70 percent as no data were available between January to March 2012. Therefore concentrations were adjusted to represent an annual mean following the methodology given in the technical guidance, LAQM.TG(09), Defra, 2009. An average adjustment factor was obtained from two long term background sites on Defra's automatic and rural network (see Table B1). Both of these sites had a high data capture rate in 2012. The factor was applied to the period mean from Queen's Gardens as shown in Section 3.

Table B1: Short term to long term adjustment factor

Site	Data capture (%)	NO_2 annual mean	NO_2 period mean (μg/m^3)	Adjustment factor (Ra)
Ladybower	98	11.0	9.9	1.1
Stoke on Trent centre	99	31.3	30.0	1.0
Average				**1.1**

B2: Diffusion tube bias adjustment factor

As the data capture rate from Queen's Gardens was low, a local bias adjustment factor was not calculated for 2012. Instead a factor was obtained from the national bias adjustment spreadsheet for the laboratory and reparation method (see Figure B1). The average adjustment factor from 27 local authority studies for 2012 was 0.97. This factor was applied to all diffusion tube concentrations.

National Diffusion Tube Bias Adjustment Factor Spreadsheet | Spreadsheet Version Number: 03/13

Follow the steps below **in the correct order** to show the results of **relevant** co-location studies
Data only apply to tubes exposed monthly and are not suitable for correcting individual short-term monitoring periods
Whenever presenting adjusted data, you should state the adjustment factor used and the version of the spreadsheet
This spreadhseet will be updated every few months: the factors may therefore be subject to change. This should not discourage their immediate use.

This spreadsheet will be updated at the end of June 2013
LAQM Helpdesk Website

The LAQM Helpdesk is operated on behalf of Defra and the Devolved Administrations by Bureau Veritas, in conjunction with contract partners AECOM and the National Physical Laboratory.

Spreadsheet maintained by the National Physical Laboratory. Original compiled by Air Quality Consultants Ltd.

Step 1:	Step 2:	Step 3:	Step 4:							
Select the Laboratory that Analyses Your Tubes from the Drop-Down List	Select a Preparation Method from the Drop-Down List	Select a Year from the Drop-Down List	**Where there is only one study for a chosen combination, you should use the adjustment factor shown with caution. Where there is more than one study, use the overall factor[3] shown in blue at the foot of the final column.**							
If a laboratory is not shown, we have no data for this laboratory.	If a preparation method is not shown, we have no data for this method at this laboratory.	If a year is not shown, we have no data[2]	If you have your own co-location study then see footnote[4]. If uncertain what to do then contact the Local Air Quality Management Helpdesk at LAQMHelpdesk@uk.bureauveritas.com or 0800 0327953							
Analysed By[1]	**Method** To undo your selection, choose (All) from the pop-up list	**Year[5]** To undo your selection, choose (All)	**Site Type**	**Local Authority**	**Length of Study (months)**	**Diffusion Tube Mean Conc. (Dm) (μg/m³)**	**Automatic Monitor Mean Conc. (Cm) (μg/m³)**	**Bias (B)**	**Tube Precision[6]**	**Bias Adjustment Factor (A) (Cm/Dm)**
Gradko	20% TEA in Water	2012	R	Gateshead Council	11	32	33	-2.6%	G	**1.03**
Gradko	20% TEA in Water	2012	R	Dudley MBC	9	55	60	-7.5%	G	**1.08**
Gradko	20% TEA in Water	2012	UB	Luton Borough Council	11	38	30	29.4%	G	**0.77**
gradko	20% TEA in water	2012	UC	Southampton City Council	11	30	33	-8.3%	G	**1.09**
Gradko	20% TEA in water	2012	R	Exeter City Council	11	34	34	-0.3%	G	**1.00**
Gradko	20% TEA in water	2012	R	Scarborough B C	11	32	37	-11.3%	G	**1.13**
Gradko	20% TEA in Water	2012	KS	Marylebone Road Intercomparison	11	106	94	12.1%	G	**0.89**
Gradko	20% TEA in water	2012	KS	New Forest DC	10	46	40	13.4%	G	**0.88**
Gradko	20% TEA in water	2012	R	New Forest DC	10	33	29	11.8%	G	**0.89**
Gradko	20% TEA in water	2012	R	Brighton & Hove City Council	11	41	37	10.5%	G	**0.91**
Gradko	20% TEA in water	2012	R	City of Lincoln Council	11	53	44	18.4%	G	**0.84**
Gradko	20% TEA in water	2012	R	Fareham Borough Council	9	38	39	-4.1%	G	**1.04**
Gradko	20% TEA in water	2012	R	NOTTINGHAM CITY COUNCIL	10	44	44	-0.2%	G	**1.00**
Gradko	20% TEA in water	2012	R	NOTTINGHAM CITY COUNCIL	11	43	41	4.9%	G	**0.95**
Gradko	20% TEA in water	2012	R	NOTTINGHAM CITY COUNCIL	10	46	47	-0.3%	G	**1.00**
Gradko	20% TEA in water	2012	R	The Highland Council	9	24	32	-24.1%	G	**1.32**
Gradko	20% TEA in water	2012	R	Wiltshire Council	10	36	35	3.9%	G	**0.96**
Gradko	20% TEA in Water	2012	UB	LB Waltham Forest	11	33	38	-11.8%	S	**1.13**
Gradko	20% TEA in water	2012		**Overall Factor[3] (27 studies)**					**Use**	**0.97**

Figure B1: Extract from the national bias adjustment spreadsheet (version 03/13).

Appendix C Traffic Data

Table C1: Local adjustment flow factors (TEMPRO) for all areas to 2012.

Base year of traffic flow	Factor	Geographical area
2011	1.0025	Madeley
2008	0.9982	Kidsgrove
2009	0.9995	Kidsgrove
2010	1.0007	Kidsgrove
2011	1.0021	Kidsgrove
2009	1.0	Town centre
2010	1.0013	Town centre
2011	1.0027	Town centre

C1: Site 1: Madeley

Table C2: Detailed breakdown of traffic data input to the Emission Factor Toolkit.

SourceID	Road type	Traffic flow	% Car	% Taxi (black cab)	% LGV	% Rigid HGV	% Artic HGV	% Bus and Coach	% Motorcycle	Speed(kph)	No of Hours
Newcastle Rd E of M6	Rural	6522	80.1	0	14.4	2.3	0	0.7	2.5	27.9	24
Newcastle Rd W of M6	Rural	6522	80.1	0	14.4	2.3	0	0.7	2.5	27.9	24
Keele Rd	Rural	10646	80.1	0	14.4	2.3	0	0.7	2.5	27.8	24
M6 SB	Rural	53036	72.9	0	10.3	3.7	12.5	0.4	0.2	113	24
M6 NB	Rural	53036	72.9	0	10.3	3.7	12.5	0.4	0.2	113	24
Crewe Rd	Rural	4267	82.3	0	14.5	1.8	0	0.7	0.7	33.7	24

Figure C1: Madeley ADMS road links and address points.

C2: Site 2: Kidsgrove

Table C3: Detailed breakdown of traffic data input to the Emission Factor Toolkit.

SourceID	Road type	Traffic flow	% Car	% Taxi (black cab)	% LGV	% Rigid HGV	% Artic HGV	% Bus and Coach	% Motorcycle	Speed(kph)	No of Hours
Liverpool Rd1	Urban	13242	81.9	0	14.7	1.3	0.1	1.4	0.6	28.6	24
LiverpoolRd2-7	Urban	12710	81.9	0	14.7	1.3	0.1	1.4	0.6	23.0	24
LiverpoolRd8	Urban	12710	81.9	0	14.7	1.3	0.1	1.4	0.6	23.0	24
LiverpoolRd8	Urban	15732	81.9	0	14.7	1.3	0.1	1.4	0.6	28.3	24
LiverpoolRd9	Urban	13860	81.9	0	14.7	1.3	0.1	1.4	0.6	28.3	24
GloucesterRd1-4	Urban	5114	85.1	0	12.8	1.1	0.0	0.4	0.6	28.1	24
SecondAve	Urban	3163	82.5	0	14.8	0.7	0.0	0.0	2.0	24.7	24
FirstAve1	Urban	6552	81.4	0	14.6	1.4	0.1	0.9	1.6	25.7	24
FirstAve2-3	Urban	3276	81.4	0	14.6	1.4	0.1	0.9	1.6	25.7	24
TheAvenue	Urban	7064	81.4	0	14.6	1.4	0.1	0.9	1.6	25.7	24
Mount Rd1-3	Urban	7543	83.7	0	15.0	0.7	0	0.1	0.5	32.3	24
Heathcote St	Urban	1000	81.9	0	14.7	1.1	0.3	1.4	0.6	25.7	24

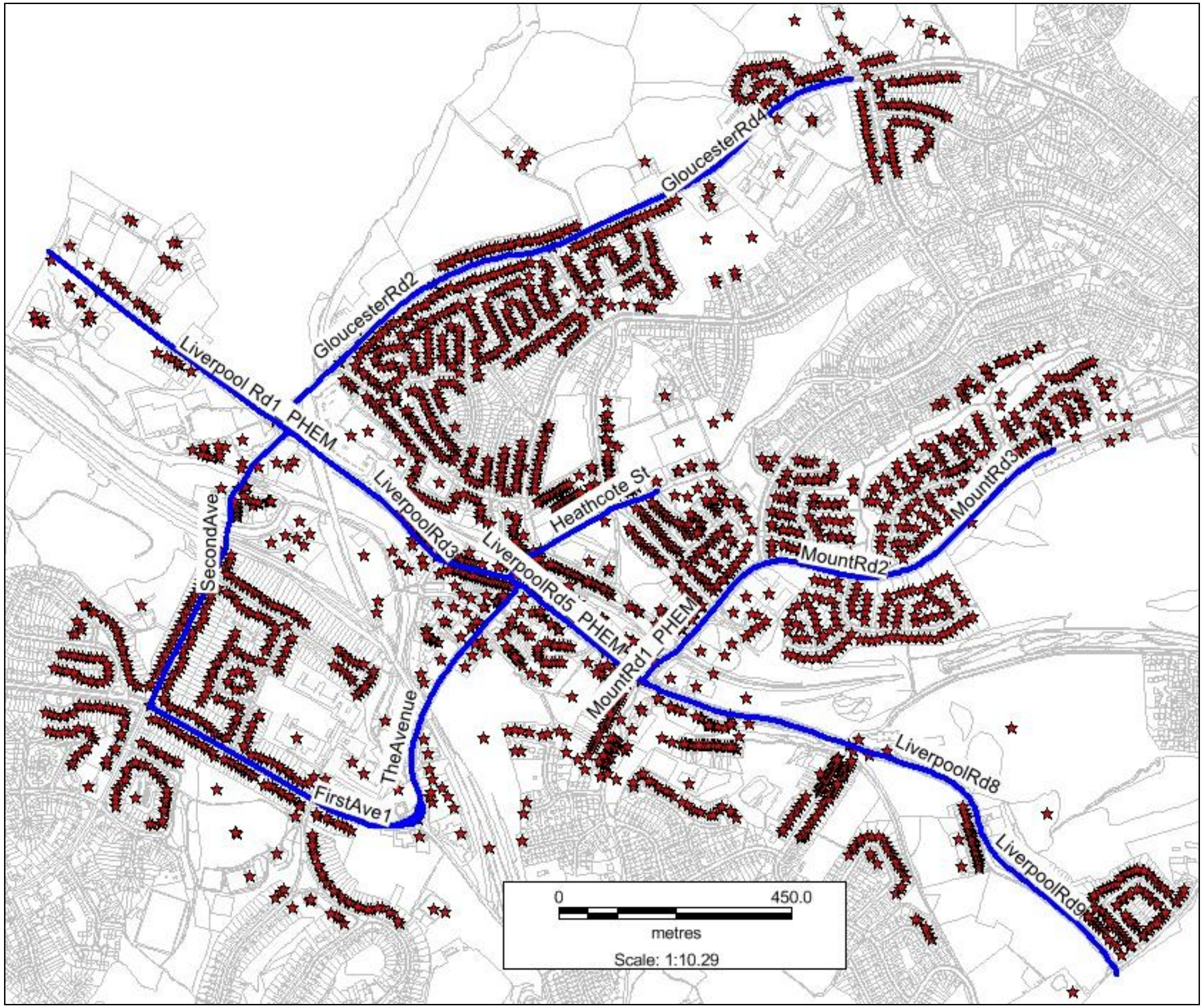

Figure C2: Kidsgrove ADMS road links and address points.

C3: Site 3: Town Centre

Table C4: Detailed breakdown of traffic data input to the Emission Factor Toolkit.

SourceID	Road type	Traffic flow	% Car	% Taxi (black cab)	% LGV	% Rigid HGV	% Artic HGV	% Bus and Coach	% Motorcycle	Speed(kph)	No of Hours
RyecroftEB	Urban	12028	86.9	0	9.8	1.2	0.2	1.1	0.8	33.8	24
RyecroftWB	Urban	10699	86.9	0	9.8	1.2	0.2	1.1	0.8	33.8	24
Ryecroft_roundabout	Urban	15000	87.48	0	9.3	1.7	0.5	0.26	0.76	17.0	24
A34SB_N	Urban	18018	87.48	0	9.3	1.7	0.5	0.26	0.76	48.3	24
A34NB_N	Urban	18018	87.48	0	9.3	1.7	0.5	0.26	0.76	48.3	24
A34SB_S	Urban	15701	87.48	0	9.3	1.7	0.5	0.26	0.76	32.2	24
A34NB_S	Urban	15759	87.48	0	9.3	1.7	0.5	0.26	0.76	38.6	24
BaracksRd_NB1	Urban	11315	85.7	0	8.4	0.7	0.2	4.4	0.6	33.1	24
BarracksRd_NB2	Urban	11346	85.7	0	8.4	0.7	0.2	4.4	0.6	33.1	24
Grosvenor_roundabout	Urban	8195	86.9	0	9.8	0.9	0.6	1.1	0.7	17.0	24
QueenSt	Urban	11504	82.3	0	14.5	2.1	0	0.4	0.7	46.3	24
QueenSt_NB	Urban	6134	82.3	0	14.5	2.1	0	0.4	0.7	29.5	24
QueenSt_SB	Urban	5370	82.3	0	14.5	2.1	0	0.4	0.7	29.8	24
BrunswickSt	Urban	17117	85.0	0	10.3	2.1	0.2	1.8	0.6	29.7	24
KingSt1	Urban	14169	85.3	0	10.1	1.8	0.2	2.2	0.4	29.0	24
KingSt2	Urban	15417	84.6	0	12.6	1.3	0.2	0.9	0.4	29.0	24
LondonRd_roundabout	Urban	13000	86.6	0	8.5	2.4	0.6	0.9	1	17.0	24
LondonRd_SB	Urban	10819	86.6	0	8.5	2.4	0.6	0.9	1	48.3	24
LondonRd_NB	Urban	10819	86.6	0	8.5	2.4	0.6	0.9	1	48.3	24
BrookLane	Urban	15551	81.4	0	14.3	2	0.1	1.5	0.7	22.5	24
HighSt	Urban	1000	86.6	0	8.5	2.4	0.6	0.9	1	13.1	24
LowerSt_EB1	Urban	13800	87.1	0	8.7	1.6	1.2	0.6	0.8	14.4	24
LowerSt_WB1	Urban	13800	87.1	0	8.7	1.6	1.2	0.6	0.8	28.9	24
LowerSt_EB2	Urban	12102	87	0	9.1	1.4	1.1	0.5	0.9	36.2	24
LowerSt_WB2	Urban	12102	87	0	9.1	1.4	1.1	0.5	0.9	36.2	24
BlackfriarsRd	Urban	13293	86.5	0	9.8	1.6	0.3	1.5	0.3	34.1	24
BlackfriarsRd_roundabout	Urban	13000	87	0	9.1	1.4	1.1	0.5	0.9	17.0	24
A34 roundabout	Urban	15000	87.48	0	9.3	1.7	0.5	0.26	0.76	17.0	24

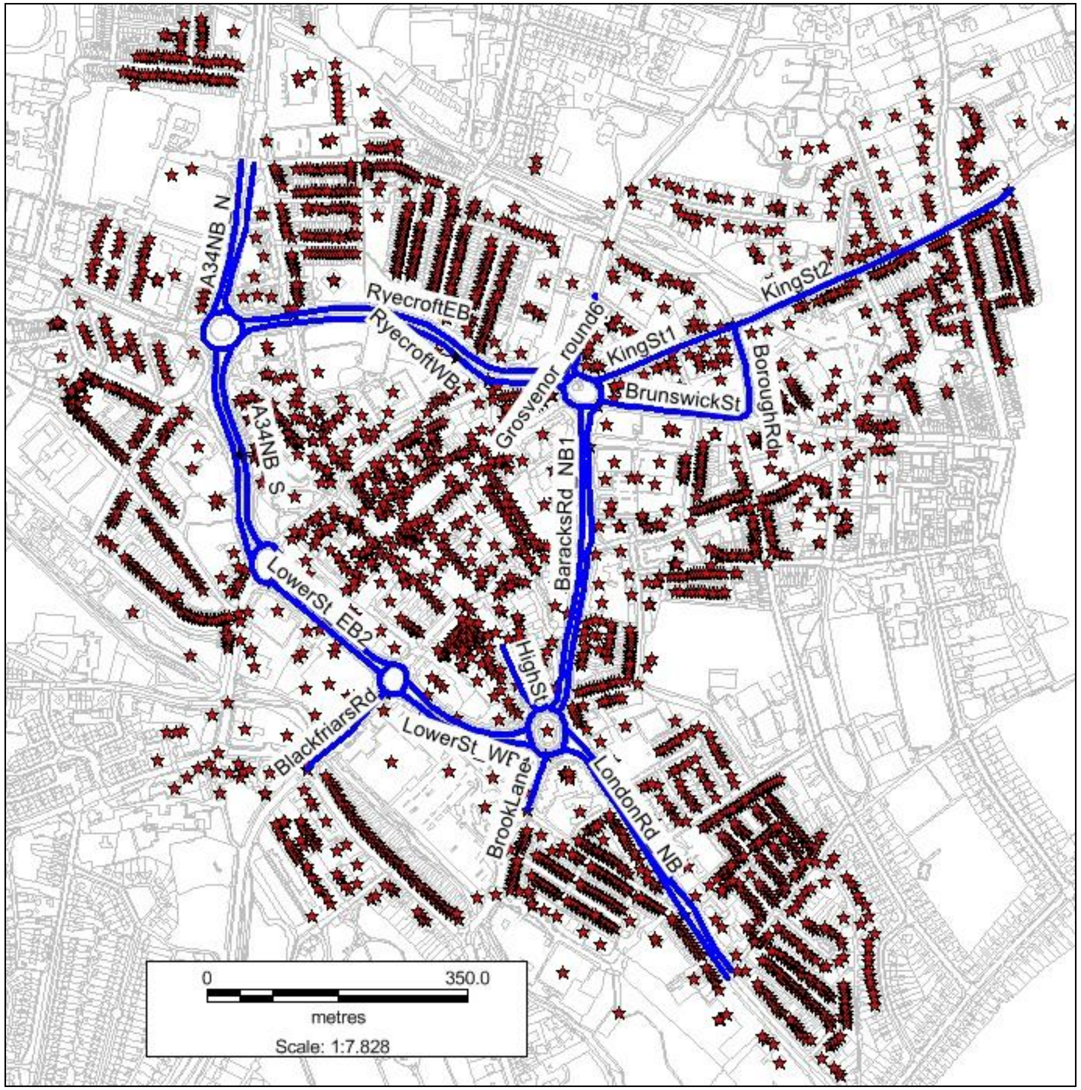

Figure C3: Town centre ADMS road links and address points.

C4: Site 4: Porthill

Table C5: Detailed breakdown of traffic data input to the Emission Factor Toolkit.

SourceID	Road type	Traffic flow	% Car	% Taxi (black cab)	% LGV	% Rigid HGV	% Artic HGV	% Bus and Coach	% Motorcycle	Speed(kph)	No of Hours
ChurchLane1-2	Urban	11688	88.9	0	8	0.4	0.1	1.5	1.1	40.7	24
BramptonRd 1-2	Urban	14776	89.4	0	8	0.5	0.2	1.2	0.7	42.3	24
BramptonRd3-4	Urban	11566	88.6	0	8	0.7	0.3	1.5	0.9	31.9	24
AlexandraRd	Urban	7787	89.8	0	8	0.7	0.3	0	1.2	30.4	24
BasfordPkRd1-2	Urban	8381	89.4	0	8	0.3	0.2	0.7	1.5	35.1	24
PorthillBank	Urban	21246	89.1	0	8	0.4	0.2	1.4	0.9	52.7	24
PorthillBankN	Urban	10565	89.1	0	8	0.4	0.2	1.4	0.9	52.7	24
PorthillBankS	Urban	10681	89.1	0	8	0.4	0.2	1.4	0.9	52.7	24
QueenswayN_slip	Urban	10565	89.1	0	8	0.4	0.2	1.4	0.9	44.6	24
QueenswayS_slip	Urban	10681	89.1	0	8	0.4	0.2	1.4	0.9	44.6	24
QueenswayNB	Urban	33933	77.2	0	14	3.7	4.5	0.1	0.5	106.2	24
QueenswaySB	Urban	33933	77.2	0	14	3.7	4.5	0.1	0.5	106.2	24
Bradwell Lane	Urban	12852	88.4	0	8	1.9	0.4	0.4	0.9	41.4	24
HighSt	Urban	12472	89.1	0	8	0.4	0.2	1.4	0.9	46.4	24
Bradwell_roundabout	Urban	17000	88.4	0	8	1.9	0.4	0.4	0.9	11.4	24

Due to the way the vehicle types are identified by the ATCs, it was difficult to distinguish the light goods vehicles (LGVs) and buses in Group 2 of the classification scheme. Therefore, based on data from the other areas it was assumed that the average composition of LGVs was 8 percent in the fleet and the numbers of buses were obtained from timetables for each road link. Any remaining vehicles in this group were assumed to be rigid HGVs.

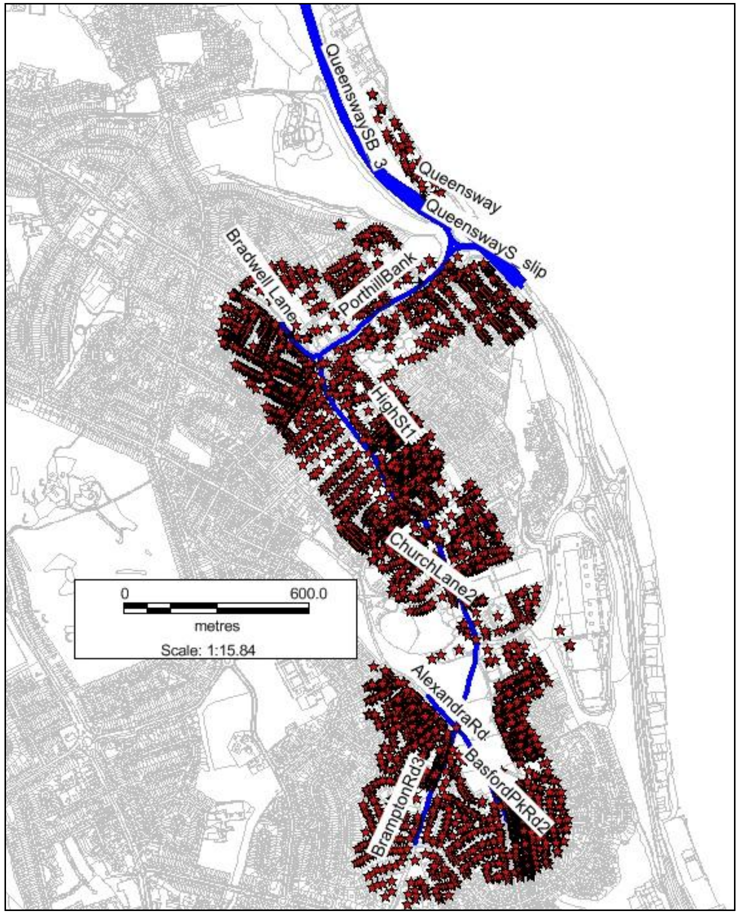

Figure C4: Porthill ADMS road links and address points.

Appendix D Traffic count survey, Porthill.

Nationwide Data Collection (NDC) undertook 7 automatic traffic counts (ATC's) in Porthill, Newcastle under Lyme. A general location plan is given in Figure D1 and site photos in Figures D2 to D8 below. The ATCs were installed at the following locations:

- Site 1: Bradwell Lane, OSGR: SJ 85088 48860
- Site 2: High Street, OSGR: SJ 85255 48614
- Site 3: High Street, OSGR: SJ 85576 48164
- Site 4: Church Lane, OSGR: SJ 85666 47761
- Site 5: Basford Park Road, OSGR: SJ 85654 47557
- Site 6: High Street, OSGR: SJ 85605 47562
- Site 7: Alexander Road, OSGR: SJ 85587 47636

METROCOUNT 5600 series automatic traffic counters, attached to pneumatic tubes, were used at all sites and the resulting data files were analysed to produce speed and class data at hourly intervals. The counters were installed for a period of one week commencing Tuesday 14th May 2013 and a summary of data for each day is given in Table D1.

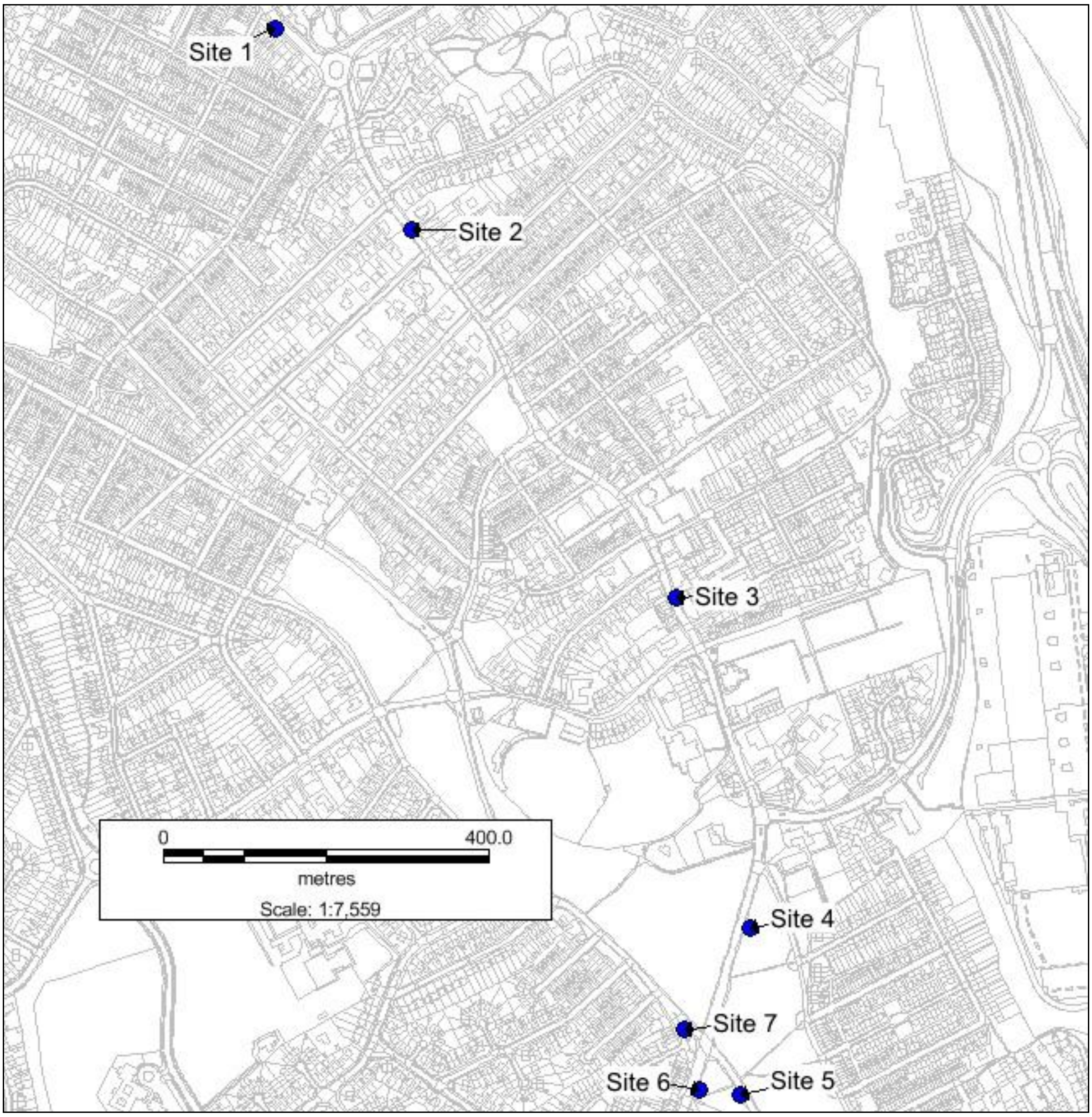

Figure D1: Location of automatic traffic counts, May 2013K, Porthill.

Figure D2: Photo of Site 1 (Bradwell Lane).

Figure D3: Photo of Site 2 (High Street).

Figure D4: Photo of Site 3 (High Street(2)).

Figure D5: Photo of Site 4 (Church Lane).

Figure D6: Photo of Site 5 (Basford Park Road).

Figure D7: Photo of Site 6 (High Street(3)).

Figure D8: Photo of Site 7 (Alexander Road).

Table D1: Summary of data from ATC sites.

Site No.	Location.	Direction.	Speed Limit - PSL (mph)	Start Date.	End Date.	Total Vehicles.	5 Day Ave.	7 Day Ave.	No. > Speed Limit.	%. > Speed Limit.	No. > ACPO Limit.	%. > ACPO Limit.	No. > DfT Limit.	%. > DfT Limit.	Mean Speed	85%ile Speed
1	Bradwell Lane, Att - Fence, OSGR: SJ 85088 48860	East	30	Tue, 14 May 2013	Mon, 20 May 2013	46032	7003	6576	7532	16.4	653	1.4	16	0.0	25.9	30.2
		West	30	Tue, 14 May 2013	Mon, 20 May 2013	43933	6751	6276	3535	8.0	359	0.8	57	0.1	25.5	28.6
		Two way	30	Tue, 14 May 2013	Mon, 20 May 2013	89965	13754	12852	11067	12.3	1012	1.1	73	0.1	25.7	29.5
2	High Street, Att - lc5, OSGR: SJ 85255 48614	North	30	Tue, 14 May 2013	Mon, 20 May 2013	43009	6495	6144	16608	38.6	3381	7.9	120	0.3	28.6	32.9
		South	30	Tue, 14 May 2013	Mon, 20 May 2013	44296	6810	6328	19363	43.7	5254	11.9	193	0.4	29.0	34.0
		Two way	30	Tue, 14 May 2013	Mon, 20 May 2013	87305	13304	12472	35971	41.2	8635	9.9	313	0.4	28.8	33.6
3	High Street, Att - Bus Shelter, OSGR: SJ 85576 48164	North	30	Tue, 14 May 2013	Mon, 20 May 2013	40116	6047	5731	6035	15.0	771	1.9	32	0.1	25.8	30.0
		South	30	Tue, 14 May 2013	Mon, 20 May 2013	41703	6383	5958	6770	16.2	992	2.4	23	0.1	24.9	30.2
		Two way	30	Tue, 14 May 2013	Mon, 20 May 2013	81819	12430	11688	12805	15.7	1763	2.2	55	0.1	25.3	30.0
4	Church Lane, Att - Direction Sign, OSGR: SJ 85666 47761	North	30	Tue, 14 May 2013	Mon, 20 May 2013	54961	8450	7852	14800	26.9	2721	5.0	97	0.2	26.9	31.8
		South	30	Tue, 14 May 2013	Mon, 20 May 2013	48472	7352	6925	11054	22.8	2223	4.6	79	0.2	25.5	31.3
		Two way	30	Tue, 14 May 2013	Mon, 20 May 2013	103433	15802	14776	25854	25.0	4944	4.8	176	0.2	26.3	31.5
5	Basford Park Road, Att - Railings, OSGR: SJ 85654 47557	North	30	Mon, 13 May 2013		2048	2048	2048	35	1.7	3	0.1	0	0.0	17.5	22.6
		South	30	Mon, 13 May 2013		2014	2014	2014	224	11.1	22	1.1	0	0.0	26.0	29.3
		Two way	30	Mon, 13 May 2013		4062	4062	4062	259	6.4	25	0.6	0	0.0	21.7	28.0

Site No.	Location.	Direction.	Speed Limit - PSL (mph)	Start Date.	End Date.	Total Vehicles.	5 Day Ave.	7 Day Ave.	No. > Speed Limit.	%. > Speed Limit.	No. > ACPO Limit.	%. > ACPO Limit.	No. > DfT Limit.	%. > DfT Limit.	Mean Speed	85%ile Speed
5	Basford Park Road, Att - Railings, OSGR: SJ 85654 47557	North	30	Tue, 14 May 2013	Mon, 20 May 2013	29666	4483	4238	679	2.3	112	0.4	7	0.0	17.8	23.3
		South	30	Tue, 14 May 2013	Mon, 20 May 2013	29000	4364	4143	3193	11.0	314	1.1	7	0.0	25.9	29.1
		Two way	30	Tue, 14 May 2013	Mon, 20 May 2013	58666	8847	8381	3872	6.6	426	0.7	14	0.0	21.8	28.0
6	High Street, Att - lc07, OSGR: SJ 85605 47562	North	30	Tue, 4 June 2013	Mon, 10 June 2013	42119	6425	6017	730	1.7	169	0.4	37	0.1	17.4	22.4
		South	30	Tue, 4 June 2013	Mon, 10 June 2013	38843	5897	5549	1629	4.2	295	0.8	31	0.1	22.5	26.6
		Two way	30	Tue, 4 June 2013	Mon, 10 June 2013	80962	12322	11566	2359	2.9	464	0.6	68	0.1	19.8	25.5
7	Alexander Road, Att - Tree, OSGR: SJ 85587 47636	North	30	Mon, 13 May 2013		1621	1621	1621	12	0.7	2	0.1	0	0.0	16.3	20.4
		South	30	Mon, 13 May 2013		1842	1842	1842	54	2.9	5	0.3	0	0.0	22.5	26.4
		Two way	30	Mon, 13 May 2013		3463	3463	3463	66	1.9	7	0.2	0	0.0	19.6	25.1
7	Alexander Road, Att - Tree, OSGR: SJ 85587 47636	North	30	Tue, 14 May 2013	Mon, 20 May 2013	26609	4101	3801	189	0.7	43	0.2	5	0.0	15.5	19.2
		South	30	Tue, 14 May 2013	Mon, 20 May 2013	27899	4180	3986	752	2.7	117	0.4	6	0.0	22.0	25.9
		Two way	30	Tue, 14 May 2013	Mon, 20 May 2013	54508	8281	7787	941	1.7	160	0.3	11	0.0	18.9	24.4

Appendix E Model verification and uncertainty

Model verification has been undertaken in line with LAQM.TG (09) (Defra, 2009). This process allows uncertainties in model results to be investigated and minimised. Monitored NO_2 concentrations have been converted to road NO_X concentrations using the calculator[12] available on the LAQM tools section of the UK Air Quality Archive website, using the relevant background concentration of NO_x and NO_2. Often an adjustment factor needs to be applied to the modelled road NO_x concentrations to minimise uncertainty in the modelled results. Every effort is made to check and then re-confirm the model set up prior to applying any adjustment to modelled results (*e.g.* traffic and queuing activity, road link alignment, receptor locations, road widths, background concentrations *etc.*). However, the verification process often requires the modelled road NO_X to be factored up.

The model was verified for the four sites in turn by comparing the annual mean monitored road NO_X concentrations with modelled road NO_X concentrations as given in Tables E.1 to E.8 and Figures E.1 to E.3.

E.1 Madeley

The model was verified against two diffusion tubes and was found to under predict concentrations. An adjustment factor of 1.26 was calculated and applied to the modelled road NO_x concentrations. Using this adjusted road NO_x concentration, the total NO_2 concentrations were obtained using the calculator tool as given in Table E1. This provides a comparison with the measured diffusion tube NO_2 concentrations and modelled NO_2 concentrations following adjustment. The results show that the modelled annual mean NO_2 concentration was not exceeded at either monitoring site in 2012 (Table E2).

Table E1: Comparison between modelled and monitored NO_X concentrations, 2012, Madeley.

	Annual mean concentration (µg/m^3)				
Site ID	**Monitored total NO_2**	**Background NO_x**	**Monitored road NO_x**	**Modelled road NO_x**	**Difference ratio (modelled road NO_X/ monitored road NO_X)**
DT3	39.6	35.0	37.5	29.9	0.8
DT52	31.1	35.0	17.8	13.8	0.8

[12] http://www.airquality.co.uk/archive/laqm/tools.php

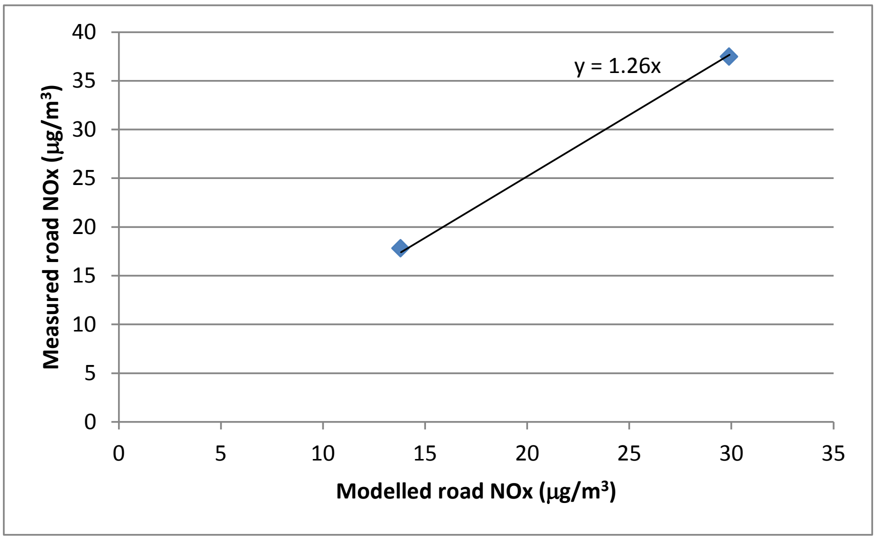

Figure E1: Relationship between modelled and measured road NO_x concentration, Madeley.

Table E2: Adjusted modelled concentrations and model performance, Madeley.

Site ID	Adjusted modelled road NO_X ($\mu g/m^3$)	Adjusted modelled total NO_2 ($\mu g/m^3$)	Annual mean monitored NO_2 ($\mu g/m^3$)	% Difference ((modelled-monitored)/ monitored) *100
DT3	37.7	39.7	39.6	0%
DT52	17.4	30.9	31.1	-1%

E.2 Kidsgrove

The model was verified against all diffusion tubes and was found to agree well with the concentrations and it was considered that no adjustment was necessary (see the uncertainty calculations in D.5). Table E3 and E4 provide a comparison between modelled and measured values. The results show that the modelled annual mean NO_2 concentration was exceeded at several sites.

Table E3: Comparison between modelled and monitored NO_X concentrations, 2012, Kidsgrove.

Site ID	Annual mean concentration ($\mu g/m^3$)				
	Monitored total NO_2	Background NO_x	Monitored road NO_x	Modelled road NO_x	Difference ratio (modelled road NO_X/ monitored road NO_X)
DT39	39.9	31.7	41.93	45.74	0.9
DT6	**45.3**	31.7	55.84	46.01	1.2
DT62	30.1	31.7	19.1	26.36	0.7
DT63	31.9	31.7	23.08	31.40	0.7
DT64	**41.1**	31.7	44.93	35.31	1.3
DT77	28.4	31.7	15.42	26.51	0.6
DT79	33.5	31.7	26.7	30.40	0.9
DT92	39.0	31.7	39.72	30.79	1.3
DT93	37.8	31.7	36.69	30.02	1.2

Site ID	Annual mean concentration (µg/m^3)				
	Monitored total NO_2	Background NO_x	Monitored road NO_x	Modelled road NO_x	Difference ratio (modelled road NO_X/ monitored road NO_X)
DT94	39.2	31.7	40.29	31.48	1.3

Table E4: Modelled NO_2 concentrations and model performance, Kidsgrove.

Site ID	Unadjusted modelled total NO_2 (µg/m^3)	Annual mean monitored NO_2 (µg/m^3)	% Difference ((modelled-monitored)/ monitored) *100
DT39	**41.42**	39.9	4%
DT6	**41.52**	**45.3**	-8%
DT62	33.35	30.1	11%
DT63	35.53	31.9	11%
DT64	37.19	**41.1**	-10%
DT77	33.42	28.4	18%
DT79	35.11	33.5	5%
DT92	35.27	39.0	-10%
DT93	34.94	37.8	-7%
DT94	35.57	39.2	-9%
DT39	**41.42**	39.9	4%

E.3 Town centre

For the Town Centre, the model was verified against diffusion tubes only. Data from the automatic monitor in Queen's Gardens was not used as it had a low data capture rate for the year. The model was found to under-predict concentrations at most of the sites. An overall adjustment factor of 1.5529 was calculated and applied to the modelled road NO_x concentrations (see Figure E2). Tables E5 and E6 provide a comparison with the measured diffusion tube NO_2 concentrations and modelled NO_2 concentrations following adjustment. The results show exceedences at several diffusion tubes across the domain.

Table E5: Comparison between modelled and monitored NO_X concentrations, 2012, town centre.

Site ID	Annual mean concentration (µg/m^3)				
	Monitored total NO_2	Background NO_x	Monitored road NO_x	Modelled road NO_x	Difference ratio (modelled road NO_X/ monitored road NO_X)
DTK2	34.2	32.4	27.47	18.00	0.7
DT11	44.7	32.4	53.43	28.99	0.5
DT31	33.8	32.4	26.59	21.00	0.8
DT33	33.6	32.4	26.2	17.36	0.7
DT34	38.7	32.4	38.22	28.26	0.7
DT41	38.9	32.4	38.66	25.14	0.7
DT46	35.3	32.4	29.99	19.92	0.7
DT47	34.4	32.4	27.93	18.40	0.7

Site ID	Annual mean concentration (µg/m³) Monitored total NO_2	Background NO_x	Monitored road NO_x	Modelled road NO_x	Difference ratio (modelled road NO_X/ monitored road NO_X)
DT50	30.2	32.4	18.62	23.32	1.3
DT72	34.4	32.4	28.1	16.89	0.6
DT73	37.6	32.4	35.58	23.16	0.7
DT74	38.8	32.4	38.32	37.60	1.0
DT76	37.0	32.4	34.13	16.96	0.5
DT84	43.9	32.4	51.36	30.46	0.6
DT85	49.1	32.4	65.49	36.33	0.6
DT86	37.0	32.4	34.11	23.71	0.7
DT87	43.4	32.4	50.05	30.60	0.6
DT88	37.7	32.4	35.8	15.14	0.4
DT89	34.9	32.4	29.05	21.98	0.8
DT96	44.9	32.4	53.97	26.35	0.5
DT97	39.6	32.4	40.44	26.87	0.7
DT95	40.8	32.4	43.34	18.86	0.4

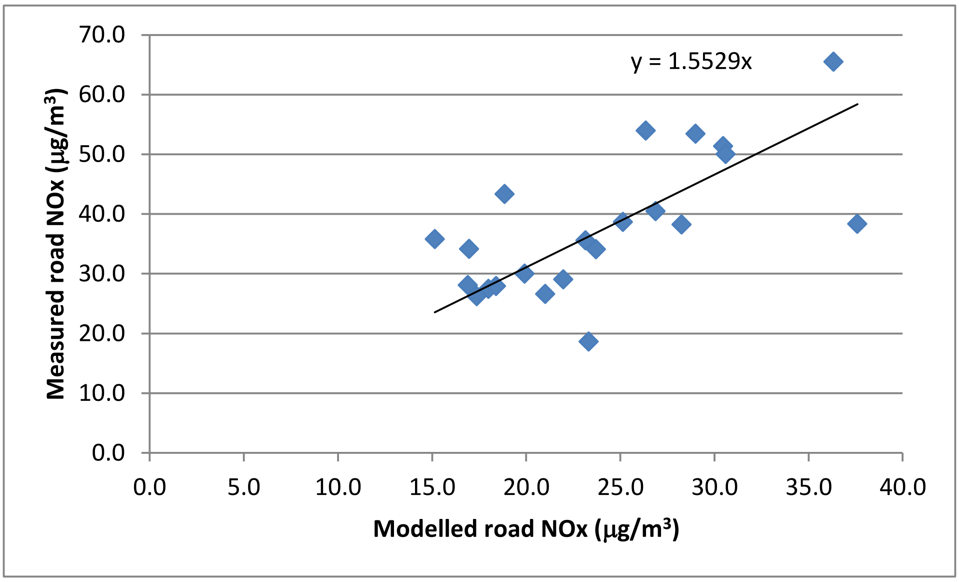

Figure E2: Relationship between modelled and measured road NO_x concentration, town centre.

Table E6: Adjusted modelled concentrations and model performance, town centre.

Site ID	Adjusted modelled road NO_X (µg/m³)	Adjusted modelled total NO_2 (µg/m³)	Annual mean monitored NO_2 (µg/m³)	% Difference ((modelled-monitored)/ monitored) *100
DTK2	27.95	34.38	34.2	1%
DT11	45.02	**41.45**	**44.7**	-7%
DT31	32.62	36.38	33.8	8%
DT33	26.97	33.95	33.6	1%
DT34	43.89	41	38.7	6%
DT41	39.04	39.05	38.9	0%

Site ID	Adjusted modelled road NO_x (µg/m^3)	Adjusted modelled total NO_2 (µg/m^3)	Annual mean monitored NO_2 (µg/m^3)	% Difference ((modelled-monitored)/ monitored) *100
DT46	30.93	35.66	35.3	1%
DT47	28.57	34.65	34.4	1%
DT50	36.22	37.89	30.2	25%
DT72	26.24	33.63	34.4	-2%
DT73	35.96	37.78	37.6	0%
DT74	58.38	**46.55**	38.8	20%
DT76	26.34	33.67	37.0	-9%
DT84	47.31	**42.35**	**43.9**	-4%
DT85	56.42	**45.82**	**49.1**	-7%
DT86	36.83	38.14	37.0	3%
DT87	47.52	**42.43**	**43.4**	-2%
DT88	23.52	32.43	37.7	-14%
DT89	34.13	37.01	34.9	6%
DT96	40.91	**39.81**	**44.9**	-11%
DT97	41.73	**40.14**	39.6	1%
DT95	29.29	34.96	**40.8**	-14%

E.4 Site 4: Porthill

Overall, the model was found to under predict concentrations slightly and an adjustment factor of 1.7334 was calculated and applied to the modelled road NO_x concentrations (see Figure E3). Using this adjusted road NO_x concentration, the total NO_2 concentrations were, as given in Table E7. The results show that the modelled annual mean NO_2 concentration was not exceeded at either monitoring site in 2012 (see Table E8).

Table E7: Comparison between modelled and monitored NO_x concentrations, 2012, Porthill.

Site ID	Annual mean concentration (µg/m^3)				
	Monitored total NO_2	Background NO_x	Monitored road NO_x	Modelled road NO_x	Difference ratio (modelled road NO_x/ monitored road NO_x)
DT40	33.8	33.8	25.12	8.74	0.3
DT9	40.4	33.8	40.8	29.22	0.7
DT49	35.6	33.8	29.26	8.48	0.3
DT24	40.9	33.8	42.04	22.25	0.5

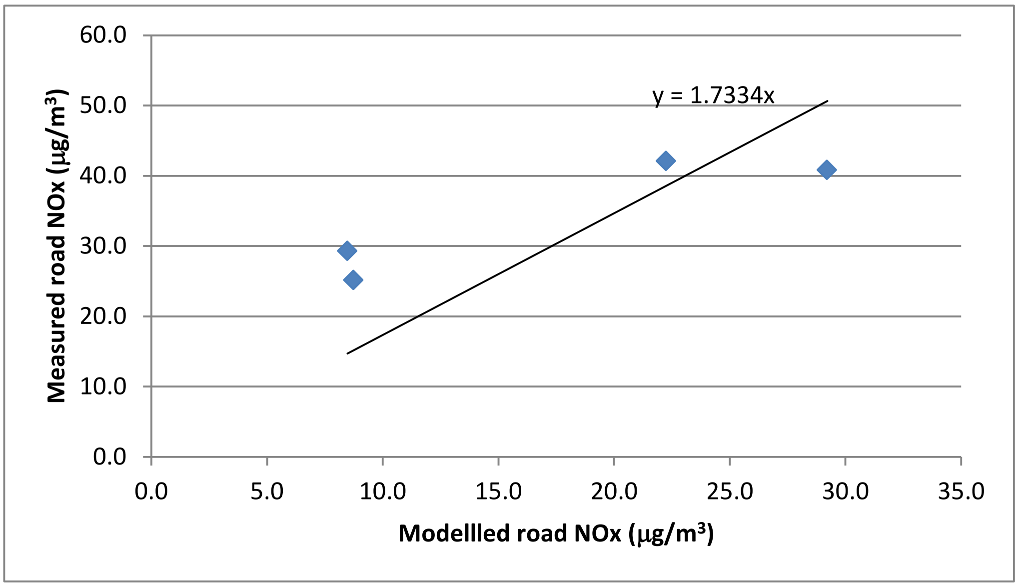

Figure E3: Relationship between modelled and measured road NO_x concentration, Porthill.

Table E8: Adjusted modelled concentrations and model performance, Porthill.

Site ID	Adjusted modelled road NO_X ($\mu g/m^3$)	Adjusted modelled total NO_2 ($\mu g/m^3$)	Annual mean monitored NO_2 ($\mu g/m^3$)	% Difference ((modelled-monitored)/ monitored) *100
DT40	15.14	29.29	33.8	-13%
DT9	50.65	**44.26**	**40.4**	10%
DT49	14.70	29.09	35.6	-18%
DT24	38.58	39.5	**40.9**	-3%

E.5 Model uncertainty

An evaluation of model performance in the form of quantification of the effects of random errors can be used to demonstrate the extent to which the modelled results agree with or diverge from the observations (*i.e.* the measured results) (Defra, 2009).

In the first instance, where a local authority wishes to assess the uncertainty of a model, the root mean square error (RMSE) is considered to be a practical calculation providing an estimate of the average error of the model in the same units as the observations. The RMSE is often easier to interpret than other than other statistical parameters and many local authorities find calculation of the RMSE the most useful of the parameters (Defra, 2009).

If the RMSE values are higher than ±25 percent of the objective being assessed, it is recommended that the model inputs and verification should be revisited in order to make improvements. For example, if the model predictions are for the annual mean NO_2 objective of 40 $\mu g/m^3$, if an RMSE of 10 $\mu g/m^3$ or above is determined for a model, the local authority would be advised to revisit the model parameters and model verification. Ideally an RMSE within 10 percent of the air quality objective would be derived, which equates to 4 $\mu g/m^3$ for the annual average NO_2 objective.

Ideally modelling uncertainty requires a minimum of four data points, however this is not always possible (e.g. for Madeley where there were only two diffusion tubes).

The RMSE is derived by applying the following formulae;

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{1}(obs_i - pre_i)^2}$$

The RMSE results based on total NO_2 annual mean concentrations (adjusted and unadjusted), for each of the four study areas are provided in Table E9.

Table E9: Modelling uncertainty results for all areas.

Site name	Unadjusted RMSE Total NO_2 ($\mu g/m^3$)	Percentage of the NO_2 annual average (%)	Adjusted RMSE Total NO_2 ($\mu g/m^3$)	Percentage of the NO_2 annual average (%)	Number of diffusion tube sites included in the statistic
Town centre	6.8	17	3.4	8.5	23
Porthill	7.7	19.4	4.5	11.2	4
Madeley	2.6	6.5	0.2	0.4	2
Kidsgrove	3.4	8.5	3.4	8.6	10

The unadjusted RMSE values shows that the model predictions for the town centre and Porthill were above 10 percent of the objective (but less than 25 percent). The RMSE predictions for Kidsgrove were similar unadjusted or adjusted, so in this case the model was not adjusted.

Having adjusted modelled road NO_X in accordance with model deviation as described in Figures E1-E3, the RMSE statistic on annual average total NO_2 concentrations was derived again. The result of this exercise is showing that the model is performing within acceptable limits.

Given an RMSE statistic of 11.2 percent, for Porthill (the lowest recorded model performance), a modelled annual average NO_2 concentration between 35.5 $\mu g/m^3$ to 44.5 $\mu g/m^3$ indicate that the objective is likely to be exceeded.

Local authorities are reminded that it is important to check that a model is performing where concentrations close to the relevant objective are being considered as is the case at Porthill, Kidsgrove and Madeley. For example, a model may over-predict at background locations, but under-predict at higher concentrations close to the objective. Therefore the average performance of a model is not necessarily a good description of the performance at all locations. However, in all for independent assessments modelling comparisons were compared with near to road monitoring site data.

In conclusion, it is advisable to take into account model uncertainty and adopt a precautionary approach in determining the exceedences. To do this, it would be assumed that the objective may be exceeded within +- the RMSE value.