Transport Research Laboratory

Local air quality management detailed assessment: Willand, Devon

by H Mao, A Savage, K Turpin

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FINAL PROJECT REPORT

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Local air quality management detailed assessment: Willand, Devon

by H Mao, A Savage and K Turpin (TRL)

Prepared for: Project Record:	**MDDC 7.11.08** **AIR QUALITY MODELLING AND DETAILED ASSESSMENT SERVICES IN WILLAND**
Client:	**Mid Devon District Council, Environmental Health and Community Development Services/Environment Team** **(Simon Newcombe)**

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Executive summary

A detailed dispersion modelling assessment has been undertaken on behalf of Mid Devon District Council (MDDC) to assist in its obligations under Local Air Quality Management, in accordance with Part IV of the Environment Act 1995 Air Quality Review and Assessment process. A third round of review and assessment commenced in 2006 and is due to be completed by all local authorities in 2009.

This report provides a summary of the detailed assessment of pollutant concentrations at locations alongside the M5 motorway in Willand. The assessment involved modelling ambient concentrations of nitrogen dioxide (NO2) across a study area (the M5 and its immediate surroundings in Willand) and comparing the modelled concentrations against monitored concentrations and national Air Quality Strategy (AQS) objectives. Where objectives were forecast to be exceeded, the local authority would be required to designate an Air Quality Management Area (AQMA) encompassing those areas where exceedences were forecast.

This study included the assessment of emissions from transport sources (local road traffic, motorway and rail) and emissions from commercial sources, domestic combustion and industrial sources. The base year is 2008, with a future year of 2009. Modelled NO2 concentrations compared fairly well with monitored concentrations, with the average difference between modelled and monitored concentrations of approximately 25% without model adjustment.

The modelling assessment concluded that the NO2 annual mean objective is unlikely to be exceeded at locations in Willand with relevant public exposure. The declaration of an Air Quality Management Area (AQMA) is not required.

1 Introduction

As part of Mid Devon District Council's (MDDC) Local Air Quality Management duties, TRL Ltd was appointed to undertake a Detailed Assessment (DA) of ambient nitrogen dioxide (NO_2) concentrations in Willand. The assessment involved a reinvestigation of pollution concentrations, through a review of monitoring data and the prediction of pollutant concentrations using the dispersion model ADMS-Roads Version 2.3. The assessment particularly focused on pollutant concentrations in the vicinity of the M5 motorway, a section of which passes close to the village of Willand.

2 Background

The Local Air Quality Management (LAQM) framework, which was introduced under Part IV of the Environment Act 1995, is designed to help local authorities review and assess current and future air quality. The LAQM framework requires local authorities to assess concentrations of various air pollutants against standards and objectives set out in the Air Quality Strategy for England, Scotland, Wales and Northern Ireland. The LAQM process and its associated objectives are subject to periodic review. The latest consultation was undertaken in April 2006, and led to the release of the revised AQS in July 2007 (Defra *et al.*, 2007). The pollutants contained within these regulations, and their relevant objectives, are presented in Table 1.

An evaluation of the first round of review and assessment recommended that local authorities should prepare annual Progress Reports between rounds of air quality review and assessment. The process is currently undergoing its third round (2006 to 2009). The first phase is an Updating and Screening Assessment (USA), which is a checklist designed to review new monitoring data and new objectives and identify new pollution sources or any significant changes to existing pollution sources which may affect air quality. A USA report is required every 3 years, and attempts to incorporate all new data available since the previous assessment. The second phase is a DA which is required where the USA report has shown that there is a risk of an air quality objective being exceeded. If the DA confirms an exceedance of an objective, it is then necessary to designate an Air Quality Management Area (AQMA) and produce an Air Quality Action Plan (AQAP). A Progress Report is required in the years following the USA and or DA.

MDDC's 2008 LAQM Progress Report recommended that a DA should be conducted to model air quality in the Willand area of mid Devon. A recently completed air quality assessment at a proposed development site in Park Street, Willand re-iterated the findings that there may be possible exceedances of the NO_2 objective in this area. On this basis, MDDC concluded that a DA would be required for NO_2 at the locations alongside the M5 motorway in Willand.

It is evident from the earlier investigations and from the monitoring data that the highest pollutant concentrations are associated with the confluence of the busy M5 and main rail line on the west side of the M5 as shown in **Error! Reference source not found.**. The main concern at Willand is public exposure to NO_2 and not particulate matter (PM_{10}[1]) (MDDC, 2008a). Therefore, this Detailed Assessment will focus on NO_2 concentrations in relation to the Air Quality Strategy objectives for the base year 2008, as well as 2009.

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[1] Particulate with an aerodynamic diameter equal to or less than 10 microns

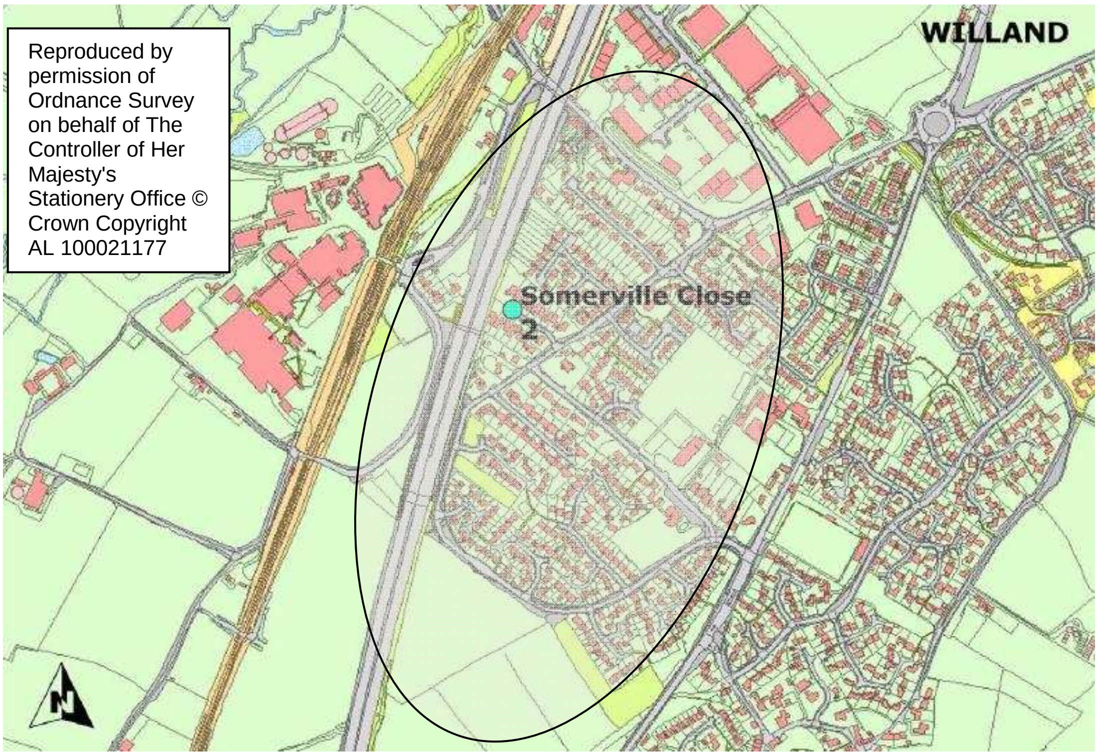

Figure 1: Footprint of area expected to have the highest pollutant concentrations.

2.1 Sources of nitrogen dioxide

In most urban areas, road vehicles are an important source of NO_2. Road vehicle exhaust contains both NO_2 and nitric oxide (NO), with the majority normally emitted in the form of NO. Collectively, these 2 gases are termed oxides of nitrogen (NO_X). The majority of the NO_2 in the atmosphere is formed by the reaction of NO with ozone (O_3) (and other oxidants), and at ambient roadside locations, NO_2 concentrations are generally limited by the local availability of O_3 rather than the emission of NO from vehicles. The NO_2 which is emitted directly from vehicle exhaust is commonly referred to as 'primary NO_2', and can range from less than 5% to over 40% of the NOx (AQEG 2007). Therefore, depending on the type of vehicle, fuel type and the exhaust after-treatment technologies employed, the proportion of primary NO_2 can vary considerably.

Table 1: Air pollutants and objectives in the UK Air Quality Strategy (Defra *et al*, 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. Annual mean concentration should not exceed 40 µg m^{-3}.	31 December 2004 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}.	31 December 2004
	Scotland: Annual mean concentration should not exceed 12 µg m^{-3}.	
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}. Annual mean concentration should not exceed 0.25 µg m^{-3}.	31 December 2004 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. 15-min mean of 266 µg m^{-3} not to be exceeded more than 35 times a year.	31 December 2004 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

3 Pollutant monitoring data

A summary of the 2008 ambient pollutant monitoring data from the Willand area is provided in this Chapter. Monitoring data are also compared in Chapter 5 with dispersion modelling predictions to evaluate the performance of the dispersion model.

Mid Devon District Council (MDDC) manages 1 permanent diffusion tube site alongside the M5 motorway in Willand. MDDC also sited 7 temporary diffusion tubes at additional locations in Willand for the purposes of this assessment. The tubes were positioned at kerbside, roadside and urban background locations. They are mounted on suitable street furniture.

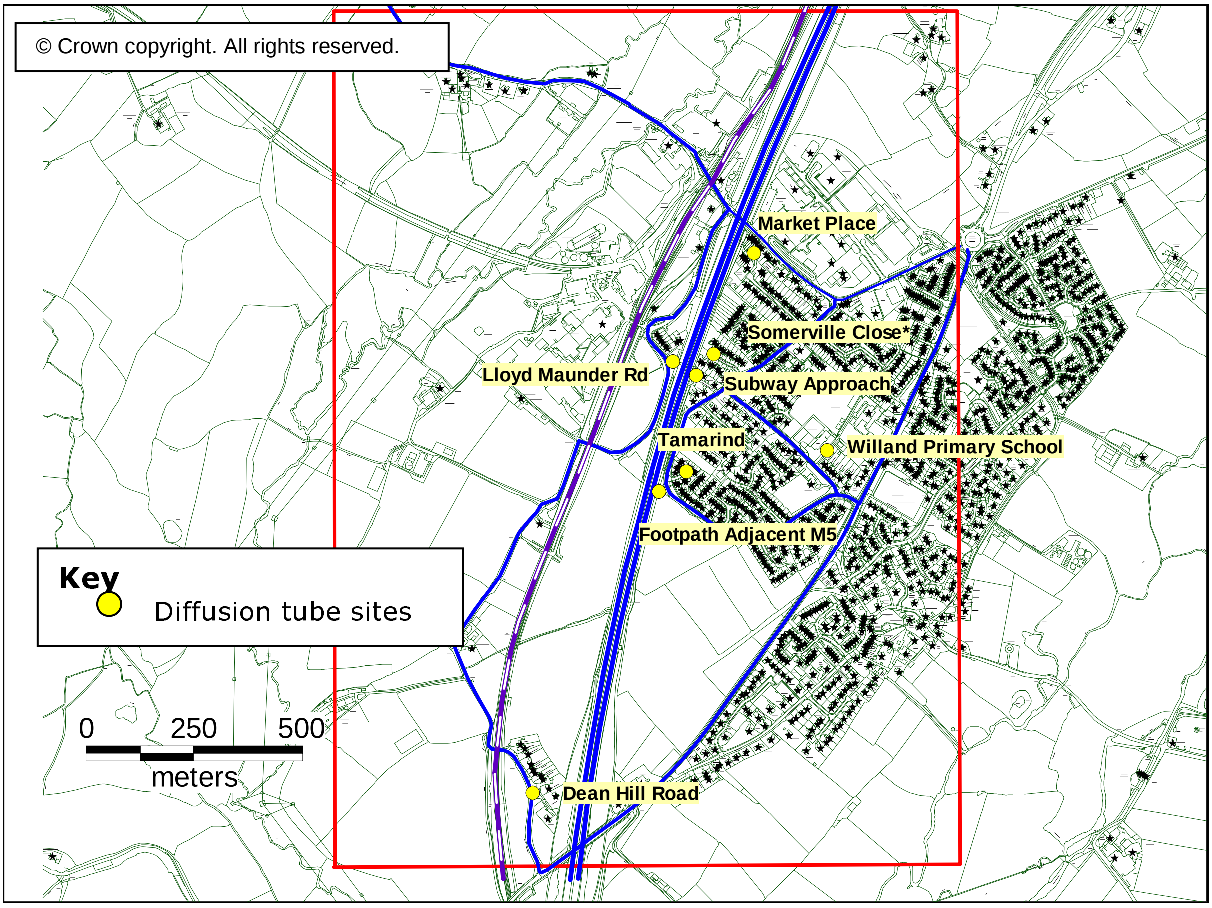

Figure 2: Diffusion tube site in Willand.

The temporary tubes were prepared and analysed by Gradko International Limited using the 20% triethanolamine (TEA) in water method[2]. The permanent diffusion tube was co-located at Somerville Close and is analytically prepared using 50% TEA. MDDC decided that it would maintain this preparation technique during the assessment, for this tube alone, for verification purposes. The advantage of diffusion tubes is that they are relatively low cost, and thus allow measurements at multiple locations. However, they

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[2] There are a variety of ways in which these tubes are prepared, which principally relates to the way in which the gauze is coated with the TEA solution, and the choice of solvent used. Various solvents are used including water and acetone, at a range of concentrations. The analytical method is by subsequent ultra-violet spectroscopy measuring NO_2 absorbed as nitrite by TEA using a variation of the Saltzman reaction. The 50% TEA/water pipetting method is longer acceptable for LAQM purposes; (previous research has reported poor precision with this method, and it is no longer widely used in the UK.

are intrinsically less precise than the continuous Chemilimuninescence approach and thus data derived from diffusion tubes should be bias adjusted. This process involves the comparison of co-located diffusion tube and Chemilimuninescence-based data to allow the derivation of an adjustment factor[3]. Owing to the absence of automatic monitoring in Willand, the diffusion tubes were bias adjusted in accordance with the latest Defra guidance[4]. Here, the approach derives a bias adjustment factor taken to be the average from a number of co-location studies which have applied similar laboratory processing techniques. Using this approach, a bias adjustment factor of 0.92 (0.88 for the co-located tube at Somerville Close) was derived for the MDDC 2008 diffusion tube data.

Results from NO$_2$ diffusion tube monitoring at sites alongside the M5 motorway in Willand for 2008 are presented in

Table 2. Short term period monitoring data (i.e. period means) were scaled to represent annual mean values. According to LAQM TG 09 at least 2 urban background sites within 50 miles should be applied to scale period averages to annual means. However, this proved impossible for Willand with the nearest background site being more than 160 km away. On this basis, period averages were scaled using the most sensible data available as shown in Table B2 in Appendix (i.e. this being a roadside site located in Exeter). These data are bias adjusted (factor of 0.92 applied). The locations of the diffusion tube monitoring sites are presented in Figure 2.

MDDC monitoring site (Willand)	Location	Tube height (m)	Distance from centre of road (m)[a]	Distance from kerbside of road (m)[a]	Period mean (µg/m^3)[b]	Annual mean (µg/m^3)[c]	Data capture rate (%)
WDA1	Lloyd Maunder Rd	2.4	32	12	32.8	30.3	100
WDA2	Market Place	3	52	32	30.3	28.0	100
WDA3	Somerville Close*	3	50	30	30.9	28.5	100
WDA4	Willand Primary School	2.2	370	350	18.6	17.7	50
WDA5	Subway Approach	3	28	8	29.5	27.3	100
WDA6	Tamarind	3	71	49	25.2	23.3	100
WDA7	Footpath Adjacent M5	2.4	21	1	38.8	35.8	100
WDA8	Dean Hill Road	2.4	120	100	18.2	16.8	100
2[d]	Somerville Close*	3	50	30	34.7	32.7	100

MDDC monitoring site (Willand)	Location	Tube height (m)	Distance from centre of road (m)[a]	Distance from kerbside of road (m)[a]	Period mean (µg/m^3)[b]	Annual mean (µg/m^3)[c]	Data capture rate (%)
WDA1	Lloyd Maunder Rd	2.4	32	12	32.8	30.3	100
WDA2	Market	3	52	32	30.3	28.0	100

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[3] A network of diffusion tubes can be used to monitor levels for trends and to study the geographic distribution of concentrations.

[4] http://www.uwe.ac.uk/aqm/review/index.html updated in late March 2009.

	Place						
WDA3	Somerville Close*	3	50	30	30.9	28.5	100
WDA4	Willand Primary School	2.2	370	350	18.6	17.7	50
WDA5	Subway Approach	3	28	8	29.5	27.3	100
WDA6	Tamarind	3	71	49	25.2	23.3	100
WDA7	Footpath Adjacent M5	2.4	21	1	38.8	35.8	100
WDA8	Dean Hill Road	2.4	120	100	18.2	16.8	100
2[d]	Somerville Close*	3	50	30	34.7	32.7	100

Table 2: Monitored NO_2 diffusion tube annual mean concentrations, 2008 (bias adjusted, period mean adjusted).

* temporary and permanent diffusion tube co-located at Somerville Close
a Distance from M5
b Data bias adjusted
c Annual mean estimated from the ratio of short-term mean/annual mean at Exeter roadside.
d Co-located tubes, different bias and period mean adjusted factor applied as stated in MDDC (2009)

The monitored concentrations in 2008 indicate no exceedance of the current NO_2 annual mean objective of 40µg/m^3. Higher annual means have been recorded at kerbside locations (e.g. at the location of Footpath Adjacent M5, rather than those locations with relevant public exposure)

4 Atmospheric dispersion modelling

The emissions and air pollution modelling was undertaken using the Gaussian-based ADMS-Roads (Extra) software suite, developed by Cambridge Environmental Research Consultants (CERC). The model allows up to 600 road sources and 25 point sources to be modelled simultaneously. In addition, industrial emissions can be modelled as volume, area or line sources. The 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, chemical reactions and background pollutant concentrations.

Modelling was undertaken for two years: 2008 and 2009. Year 2008 was the most recent year for which monitoring and meteorological data were available, and was thus selected as the baseline year. Modelling was also undertaken for 2009, to allow direct comparison between modelled NO_2 concentrations and the NO_2 objectives. Year 2008 measured traffic levels were factored forward to 2009 using growth rates from the national transport statistics (DfT, 1997).

4.1 Emissions source activity data

4.1.1 Road traffic and rail activity

The majority of emissions in Willand are from road sources (the M5 motorway between Junctions 27-28 and local roads) and rail transport emissions (from the SW main rail line). The approximate annual average daily total (AADT) flows between Junction 27-28 and 28-27 on the M5 motorway at this location are 27,235 and 29,649 vehicles per day (vpd)[5] respectively in 2008. There is also up to 130 diesel rail movements per day on the adjacent Bristol to Exeter main rail line (MDDC, 2008) which is assumed to be the same in 2009. Vehicle movements are projected for the future year (2009) using a Tempro[6] growth factor for individual vehicle category.

Information on traffic activity on local roads was obtained via 5 automatic traffic counters installed between the 6th December and the 13th December 2008, allowing for the traffic flows and speeds on 5 local roads in the area alongside the M5 motorway in Willand to be derived. These roads are shown in Figure 3. In addition to these specific links, the turning movements into 6 other roads, as shown in Figure 4 (pink colour), were also considered.

Figure 3: Traffic counter locations.

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[5] Data obtained from the Highway Agency's TRADs database.

[6] TEMPRO is a computer program used to access the National Trip End Model forecasts of growth in person trips on most modes of surface transport.

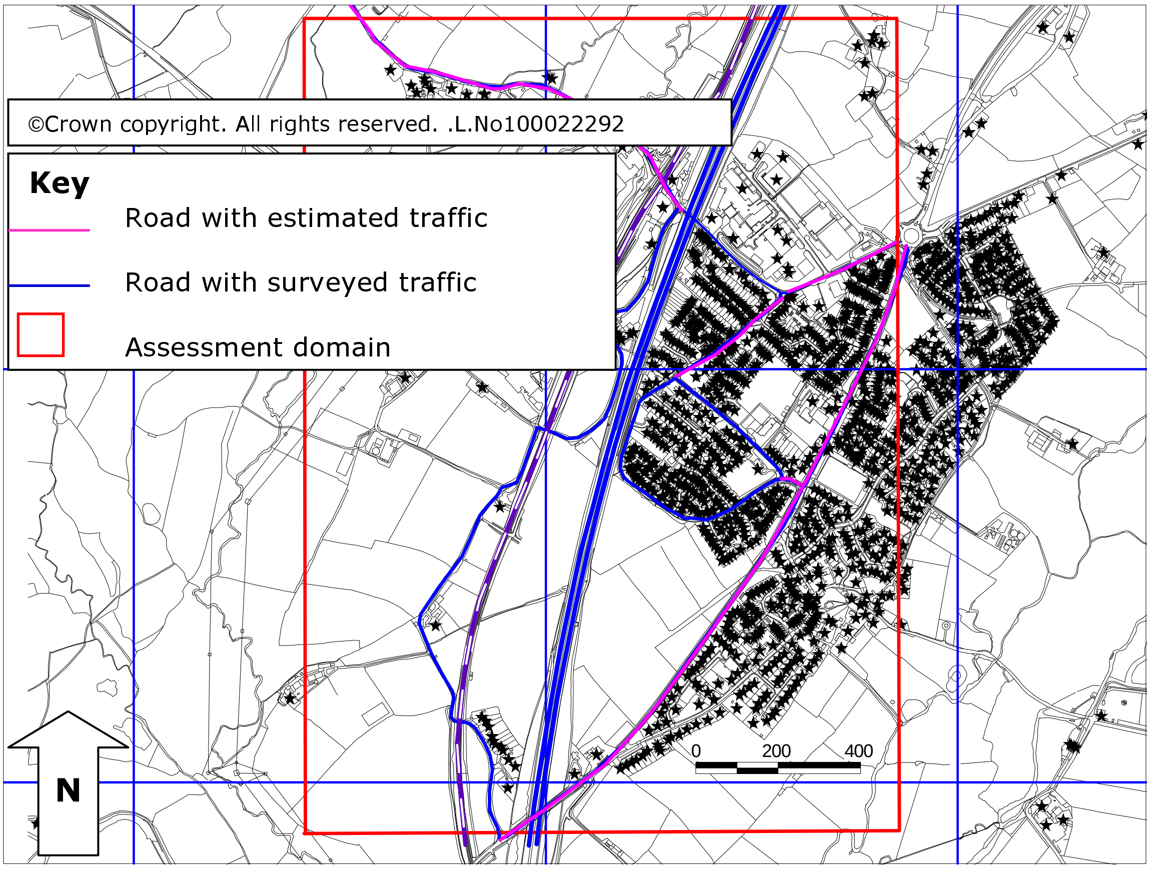

Figure 4: Roads with surveyed and estimated average daily traffic flows.

Traffic data from the automatic traffic counters were post-processed together with information from the roadside surveys to provide the baseline (2008) traffic database including traffic flow, average vehicle speed and average vehicle fleet composition for all roads considered within the assessment. The automatic counts also provided the basis of traffic flow variation profiles within ADMS-Roads, allowing emissions to vary over the day.

Traffic count data were manipulated into the Design Manual for Roads and Bridges spreadsheet (HA *et al*, 2007) to provide estimated pollutant emissions which were then input to ADMS Roads to assess the resulting impact on local air quality. In total, 13 individual segments (including roads and the railway) were assessed. Generally there is no characterised zone of periodic queuing observed in Willand. The extent of the modelled road network and assessment domain is shown in Figure 4.

4.1.2 Emission factor database

Although the air pollution prediction methodology within the DMRB spreadsheet is rather simplistic; the emission factors are the same as those used in more sophisticated models. For each defined road link, the DMRB spreadsheet was used to calculate emissions of oxides of nitrogen (NO_x). In order to use the DMRB to produce an emissions estimate for the link, the following information is required:

- The year (2008 and 2009).
- The length of the link.
- The annual average daily traffic flow (AADT).
- The annual average speed.
- The road type (A, B, C or D), where:

  - A = all motorways and A roads.
  - B = urban roads which are neither motorways nor A roads.
  - C = any other roads.
  - Type D = selected when the fleet composition on the link is known.
- Fleet composition (i.e. percentage HGV/LGV).

The DMRB calculates emissions on an annual basis. These are then manipulated to derive emissions rates in g/km/s (i.e. suitable for use by ADMS Roads).

The 'road type' parameter acts as a proxy for differences in the coarse composition of the traffic under different conditions. When selecting road types A, B or C, only the proportions of light-duty vehicles (LDVs) and heavy-duty vehicles (HDVs) need to be specified. The selection of road type D allows a slightly more detailed classification to be specified by the user (*i.e.* passenger cars, LGVs, buses and coaches, rigid HGVs and articulated HGVs). Road type D was therefore used for this assessment. The more detailed breakdown of the traffic *within* the generic vehicle categories is internal to the DMRB model.

4.1.3 Additional aspects of road emissions

There has been recent concern that changes in the national vehicle fleet, the increase in dieselisation and use of pollution abatement systems (*e.g.* oxidation catalysts and diesel particle traps) has led to an increase in the proportion of NO_X that is released directly as NO_2 from vehicle exhausts (AQEG, 2007). A value of approximately 5% primary NO_2 was considered appropriate, but a number of studies have indicated that the average proportion for the UK vehicle fleet has increased. Values in excess of 20-30% can be associated with the use of specific continuously regenerating traps (CRT) (Lemaire J). The approach adopted within this study for the derivation of NO_2 is described in Section 4.8.

4.2 Road geometry

The geometry of each road was determined through a combination of GIS mapping data and information provided by MDDC. The geometry of each road was defined in terms of the kerb-to-kerb road width and, where appropriate, the height of any surrounding buildings, particularly where street canyons are formed. For air pollution modelling assessments, a street canyon is defined where the building heights are higher than the building-to-building road width (aspect ratio greater than 1.0). This effect is not observed for any of the roads being modelled in Willand, therefore the street canyon module in ADMS-Roads was not applied in this study.

4.3 Time-varying emissions

Time-varying profiles are designed to take account of how road traffic volumes vary throughout the day, with peak traffic in the AM and PM peak periods and little traffic during the night time period. The time-varying data were calculated from the traffic count data, producing a separate profile for all local roads (*i.e.* profiles were obtained in 10 directions from the 5 traffic count sites installed, with the exception of the M5 motorway, which combines the flow in 2 directions). The time-varying file also included a separate profile used to control emissions input from the railway, with the setting to "on" during the train's operational hours and "off" at all other times of the day and night (*i.e.* off between 00:00 to 18:00 and on at all other times of day). In essence, profiles allow scaling of emissions to represent the activity in any given hour.

A summary of all road traffic emissions and time variation factors used in the modelling assessment are presented in Appendix A.

4.4 Emission from other sources

In addition to the road source, another major source of NO_2 within the assessed area is emissions from the railway. There are up to 130 diesel rail movements per day on the railway line. Emissions were estimated from the spreadsheet created by TRL according to the methodology used in the ARTEMIS model: "Artemis_Rail.xls" (Cordeiro *et al*, 2005). A summary of emissions is presented in Appendix A.

Under LAQM.TG (03), emissions from other sources in the assessment area were obtained from the National Atmospheric Emission Inventory (NAEI)[7], which provides information on pollutant emissions in tonnes per year in 1-km^2 grids. Emissions are categorised into sectors including energy production; commercial, institutional and residential combustion; industrial combustion; industrial processes; fossil fuel production; road transport; other transport (non-road); waste treatment and disposal; agriculture and nature. To avoid double-counting of road traffic emissions, the quantity of pollutants emitted annually from the explicitly modelled roads should be calculated in the area of each volume source. This can then be subtracted from the total emitted from the NAEI road transport sector in the relevant grid square. However, since the release of Local Air Quality Management Technical Guidance LAQM.TG (09) in February 2009, the above methodology has changed and it is now not necessary to model volume emissions and hence avoid the issue of "double-counting".

4.5 Modelled domain and receptors

Modelling predictions were undertaken over a calculation grid (modelling domain) and at a selection of receptors. For the purposes of this assessment 13 receptors were specifically selected to:

a) Coincide with the locations of existing monitoring sites generally representing locations of maximum public exposure e.g. WDA1 - WDA8,

b) Coincide with locations not accounted for by local monitoring but where the public may be exposed (e.g. WDA9 - WDA13),

c) Indicate the pollutant gradient between roadside and background sites (WDA4).

For the modelling domain, concentrations were calculated over an area of 1400m by 2000m, centred alongside the M5 motorway in Willand (see Figure 4). Pollutant concentrations were calculated with a grid resolution of 47m by 66m. The "intelligent gridding" feature of ADMS-Roads was also utilised. This feature adds extra grid points along each main road emission source enhancing the modelling resolution close to these roads.

Pollutant concentrations were also calculated at a number of specified receptors, listed in Table 3, which include locations where MDDC deploy NO_2 diffusion tubes.

The extent of the modelled domain is shown in Figure 4 and the specified receptors are shown in Figure 5. For each receptor, the selection criteria is listed in line with a, b and c above.

Table 3: Specified air pollution receptors.

Receptor ID	X (m)	Y (m)	Height (m)	Name of location	Selection criteria	MDDC NO_2 diffusion tube ID
WDA1	303196	111042	2.5	Lloyd Maunder Rd	a	WDA1
WDA2	303383	111292	2.5	Market Place	a	WDA2

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[7] http://www.naei.org.uk/data_warehouse.php

WDA3	303290	111059	2.5	Somerville Close	a	WDA3
WDA4	303552	110837	2.5	Willand Primary School	a&c	WDA4
WDA5	303250	111010	2.5	Subway Approach	a	WDA5
WDA6	303227	110788	2.5	Tamarind	a	WDA6
WDA7	303164	110742	2.5	Footpath Adjacent M5	a	WDA7
WDA8	302873	110047	2.5	Dean Hill Road	a	WDA8
WDA9	303371	111327	0	Market Place_a	b	NA
WDA10	303260	111041	0	Subway Approach_a	b	NA
WDA11	303213	111091	0	Lloyd Maunder Rd_a	b	NA
WDA12	303202	110786	0	Footpath Adjacent M5_a	b	NA
WDA13	302926	111040	0	Dean Hill Road_a	b	NA

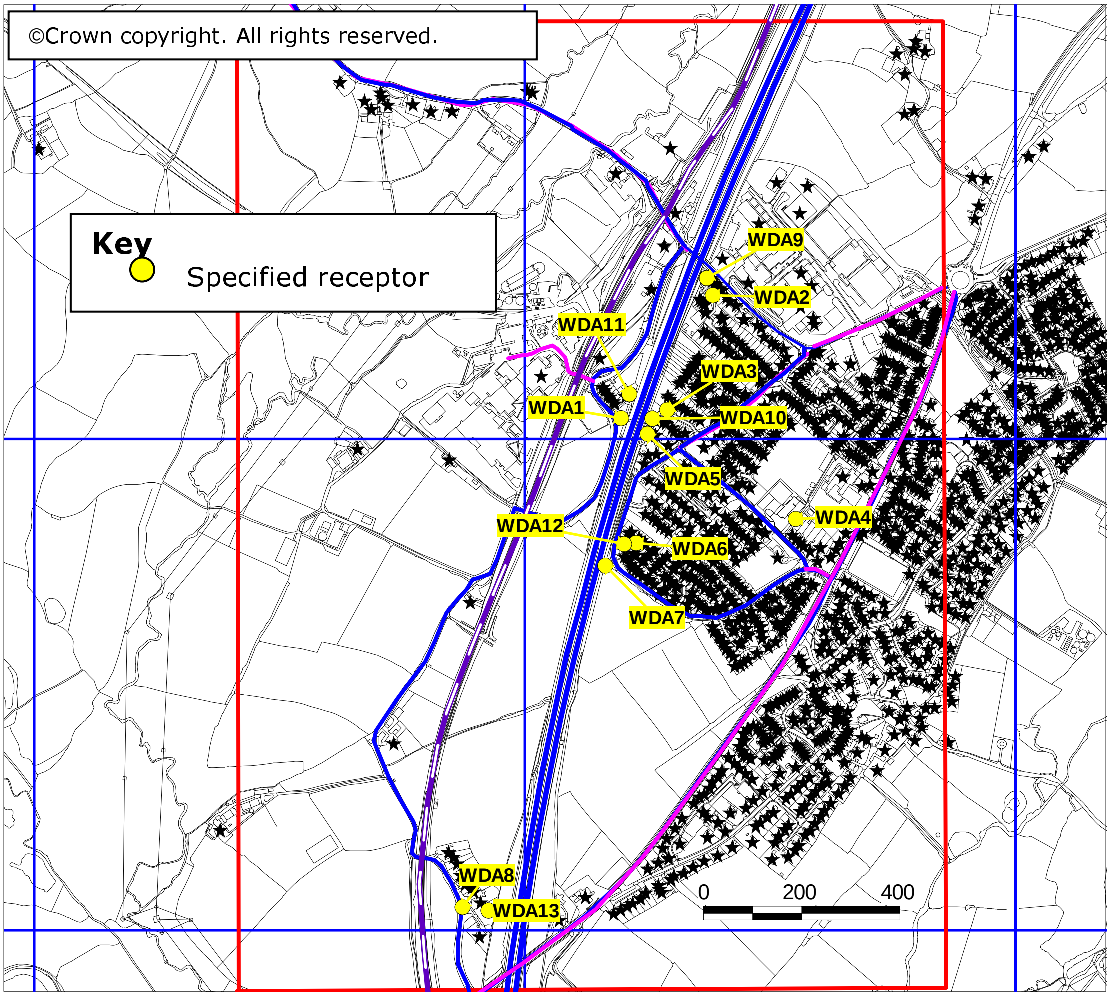

Figure 5: Receptor locations.

4.6 Meteorological data

ADMS-Roads applies hourly sequential meteorological data to calculate atmospheric dispersion. This involves a number of meteorological parameters including wind speed and direction, cloud cover and near surface temperature. The latter two being important parameters for the calculation of atmospheric buoyancy. The nearest site which records all of the required parameters except cloud cover was located at Dunkeswell which is approximately 15km to the east of Willand, while the cloud cover data were taken from Yeovilton, approximately 60km east of Willand. Meteorological data for 2008 was used in this study in order to allow a direct comparison with monitored NO_2 data. A wind rose of the 2008 data is presented in Figure 6: the most frequent winds were from the south-west direction.

ADMS-Roads includes a facility whereby the user can specify the surface roughness length of the site where meteorological data had been recorded (*i.e.* should the surface roughness length differ from that of the area being assessed). In this way, ADMS-Roads modifies the meteorological data to accommodate differences in surface roughness between the modelling domain and the area of the meteorological measurements. The surface roughness length used in this assessment, to be representative of Willand was 0.5m (also see Section 4.9).

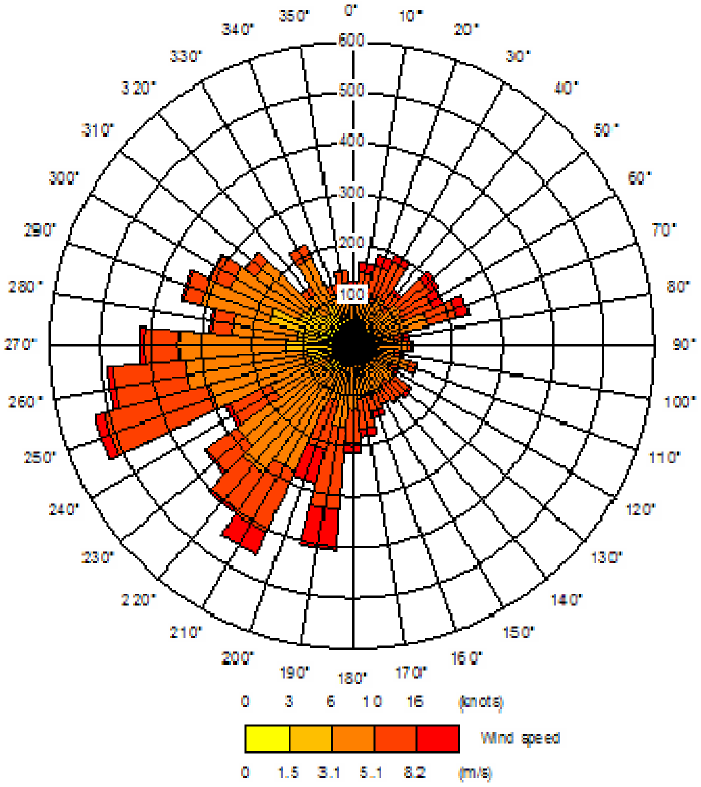

Figure 6: Wind rose at Dunkeswell 2008.

4.7 Background concentrations

New background maps for nitrogen oxides (NO_X) and nitrogen dioxide (NO_2) have been produced alongside LAQM TG (09). These maps are derived from a 2006 base year, and are provided for all years up to 2020. These maps mean that it is now much simpler to avoid the problem of "double-counting" where, for example, a very busy road (such as the M5 motorway) passes through a grid square in a rural or suburban area. Source contributions are included in the background concentration for each 1x1 km grid square, such that it is possible to remove those sources that are explicitly modelled (i.e. to avoid double-counting of emissions from the M5 motorway which have contributed to the NOx concentration in the modelled grid square). The contribution of the M5 motorway (named 'Motorway In') in the background concentration can be subtracted from the total background NOx within the 1 km grid square, because the contribution of the M5 motorway to the NOx concentration in the air has been included in the model.

Estimated gridded background air pollution maps of NO_X and NO_2 for 2008 for MDDC were downloaded[8] and recalculated after excluded road (e.g. motorway/rail for this study) sources from the assessed grids as presented in Appendix B. For further information please refer to the DEFRA website[9] and the LAQM Help Desk[10].

4.8 Atmospheric chemistry

The concentration of NO_2 at a given location is determined by a combination of emissions, meteorology and atmospheric chemistry. Some NO_2 is emitted directly from vehicle exhausts (primary NO_2), mainly from diesel vehicles, but NO_x vehicle emissions are primarily in the form of NO (AQEG, 2007). This NO 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. Therefore, at heavily trafficked roadside locations, there is not a linear relationship between changes in NO_X emissions and NO_2 concentrations.

Whilst ADMS-Roads includes a chemistry module for the direct derivation of NO_2, this was not applied within this study. The use of the chemistry module requires local knowledge both of the emissions of primary NO_2, and also the concentration of O_3 across the modelling domain. As these inputs remain uncertain within this geographic area, a new approach has been developed for LAQM TG (09) as a simple spreadsheet calculator which can be downloaded from the internet[11]. This calculator allows the calculation of NO_2 from NO_X and vice versa. It differs from previous versions in that it allows for varying proportions of primary NO_2 and allows more than one calculation to be performed at once.

4.9 Surface roughness

The interaction of wind flow with the earth's surface generates turbulence, influencing pollutant dispersion. The strength of this turbulence is dependent on the land use, with built-up areas generating more turbulence than open countryside. The ADMS-Roads user guide indicates that a surface roughness length of 1m is suitable for cities and woodland, while 0.5m is suitable for parkland and open suburbia. This study therefore used a surface roughness of 0.5m.

4.10 Model performance

In order to evaluate the performance of the model, predictions were made at locations that correspond to monitoring locations. The modelled concentrations were made at averaged heights of 2.5m, as this corresponds to the approximate height of the diffusion tubes. Of the 8 diffusion tubes which could have been used for this assessment, 1 was discounted due to poor data capture of 50% (WDA4). Caution should be applied when integrated the results of WDA5 into the verification process owing to their close proximity to the M5 motorway. The performance of ADMS-Roads in modelling pollutant concentrations under such circumstances was uncertain, hence for this location, there was a noticeable over-prediction. As a result, 7 monitoring sites were applied to verify the model output. This is in line with minimum requirements stipulated in the NSCA guidance (NSCA, 2000).

The NO_2 concentrations were calculated from the modelled NO_X concentrations using the method outlined in TG(09) (spreadsheet calculator[12]). The results of the model

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[8] www.airquality.co.uk/archive/laqm/tools.php?tool=background06

[9] http://www.defra.gov.uk/environment/airquality/local/guidance/index.htm

[10] http://www.airquality.co.uk/archive/laqm/helpline.php

[11] www.airquality.co.uk/archive/laqm/tools.php

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

comparison are presented in Table 4. All modelling results were within 27% of the monitored values.

In order to undertake a step wise sensitivity analysis, typically two years of metrological data would be preferred in order to establish a 'worst case' pollution year. As the nature of this assessment work, only 2008 meteorological data was employed.

Table 4: Model comparison with monitored data 2008– NO_2 diffusion tubes.

MDDC diffusion tube ID	Receptor ID	Location	Monitored annual mean 2008 (μgm^{-3})	Modelled annual mean, 2008 (μgm^{-3})	Over/under estimation (%)
WDA1	WDA1	Lloyd Maunder Rd	30.3	22.2	-26.7%
WDA2	WDA2	Market Place	28.0	21.9	-21.8%
WDA3	WDA3	Somerville Close	28.5	22.7	-20.2%
WDA5	WDA5	Subway Approach	27.3	29.5	8.3%
WDA6	WDA6	Tamarind	23.3	19.1	-17.9%
WDA7	WDA7	Footpath Adjacent M5	35.8	31.9	-10.9%
WDA8	WDA8	Dean Hill Road	16.8	13.2	-21.6%

4.11 Model verification

The output data from the model were examined in accordance with the methodology presented in LAQM.TG (09).

The modelled results (NO_2) at the receptors in 2008 were compared with the estimated annual mean concentration for 2008 scaled using automatic monitoring data from Exeter Roadside as shown in Table B2 in Appendix B. The objective of this was to determine whether the modelled results provided a close representation of the monitored data and if not, to determine a correction factor that could be applied to the modelled results.

The comparison of modelled data with data from the diffusion tubes at all available monitoring sites (7 diffusion tubes sites) suggests that the model is performing reasonable well all locations. Generally the difference between modelled and monitored data is within 25% for the majority of the modelled results (in this case the average deviation being 15.8%), although the model is showing under-predict at sites of WDA1, 2, 3, 6, 7 & 8 and over-predicting at site WDA5.

Kerbside sites are not recommended for the adjustment of road traffic modelling results in TG (09) because the inclusion of these sites may lead to an over-adjustment of modelling at roadside sites (which has been observed in this study: higher modelled concentrations than monitoring concentrations were found close to the M5 motorway). In exceptional circumstances where kerbside sites are closer to a relevant exposure, this site was included in model verification process together with others as worst case. This could occur where, for example, properties are directly on the roadside. In this case, kerbside sites may be used to verify the modelled concentrations.

Figure 7 shows the modelled total NO_2 versus monitoring data total NO_2 concentrations, and a linear regression line (through zero) has been derived. The equation slope of this line is 1.24 and could be used to further adjust the modelled total NO_2 concentrations; however, in this case the adjustment was not necessary as the majority of the modelled results being within 25% of the measured results according TG(09).

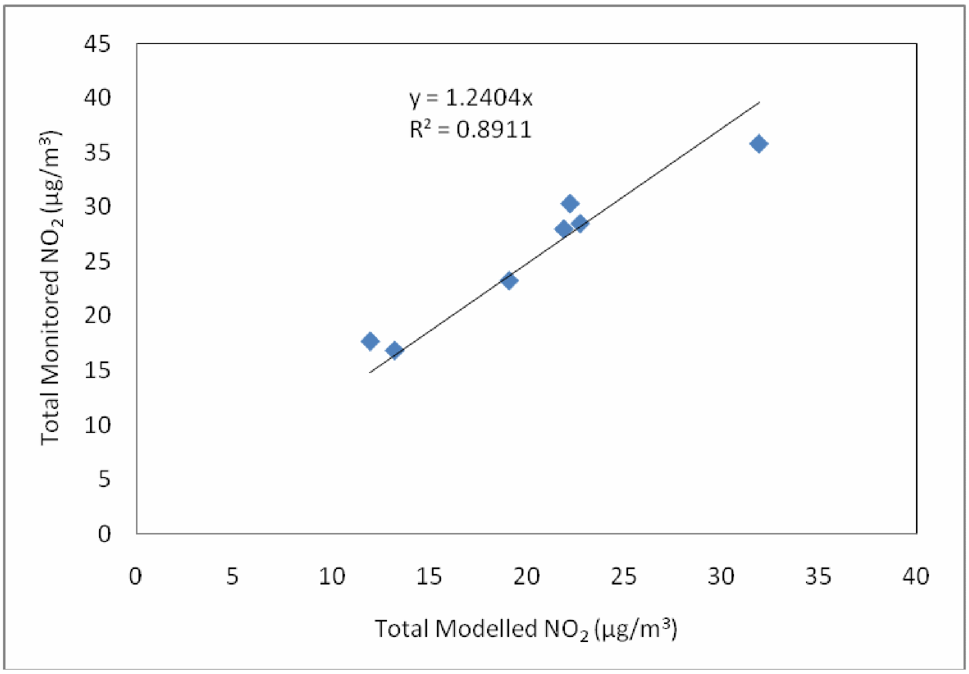

Figure 7: Plot of the 2008 monitored and modelled 2008 NO_2 data.

4.12 Model uncertainty

The purpose of this section is to provide an indication of uncertainty of dispersion model predictions. The methodology applied is consistent with that described in LAQM TG(09), in which a number of statistical procedures are recommended to evaluate model performance and assess the uncertainties. These statistical parameters include (but are not limited to):

- Correlation Coefficient (r): used to measure the linear relationship between predicted and observed data. A value of zero means no relationship and a value of 1 means absolute relationship. This statistic can be particularly useful when comparing a large number of model and observed data points.
- Fractional Bias (FB): used to identify if the model shows a systematic tendency to over or under predict. FB values vary between +2 and -2 and has an ideal value of zero. Negative values suggest a model over-prediction and positive values suggest a model under-prediction.
- Root Mean Square Error (RMSE): used to define the average error or uncertainty of the model. The units of RMSE are the same as the quantities compared.

$$r= \frac{\sum_{i}^{N} (\mathrm{Obs_i} - \mathrm{Avg.Obs})(\mathrm{Predi_i} - \mathrm{Avg.Pred})}{\mathrm{Stedv.Obs} \times \mathrm{Stedv.Pred}}$$

$$\mathrm{RMSE}= \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\mathrm{Obs_i} - \mathrm{Pred_i})^2}$$

$$\mathrm{BF}= \frac{(\mathrm{Avg.Obs - Avg.Pred})}{0.5(\mathrm{Avg.Obs + Avg.Pred})}$$

Where:
N = total number of observations compared, Obs = observed concentration,
Pred = predicted concentration,
Avg.Obs = average of all observed concentrations,
Avg.Pred = average of all predicted concentrations,
Stdev.Obs = standard deviation of observed concentrations,
Stdev.pred = standard deviation of predicted concentrations.

The statistic for uncertainty is shown in **Table 5:** The statistic of uncertainty for modelled NO_2 concentrations**.**

Table 5: The statistic of uncertainty for modelled NO_2 concentrations.

Statistic	Results before verification and adjustment	Results after verification and adjustment	Comments (view examples for full details of verification and adjustment)
RMSE	5.2	n/a	No model adjustment was
Correlation	0.89	n/a	No model adjustment was
Fractional	0.17	n/a	No model adjustment was

The uncertainty of the model (U) could be expressed as the Root Mean Square Error (RMSE) divided by the averaged observation. It is calculated using the following formula:

$$U = RMSE / NO_2 \ (\mu gm^{-3}) \text{ annual mean objective value}$$

In this case:

$$U = 5.2/27$$

$$U = 19\%$$

This equates to an uncertainty of 19% for annual mean NO_2 and means that the RMSE value is 19% of the air quality objective being assessed i.e. 7.6 $\mu g/m^3$ for NO_2.

4.13 Summary of model performance

In summary, the model predictions are considered to compare moderately well to monitoring concentrations for the annual mean NO_2 concentrations (*i.e.* within an average of 25%) (TG (09)). It must also be noted, however, that diffusion tube concentrations are less accurate than concentrations measured by automatic monitors using continuous chemiluminesence-based techniques. Less confidence can therefore be taken from the comparison of model predictions to diffusion tube measurements than can be taken from comparisons with chemiluminescence-based measurements. It is also noted that there are difficulties in modelling emissions on busy roads such as the M5 motorway, which is the main source and contributes an average of approximately 50% NO_2 to the total NO_2 at receptors in the assessed area for 2008. It is not possible (within the time and budget constraints of this assessment) to replicate the actual traffic patterns such as specific driving characteristics and detailed fleet. It may therefore be expected that there will be discrepancies between modelled and monitored concentrations at these locations.

Adjustments have not been made to the results presented in this report in line with TG (09), while the uncertainty of model results was discussed in the section 4.12.

5 Results

The modelled NO_2 (not adjusted) and PM_{10} concentrations in 2008 and 2009 at the specified receptors are presented in Table 6 and Table 7. Figure 8 shows the locations individual contour plot both for 2008 and 2009 in Willand. The ground level modelled NO_2 concentrations across the study area are presented in a series of concentration contour plots (Figure 9 to Figure 18). These contour plots show compliance with the objective annual mean concentration (i.e. not exceeding the annual mean concentration of 40 µg m^{-3}), at those receptors where relevant exposure exists (i.e. WDA9 – WDA13). The modelled results are discussed in more detail in Chapter 6.

Table 6: Modelled pollutant concentrations at specified points for year 2008.

Receptor ID	**Height (m)**	**Location**	**Unadjusted NOx annual average from road (μgm^{-3})**	**Unadjusted NO_2 annual average (μgm^{-3})**	**Road contribution to NO_2 (%)**
WDA1	2.5	Lloyd Maunder Rd	25.22	22.22	51%
WDA2	2.5	Market Place	24.45	21.90	51%
WDA3	2.5	Somerville Close	26.47	22.74	53%
WDA4	2.5	Willand Primary School	4.43	11.96	18%
WDA5	2.5	Subway Approach	44.11	29.51	63%
WDA6	2.5	Tamarind	20.03	19.09	49%
WDA7	2.5	Footpath Adjacent M5	53.56	31.92	69%
WDA8	2.5	Dean Hill Road	8.26	13.21	30%
WDA9	0	Market Place_a	44.45	29.63	64%
WDA10	0	Subway Approach_a	52.15	32.30	67%
WDA11	0	Lloyd Maunder Rd_a	28.87	23.72	54%
WDA12	0	Footpath Adj M5_a	31.02	23.66	59%
WDA13	0	Dean Hill Road_a	3.34	10.85	15%

a indicates a possible human exposure location closest to motorway

Table 7: Modelled pollutant concentrations at specified points for year 2009.

Receptor ID	Height (m)	Location	Unadjusted NOx annual average from road (μgm^{-3})	Unadjusted NO_2 annual average (μgm^{-3})	Road contribution to NO2 (%)
WDA1	2.5	Lloyd Maunder Rd	23.6	20.91	52%
WDA2	2.5	Market Place	22.8	20.57	51%
WDA3	2.5	Somerville Close	24.7	21.37	53%
WDA4	2.5	Willand Primary School	4.16	11.46	18%
WDA5	2.5	Subway Approach	41	27.82	64%
WDA6	2.5	Tamarind	18.7	18.19	48%
WDA7	2.5	Footpath Adjacent M5	49.8	30.44	69%
WDA8	2.5	Dean Hill Road	7.95	12.73	30%
WDA9	0	Market Place_a	41.4	27.97	64%
WDA10	0	Subway Approach_a	48.5	30.53	67%
WDA11	0	Lloyd Maunder Rd_a	27	22.33	55%
WDA12	0	Footpath Adj M5_a	28.9	22.52	58%
WDA13	0	Dean Hill Road_a	3.2	10.43	15%

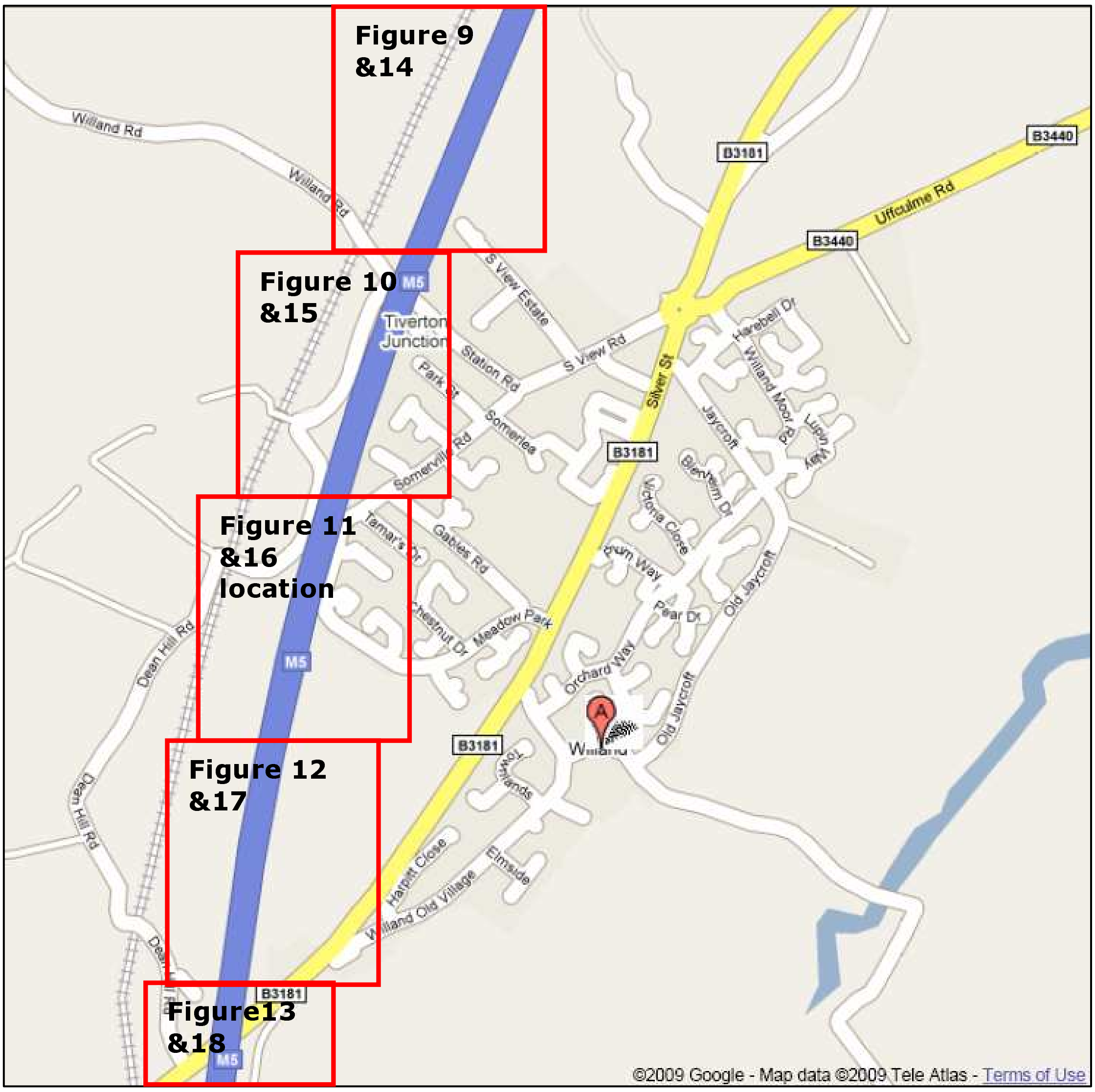

Figure 8 Individual contour plot location

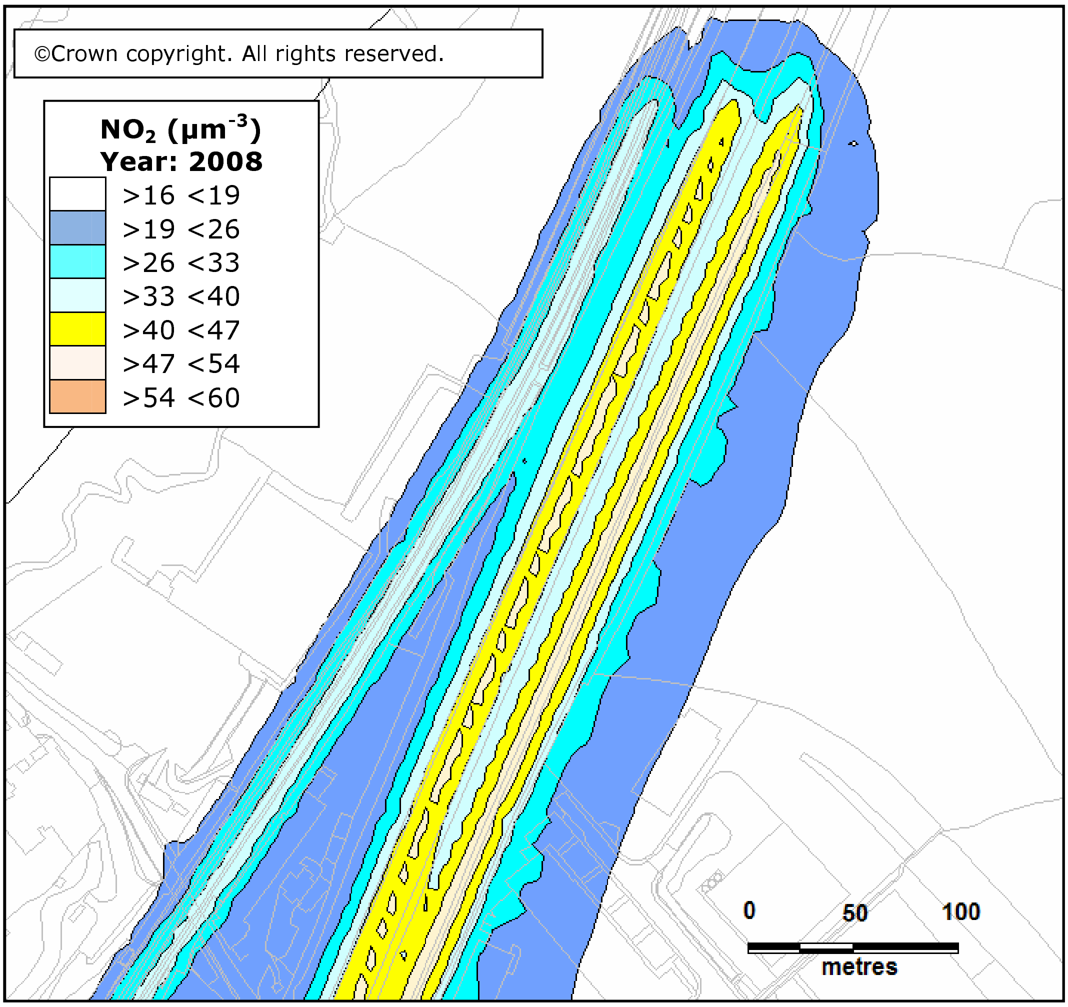

Figure 9: Contour plot: 2008 NO_2 annual mean.

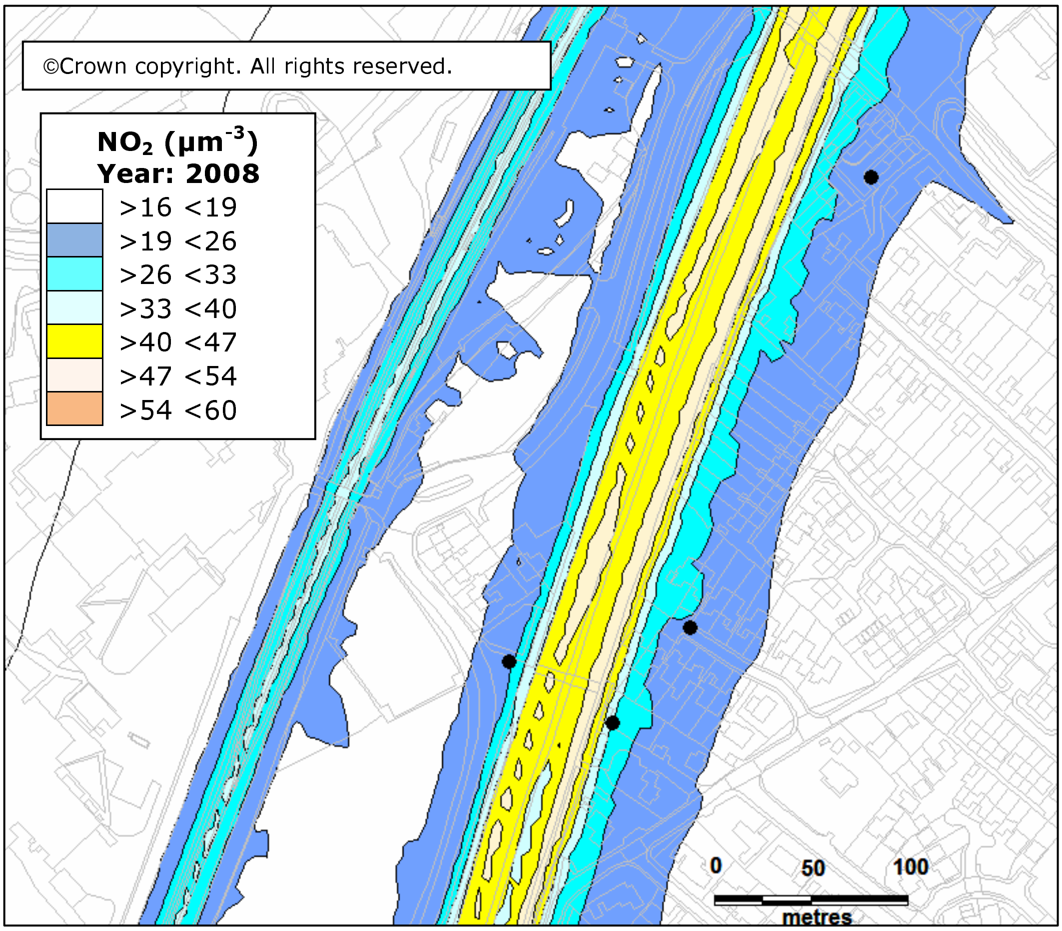

Figure 10: Contour plot: 2008 NO_2 annual mean.

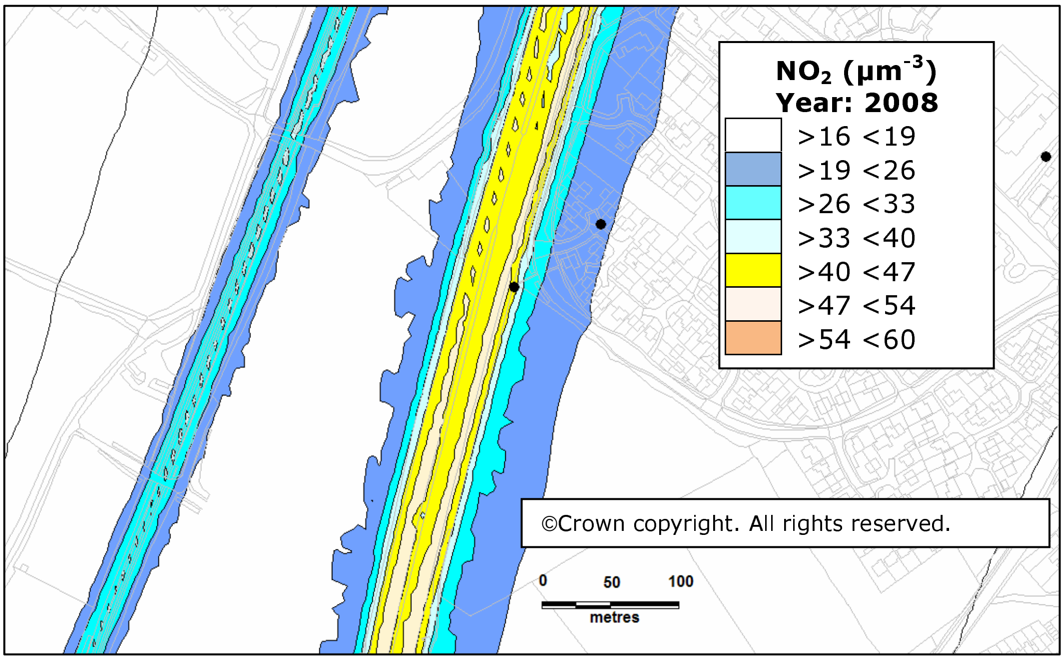

Figure 11: Contour plot: 2008 NO_2 annual mean.

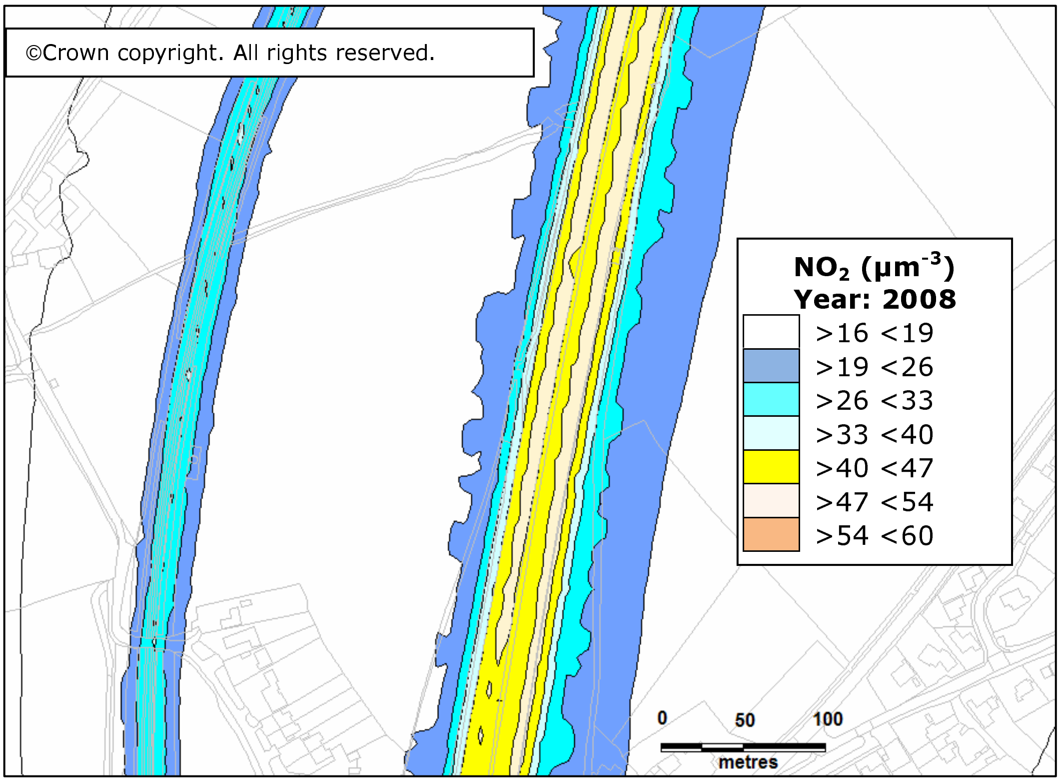

Figure 12: Contour plot: 2008 NO2 annual mean.

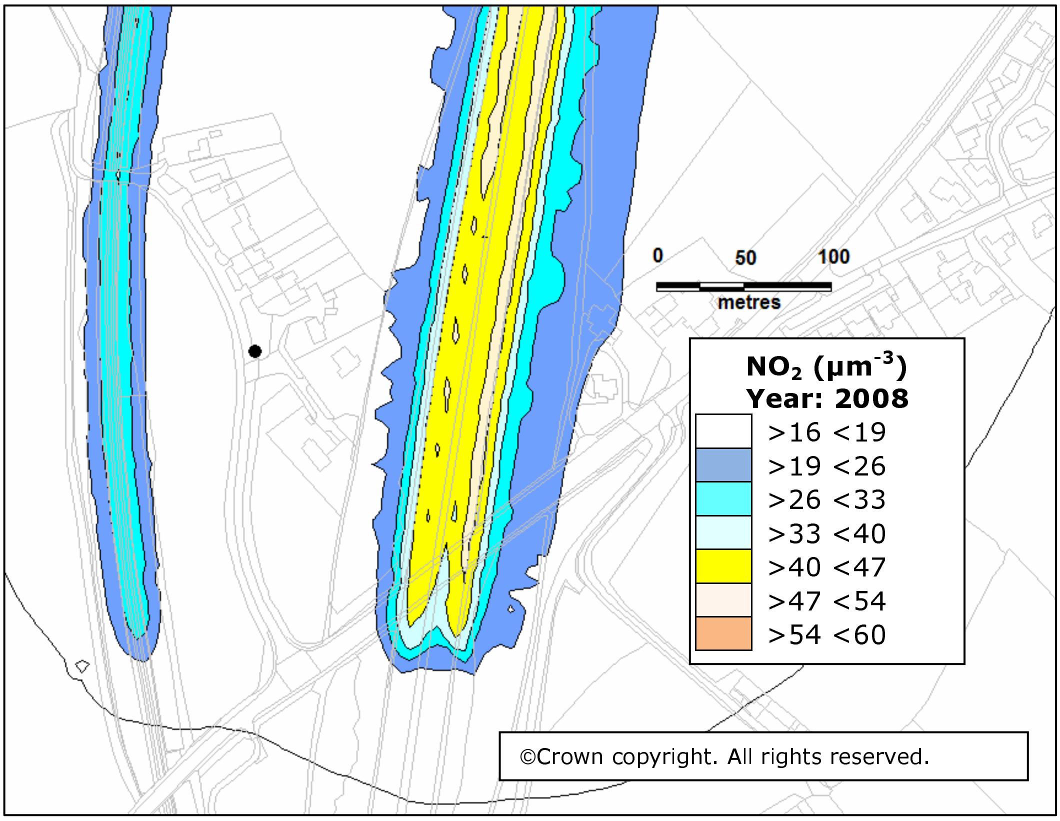

Figure 13: Contour plot: 2008 NO2 annual mean.

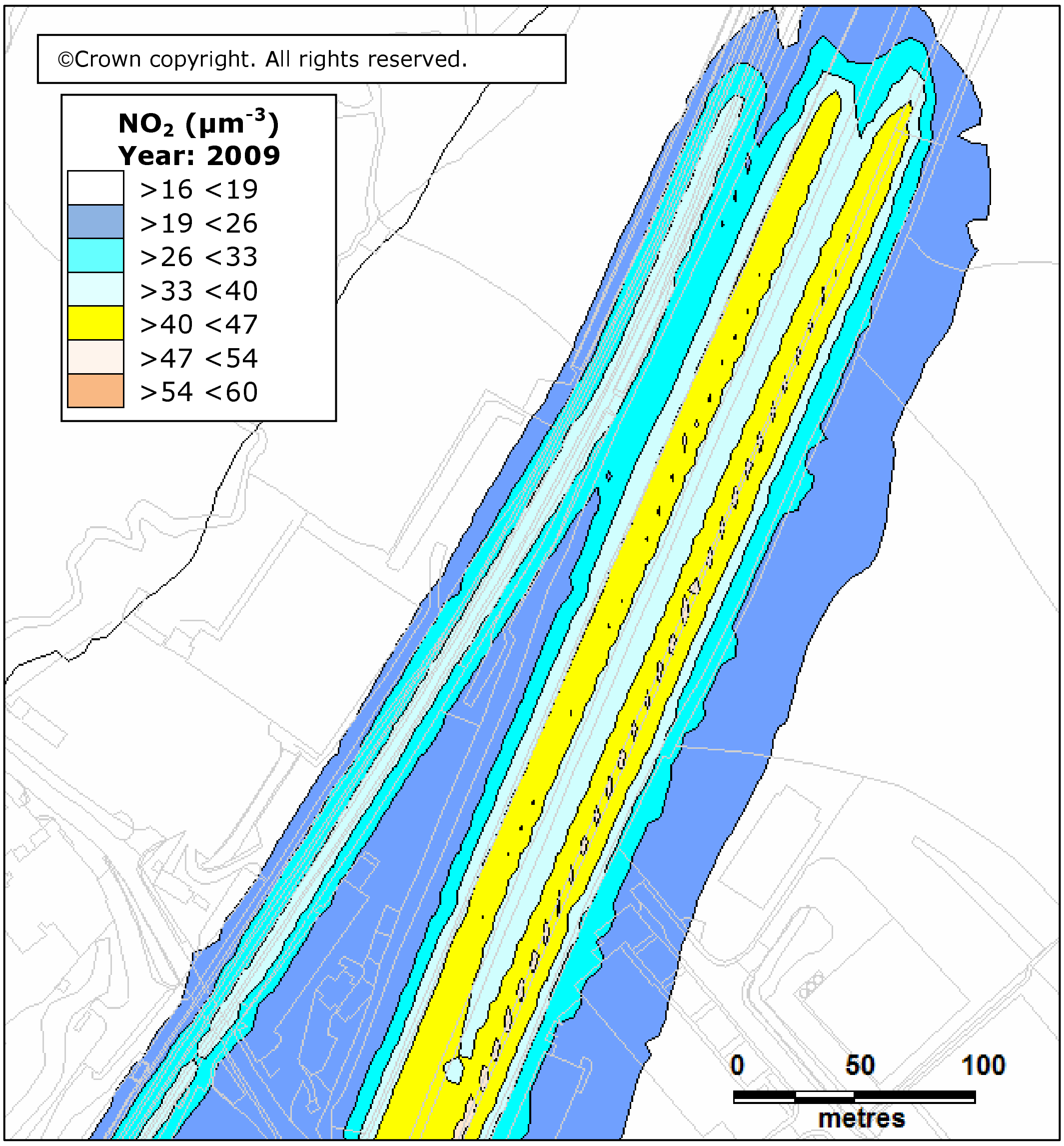

Figure 14: Contour plot: 2009 NO_2 annual mean.

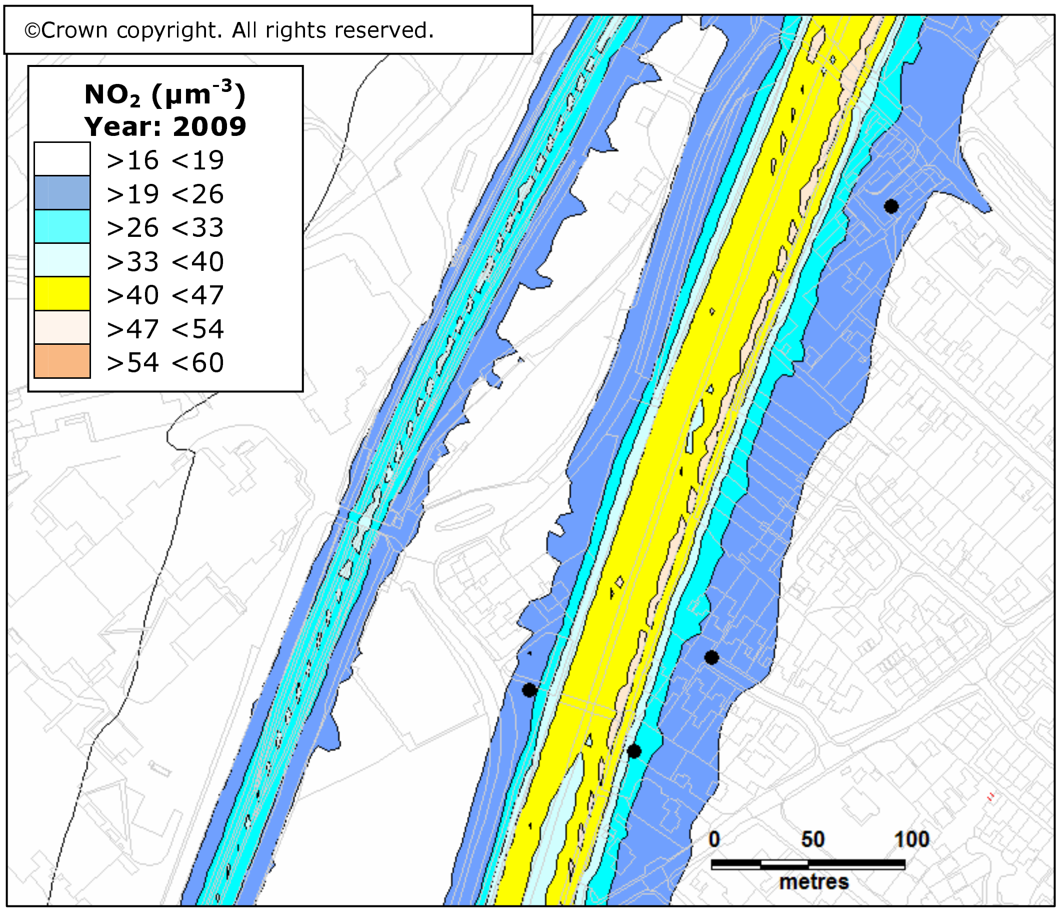

Figure 15: Contour plot: 2009 NO_2 annual mean

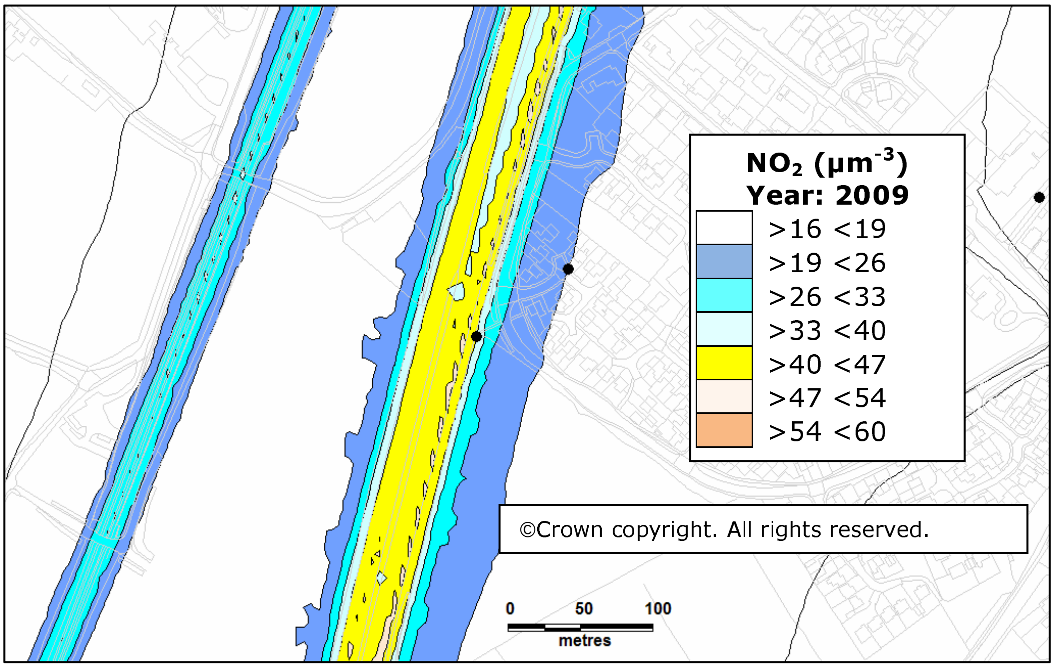

Figure 16: Contour plot: 2009 NO_2 annual mean

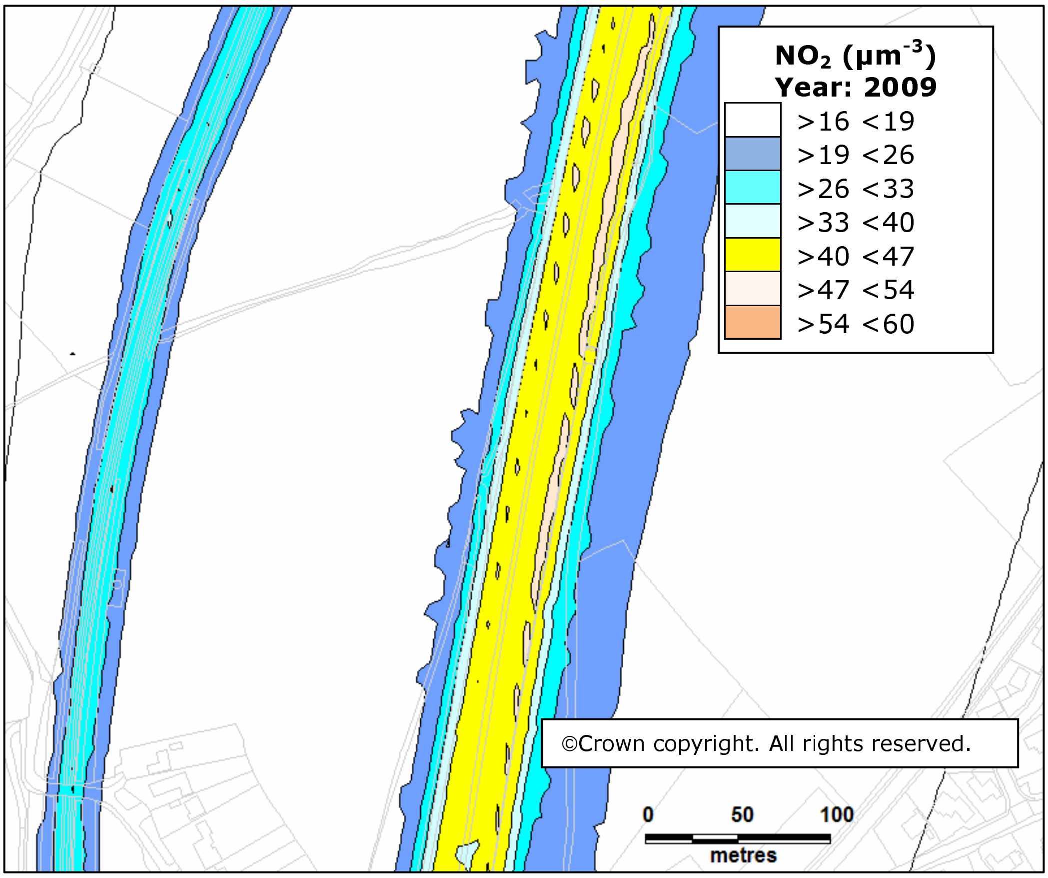

Figure 17: Contour plot: 2009 NO_2 annual mean

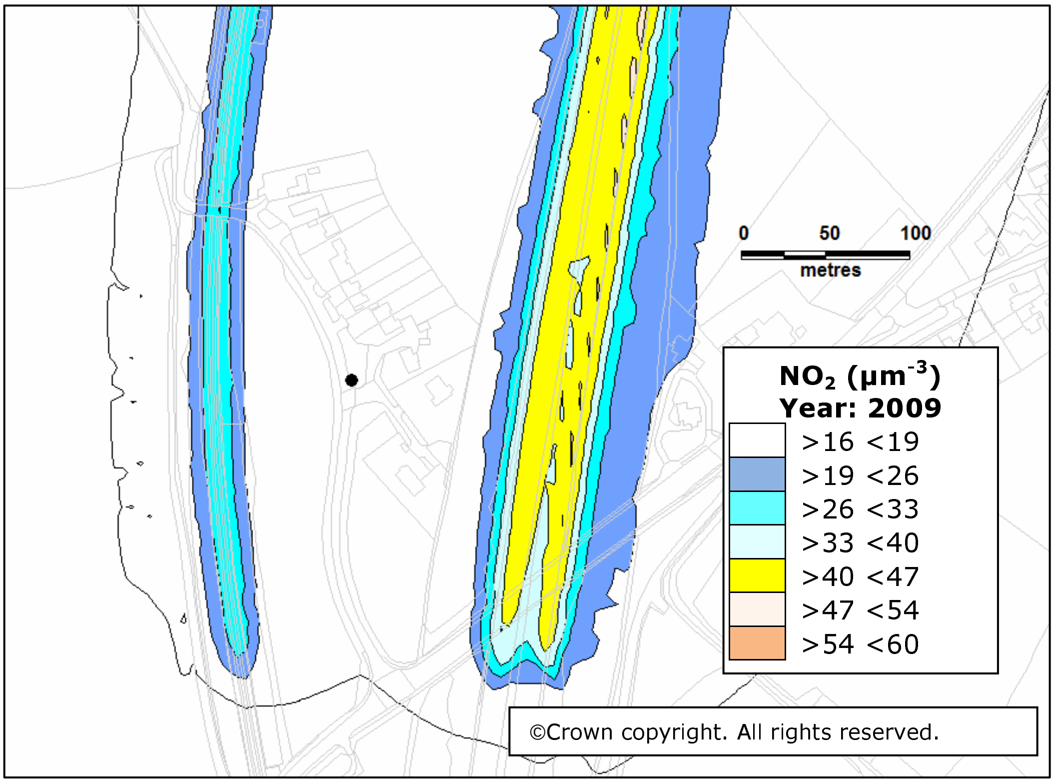

Figure 18: Contour plot: 2009 NO_2 annual mean

6 Discussion of results

The contour maps (from Figure 9 to Figure 18) show that by 2009, modelled NO_2 concentrations are expected to have declined and the average reduction in the concentration of NO_2 for all 13 receptors compared to 2008 concentrations is around 1.2 μgm^{-3}, which is approximately 5.6% of total NO_2. Taking the predicted area of exceedence to be the yellow boundary, within which there are no receptors with relevant exposure (e.g. WDA9 – WDA13),

The standard deviation of the modelling results represents 7.6 µg/m3, for NO2. This means that there is a probability that locations currently within the concentration banding of 33 µg/m3 and 40 µg/m3 (light blue band) will exceed the objective (i.e. if one takes the precautionary approach). Given that there are no residencies within the precautionary bandwidth, mean that relevant exposure is very unlikely.

The plots indicate that the highest pollutant concentrations are predicted at kerbside and roadside locations WDA7 (Footpath adjacent M5) and WDA10 (Subway Approach), and that the latter is located in front of a property which is the closest to the M5 with relevant exposure. Therefore, this study would recommend positioning a diffusion tube for a further 6 months at this location. Subsequent to this, modelling uncertainty would need to re-examine the results to compare with modelling predictions.

Furthermore, this assessment would benefit from a more detailed investigation of rail emissions (i.e. operational characterisation) as well as vehicle fleet characterization of M5.

Given the conclusion discussed above, no evidence has been provided by the modelled results to support the declaration of an AQMA within the assessed area in Willand.

Acknowledgements

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7 Appendix A: Traffic data and associated emission rates input to the air pollution model

This appendix includes the relevant data used for the air quality assessment. Table A1 shows the traffic data derived for each modelled road link. Each road may comprise several links hence the need to post-script each one with the direction of traffic flow (*e.g.* NB- northbound) or a number (*e.g.* STATION_RD_NB_3) or in most instances using a combination of notations. Tables A2 show the emission for each link modelled within Willand for the year 2008 and 2009 and time variation for the model. Tables A3 show the time varying factors used to vary emissions rates over 24 hour periods as well as the train operational hours which are for the model to switch on/off.

Table A1: Surveyed Road traffic data (2008).

Modelled links	Road .ength (km)	Average Daily Vehicles (2008)	Average speed (km/h)	Cars (%)	Light goods vehicles (%)	Buses (%)	Heavy goods vehicles-rigid (%)	Heavy goods vehicles-articulated (%)
LLOYD_MAUNDER_RD_NB_1	0.35	451	43	82.5	6.1	0.8	4.7	6.0
LLOYD_MAUNDER_RD_SB_1	0.35	451	42	84.1	6.2	0.2	3.9	5.6
LLOYD_MAUNDER_NB_2	1.614	136	46	91.3	5.5	0.5	2.7	0.0
LLOYD_MAUNDER_SB_2	1.614	134	47	93.0	4.2	0.3	2.5	0.0
STATION_RD_NB_3	0.331	2178	43	89.4	4.5	0.3	4.1	1.7
STATION_RD_SB_3	0.331	2193	44	89.1	4.6	0.4	4.2	1.8
SOMERVILLE_RD_NB_4	0.745	274	41	82.1	1.9	0.4	15.6	0.0
SOMERVILLE_RD_SB_4	0.745	308	39	87.1	2.0	0.1	10.8	0.0
GABLES_RD_NB_5	0.356	923	42	95.1	3.5	0.1	1.3	0.1
GABLES_RD_SB_5	0.356	926	41	95.1	3.6	0.0	1.1	0.1
SILVER_ST_ALL_6[a]	1.636	5500	41	95.1	3.5	0.0	1.2	0.1
S_VIEW_RD_ALL_7[a]	0.304	4000	44	89.2	4.5	0.3	4.1	1.8
SOMERVILLE_RD_ALL_8[a]	0.33	1800	41	95.1	3.5	0.0	1.2	0.1
WILLAND_RD_ALL_9[a]	0.955	3300	44	89.2	4.5	0.3	4.1	1.8
LLOYD_MAUNDER_RD_SLIP _ALL_10[a]	0.229	640	43	83.3	6.2	0.5	4.3	5.8
MEADOW_PARK_RD_ALL_11[a]	0.057	2400	41	95.1	3.5	0.0	1.2	0.1
M5_J28_27_NB[b]	2.06	29649	113	87.5		12.5		
M5_J27_28_SB[b]	2.06	27235	113	86.5		13.5		

a from estimated
b from internet (http://trads.hatris.co.uk)

Table A2b: Projected Road traffic data (2009).

Modelled links	Road Length (km)	Average Daily Vehicles (2008)	Average Speed (km/h)	Cars (%)	Light Goods Vehicles (%)	Buses (%)	Heavy Goods vehicles-rigid (%)	Heavy goods vehicles-articulated (%)
LLOYD_MAUNDER_RD_SB_1	0.35	918	43	83.4	6.2	0.5	4.2	5.7
LLOYD_MAUNDER_NB_2	1.614	274	47	92.2	4.9	0.4	2.5	0.0
STATION_RD_NB_3	0.331	4448	43	89.3	4.6	0.3	4.1	1.8
SOMERVILLE_RD_NB_4	0.745	592	40	84.8	2.0	0.2	13.0	0.0
GABLES_RD_NB_5	0.356	1882	41	95.1	3.5	0.0	1.2	0.1
SILVER_ST_ALL_6	1.636	15264	55	95.1	3.5	0.0	1.2	0.1
S_VIEW_RD_ALL_7	0.304	4070	43	89.3	4.6	0.3	4.1	1.8
SOMERVILLE_RD_ALL_8	0.33	1832	41	95.1	3.5	0.0	1.2	0.1
WILLAND_RD_ALL_9	0.955	3358	43	89.3	4.6	0.3	4.1	1.8
LLOYD_MAUNDER_RD_SLIP_ALL_10	0.229	651	43	83.4	6.2	0.5	4.2	5.7
MEADOW_PARK_RD_ALL_11	0.057	2442	41	95.1	3.5	0.0	1.2	0.1
M5_J28_27_NB	2.06	30284	113	87.5		12.5		
M5_J27_28_SB	2.06	27819	113	86.5		13.5		

Increase Factor 2008-2009 from English Regional Traffic Growth and Speed Forecasts, Published Oct 2007,Rev 1.1 April 2008.

Table A3a: Line source (road + rail) model input data 2008.

		Emissions						
Link Name	**Length**	**CO**	**THC**	**NOx**			**PM10**	**C**
	(km)	**(kg/year)**	**(kg/year)**	**(kg/year)**	**g/sec**	**g/km/sec**	**(kg/year)**	**(tonnes/year)**
LLOYD_MAUNDER_RD_1	0.35	121	19	111	0.0035	0.0100	3	8
LLOYD_MAUNDER_2	1.61	148	17	60	0.0019	0.0012	2	8
STATION_RD_3	0.33	529	70	312	0.0099	0.0299	9	30
SOMERVILLE_RD_4	0.75	165	24	129	0.0041	0.0055	3	11
GABLES_RD_5	0.36	251	28	76	0.0024	0.0068	2	12
SILVER_ST_ALL_6	1.64	7504	839	2805	0.0889	0.0544	78	396
S_VIEW_RD_ALL_7	0.30	445	59	263	0.0083	0.0274	7	25
SOMERVILLE_RD_ALL_8	0.33	226	26	69	0.0022	0.0066	2	11
WILLAND_RD_ALL_9	0.96	1152	153	681	0.0216	0.0226	19	65
LLOYD_MAUNDER_RD_SLIP _ALL_10	0.23	56	9	51	0.0016	0.0071	1	4
MEADOW_PARK_RD_ALL_11	0.06	52	6	16	0.0005	0.0088	1	2
M5_J28_27_NB	2.06	19344	2828	29068	0.9217	0.4474	957	1942
M5_J27_28_SB	2.06	17956	2700	28119	0.8917	0.4328	911	1832
REGIONAL_TRAIN_LINE	2.12	13643	3820	72033	2.2841	1.0774	4366	1114
Total	**13.15**	**61591**	**10598**	**133792**	**4.24**	**2.14**	**6362**	**5459**

Table A2b: Line source (road + rail) model input data 2009.

Link Name	Length	CO	THC	NOx			PM10	C
		Emissions						
	(km)	(kg/year)	(kg/year)	(kg/year)	g/sec	g/km/sec	(kg/year)	(tonnes/year)
LLOYD_MAUNDER_RD_1	0.35	118	19	101	0.0032	0.0092	3	8
LLOYD_MAUNDER_2	1.61	145	17	57	0.0018	0.0011	2	8
STATION_RD_3	0.33	518	68	290	0.0092	0.0277	8	30
SOMERVILLE_RD_4	0.75	162	23	119	0.0038	0.0051	3	11
GABLES_RD_5	0.36	246	28	72	0.0023	0.0064	2	12
SILVER_ST_ALL_6	1.64	7369	820	2658	0.0843	0.0515	73	395
S_VIEW_RD_ALL_7	0.30	436	57	243	0.0077	0.0254	7	25
SOMERVILLE_RD_ALL_8	0.33	222	25	65	0.0021	0.0063	2	11
WILLAND_RD_ALL_9	0.96	1129	148	631	0.0200	0.0209	18	65
LLOYD_MAUNDER_RD_SLIP_ALL_10	0.23	55	9	47	0.0015	0.0065	1	4
MEADOW_PARK_RD_ALL_11	0.06	51	6	15	0.0005	0.0084	0	2
M5_J28_27_NB	2.06	18168	2725	26911	0.8533	0.4142	878	1943
M5_J27_28_SB	2.06	16859	2602	26015	0.8249	0.4004	835	1833
REGIONAL_TRAIN_LINE	2.12	13643	3820	72033	2.2841	1.0774	4366	1114
Total	**13.15**	**59120**	**10365**	**129256**	**4.10**	**2.06**	**6197**	**5461**

Table A3: Time variation factors.

Time (hour starting)	Averaged Minor Road Flow			Averaged Major Road Flow			Motorway			Rail Operational time (on/off)		
	W'day	**Sat**	**Sun**	**W'day**	**Sat**	**Sun**	**W'day**	**Sat**	**Sun**	**W'day**	**Sat**	**Sun**
0	0.07	0.15	0.36	0.13	0.23	0.28	0.15	0.19	0.17	0	0	0
1	0.03	0.12	0.00	0.06	0.15	0.10	0.12	0.14	0.11	0	0	0
2	0.00	0.10	0.04	0.09	0.10	0.12	0.12	0.14	0.09	0	0	0
3	0.02	0.09	0.12	0.18	0.16	0.14	0.14	0.14	0.08	0	0	0
4	0.04	0.06	0.00	0.23	0.20	0.20	0.20	0.16	0.07	0	0	0
5	0.18	0.15	0.09	0.52	0.26	0.24	0.35	0.21	0.10	0	0	0
6	0.43	0.31	0.09	0.55	0.22	0.07	0.83	0.32	0.18	0	0	0
7	1.55	0.69	0.09	1.48	0.42	0.24	1.75	0.58	0.30	1	1	1
8	2.40	1.01	0.21	2.16	0.66	0.28	2.08	0.91	0.46	1	1	1
9	1.47	1.47	0.80	1.59	1.53	0.71	1.72	1.26	0.89	1	1	1
10	1.42	1.86	1.20	1.55	1.67	1.29	1.59	1.54	1.25	1	1	1
11	1.65	1.74	1.49	1.52	2.06	1.37	1.64	1.70	1.53	1	1	1
12	1.44	1.95	1.50	1.70	1.78	1.36	1.64	1.60	1.53	1	1	1
13	1.60	1.72	1.44	2.18	1.93	1.09	1.72	1.46	1.49	1	1	1
14	1.42	1.62	1.40	1.79	1.60	1.21	1.78	1.37	1.60	1	1	1
15	2.30	1.75	1.69	1.97	1.65	1.20	1.89	1.31	1.82	1	1	1
16	1.92	1.31	1.01	2.10	1.54	1.13	2.10	1.31	2.00	1	1	1
17	2.27	1.46	1.37	2.31	1.49	1.02	2.06	1.28	1.74	1	1	1
18	1.65	2.11	0.93	1.43	1.05	0.67	1.43	1.03	1.45	1	1	1
19	1.35	1.04	0.95	0.97	0.88	0.49	0.90	0.68	1.09	1	1	1
20	0.84	0.87	0.99	0.70	0.44	0.35	0.62	0.51	0.84	1	1	1
21	0.78	0.64	0.53	0.57	0.40	0.32	0.45	0.35	0.60	1	1	1
22	0.47	0.65	0.32	0.51	0.33	0.16	0.34	0.29	0.40	1	1	1
23	0.24	0.62	0.13	0.24	0.43	0.09	0.23	0.22	0.26	1	1	1

8 Appendix B: Verification approach

The methodology adopted within this study conforms with the guidance detailed in LAQM.TG(03) and LAQM.TG(09).

The modelled base year was 2008, which was used for undertaking model verification. Monitored NO_2 concentrations for 2008 were obtained from 8 diffusion tube sites among them one site (WDA4) with a low data capture rate. Therefore the modelled results were verified at 7 monitoring locations in line with background data that are presented in Table B1.

Table B1: Background concentrations for NO_x and NO_2 within assessment area*.

Locations				Background 2008		Background 2009	
				NO_x	NO_2	NO_x	NO_2
ID	**Receptor name**	**X(m)**	**Y(m)**	**(µgm^{-3})**	**(µgm^{-3})**	**(µgm^{-3})**	**(µgm^{-3})**
WDA1	Lloyd Maunder Rd	303196	111042	13.18	10.80	12.17	10.06
WDA2	Market Place	303383	111292	13.18	10.80	12.17	10.06
WDA3	Somerville Close*	303290	111059	13.18	10.80	12.17	10.06
WDA4	Willand Primary School	303552	110837	11.80	9.79	11.30	9.42
WDA5	Subway Approach	303250	111010	13.18	10.80	12.17	10.06
WDA6	Tamarind	303227	110788	11.80	9.79	11.30	9.42
WDA7	Footpath Adjacent M5	303164	110742	11.80	9.79	11.30	9.42
WDA8	Dean Hill Road	302873	110047	11.03	9.20	10.56	8.85
WDA9	Market Place_a	303371	111327	13.18	10.80	12.17	10.06
WDA10	Subway Approach_a	303260	111041	13.18	10.80	12.17	10.06
WDA11	Lloyd Maunder Rd_a	303213	111091	13.18	10.80	12.17	10.06
WDA12	Footpath Adj M5_a	303202	110786	11.80	9.79	11.30	9.42
WDA13	Dean Hill Road_a	302926	111040	11.03	9.20	10.56	8.85

*background calculated exclusively from rail and motorway in each grid.

Table B2: Estimation of annual mean concentrations of NO2 from short-term monitoring data

Tube No (WDA)	Long term site	Annual mean 2008(Am) (µgm^{-3})	Period Mean 2008 (Pm) (µgm^{-3})	Ratio (Am/Pm)	Period for Mean
1,2,3,5,6,7,8	Exeter Roadside	38.5	41.7	0.923	01/Aug/2008-31/Jan/2009
4	Exeter Roadside	38.5	40.4	0.953	Aug. ,Nov. Dec 2008