Environment Act 1995 Part IV

Local Air Quality Management

Detailed Assessment 2008

City of Norwich

NORWICH
City Council

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AEA
The Gemini Building
Fermi Avenue
Harwell International Business Centre
Didcot
OX11 0QR

t: 0870 190 3821
f: 0870 190 6318

AEA is a business name of AEA Technology plc

AEA is certificated to ISO9001and ISO14001

Author	Name	Agnieszka Griffin
Approved by	Name	Beth Conlan
	Signature	
	Date	March 2009

Executive summary

The Government prepared the Air Quality Strategy for England, Scotland, Wales and Northern Ireland for consultation in August 1999. It was published in January 2000 (DETR, 2000). A revised version was published in July 2007 (DEFRA, 2007).

At the centre of the Air Quality Strategy is the use of national air quality standards to enable air quality to be measured and assessed. These also provide the means by which objectives and timescales for the achievement of objectives can be set.

Local authorities are required to review and assess the air quality in their areas from time to time to determine whether the air quality objectives are likely to be met.

This report is a Detailed Assessment for Norwich Council as outlined in the Government's published guidance.

The general approach taken to this Detailed Assessment was to:

- Identify potential "hot spots" where there is expected to be the greatest potential for public exposure in the general area identified in the Updating and Screening Assessment as being at risk of exceedence;
- Collect and interpret additional data to support the detailed assessment, including detailed traffic flow data around potential hotspots;
- Consider recent continuous monitoring and diffusion tube measurements;
- Use monitoring data from the diffusion tubes to assess the ambient concentrations produced by the road traffic and to calibrate the output of modelling studies;
- Model the concentrations of nitrogen dioxide around the potential hotspots, concentrating on the locations (receptors) where people might be exposed over the relevant averaging times of the air quality objectives;
- Present the concentrations as contour plots and assess the uncertainty in the predicted concentrations;
- Assess the contribution made from various sources to the pollutant concentrations;
- Consider whether the authority should declare an Air Quality Management Area and provide recommendations on the scope and extent of any proposed Air Quality Management Area.

The results from the diffusion tube survey and automatic continuous monitoring of nitrogen dioxide in 2007 has confirmed that the annual mean objective of 40μg m^{-3} has been not met in 2007 at many locations in Norwich.

Air dispersion modelling was carried out for Norwich City Council covering the following locations:
- Grapes Hill;
- King Street;
- Riverside Road;
- Magdalen Street;
- Boundary Road.

However, following completion of this modelling work, the 2008 diffusion tube monitoring data have become available which show much lower concentrations in the City.

Grapes Hill

The Grapes Hill AQMA has been modelled and the modelling results suggests the following:

- The modelled nitrogen dioxide concentrations on the west facing side of Grapes Hill are below the objective of 40μg m^{-3} in 2007;
- The modelled and measured nitrogen dioxide concentrations on the east facing side of Grapes Hill are below or very close to the air quality objective in 2007;
- The measured nitrogen dioxide concentrations in Grapes Hill AQMA are below the objective with the maximum measured concentration of 37μg m^{-3} at Wellington Lane Lower.
- Monitored concentrations in 2008 are lower with a maximum measured annual average of 25 μg m^{-3}.

On the basis of the modelled and measured results in the Grapes Hill AQMA and that the nitrogen dioxide concentrations are predicted to fall in 2010 the Council could consider revoking Grape Hill AQMA. However, as pollution concentrations are variable due to meteorological conditions from year to year, we recommend that this AQMA is retained for the present.

King Street

King Street has been modelled at the location of the diffusion tube 256 King Street and the modelling results suggests the following:

- The modelled nitrogen dioxide concentrations are above the objective of 40μg m^{-3} in 2007 at King Street;
- The measured nitrogen dioxide concentration at 256 King Street was 45 μg m^{-3};
- The predicted concentration for 2010 at 256 King Street is 41 μg m^{-3}.
- The measured concentration was 38 μg m^{-3} in 2008.

On the basis of the modelled and measured results in King Street it is recommended that the Norwich City Council continue to monitor this site and review each year. Should the 2009 data exceed the objective we recommend that this area is declared an AQMA.

Riverside Road

Riverside Road has been modelled at the location of the diffusion tube 5/6 Riverside Road and the modelling results suggests the following:

- The measured nitrogen dioxide concentration in 5/6 Riverside Road was 49 μg m^{-3} in 2007;
- The predicted concentrations at Riverside Road are above the air quality limit at the facades of the buildings situated on the east facing side of the road;
- The forecast concentration for 2010 based on the diffusion tube at 5/6 Riverside Road is 44μg m^{-3}.
- The measured nitrogen dioxide concentration in 2008 was 42 μg m^{-3}.

It is suggested that the Council consider improved synchronised fixed time traffic signalising system to reduce queuing effect in Riverside Road. It is recommended that the Norwich City Council declare an AQMA in this area.

Magdalen Street

Magdalen Street has been modelled at the location of the diffusion tube 130 Magdalen Street and the modelling results suggests the following:

- The measured nitrogen dioxide concentration in Magdalen Street was 40μg m^{-3} in 2007;
- The predicted concentration at the location of the tube is 37μg m^{-3}.
- The measured nitrogen dioxide concentration in Magdalen Street was 33 μg m^{-3} in 2008.

Taking into account that the concentration measured at the location of the diffusion tube in Magdalen Street marginally exceeded the objective in 2007 and was under the objective in 2008 it is recommended that Norwich City Council continue to monitor the area. It is not recommended to declare this area as an AQMA.

Boundary Road
Boundary Road has been modelled at the A140/A1042 junction and the modelling results suggests the following:

- The predicted concentrations in Boundary Road are above the air quality limit at the facades of two buildings in 2007.
- A diffusion tube was located at this site and 2008 annual average data are now available which indicate that concentrations (23 $\mu g\ m^{-3}$) are below the objective.

On the basis of the 2008 monitoring results in Boundary Road it is recommended that the Council continue to monitor the area. An AQMA is not recommended for this location at present.

The 2007 monitoring data reviewed in this detailed assessment have identified further sites: Queens Road, St Stephens Street and Exchange Street, which are exceeding the air quality objective in 2007. Following a review of the 2008 data, the only one of these sites exceeding the objective is St Stephens Street. The diffusion tube at this site is not at the building façade, and further investigation by the City Council has confirmed that at present there is no relevant exposure and therefore no Detailed Assessment or AQMA is required at this site. However, the Council should review the personal exposure at this site on a regular basis.

It is recommended that when Norwich City Council moves to a Further Assessment for the Riverside location, a comprehensive assessment of the peak and off-peak queuing within Norwich should be carried out. It would also be advantageous to carry out a traffic survey to provide up to date annual average diurnal traffic flows for the Norwich area.

Table of contents

1 Introduction

This section outlines the purpose of this Detailed Assessment for Norwich City Council, and the scope of the assessment.

1.1 National Air Quality Strategy

The Government prepared the Air Quality Strategy for England, Scotland, Wales and Northern Ireland for consultation in August 1999. It was published in January 2000 (DETR, 2000). A revised version was published in July 2007 (DEFRA, 2007).

At the centre of the Air Quality Strategy is the use of national air quality standards to enable air quality to be measured and assessed. These also provide the means by which objectives and timescales for the achievement of objectives can be set. These standards and associated specific objectives to be achieved between 2003 and 2010 are shown in Table 1-1.

Local authorities are required to review and assess the air quality in their areas from time to time to determine whether the air quality objectives are likely to be met.

1.2 Purpose of the Detailed Assessment

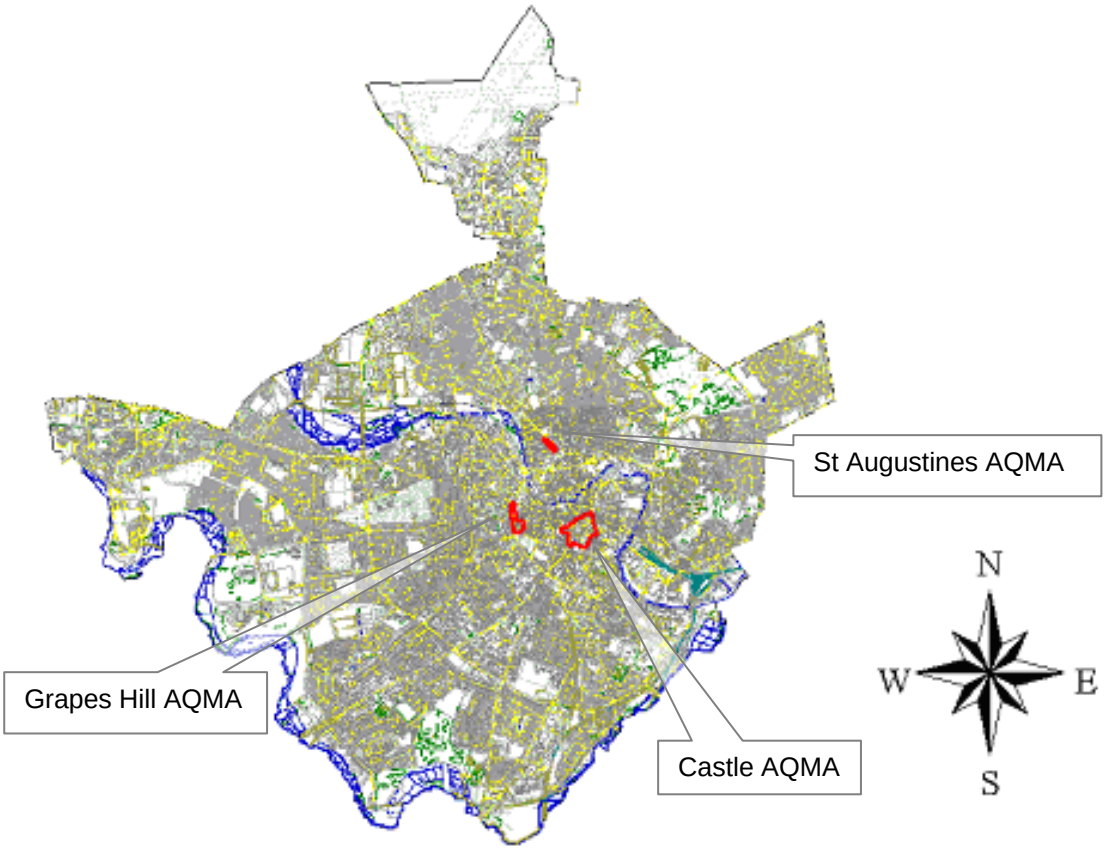
The **first round** of air quality review and assessments is now complete and all local authorities should have completed all necessary stages. Where the likelihood of exceedences of air quality objectives has been identified in areas of significant public exposure, an air quality management area (AQMA) should have been declared, followed by a further Stage 4 review and assessment, and the formulation of an action plan to eliminate exceedences. Norwich Council carried out the first round of the review and assessment in accordance with the Guidance, given at the time and in three stages. The last, Stage 3, was completed in 2001. Overall, the outcome of the three Stages of the Review and Assessment – Round 1, was that Norwich Council proposed three areas in the city – Grapes Hill, Castle and St Augustines as a potential Air Quality Management Areas for nitrogen dioxide (NO_2).

Norwich Council carried out an **Updating and Screening Assessment (USA)** in 2003. The conclusion of this report was to declare three areas as Air Quality Management Areas in Norwich City Council. This decision was made on the basis on traffic growth scenarios used in modelling, the location of relevant receptors and the conclusion of the 2002 USA report. These areas are shown in Figure 1-1: Grapes Hill, Castle and St Augustines.

Local authorities were required to proceed to the **second round** of review and assessment in which sources of emissions to air are reassessed to identify whether the situation has changed since the first round of review and assessment, and if so, what impact this may have on predicted exceedences of the air quality objectives. Such changes might include significant traffic growth on a major road, which had not been foreseen, construction of a new industrial plant with emissions to air, or significant changes in the emissions of an existing plant.

The second round of review and assessment is undertaken in two steps. The first step is an Updating and Screening Assessment, which updates the Stage 1 and 2 review and assessments previously undertaken for all pollutants identified in the Air Quality Regulations. Where a significant risk of exceedence is identified outside the AQMA for a pollutant it is necessary for the local authority to proceed to a Detailed Assessment, equivalent to the previous Stage 3 assessments. Where a local authority does not need to undertake a Detailed Assessment, a Progress Report is required instead.

Figure 1-1 Air Quality Management Areas in Norwich City Council



The 2004 **Updating and Screening Assessment** and the 2005 **Progress Report** concluded that there was no need to make any changes to the AQMAs already in place. No action was required for any of the other pollutants considered.

The **third round** of review and assessment is now in progress. Once again, the assessment is carried out in two steps. Norwich City Council carried out an Updating and Screening Assessment (USA) in 2006 and concluded that it was not required to carry out a Detailed Review and Assessment by Norwich City Council.

However, recently the Council have rationalized their diffusion tube monitors to include mainly building facades locations. Where monitoring show exceedences of the objective, the Council will confirm any personal exposure prior to undertaking any Detailed Assessment.

Diffusion tube monitoring in 2007 showed exceedences and therefore the Council have therefore undertaken this air quality detailed assessment, which indicates whether the UK air quality objectives are likely to be exceeded in this area as a result of the presence of traffic and, if so, to assess the distance from the road up to which the objectives are exceeded.

1.3 Overview of the approach taken

The general approach taken to this Detailed Assessment was to:

- Identify potential “hot spots” where there is expected to be the greatest potential for public exposure in the general area identified in the diffusion tube survey;
- Collect and interpret additional data to support the detailed assessment, including detailed traffic flow data around potential hotspots;
- Consider recent continuous monitoring and diffusion tube measurements;
- Use monitoring data from the diffusion tubes to assess the ambient concentrations produced by the road traffic and to calibrate the output of modelling studies;
- Model the concentrations of nitrogen dioxide around the potential hotspots, concentrating on the locations (receptors) where people might be exposed over the relevant averaging times of the air quality objectives;
- Present the concentrations as contour plots and assess the uncertainty in the predicted concentrations;
- Assess the contribution made from various sources to the pollutant concentrations;
- Consider whether the authority should declare an Air Quality Management Area and provide recommendations on the scope and extent of any proposed Air Quality Management Area;
- Consider whether the authority should revoke an Air Quality Management Area and provide recommendations.

1.4 Relevant DEFRA documentation used

This report takes into account the guidance in LAQM.TG(03), published January 2003 and updated guidance available as Frequently Asked Questions on the Review and Assessment website hosted by the University of the West of England (UWE).

1.5 Pollutants considered in this report

Table 1-1 lists the pollutants included in the Air Quality Regulations for the purposes of Review and Assessment. Nitrogen dioxide is considered in this report. However the Updating and Screening Assessment concluded that detailed assessment of other pollutants was not required, the new locations of the diffusion tubes identified new areas of exceedances and also that Grapes Hill AQMA could be revoked.

Table 1-1 Objectives included in the Air Quality Regulations 2000 and (Amendment) Regulations 2002 for the purpose of Local Air Quality Management

Pollutant	Air Quality Objective		Date to be achieved by
	Concentration	Measured as	
Benzene			
All authorities	16.25 μg m^{-3}	Running annual mean	31.12.2003
England and Wales only	5.00 μg m^{-3}	Annual mean	31.12.2010
Scotland and Northern Ireland	3.25 μg m^{-3}	Running annual mean	31.12.2010
1,3-Butadiene	2.25 μg m^{-3}	Running annual mean	31.12.2003
Carbon monoxide	10.0 mg m^{-3}	Maximum daily running 8-hour mean	31.12.2003
England, Wales & N. Ireland			
Scotland only	10.0 mg m^{-3}	Running 8-hour mean	31.12.2003
Lead	0.5 μg m^{-3}	Annual mean	31.12.2004
	0.25 μg m^{-3}	Annual mean	31.12.2008
Nitrogen dioxide	200 μg m^{-3} not to be exceeded more than 18 times a year	1-hour mean	31.12.2005
	40 μg m^{-3}	Annual mean	31.12.2005
Particles (PM_{10}) (gravimetric)	50 μg m^{-3}, not to be exceeded more than 35 times a year	24-hour mean	31.12.2004
All authorities	40 μg m^{-3}	Annual mean	31.12.2004
Scotland only	50 μg m^{-3}, not to be exceeded more than 7 times a year	24-hour mean	31.12.2010
	18 μg m^{-3}	Annual mean	31.12.2010
Particles ($PM_{2.5}$) (gravimetric) *	25 µg m^{-3} (target)	Annual mean	2020
All authorities	15% cut in urban background exposure	Annual mean	2010 - 2020
Scotland only	12 µg m^{-3} (limit)	Annual mean	2010
Sulphur dioxide	350 μg m^{-3}, not to be exceeded more than 24 times a year	1-hour mean	31.12.2004
	125 μg m^{-3}, not to be exceeded more than 3 times a year	24-hour mean	31.12.2004

	266 μg m^{-3}, not to be exceeded more than 35 times a year	15-minute mean	31.12.2005
PAH *	0.25 ng m^{-3}	Annual mean	31.12.2010
Ozone *	100 μg m^{-3} not to be exceeded more than 10 times a year	Daily maximum of running 8-hour mean	31.12.2005

** not included in regulations at present.*

1.6 Timescales to achieve the objectives for the pollutants in the Air Quality Strategy

In most local authorities in the UK, objectives will be met for most of the pollutants within the timescale of the objectives shown in Table 1-1. The Government has recognised the problems associated with achieving the standard for ozone and this will not therefore be a statutory requirement. Ozone is a secondary pollutant and transboundary in nature and it is recognised that local authorities themselves can exert little influence on concentrations when they are the result of regional primary emission patterns.

1.7 Air Quality Reviews – the approaches and expected outcomes

A Technical Guidance has been issued in 'Review and Assessment: Technical Guidance' LAQM.TG (03) to enable air quality to be monitored, modelled, reviewed and assessed in an appropriate and consistent fashion. This detailed assessment has considered the procedures set out in this technical guidance.

The primary objective of undertaking a review of air quality is to identify any areas that are unlikely to meet national air quality objectives and ensure that air quality is considered in local authority decision-making processes. The complexity and detail required in a review depends on the risk of failing to achieve air quality objectives and it has been proposed therefore that reviews should be carried out in two steps. Both steps of review and assessment may be necessary and every authority is expected to undertake at least the first of these in their authority area. The steps are briefly described in the following table, Table 1-3.

Table 1-2 Brief details of steps in the second Round of the Air Quality Review and Assessment process

Level of Assessment	Objective	Approach
Updating and Screening	To identify those matters that have changed since the last review and assessment, which might lead to a risk of an air quality objective being exceeded	Use a checklist to identify significant changes that require further consideration. Where such changes are identified, then apply simple screening tools to decide whether there is sufficient risk of an exceedence of an objective to justify a Detailed Assessment
Detailed Assessment	To provide an accurate assessment of the likelihood of an air quality objective being exceeded at locations with relevant exposure. This should be sufficiently detailed to allow the designation or amendment of any necessary AQMAs	Use quality-assured monitoring and validated modelling methods to determine current and future pollutant concentrations in areas where there is a significant risk of exceeding an air quality objective.
Annual Progress Reports	Local authorities should prepare annual air quality Progress Reports between subsequent rounds of reviews and assessments. The concept is that this will ensure continuity in the LAQM process.	The precise format for the Progress Report has not yet been determined, but will essentially follow the checklist approach that is set out in subsequent chapters of this document. Further details on the Progress Reports are provided via the Helpdesks. It is envisaged that these Progress Reports could be useful for the compilation of annual 'state of the environment' reports that many authorities already prepare.

1.8 Locations that the review and assessment must concentrate on

For the purpose of review and assessment, the authority should focus their work on locations where members of the public are likely to be exposed over the averaging period of the objective. Table 1-4 summarises the locations where the objectives should and should not apply.

Table 1-3 Typical locations where the objectives should and should not apply

Averaging Period	Pollutants	Objectives *should* apply at …	Objectives should *not* generally apply at …
Annual mean	1,3 Butadiene Benzene Lead Nitrogen dioxide Particulate Matter (PM_{10})	All background locations where members of the public might be regularly exposed.	Building facades of offices or other places of work where members of the public do not have regular access.
		Building facades of residential properties, schools, hospitals, libraries etc.	Gardens of residential properties.
			Kerbside sites (as opposed to locations at the building facade), or any other location where public exposure is expected to be short term
24 hour mean and 8-hour mean	Carbon monoxide Particulate Matter (PM_{10}) Sulphur dioxide	All locations where the annual mean objective would apply.	Kerbside sites (as opposed to locations at the building facade), or any other location where public exposure is expected to be short term.
		Gardens of residential properties.	
1 hour mean	Nitrogen dioxide Sulphur dioxide	All locations where the annual mean and 24 and 8-hour mean objectives apply.	Kerbside sites where the public would not be expected to have regular access.
		Kerbside sites (e.g. pavements of busy shopping streets).	
		Those parts of car parks and railway stations etc. which are not fully enclosed.	
		Any outdoor locations to which the public might reasonably be expected to have access.	
15 minute mean	Sulphur dioxide	All locations where members of the public might reasonably be exposed for a period of 15 minutes or longer.	

It is unnecessary to consider exceedences of the objectives at any location where public exposure over the relevant averaging period would be unrealistic. Locations should also represent non-occupational exposure.

2 Information used to support this assessment

This section lists the key information used in this review and assessment.

2.1 Review and Assessment reports

This report draws on information presented in previous Review and Assessment reports:

Norwich City Council has completed the following review and assessments of air quality to date:

- Stage 3 update (2002), and Stage 4 (2003)
- Updating and Screening Assessment (January 2004)
- Progress report in 2004
- Progress report in 2005
- Updating and Screening Assessment (2006)
- Progress report in 2007

The previous assessments of the air quality in Norwich concluded that there were likely exceedances of the annual mean objective for nitrogen dioxide as a result of both industrial and traffic sources. Three AQMAs were declared in the city - Grapes Hill, Castle and St Augustines – following the stage three assessment. The locations of the three AQMAs are illustrated in Figure 1-1. The 2004 Updating and Screening Assessment and the 2005 Progress Report concluded that there was no need to make any changes to the AQMAs already in place. Also the 2006 Updating and Screening Assessment concluded that Norwich City Council was not required to proceed to the detailed assessment. However the rationalization of the locations of the diffusion tubes identified new areas of exceedances and also that Grapes Hill AQMA may be revoked.

2.2 Maps and distances of receptors from roads

Norwich City Council provided electronic OS LandLine™ data, which were used in the Geographical Information System (GIS), used in this assessment. The maps were used to provide details of the location of road centrelines and road widths. Individual buildings or groups of buildings (receptors) were also identified. The distances of these receptors from the road were accurately determined from the maps.

2.3 Road traffic data

Traffic data were taken from:

- 2006 NAEI roads database;
- 2007 modelled traffic data provided by the Norwich City Council.

The base year for the traffic flows was 2007. In the case when the provided data was for a different year, traffic flows were estimated using traffic growth factors derived from TEMPRO v 5. In addition, TEMPRO v 5 was used to project traffic flows for future years using scaling factors for the appropriate year.

Table 2-1 Tempro Factors

Year		Norwich City Council
From	To	
2007	2007	1
2007	2010	1.0305

2.4 Ambient Monitoring

The assessment has considered continuous automatic monitoring data for 2007 from three continuous monitoring stations in Norwich City Council. Pollutant concentrations have been monitored at Norwich Centre, which was urban centre site located within the south western corner of a central Norwich public garden (OS 623078, 308910). The pollutants measured include oxides of nitrogen, nitrogen dioxide, ozone, carbon monoxide, sulphur dioxide, particulate matter, PM_{10}. Oxides of nitrogen and nitrogen dioxide concentrations have been monitored at the Norwich Forum Roadside, which was a roadside site (OS 622800, 308400). Norwich Centre and Norwich Forum Roadside were a part of Defra's Automatic Urban and Rural Network (AURN), the sites were closed in May 2008 and September 2007, respectively.
Oxides of nitrogen, nitrogen dioxide and nitric oxides have been monitored at Norwich Castle Meadow site, which is a roadside urban monitoring site (OS 623213, 308628). Norwich Castle Meadow continuous monitoring station is part of the Calibration Club managed by AEA. Data from the Norwich Castle Meadow site is quality assured to the high AURN standards as part of the Calibration Club.

Nitrogen dioxide concentrations are measured by ozone chemiluminescence. Ozone chemiluminescence is the reference method specified by the EU NO_2 Directives. Routine calibration of the NOx analyser was undertaken by AEA, using on-site certified calibration gas cylinders provided by Messer UK and traceable to National Calibration Standards. In addition a QA/QC audit which includes calibration of the analyser using zero and span gas standards, and other tests, including for linearity and NOx converter efficiency was undertaken by AEA. Data were fully ratified by AEA staff using procedures as applied to data from the other AURN UK national monitoring network sites.

In addition to the continuous monitoring undertaken in Norwich City Council, this report also took into account the automatic monitoring site located on the boarder between Norwich City Council and Broadland District Council. The monitoring at the A140/A1042 junction lasted for less than a year in 2007 therefore the annual mean NO_2 concentration at the site was to be estimated using monitoring data at the junction and at nearby long-term sites following the guidance given in LAQM TG(03). The estimated annual mean at the junction was 38.2 $\mu g/m^3$ in 2007 using the automatic monitoring data at two sites which are less than 50 miles away.

The locations of the automatic continuous monitoring stations are included in Table 2-2 and also shown on a map in Figure 2-1

Table 2-2 Continuous monitoring data

Site	X Grid reference	Y Grid Reference	Type
Norwich Centre	623078	308910	Urban centre
Norwich Forum Roadside	622800	308400	Roadside
Norwich Castle Meadow	623213	308628	Roadside

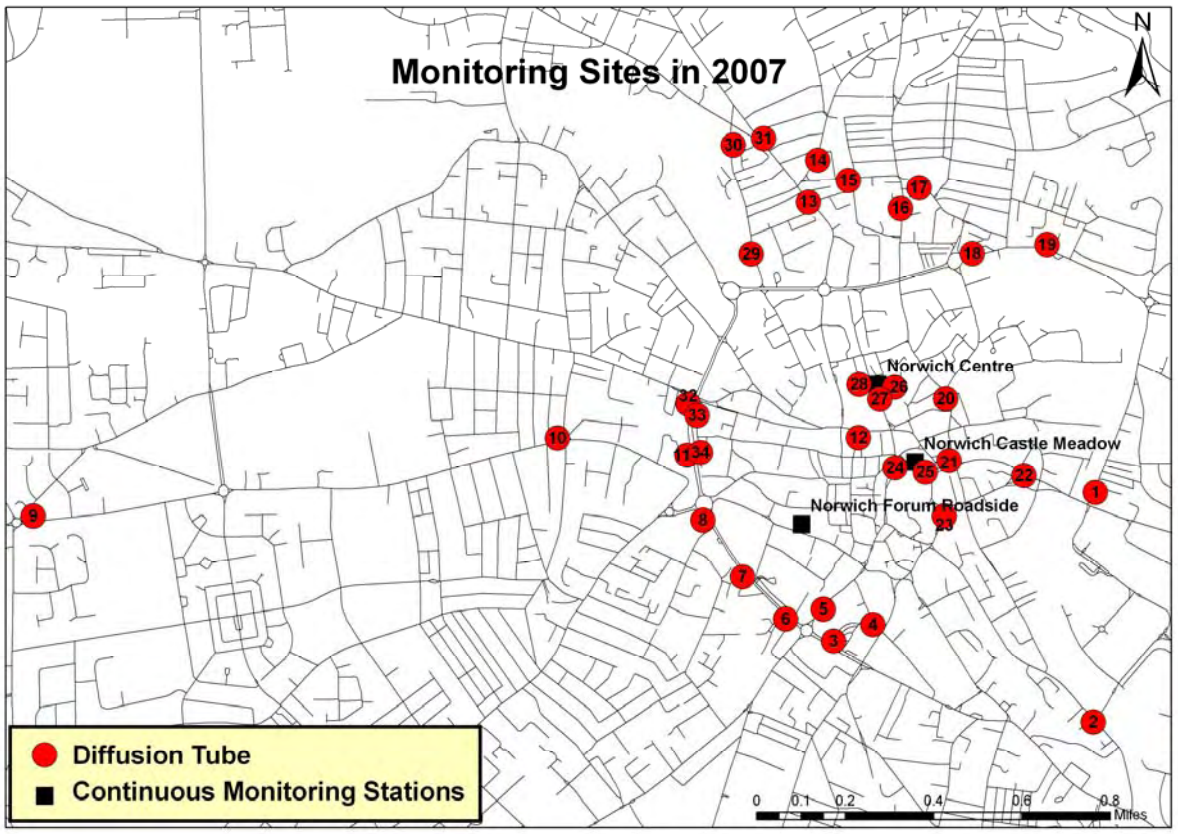
Norwich City Council operates a network of 34 nitrogen dioxide diffusion tubes across the Council. The diffusion tubes were analysed by Gradko Services by using 50% triethylamine in acetone. Ten of the diffusion tubes are located within or in a close proximity to the existing AQMAs.

The locations of the diffusion tubes are listed in Table 2-3. In addition, diffusion tubes were collocated with the Norwich Centre monitoring site in 2007.

Table 2-3 Diffusion tubes' locations

No	Location	Easting	Northing
1	5/6 Riverside Rd	623870.26	308515.77
2	256 King St	623863.04	307678.60
3	Queens Rd - Travelodge	622917.08	307974.49
4	25-27 Surrey St	623060.33	308034.28
5	St Stephens St (mid)	622879.16	308089.96
6	Chapelfield/Wessex St	622741.68	308054.79
7	Chapelfield/Crescent	622584.86	308207.64
8	8 B26 Johnson Place	622440.96	308415.09
9	(8A) 557 Earlham Rd-Linden House	620000.91	308430.20
10	63 Earlham Rd	621910.97	308715.67
11	Grapes Hill – Upper	622383.05	308653.15
12	Exchange St	623007.27	308716.34
13	St Augustines	622825.70	309572.99
14	158 Waterloo Rd	622859.37	309725.91
15	62 Magpie Rd	622970.72	309652.02
16	130 Magdalen Street	623160.89	309550.43
17	26 Bull Close Rd	623228.63	309625.14
18	24-28 Bargate Court	623422.42	309388.23
19	124 Barrack St	623694.61	309420.59
20	Tombland	623325.49	308857.07
21	Upper King St	623337.40	308632.52
22	73 Prince Of Wales Road	623610.05	308577.12
23	27 Cattlemarket St	623320.58	308430.88
24	Castlemeadow (Mid)	623141.06	308606.69
25	Castlemeadow Shire Hall	623250.50	308590.12
26	St Georges 1	623079.80	308905.00
27	St Georges 2	623079.80	308905.00
28	St Georges 3	623079.80	308905.00
29	32 Key & Castle Yard	622616.95	309385.95
30	29 St Martins Rd	622551.54	309780.86
31	13 Aylsham Rd	622661.32	309805.12
32	Grapes Hill – Lower	622386.31	308838.52
33	Wellington Lane Lower	622419.52	308797.22
34	Wellington Lane - 71 Dukes Court	622431.35	308663.05

Figure 2-1 Monitoring sites' locations in 2007



2.5 Emission factors

The vehicle emission factors used for national mapping have recently been revised by DEFRA and the devolved administrations. The most recent emission factors have been used in this detailed assessment.

Emissions from stationary traffic in queues were estimated using the emission factor for vehicles moving at 5 km h^{-1} and taking account of the proportion of time stationary vehicles are present and the length of road over which emissions take place. The average length of a vehicle queue was based on satellite photographs of the area from Google Earth (2008) along with the assumption that a car length is about 5 metres. These data were verified with local knowledge and site visits.

3 Detailed Assessment for Nitrogen Dioxide

3.1 The national perspective

The principal source of oxides of nitrogen emissions is road transport, which accounted for about 46% of total UK emissions in 2001. Major roads carrying large volumes of high-speed traffic (such as motorways and other primary routes) are a predominant source, as are conurbations and city centres with congested traffic. Within most urban areas, the contribution of road transport to local emissions will be much greater than for the national picture.

Meeting the annual mean objective of 2005 is expected to be considerably more demanding than achieving the 1-hour objective. National studies have indicated that the annual mean objective was likely to be achieved at all urban background locations outside of London by 2005, but that the objective may be exceeded more widely at roadside sites throughout the UK in close proximity to busy road links. Projections for 2010 indicate that the EU limit value may still be exceeded at urban background sites in London, and at roadside locations in other cities.

3.2 Standards and objectives for nitrogen dioxide

The Government and the Devolved Administrations have adopted two Air Quality Objectives for nitrogen dioxide, as an annual mean concentration of 40 μg m^{-3}, and a 1-hour mean concentration of 200 μg m^{-3} not to be exceeded more than 18 times per year. The objectives were to be achieved by the end of 2005.

3.3 Background concentrations for nitrogen dioxide

The estimated annual average background nitrogen dioxide concentration provided by the UK background maps for 2007 was 18.2 μg m^{-3} averaged across Norwich City Council with a maximum concentration of 23.2 μg m^{-3}.

The estimated annual average background oxides of nitrogen concentration provided by the UK background maps for 2007 was 26.6 μgm^{-3} averaged across Norwich City Council with a maximum concentration of 35.0μgm^{-3}.

3.4 Assessment of monitoring data

3.4.1 Continuous monitoring data

Table 3 -1 summarises the measurements of nitrogen dioxide concentrations at continuous monitoring stations in Norwich City Council and a monitor located in neighbouring Broadland District Council at the A140/A1042 junction in 2007.

Table 3-1 Continuous monitoring data

Site	Period	NO_2 Concentration, $\mu g\ m^{-3}$	Data capture %
		Average	
Norwich Centre	2007	22	99
Norwich Forum Roadside	Jan 2007 – Sep 2007	33	71
Norwich Castle Meadow	2007	46	93
A140/A1042 junction (Broadland)	2007	38.2	-

The 2007 annual mean nitrogen dioxide concentration measured at Norwich Centre and Norwich Forum Roadside were markedly less than the air quality objective of 40 $\mu g\ m^{-3}$. The Norwich Forum Roadside monitoring station was operating for nine months in 2007. Norwich Castle Meadow site measured nitrogen dioxide concentration above the air quality objective. The automatic monitor at the A140/A1042 junction measured nitrogen dioxide concentration below the objective of 40$\mu g\ m^{-3}$.

3.4.2 Diffusion Tube Results

Diffusion tube measurements for nitrogen dioxide were taken at 34 locations over the period of January 2007 – December 2007 and at an additional site in 2008.

The laboratory bias correction factor was calculated using the “diffusion tube” spreadsheet tool and co-location study at Norwich Centre site. This “diffusion tube” spreadsheet tool is published by Air Quality Consultants Ltd on behalf of Defra, the Welsh Assembly Government, the Scottish Executive and the Department of the Environment Northern Ireland and it is available on the UWE website (2008). For 2007 data, a bias adjustment factor of 0.93 was calculated from this - “diffusion tube” - spreadsheet tool, which used 6 studies of Gradko Services for 2007 (Appendix 4, Table A4-1). A bias adjustment factor of 1.051 was calculated from the diffusion tubes co-located with the Norwich Centre site. This was done by using the AEA Energy and Environments “Spreadsheet for calculating Precision, Accuracy and Bias Adjustment factors of Diffusion Tubes’’. The local bias adjustment factor will be used for this report and subsequent references to diffusion tube measurements assume that the measurements have been adjusted using that factor (Appendix 4, Table A4-2).

However, for 2008 data a local factor was not calculated because there was low data capture (5 months). The 2008 data have therefore been adjusted with the national factor of 0.85 obtained from the UWE bias adjustment spreadsheet (Gradko laboratory, 2008, 50% acetone tube preparation method).

In order to predict 2010 concentrations, “Year Adjustment Calculator (v2.2a)” was used from the UK National Air Quality Information Archive website (2008). The factor of 0.90 was applied to estimate annual average concentrations in 2010 from 2007 data.

Table 3-2 shows the nitrogen dioxide concentration measured by diffusion tubes located within or in the close proximity to AQMAs.

Table 3-2 Annual Mean Nitrogen Dioxide Concentrations at sites within the AQMAs, µg m^{-3}

Site Name	AQMA	2007 Annual Mean	2007 Corrected with local bias adjustment factor	2007 data scaled to 2010	2008 Annual Mean	2008 Corrected with National bias adjustment factor
Upper King St	Castle	36.0	37.8	34.3	34.8	29.6
27 Cattlemarket St	Castle	**50.3**	**52.8**	**47.9**	**46.3**	39.4
Castlemeadow (Mid)	Castle	**50.4**	**52.9**	**48.1**	**52.4**	**44.6**
Castlemeadow Shire Hall	Castle	**44.4**	**46.6**	**42.3**	**48.7**	**41.4**
St Augustines	St Augustines	**49.6**	**52.1**	**47.3**	**54.7**	**46.5**
Grapes Hill - Lower	Grapes Hill	29.2	30.7	27.9	30.1	25.6
Grapes Hill - Upper	Grapes Hill	27.0	28.4	25.7	25.0	21.2
Wellington Lane Lower	Grapes Hill	34.9	36.7	33.3	34.5	29.4
Wellington Lane - 71 Dukes Court	Grapes Hill	29.6	31.1	28.2	29.7	25.3
B26 Johnson Place	Grapes Hill	32.1	33.7	30.8	26.1	22.2

There are 10 diffusion tubes located within designated AQMAs, four of the diffusion tubes measured the concentrations greater than the objective of 40 µg m^{-3} in 2007, three sites measured greater than the objective in 2008.

Table 3-3 shows the nitrogen dioxide concentrations measured outside the existing AQMAs.

Table 3-3 Annual Average Nitrogen concentrations at the diffusion tubes sites outside the AQMAs, µg m^{-3}

Site name	2007 Annual Mean	2007 corrected with local bias adjustment factor	2007 data scaled to 2010	2008 Annual Mean	2008 corrected with national bias adjustment
5/6 Riverside Rd	**46.2**	**48.6**	**44.0**	**49.9**	**42.4**
256 King St	**43.0**	**45.2**	**40.9**	**44.3**	37.6
Queens Rd - Travelodge	**39.8**	**41.9**	37.9	35.3	30.0
25-27 Surrey St	31.8	33.5	30.3	29.3	24.9
St Stephens St (mid)	**44.2**	**46.4**	**42.1**	**52.0**	**44.2**
Chapelfield/Wessex St	33.9	35.6	32.3	32.8	27.8
Chapelfield/Crescent	26.0	27.3	24.8	23.1	19.6
557 Earlham Rd-Linden House	25.0	26.3	23.9	27.9	23.7
63 Earlham Rd	26.1	27.5	24.9	25.2	21.4
Exchange St	**40.2**	**42.3**	**38.3**	**44.1**	37.5
158 Waterloo Rd	39.1	**41.1**	37.2	25.8	21.9
62 Magpie Rd	33.2	34.9	31.7	35.1	29.8
130 Magdalen Street	38.1	40.1	36.3	39.5	33.5
26 Bull Close Rd	38.0	39.9	36.2	38.2	32.5
24-28 Bargate Court	36.5	38.4	34.8	35.2	30.0
124 Barrack St	30.6	32.1	29.2	26.8	22.8
Tombland	**45.4**	**47.7**	**43.3**	29.9	25.4
73 Prince Of Wales Road	37.2	**39.1**	35.4	34.2	29.1
St Georges 1	20.2	21.3	19.3	22.4*	19.1**
St Georges 2	21.1	22.2	20.1		
St Georges 3	22.4	23.6	21.4		
32 Key & Castle Yard	33.9	35.6	32.3	34.3	29.2
29 St Martins Rd	24.1	25.3	22.9	24.4	20.8
13 Aylsham Rd	31.1	32.7	29.6	28.8	24.5
Boundary/414 Aylsham Rd	na	na	na	26.8	22.8

*averaged for the three triplicate sites, data are for 5 months only.
**an estimated bias correction (individual triplicate data will be reported in the Updating and Screening assessment)

In 2007 there were 24 diffusion tubes located outside the existing AQMAs. In 2007 Norwich City Council rationalized the locations of the diffusion tubes to include mainly building façades locations. This action resulted in the identification of the locations outside the existing AQMAs where the objective of 40 µg m^{-3} was not met. Also it identified that nitrogen dioxide concentrations measured in Grapes Hill AQMA at the building façades are below the objective ranging from 31.1 µg m^{-3} to 36.7 µg m^{-3}.
In 2008 the Tombland, diffusion tube location was changed to the building façades and the measured concentration was below the objective.

The locations of particular concern as exceeding the air quality objective, which are outside the existing AQMAs, are:

- Riverside Road
- St Stephen St.

3.5 Overview of the air quality modelling

3.5.1 Summary of the models used

The air quality impact from roads has been assessed using our proprietary urban model (LADS Urban). There are two parts to this model:

- The *Local Area Dispersion System (LADS) model*. This model calculates background concentrations of oxides of nitrogen on a 1 km x 1 km grid. The estimates of emissions of oxides of nitrogen for each 1 km x 1 km area grid square were obtained from the 2006 National Atmospheric Emissions Inventory.
- The *DISP model*. This model is a tool for calculating atmospheric dispersion using a 10 m x 10 m x 3 m volume-source kernel derived from ADMS4 to represent elements of the road. The volume source depth takes account of the initial mixing caused by the turbulence induced by the vehicles. Estimates of emissions from vehicles have been calculated using the latest vehicle emission factors.

Particular attention was paid to the avoidance of "double counting" of the contribution from major roads in the modelled areas. Thus the emissions from sections of roads modelled using DISP were removed from the LADS inventory.

Hourly sequential meteorological data for the nearest suitable meteorological station with adequate data capture was obtained at Marham near King's Lynn for 2006 and was used for this assessment. The meteorological data provided information on wind speed and direction and the extent of cloud cover for each hour of the year.

A surface roughness of 1 m was used in the modelling to represent the urban conditions corresponding to the most exposed sites. A limit for the Monin-Obukhov length of 30 m was applied. An intelligent gridding system was used with receptors at 10 m intervals on a rectangular grid within 150 m of the modelled roads and more widely spaced receptors elsewhere.

The netcen primary oxides of nitrogen model (AQEG 2007) was used to calculate nitrogen dioxide concentrations from the oxides of nitrogen concentrations predicted by LADS Urban. The model takes into account the background ozone, nitrogen dioxide and nitric oxide concentrations, the proportion of the oxides of nitrogen released from vehicles as nitrogen dioxide and the exposure of the site to sunlight. The model was used first to analyse the diffusion tubes monitoring data to estimate the proportion of oxides of nitrogen released as nitrogen dioxide. The analysis took account of background measurements of ozone, oxides of nitrogen and nitrogen dioxide concentrations at the diffusion tubes locations in the area of interest.

A rural background oxides of nitrogen concentration of 15.6 $\mu g\ m^{-3}$ was estimated for 2007 from the UK background maps for the area of Norwich City Council.

3.5.2 Validation and verification of the model

In simple terms, model validation is where the model is tested at a range of locations and is judged suitable to use for a given application. The modelling approach used in this assessment has been validated, and used in numerous **AEA** air quality review and assessments.

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations. Table 3-4 compares modelled predictions using LADS Urban of oxides of nitrogen and nitrogen dioxide concentrations with measured values at the diffusion tubes locations in the study area.

The model gave a good agreement between the modelled and the measured oxides of nitrogen concentrations for most of the diffusion tubes locations. Modelled nitrogen dioxide concentrations were compared with measured nitrogen dioxide concentrations. Table 3-4 shows the comparison between

the modelled nitrogen dioxide with measured nitrogen dioxide. As can be seen from the table 3-4, all modelled nitrogen dioxide results have a very good agreement with the nitrogen dioxide measured concentrations.

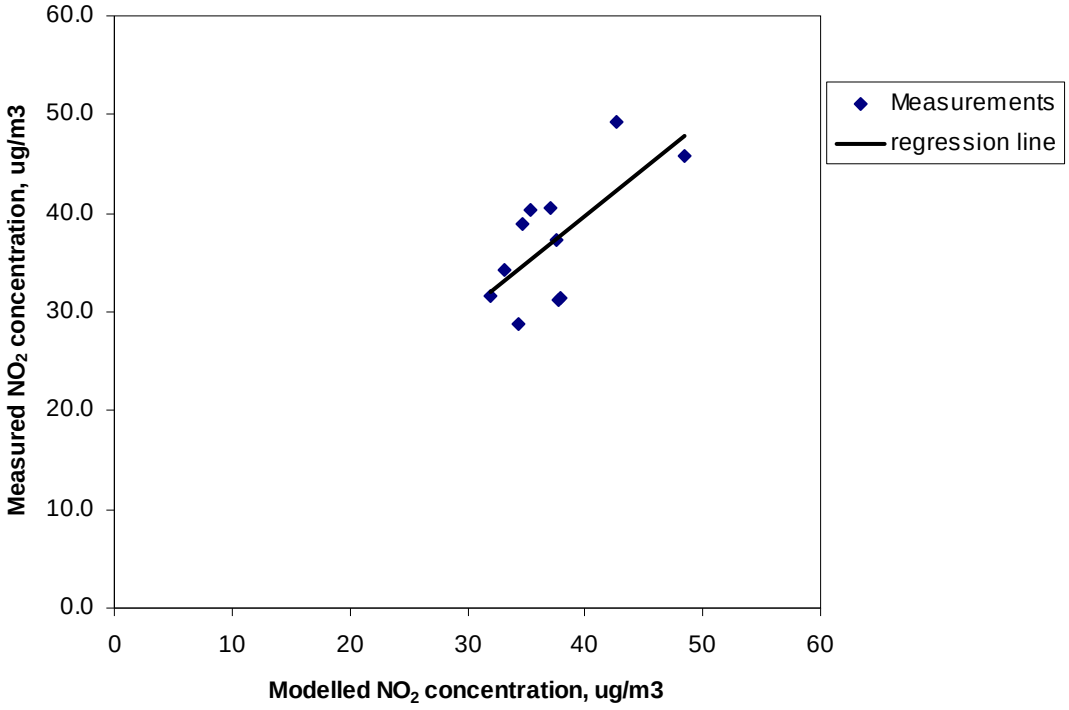
Table 3-4 Comparison of modelled and measured nitrogen dioxide concentrations, 2007

Site	Nitrogen dioxide concentration, μg m^{-3}		Difference %
	Modelled	Measured	
5/6 Riverside Road	42.5	48.6	-13
256 King Street	45.6	45.2	1
B26 Johnson Place	33.2	33.7	-1
Grapes Hill-Upper	34.4	28.4	21
Magdalen Street	37.0	40.1	-8
26 Bull Close Road	41.5	39.9	4
124 Barrack Street	34.5	32.1	7
Grapes Hill – Lower	37.8	30.7	23
Wellington Lane-Lower	37.6	36.7	2
Wellington Lane – 71 Duke Court	37.9	31.1	22

The model predicts well the adjusted diffusion tube data in Norwich in 2007. In the modelled area the model predicts within 25% of the diffusion tube value at all of the sites and within 10% at six of the ten sites.

The agreement between modelled nitrogen dioxide and measured nitrogen dioxide are shown in Table 3-4 and Figure 3-1.

Figure 3-1 The agreement between modelled and measured NO_2 concentrations



There are a number of possible explanations accounting for the discrepancies between measured and modelled concentrations. Uncertainty regarding traffic speeds, queuing and congestion are likely to

have led to some errors in the calculation of emissions; local street canyons should have also contributed to the differences.

3.5.3 Model uncertainty

The results of dispersion modelling of pollutant concentrations are necessarily uncertain because of the uncertainties in the estimation of rates of emission, meteorological data and dispersion conditions. Table 3-5 shows confidence levels for modelled nitrogen dioxide concentrations based on a statistical analysis of a comparison of modelled and measured concentrations in London. In this report, we present predicted concentrations as isopleths (lines of constant concentration) superimposed on a map of the local area. The concentration values selected reflect the uncertainty bands shown in Table 3-5. Predicted concentrations in excess of 40 $\mu g\ m^{-3}$ indicate that there is more than 50 % chance of exceeding the annual average objective for nitrogen dioxide. Public exposure in these areas should be considered in order to assess whether it will be necessary to declare an Air Quality Management Area for nitrogen dioxide.

Table 3-5 Confidence levels for modelled concentrations for future years based on symmetrical concentration intervals and concentration intervals derived purely from the statistics

Description	Chance of exceeding objective	Likelihood of exceeding annual average objective	Likelihood of exceeding hourly average objective
Very unlikely	Less than 5%	< 28	<32
Unlikely	5 to 20%	28 to 34	38-52
Possible	20 to 50%	34 to 40	52-67
Probable	50 to 80%	40 to 46	67-82
Likely	80 to 95%	46 to 52	82-95
Very likely	More than 95%	> 52	>95

3.6 Detailed modelling results

In this section, nitrogen dioxide concentrations modelled for 2007, and predicted for 2010 are presented as a series of contour plots. The plots show the areas around the potential hotspots identified by the diffusion tube survey in 2007. The residential buildings are illustrated in green colour. These are:

- Grapes Hill
- King Street
- Magdalen Street
- Riverside
- Boundary Road

3.6.1 Grapes Hill scenarios for 2007 and 2010

Figures 3-2 and 3-3 shows the modelled nitrogen dioxide concentrations for 2007 and 2010 respectively in Norwich City Council along Grapes Hill.

The plot shows that both modelled and measured concentrations on the west facing side of Grapes Hill road are below the air quality objective in 2007 and 2010. Measured and modelled concentrations on the east facing side of Grapes Hill at the housing properties are very close to the air quality objective of 40 $\mu g\ m^{-3}$ in 2007 with only three housing properties in an area where the modelled concentration is above the objective.

The model predicts that it is ***probable*** that the nitrogen dioxide annual mean has been exceeded in 2007. We recommend that this AQMA is retained for the present.

3.6.2 King Street/Magdalen Street/Riverside Road for 2007 and 2010

Figures 3 - 4 and 3 - 5 show an area modelled in Norwich City Council. The modelled area includes King Street, Magdalen Street and Riverside Road in 2007 and 2010 respectively.

King Street

Figure 3-6 shows the modelled nitrogen dioxide concentrations for 2007 in King Street. The modelling has taken into account the queuing traffic. The predicted concentrations exceeded the objective of 40 $\mu g\ m^{-3}$. However, an exceedence at a residential building façade is only likely to occur at the site of the 256 King Street diffusion tube. At this site the model predicts a concentration of 45.6 $\mu g\ m^{-3}$ while the diffusion tube measurement was 45.2 $\mu g\ m^{-3}$.

The model predicts that it is ***likely*** that the nitrogen dioxide annual mean has been exceeded in this area in 2007.

Figure 3-7 shows the predicted concentrations for 2010. The plot shows that nitrogen dioxide concentrations are expected to decrease, however the concentrations at residential properties in the area will not meet the objective of 40 $\mu g\ m^{-3}$.

The model predicts that it is ***probable*** that the nitrogen dioxide annual mean will be exceeded in this area in 2010.

Taking into consideration that the model predicts exceedances at the facade of the building in 2007 and 2010 it is recommended that Norwich City Council declare this area an as AQMA.

Riverside Road

Figure 3-8 shows the modelled nitrogen dioxide concentrations for 2007 in Riverside Road. The modelling has taken into account queuing traffic at traffic lights at the junction of Riverside Road and Thorpe Road. There is a diffusion tube located at 5/6 Riverside Road. The model predicts a concentration of 42.5$\mu g\ m^{-3}$, a 24% under-prediction of the diffusion tube measurement of 48.6$\mu g\ m^{-3}$. One of the reasons for this discrepancy could be that the assumed queuing conditions for the peak hours of the day were under-representative.

The model predicts that it is ***probable*** that the annual mean objective has been exceeded in 2007.

Figure 3-9 shows the modelled nitrogen dioxide concentrations for 2010 in Riverside Road. The plot shows that nitrogen dioxide concentrations are expected to decrease so that the concentrations at residential properties in the area will not exceed the objective of 40$\mu g\ m^{-3}$.

The model predicts that it is ***possible*** that the annual mean objective will be exceeded in 2010.

Taking into consideration that the model predicts that it is possible that the annual mean will be exceeded in 2010 it is recommended that Norwich Council declare this area as an AQMA.

Magdalen Street

Figure 3-10 shows the modelled nitrogen dioxide concentrations for 2007 along Magdalen Street. The modelling has taken into account queuing traffic and bus stops. It has been assumed that during rush hours the length of Magdalen Street from St Crispins Road to Magpie Road is congested with slow moving traffic. The predicted nitrogen dioxide concentrations exceeded the objective of 40 $\mu g\ m^{-3}$ are found along of this road.

The model predicts that it is ***probable*** that the nitrogen dioxide annual mean has been exceeded in 2007 along Magdalen Street.

There is a diffusion tube located at 130 Magdalen Street. The model predicts a concentration of 37.3 $\mu g\ m^{-3}$, an 8% under-prediction of the diffusion tube measurement of 40.1 $\mu g\ m^{-3}$. There could be a

number of reasons for this discrepancy one of which might be that the assumed queuing conditions for the peak hours of the day were under-representative. Also the length of Magdalen Street from Edward Street to Magpie Road is an example of a canyon street. Many models cannot accurately predict concentrations within street canyons due to the complex nature of the dispersion in these environments. Many physical parameters affect the pattern of dispersion within a street canyon such that very complicated wind flows and vortices may form under certain conditions making it very difficult to fully understand and predict accurately the concentrations at specific locations.

Figure 3-11 shows the predicted concentrations for 2010 in Magdalen Street. The plot shows that nitrogen dioxide concentrations are expected to decrease so that the concentrations at residential properties in the area will not exceed the objective of 40μg m^{-3}.

Taking into consideration that the model predicts the concentration below the objective at the location of the diffusion tube and that the measurements marginally exceeded the objective it is recommended that Norwich City Council continue to monitor the area. It is not recommended to declare an AQMA for Magdalen Street.

3.6.3 Boundary Road scenarios for 2007 and 2010

Figure 3-12 and 3-13 shows the modelled annual mean nitrogen dioxide concentrations at the A140/A1042 junction in 2007 and 2010 respectively.

The model has predicted that the annual mean objective of 40μg m^{-3} for nitrogen dioxide has been exceeded at the junction A140/a1042 in 2007. The highest predicted nitrogen dioxide concentration is 52 μg m^{-3}. However predicted exceedances are in the area where there is no public exposure over the relevant averaging period of time. The model predicts that the nitrogen dioxide exceedances were found on two housing properties in Boundary Road in 2007.

Within this area, the model predicts that it is ***probable*** that the annual mean objective has been exceeded in 2007.

Figure 3-13 shows the modelled annual mean nitrogen dioxide concentrations at the junction in 2010. The predicted fall of background nitrogen dioxide concentration due to national measures in 2010, the model predicts that the annual mean objective of 40μg m^{-3} for nitrogen dioxide will be exceeded at the junction in 2010. The highest predicted annual mean nitrogen dioxide concentration in this area is 46 μg m^{-3}, however the model predicts no exceedances of nitrogen dioxide concentration at the facades of the housing properties in 2010.

Within this area, the model predicts that it is ***possible*** that the annual mean objective for nitrogen dioxide will be exceeded in 2010.

Taking into consideration that the background nitrogen dioxide concentration is predicted to fall in 2010 and that the annual mean nitrogen dioxide concentration at building facades in this area is predicted to be a maximum of 40 μg m^{-3} in 2010 it is recommended that Norwich City Council start to monitor this area. It is not recommended to declare this area as an AQMA.

3.7 Source apportionment

3.7.1 Source apportionment of 'base case' predictions

Source apportionment is the process whereby the contributions from the sources of a pollutant are determined. In local air quality, the relevant sources could include: traffic; local background; industrial and domestic. Contributions from the different types of vehicles (for example, cars, lorries and buses) can also be considered to highlight which class of vehicle is contributing most to the emissions from

traffic. Source apportionment allows the most important source or sources to be identified and options to reduce ambient concentrations of pollutants can then be considered and assessed.

The source apportionment should:

- Confirm that exceedences of nitrogen dioxide are due to road traffic;
- Determine the extent to which different vehicle types are responsible for the emission contributions to nitrogen dioxide: this will allow traffic management scenarios to be modelled/tested to reduce the exceedences;
- Quantify what proportion of the exceedences of nitrogen dioxide is due to background emissions, or local emissions from busy roads in the local area. This will help determine whether local traffic management measures could have a significant impact on reducing emissions in the area of exceedence, or, whether national measures would be a suitable approach to achieving the air quality objectives.

3.7.2 What is the 'base case'?

The base case in this assessment is defined as the annual mean concentrations of nitrogen dioxide that are predicted in 2007 in the absence of any measures to improve air quality in Norwich. These are the concentrations that should be relevant to defining the extent of Air Quality Management Areas.

3.7.3 Receptors considered

The most affected receptors where there is potential relevant public exposure outside have been considered: these are shown in Table 3-5.

Table 3-6 Most affected receptors exceeding annual average objective

General Area	Description	OS Grid reference of receptor
Grapes Hill	Facades of the building	622387; 308845
Grapes Hill	Facades of the building	622401; 308597
Grapes Hill	Facades of the building	622431; 308672
Grapes Hill	Facades of the building	622441; 308567
Boundary Road	Facades of the building	621662; 311517
Boundary Road	Facades of the building	621774; 311568
Boundary Road	Facades of the building	621803; 311593
Boundary Road	Facades of the building	621854; 311619
Magdalen Street	Facades of the building	623161; 309610
Magdalen Street	Facades of the building	623171; 309562
Riverside Road	Facades of the building	623859; 308488
King Street	Facades of the building	623867; 307673
King Street	Facades of the building	623880; 307657
Riverside Road	Facades of the building	623889; 308558

3.7.4 Sources of pollution considered

We have considered the effect of the following sources in this detailed assessment at the receptors considered:

- Background from sources outside the local area;
- Traffic;
- Heavy duty vehicles (buses, coaches and heavy goods);
- Stationary vehicles in queue.

The concentrations of oxides of nitrogen concentrations apportioned to each source category and the fractions of the total concentrations are shown in Table 3-6. Table 3-6 shows the contributions from

the rural background, modelled background contribution from Norwich and surrounding district sources and the modelled local roads contribution. It then shows the breakdown of the local road contribution between heavy and light duty vehicles and between moving and stationary vehicles (in queues).

Table 3-7 Apportionment of oxides of nitrogen concentrations at most affected receptors

Area	Contribution to oxides of nitrogen concentration, μg m^{-3}							
	Total	Rural background	Modelled background	Local roads	Local HDV	Local LDV	Moving vehicles	Stationary vehicles
Grapes Hill	59.1	15.6	17.9	25.6	28.9	32.9	32.9	28.5
Grapes Hill	62.9	15.6	17.8	29.5	31.6	33.9	31.5	33.6
Grapes Hill	67.2	15.6	18.0	33.6	35.2	34.9	26.7	42.9
Grapes Hill	75.0	15.6	17.9	41.5	38.5	39.6	31.8	45.7
Boundary Road	78.5	15.6	5.8	57.1	49.0	19.6	21.5	47.2
Boundary Road	61.8	15.6	6.7	39.5	34.9	17.9	22.9	30.0
Boundary Road	67.0	15.6	6.9	44.5	39.7	18.6	21.6	36.7
Boundary Road	62.1	15.6	7.3	39.2	36.2	17.7	20.9	32.9
Magdalen Street	77.2	15.6	19.4	42.2	56.3	24.7	42.2	38.8
Magdalen Street	71.6	15.6	19.7	36.3	51.8	24.0	39.4	36.4
Riverside Road	71.7	15.6	14.8	41.3	40.2	30.8	35.3	35.7
King Street	74.8	15.6	13.4	45.8	38.9	33.8	32.9	39.8
King Street	66.1	15.6	13.3	37.2	33.8	29.9	30.2	33.7
Riverside Road	59.9	15.6	14.9	29.4	33.0	26.1	35.8	23.8

It can be seen from the table that although the HDVs are only a small percentage of AADT, they still make a large contribution to the local roads oxides of nitrogen concentrations.

Figure 3-2 Modelled NO_2 concentrations in Grapes Hill, Norwich Council for 2007

Figure 3-3 Modelled NO_2 concentrations in Grape Hill, Norwich Council for 2010

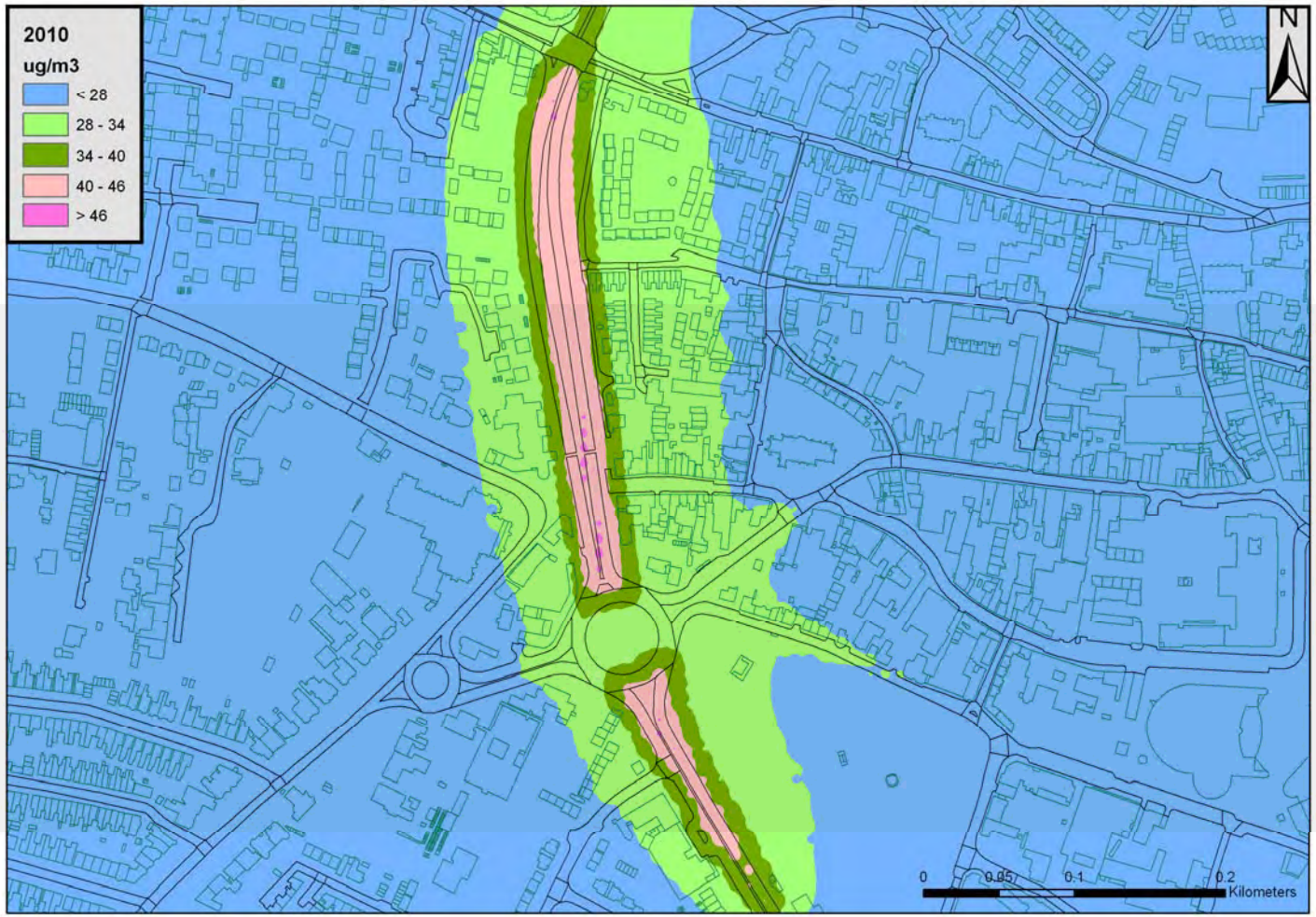


Figure 3-4 Modelled NO_2 concentrations in Norwich City Council for 2007

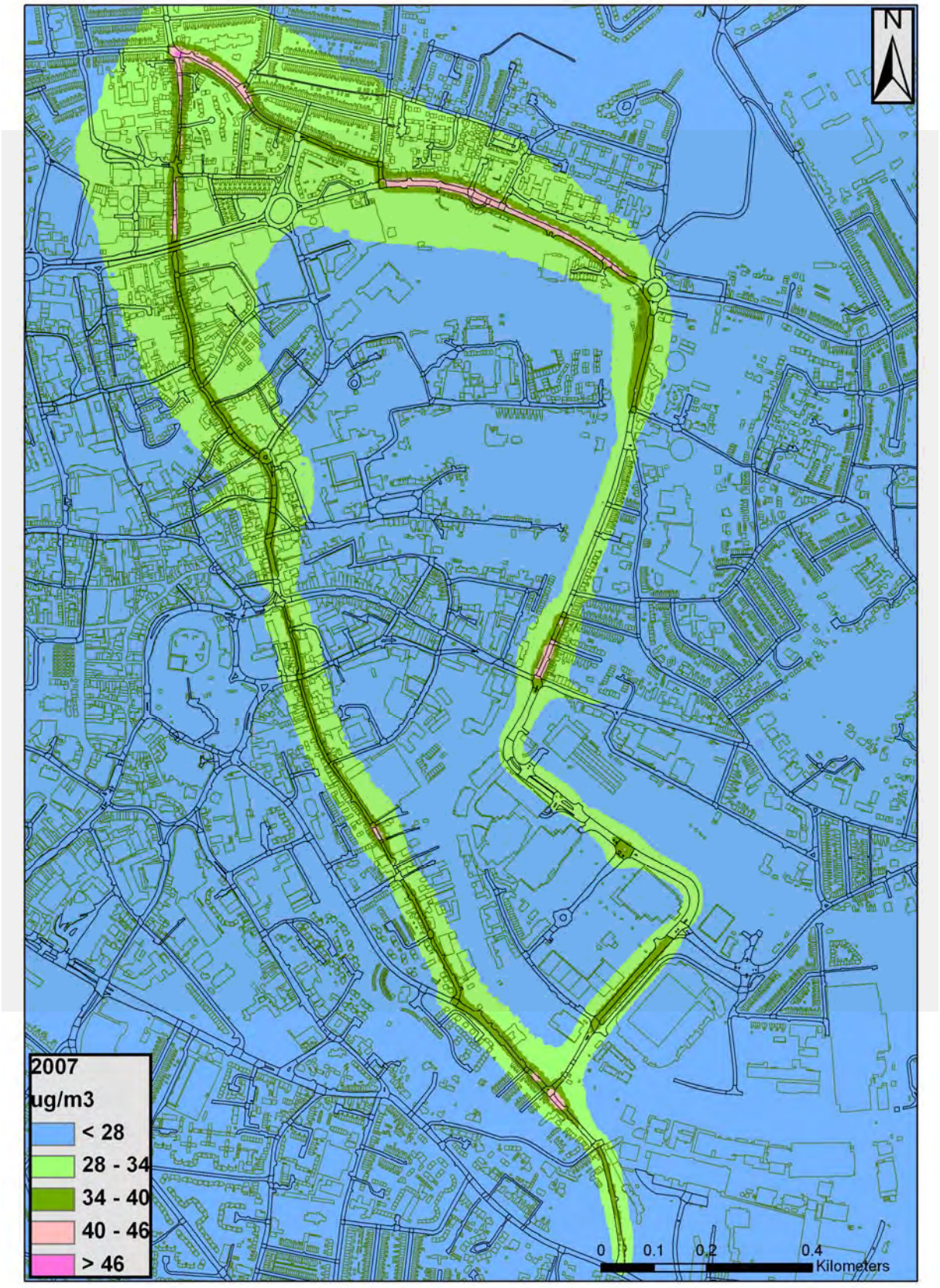


Figure 3-5 Modelled NO_2 concentrations in Norwich City Council for 2010

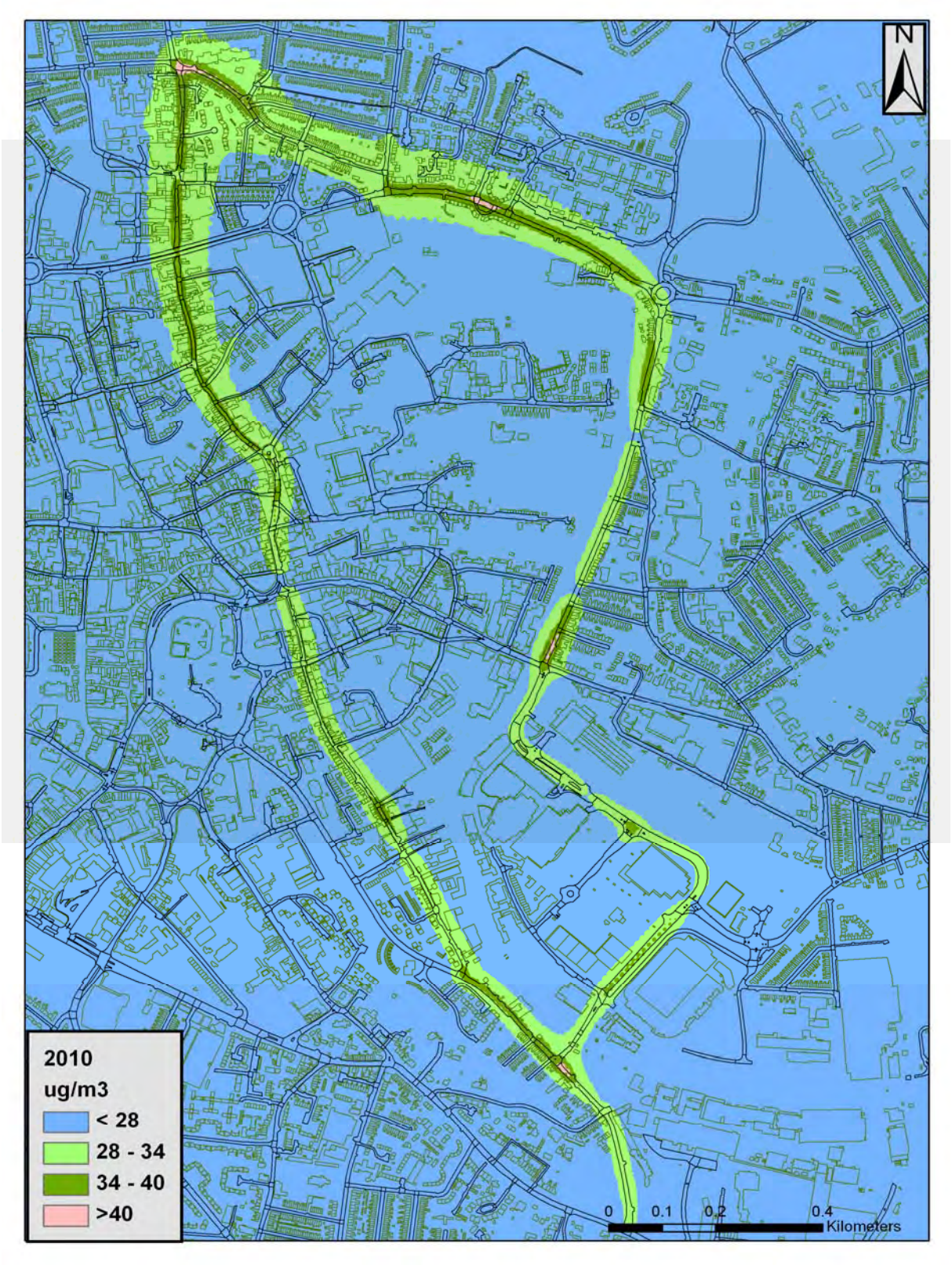


Figure 3-6 Modelled NO_2 concentrations in King Street, Norwich City Council for 2007

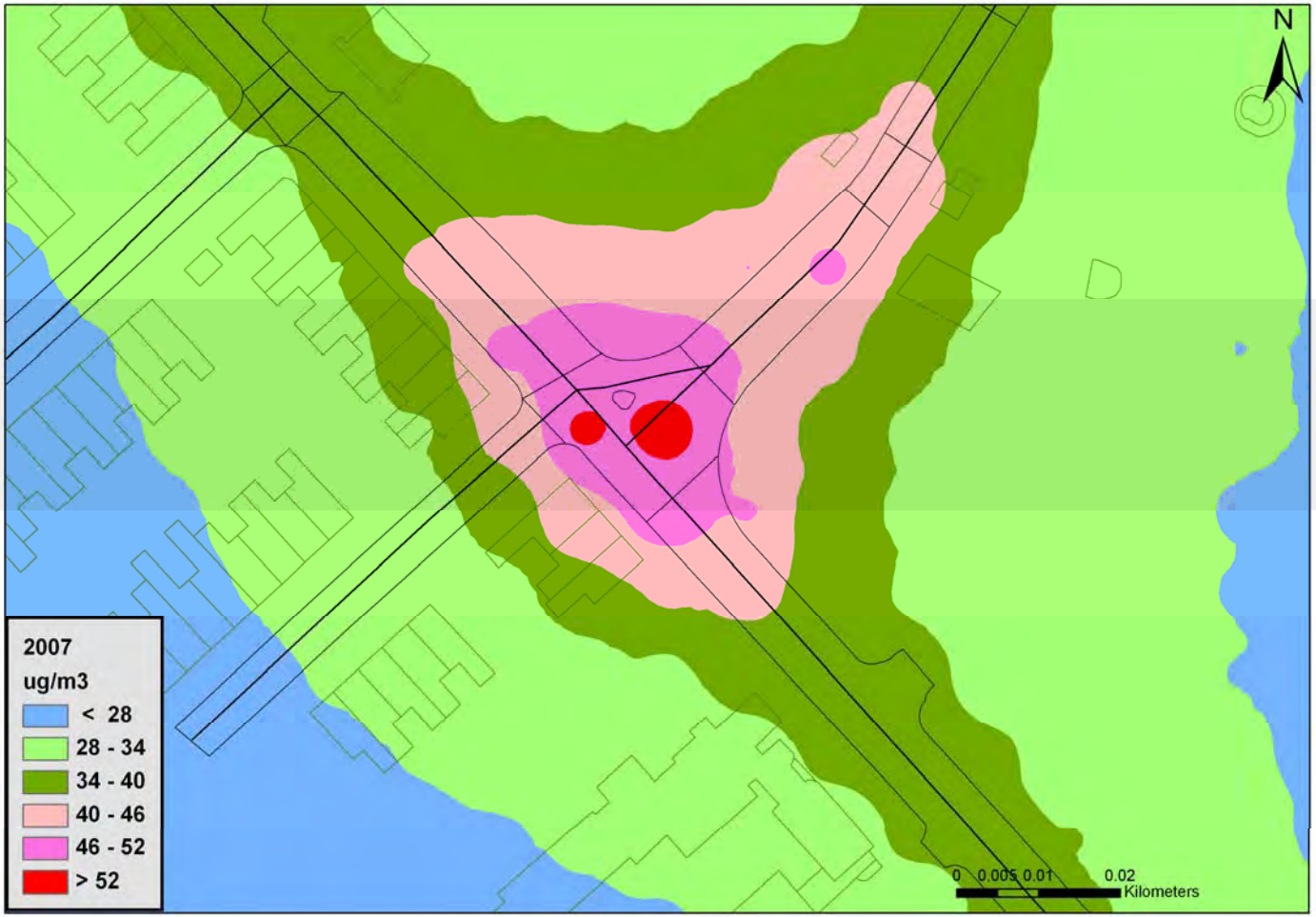


Figure 3-7 Modelled NO_2 concentrations in King Street, Norwich City Council for 2010

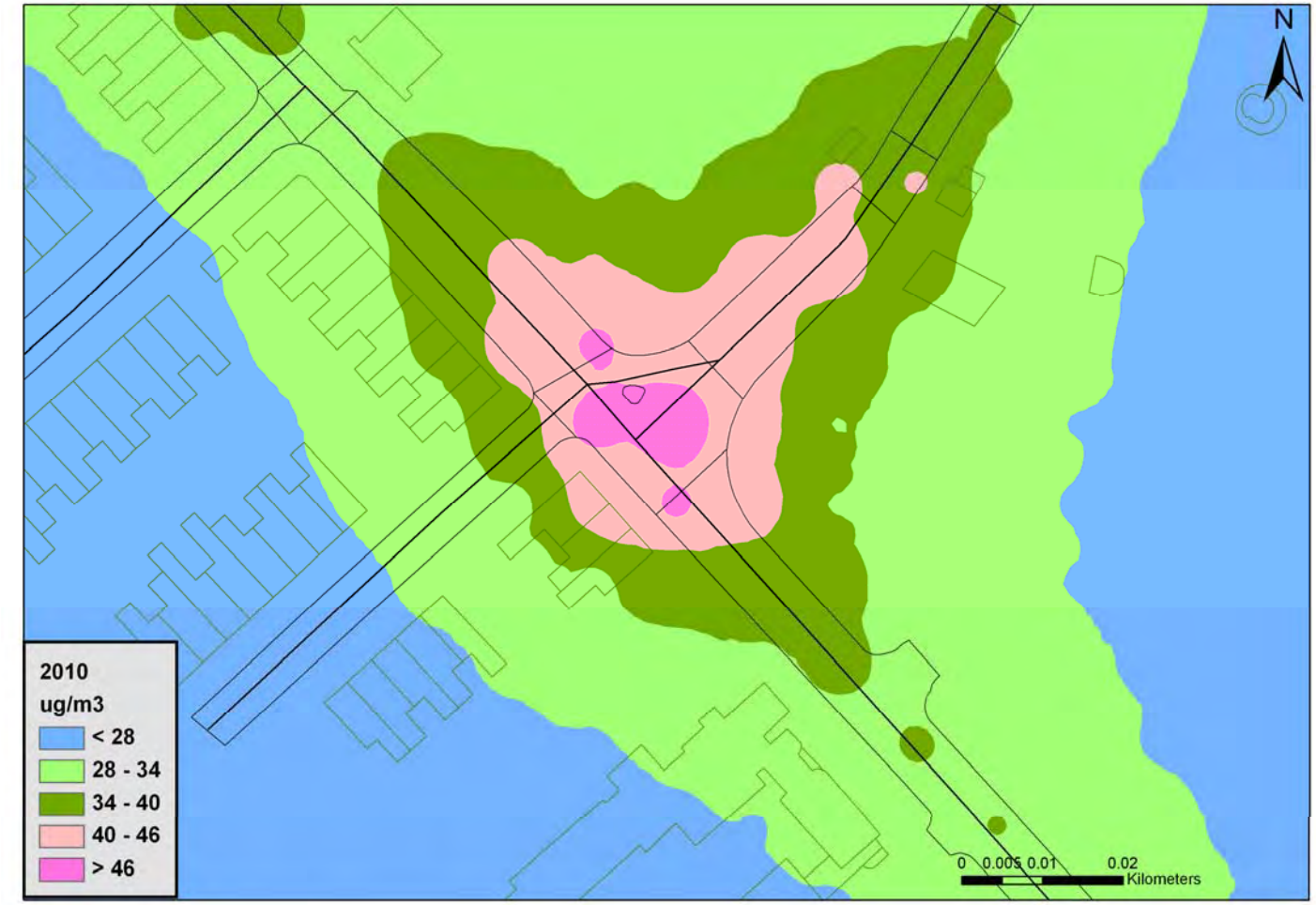


Figure 3-8 Modelled NO_2 concentrations in Riverside Street, Norwich City Council for 2007

Figure 3-9 Modelled NO_2 concentrations in Riverside Street, Norwich City Council for 2010

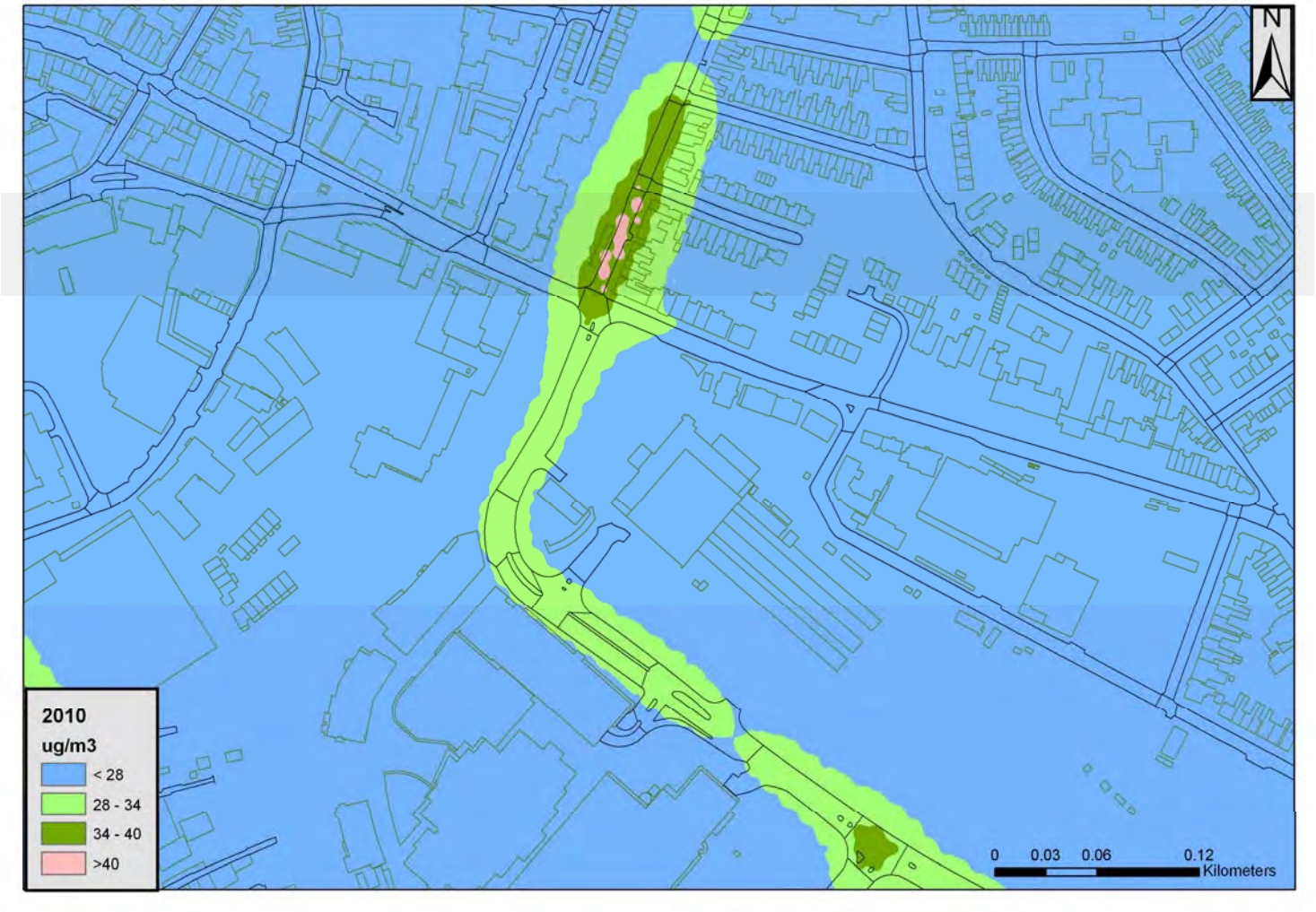


Figure 3-10 Modelled NO_2 concentrations in Magdalen Street, Norwich City Council for 2007

Figure 3-11 Modelled NO_2 concentrations in Magdalen Street, Norwich City Council for 2010

Figure 3-12 Modelled NO_2 concentrations in Norwich Council, Boundary Road, junction A140/A1042 for 2007

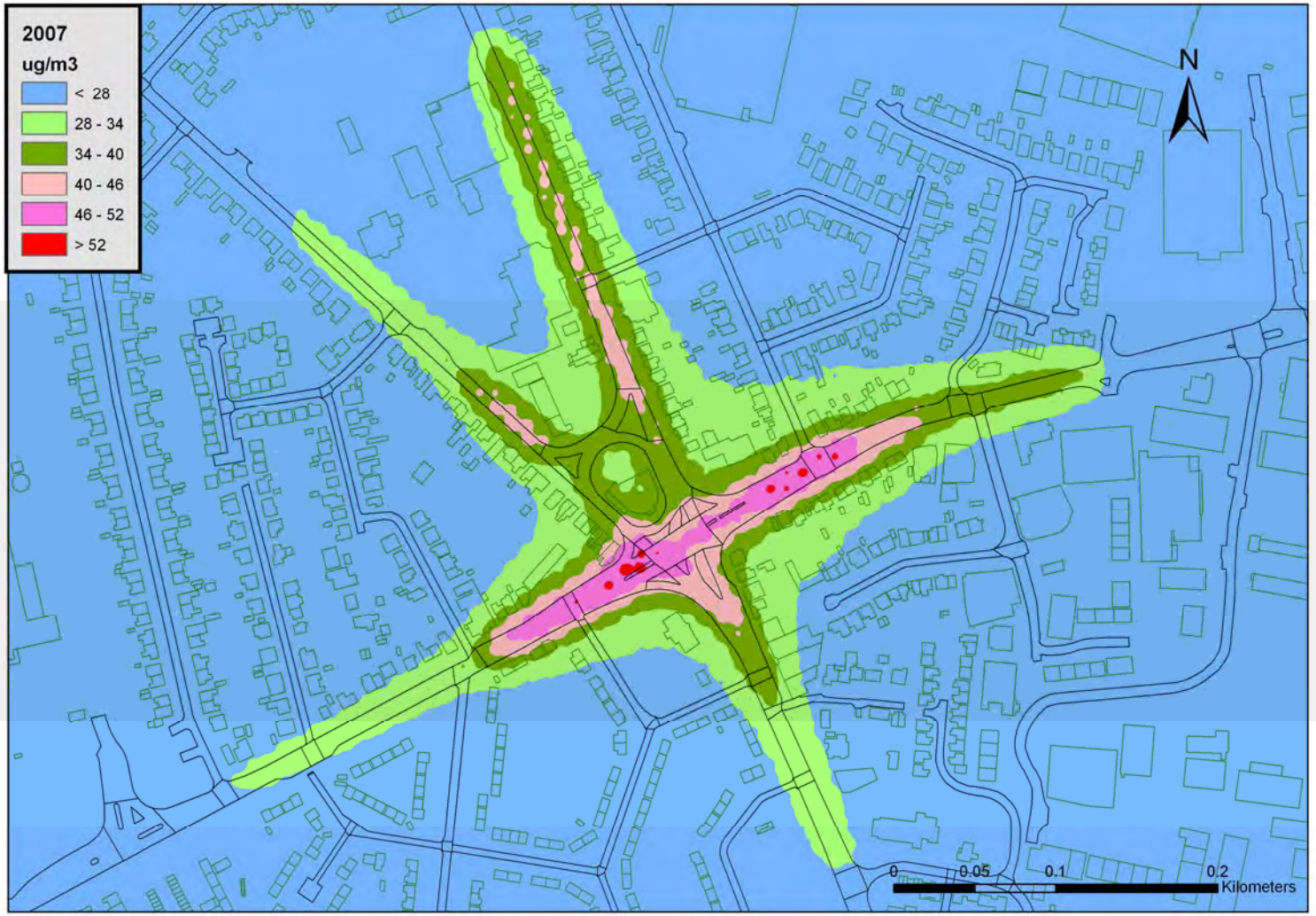
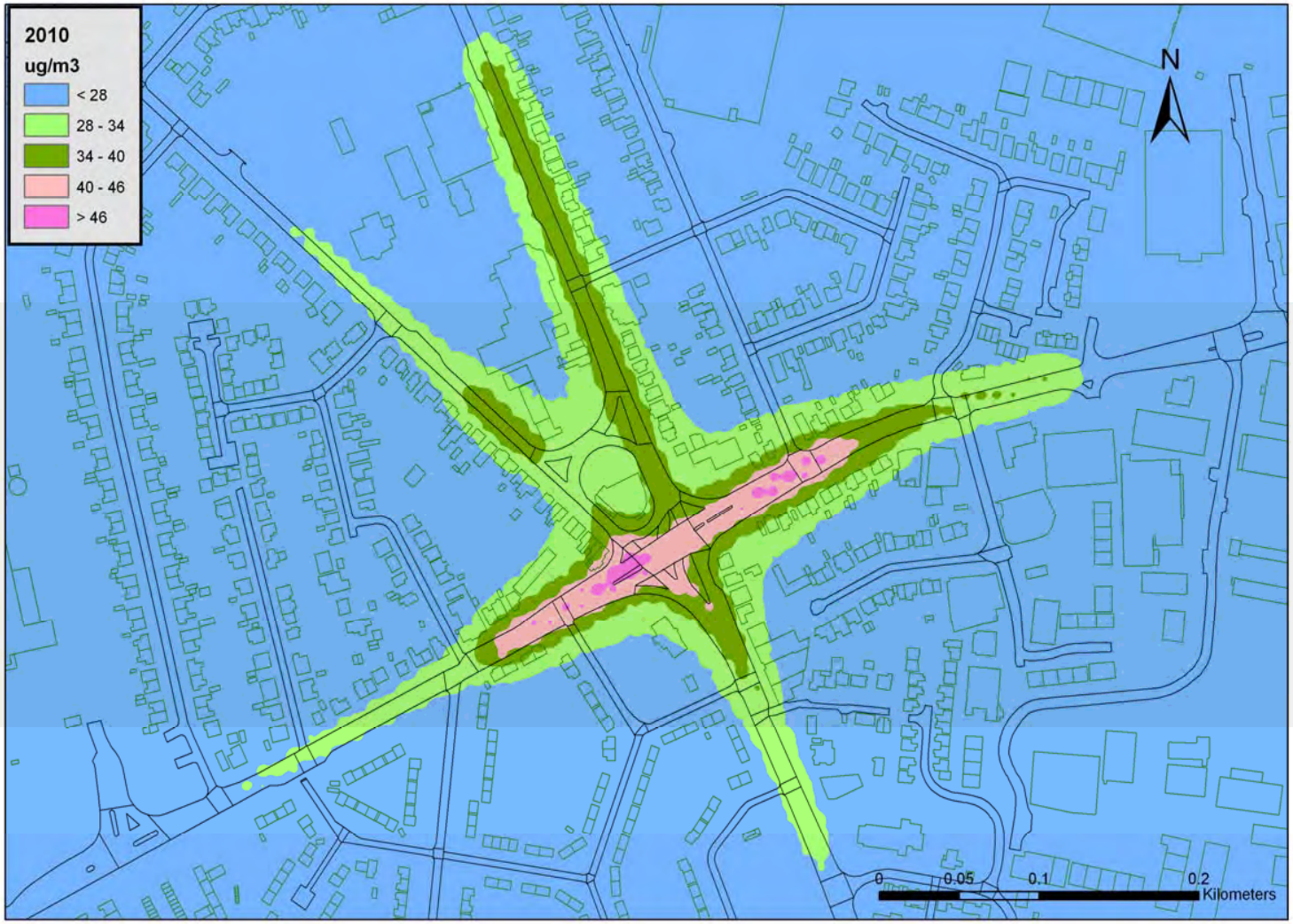


Figure 3-13 Modelled NO_2 concentrations in Norwich Council, Boundary Road, A140/A1042 junction for 2010



4 Conclusions

The results from the diffusion tube survey and automatic continuous monitoring of nitrogen dioxide in 2007 has confirmed that the annual mean objective of 40μg m^{-3} has been not met in 2007 at many locations in Norwich.

Air dispersion modelling was carried out for Norwich City Council covering the following locations:

- Grapes Hill;
- King Street;
- Riverside Road;
- Magdalen Street;
- Boundary Road.

However, following the modelling work, the 2008 diffusion tube monitoring data have become available which show much lower concentrations in the City.

Grapes Hill

The Grapes Hill AQMA has been modelled and the modelling results suggests the following:

- The modelled nitrogen dioxide concentrations on the west facing side of Grapes Hill are below the objective of 40μg m^{-3} in 2007;
- The modelled and measured nitrogen dioxide concentrations on the east facing side of Grapes Hill are below or very close to the air quality objective in 2007;
- The measured nitrogen dioxide concentrations in Grapes Hill AQMA are below the objective with the maximum measured concentration of 37μg m^{-3} at Wellington Lane Lower.
- Monitored concentrations in 2008 are lower with a maximum measured annual average of 25 μg m^{-3}.

On the basis of the modelled and measured results in the Grapes Hill AQMA and that the nitrogen dioxide concentrations are predicted to fall in 2010 the Council could consider revoking Grapes Hill AQMA. However, as pollution concentrations are variable due to meteorological conditions from year to year, we recommend that this AQMA is retained for the present.

King Street

King Street has been modelled at the location of the diffusion tube 256 King Street and the modelling results suggests the following:

- The modelled nitrogen dioxide concentrations are above the objective of 40μg m^{-3} in 2007 at King Street;
- The measured nitrogen dioxide concentration at 256 King Street was 45 μg m^{-3} in 2007;
- The predicted concentration for 2010 (based on 2007 data) at 256 King Street is 41 μg m^{-3}.
- The measured concentration was 38 μg m^{-3} in 2008.

On the basis of the modelled and measured results in King Street it is recommended that the Norwich City Council should continue to monitor this site and review each year. Should the 2009 data exceed the objective we recommend that this area is declared an AQMA.

Riverside Road

Riverside Road has been modelled at the location of the diffusion tube 5/6 Riverside Road and the modelling results suggests the following:

- The measured nitrogen dioxide concentration in 5/6 Riverside Road was 49 μg m^{-3} in 2007;
- The predicted concentrations at Riverside Road are above the air quality limit at the facades of the buildings situated on the east facing side of the road;

- The forecast concentration for 2010 based on the diffusion tube at 5/6 Riverside Road is 44μg m^{-3}.
- The measured nitrogen dioxide concentration in 2008 was 42 μg m^{-3}.

It is suggested that the Council consider improved synchronised fixed time traffic signalising system to reduce queuing effect in Riverside Road. It is recommended that the Norwich City Council declare an AQMA in this area.

Magdalen Street

Magdalen Street has been modelled at the location of the diffusion tube 130 Magdalen Street and the modelling results suggests the following:

- The measured nitrogen dioxide concentration in Magdalen Street was 40 μg m^{-3} in 2007;
- The predicted concentration at the location of the tube is 37μg m^{-3} in 2007.
- The measured nitrogen dioxide concentration in Magdalen Street was 33 μg m^{-3} in 2008.

Taking into account that the concentration measured at the location of the diffusion tube in Magdalen Street marginally exceeded the objective in 2007 and was under the objective in 2008 it is recommended that Norwich City Council continue to monitor the area. It is not recommended to declare this area as an AQMA.

Boundary Road

Boundary Road has been modelled at the A140/A1042 junction and the modelling results suggests the following:

- The predicted concentrations in Boundary Road are above the air quality limit at the facades of two buildings in 2007.
- A diffusion tube was located at this site and 2008 annual average data are now available which indicate that concentrations (23 μg m^{-3}) are below the objective.

On the basis of the 2008 monitoring results in Boundary Road it is recommended that the Council continue to monitor the area. An AQMA is not recommended for this location at present.

The 2007 monitoring data reviewed in this detailed assessment have identified further sites: Queens Road, St Stephens Street and Exchange Street, which are exceeding the air quality objective in 2007. Following a review of the 2008 data, the only one of these sites exceeding the nitrogen dioxide objective is St Stephens Street. The diffusion tube at this site is not at the building façade, and further investigation by the City Council has confirmed that at present there is no relevant exposure and therefore no Detailed Assessment or AQMA is required at this site. However, the Council should review the personal exposure at this site on a regular basis.

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Acknowledgments

We are grateful for the help of Mark Leach from Norwich City Council

Appendices

Appendix 1: Monitoring Sites details

Appendix 2: Monitoring data for Broadland District Council

Appendix 3: Traffic data

Appendix 1

Monitoring sites details

Norwich Centre: The monitoring station is within a self-contained, air-conditioned housing located within the south south/western corner of a central Norwich public garden. The nearest road is located approximately 12 metres away at St George's Street although traffic flow is free flowing and very light (1 or 2 vehicles per minute observed off peak). The manifold inlet is approximately 3 metres high. The surrounding area is generally open and comprises of residential and light industrial premises. **Monitoring has been suspended pending relocation. July 2008**

Norwich Forum Roadside: Height above sea level 25m Description The monitoring station is within the City Hall, approximately 5 metres from a 2-lane urban
street. Traffic flow is moderate and is subject to occasional queuing. The manifold inlet is approximately 4 metres high and is mounted close to the building facade. The surrounding area comprises retail outlet and business premises. **Site re-opened as Norwich Forum Roadside April 2005 - previously Norwich Roadside. Monitoring has been suspended.**

Appendix 2

Monitoring data for Broadland District Council

Table A2-1 Estimating annual mean NO_2 concentration at the junction based on monitoring data at nearby long-tern sites

	Annual mean NO_2 concentration in 2006 (Am)	Period mean between 09/01/06-19/09/06 (Pm)	Ratio (Am/Pm)
Norwich Centre	21.4	19.5	1.097
Norwich Forum Roadside	35.1	32.4	1.083
Area average (Am/Pm)			1.09
A140/A1042 junction	**38.2**	35	1.09

Figure A2-1 Air pollution report for the automatic monitoring at the A140/A1042 junction in Upper Hellesdon

Air Pollution Report

Produced by AEA Energy & Environment on behalf of Broadland DC

BROADLAND
10 January to 19 September 2007

These data have been fully ratified by AEA Energy & Environment

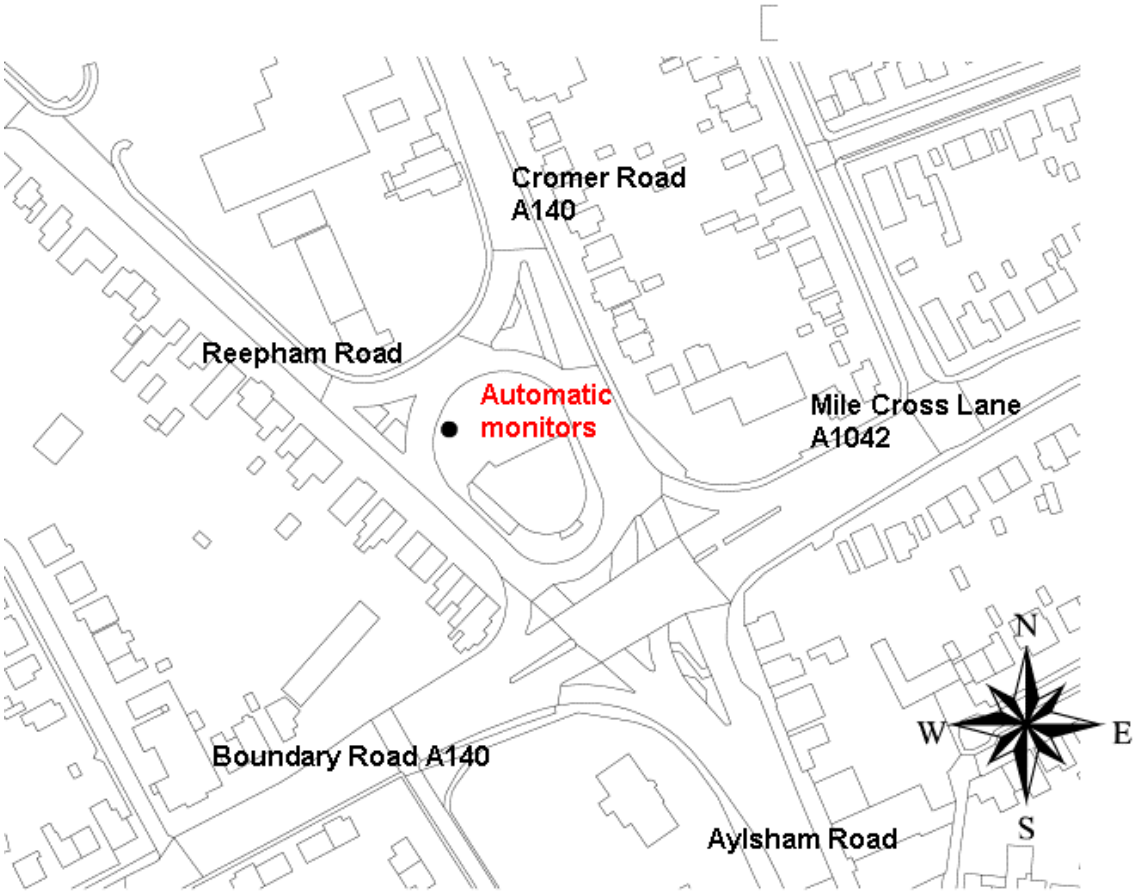
POLLUTANT	PM_{10}*+	NO_2	NO_X
Number Very High	-	0	-
Number High	-	0	-
Number Moderate	-	0	-
Number Low	-	5630	-
Maximum 15-minute mean	156 µg m^{-3}	138 µg m^{-3}	605 µg m^{-3}
Maximum hourly mean	156 µg m^{-3}	122 µg m^{-3}	525 µg m^{-3}
Maximum running 8-hour mean	105 µg m^{-3}	99 µg m^{-3}	365 µg m^{-3}
Maximum running 24-hour mean	93 µg m^{-3}	75 µg m^{-3}	198 µg m^{-3}
Maximum daily mean	92 µg m^{-3}	73 µg m^{-3}	180 µg m^{-3}
Average	25 µg m^{-3}	35 µg m^{-3}	69 µg m^{-3}
Data capture	85.8 %	92.7 %	92.7 %

* PM_{10} in gravimetric units
+ PM_{10} instrument: FDMS Gravimetric factor 1.00000
All mass units are at 20'C and 1013mb
NO_X mass units are NO_X as NO_2

Pollutant	Air Quality (England) Regulations 2000 and (Amendment) Regulations 2002	Exceedences	Days
PM_{10} Particulate Matter (Gravimetric)	Daily mean > 50 µg m^{-3}	11	11
PM_{10} Particulate Matter (Gravimetric)	Annual mean > 40 µg m^{-3}	-	-
Nitrogen Dioxide	Annual mean > 40 µg m^{-3}	-	-
Nitrogen Dioxide	Hourly mean > 200 µg m^{-3}	0	0
Nitrogen Oxides (NO_2)	Annual mean > 30 µg m^{-3}	-	-

AEA Energy & Environment
From the AEA group

Figure A2-2 NO_2 monitoring site at the junction A140/A1042



Appendix 3
Traffic Data

Figure A3-1 Annual Average Daily Traffic in Grapes Hill, 2007

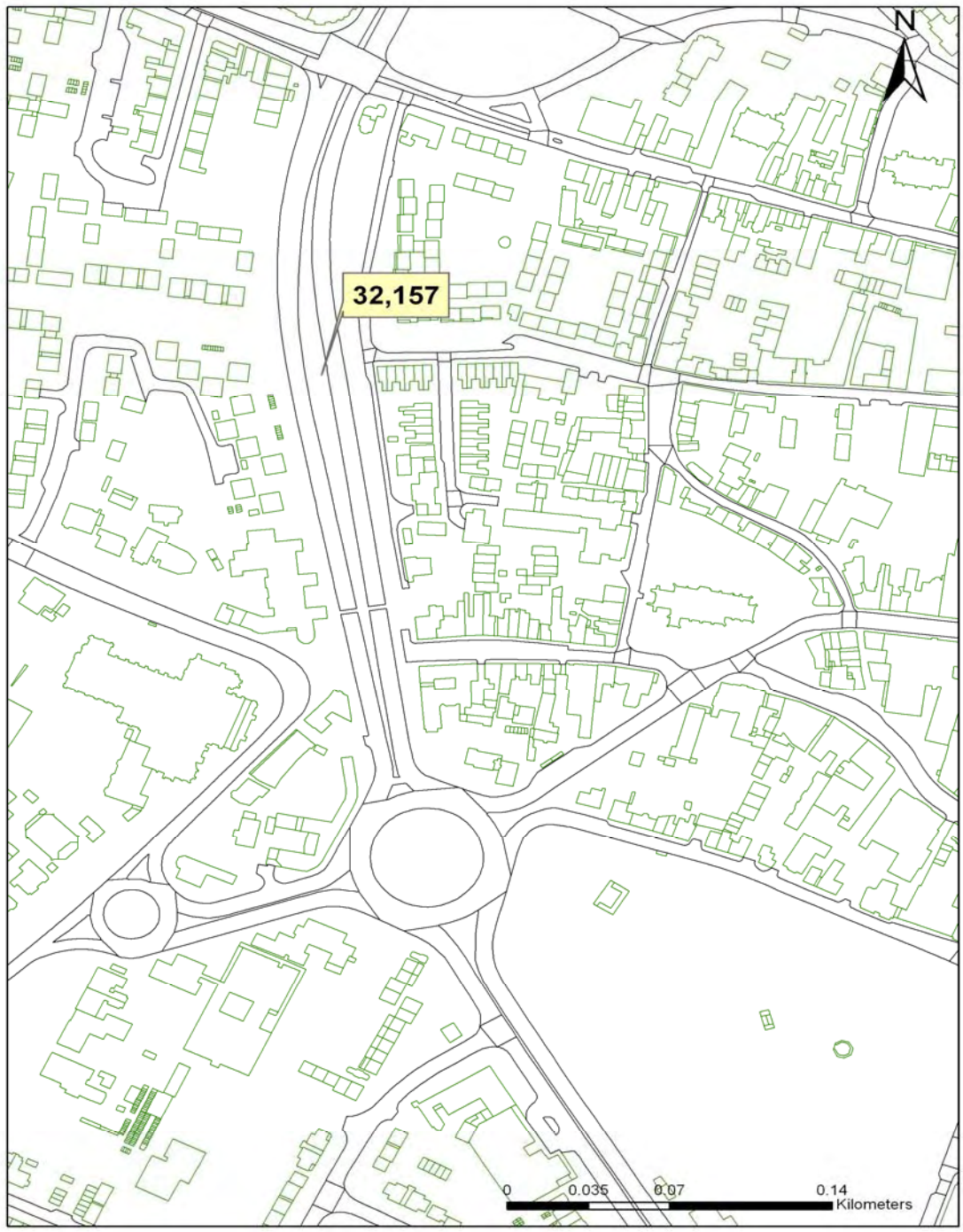
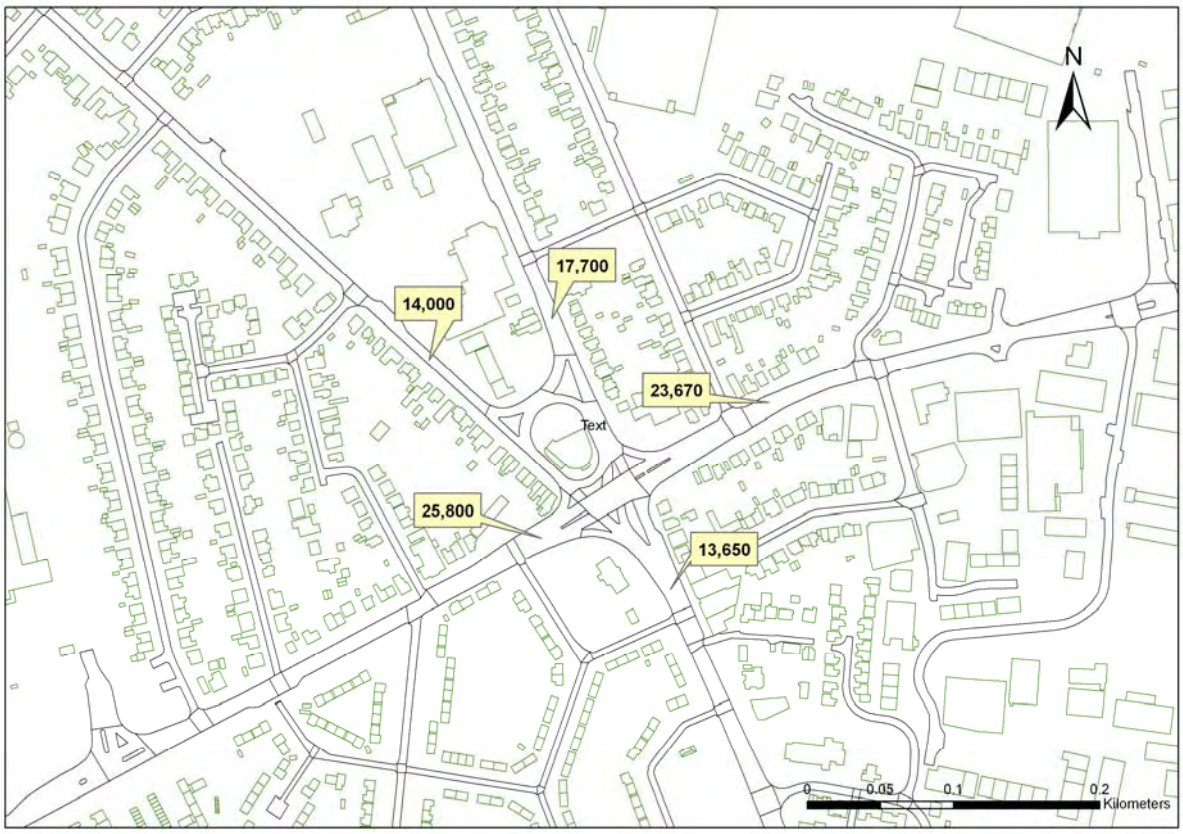


Figure A3-2 Annual Average daily Traffic: King Street, Riverside Road, Bracondale, 2007

Figure A3-3 Annual Average Daily Traffic: Magdalen street, Tombland, Bull Close Road, 2007

Figure A3-4 Annual Average Traffic at A140/A1042 junction, 2007



Appendix 4
Bias adjustment calculation

Table A4-1 Bias adjustment UWE spreadsheet

Spreadsheet Version Number: 03/08

Follow the steps below **in the correct order** to show the results of **relevant** collocation studies

This spreadsheet will be updated in late September 2008 on the R&A website

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

This spreadhseet will be updated every few months: the factors may therefore be subject to change. This should not discourage their immediate use.

Published by Air Quality Consultants Ltd on behalf of Defra, the Welsh Assembly Government, the Scottish Executive and the Department of the Environment Northern Ireland

Step 1: Select the Laboratory that Analyses Your Tubes from the Drop-Down List. If a laboratory is not shown, we have no data for this laboratory.

Step 2: Select a Preparation Method from the Drop-Down List. If a preparation method is not shown, we have no data for this method at this laboratory.

Step 3: Select a Year from the Drop-Down List. If a year is not shown, we have no data[2].

Step 4: 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 you have your own collocation study then see footnote[4]. If uncertain what to do then contact the Review and Assessment Helpdesk 0117 328 3668 aqm-review@uwe.ac.uk.

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	50% TEA in Acetone	2007	R	Boston BC	9	41	33	26.4%	G	**0.79**
Gradko	50% TEA in Acetone	2007	R	LB Hammersmith and Fulham	12	89	79	11.8%	S	**0.89**
Gradko	50% TEA in Acetone	2007	UB	Reading BC	12	25	24	5.9%	G	**0.94**
Gradko	50% TEA in Acetone	2007	R	Stevenage BC	12	39	32	20.5%	G	**0.83**
Gradko	50% TEA in Acetone	2007	K	AEA Tech Intercomparison	12	97	103	-5.3%	G	**1.06**
Gradko	50% TEA in Acetone	2007	UC	Norwich CC	12	21	22	-7.2%	G	**1.08**
Gradko	50% TEA in Acetone	2007		**Overall Factor[3] (6 studies)**				**Use**		**0.93**

[1] For Casella Stanger/Bureau Veritas (NOT Bureau Veritas Labs) use Gradko 50% TEA in Acetone; for Bureau Veritas Labs and Eurofins use Casella Seal/GMSS/Casella CRE/Bureau Veritas Labs/Eurofins; for Staffordshire County Analyst use Staffordshire CC SS

[2] In this situation it would be reasonable to use data from the nearest year.

[3] Overall factors have been calculated using orthogonal regression to allow for uncertainty in both the automatic monitor and diffusion tube. The uncertainty of the diffusion tube has been assumed to be double that of the automatic monitor.

[4] If you have your own collocation study, please send your data to us, so that it can be included here. If this is not possible, but you wish to combine these factors with your own, select and copy the relevant data from this spreadsheet and paste them into a new one (otherwise your calculations will include hidden data). Then add your own data and calculate the bias. To obtain a new correction factor that includes your data, average the bias (B) values, expressed as a factor, i.e. -16% is -0.16. Next add 1 to this value, e.g. -0.16 + 1.00 = 0.84 in this example, then take the inverse to give the bias adjustment factor 1/0.84 = 1.19. (This will not be exactly the same as the correction factor calculated using orthogonal regression as used in this spreadsheet, but will be reasonably close).

[5] Where an annual data set falls into two years it has been ascribed to the year in which most of the data fall.

[6] Tube precision is determined as follows: G = Good precision - coefficient of variation (CV) of diffusion tube replicates is considered good when the CV of eight or more periods is less than 20%, and the average CV of all monitoring periods is less than 10%; P = Poor precision - CV of four or more periods >20% and/or average CV >10%; S = Single tube, therefore not applicable; na = not available.

Table A4-2 Bias adjustment calculation, AEA spreadsheet

Checking Precision and Accuracy of Triplicate Tubes

netcen

Diffusion Tubes Measurements											Automatic Method		Data Quality Check	
Period	Start Date dd/mm/yyyy	End Date dd/mm/yyyy	Tube 1 μgm^{-3}	Tube 2 μgm^{-3}	Tube 3 μgm^{-3}	Triplicate Mean	Standard Deviation	Coefficient of Variation (CV)	95% CI of mean		Period Mean	Data Capture (DC)	Tubes Precision Check	Automatic Monitor Data Capture Check
1														
2	31/01/2007	28/02/2007	23.72	29.12	35.69	29	5.9	20	14.8		30	97%	Poor Precision	Good
3	28/02/2007	04/04/2007	21.61	27.46	30.08	25	4.7	19	11.6		27	99%	Good	Good
4	04/04/2007	02/05/2007	17.47	17.58	19.95	18	1.4	8	3.5		21	100%	Good	Good
5	02/05/2007	30/05/2007	14.12	14.52	14.17	14	0.2	2	0.5		15	99%	Good	Good
6	30/05/2007	03/07/2007	15.36	14.07	15.36	15	0.7	5	1.8		14	100%	Good	Good
7	03/07/2007	01/08/2007	16.77	16.66	16.00	16	0.4	3	1.0		15	100%	Good	Good
8	01/08/2007	05/09/2007	16.82	15.89	15.90	16	0.5	3	1.3		16	96%	Good	Good
9	05/09/2007	03/10/2007	17.38	14.70	15.10	16	1.4	9	3.6		17	100%	Good	Good
10	03/10/2007	31/10/2007	26.95	26.23	25.83	26	0.3	1	0.7		29	100%	Good	Good
11	31/10/2007	28/11/2007	26.54	30.37	28.49	29	2.2	8	5.5		32	100%	Good	Good
12	28/11/2007	02/01/2008	26.59	29.79	30.15	29	2.0	7	4.9		30	100%	Good	Good
13														

It is necessary to have results for at least two tubes in order to calculate the precision of the measurements

Overall survey --> Good precision | Good Overall DC

(Check average CV & DC from Accuracy calculations)

Precision 10 out of 11 periods have a Coefficient of Variation smaller than 20%

Accuracy (with 95% confidence)

without periods with CV larger than 20%

Bias calculated using 10 periods of data

Bias factor A 1.051 +/- 0.058

Bias B -4 +/- 6 %

Diffusion Tubes Mean: 20 μgm^{-3}

Mean CV (Precision): 6

Automatic Mean: 22 μgm^{-3}

Data Capture for periods used: 99%

Adjusted Tubes Mean: 21 +/-1 μgm^{-3}

Accuracy (with 95% confidence)

with all the data

Bias calculated using 11 periods of data

Bias factor A 1.051 +/- 0.053

Bias B -4 +/- 5 %

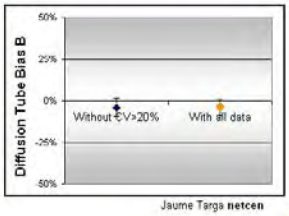
Diffusion Tubes Mean: 21 μgm^{-3}

Mean CV (Precision): 8

Automatic Mean: 22 μgm^{-3}

Data Capture for periods used: 99%

Adjusted Tubes Mean 22 +/-1 μgm^{-3}



Jaume Targa netcen

jaume.targa@aeat.co.uk

Beta 3 - February 2004

M G Stephenson
Regulatory services manager

If you require this document in another language or format, eg large print, audio cassette or Braille, please contact:

Regulatory services
City Hall
Norwich
NR2 1NH
t: 0844 980 3333 (0344 980 3333 from 3 August 2009)
e: info@norwich.gov.uk

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