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Ipswich Borough Council 2008 Further Assessment
Local Air Quality Management

Ipswich Borough Council
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1 Introduction

Faber Maunsell was commissioned by Ipswich Borough Council to undertake a Further Assessment of air quality, after the completion of the Detailed Assessment in 2005, and the resultant designation of three Air Quality Management Areas (AQMAs). This Assessment was previously known as the 'Stage IV Assessment' and forms part of the local authority Review and Assessment process.

The aim of this study was to examine the extent and suitability of the current AQMAs with respect to the pollutant nitrogen dioxide (NO_2). The impact of NO_2 emissions on the local environment have been assessed and compared with the National Air Quality Standards[1]. The results of the modelling have been verified against local monitoring data collected during 2007.

[1] Defra (2007) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, 2007 http://www.defra.gov.uk/environment/airquality/strategy/index.htm

2 Literature Review

2.1 Overview of Recent Air Quality Legislation and Policy

The provisions of Part IV of the Environment Act 1995 establish a national framework for air quality management, which requires all local authorities in England, Scotland and Wales to conduct local air quality reviews. Section 82(1) of the Act requires these reviews to include an assessment of the current air quality in the area and the predicted air quality in future years. Should the reviews indicate that the standards prescribed in the National Air Quality Strategy (NAQS)[2] and the Air Quality Standards Regulations 2007[3] will not be met, the local authority is required to designate an Air Quality Management Area (AQMA). Action must then be taken at a local level to ensure that air quality in the area improves. This process is known as 'local air quality management'.

2.2 National Air Quality Strategy

NAQS identifies nine ambient air pollutants that have the potential to cause harm to human health. These pollutants are associated with local air quality problems, with the exception of ozone, which is instead considered to be a regional problem. The Air Quality Regulations set standards for the eight pollutants that are associated with local air quality. These objectives aim to reduce the health impacts of the pollutants to negligible levels. The current National Air Quality Objectives and EU Limit Values are given in Appendix A.

2.3 The Phased Approach to Review and Assessment

Each round of the Review and Assessment process has been split into two phases (as required by legislation and government guidance): an Updating and Screening Assessment and a Detailed Assessment.

The aim of the first phase, the Updating and Screening Assessment (USA), is to review the changes in air quality that have occurred within each local authority since the previous round of review and assessment and to re-examine locations and sources that were highlighted as issues at that stage.

Where the USA identifies a risk that an air quality objective may be exceeded, which had not been identified previously, the local authority must undertake a Detailed Assessment. The aim of this assessment is to determine with as much certainty as is possible whether or not an air quality objective will be exceeded. If an exceedence is predicted, the local authority should designate an AQMA to cover the area of the exceedence.

After the declaration of an AQMA the local authority has twelve months to undertake a Further Assessment (previously known as the Stage IV assessment) of air quality, the purpose being to supplement any additional information on local air quality, re-assess the area of the AQMA and to determine the suitability of the AQMA. Following the conclusions of the Further Assessment it may be necessary to revoke or amend the AQMA.

In addition, local authorities are required to produce annual air quality Progress Reports, but only for years when no Updating and Screening or Detailed Assessments are due. All monitoring data and other information important with regard to local air quality should be included in the Progress Reports.

2.4 Ipswich Borough Council

Ipswich Borough Council (IBC) is situated in the county of Suffolk, East of England. There are several busy road links in the region, such as the A14, and the main pollutant source in the Borough is road traffic.

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[2] Defra (2007) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, 2007 http://www.defra.gov.uk/environment/airquality/strategy/index.htm

[3] Defra (2007) The Air Quality Standards Regulations 2007 http://www.opsi.gov.uk/si/si2007/uksi_20070064_en_1

2.5 Previous Air Quality Review and Assessments

2.5.1 *USA 2003*

IBC completed their USA in 2003[4]. This study found that the air quality standards and objectives were unlikely to be exceeded for the pollutants carbon monoxide, 1,3-butadiene, lead, benzene and sulphur dioxide. Consequently, no additional assessments for these pollutants were recommended.

However, the USA identified that the standards and objectives relating to NO_2 were likely to be exceeded at three locations in Ipswich, attributed to road traffic emissions. The three areas were St Margaret's Street, Star Lane and Norwich Road. The report also stated that PM_{10} emissions from road traffic and an industrial site should be further investigated. Thus, the report concluded that a Detailed Assessment of NO_2 and PM_{10} was necessary.

2.5.2 *Detailed Assessment 2005*

Faber Maunsell was commissioned by Ipswich Council to undertake a detailed modelling study of NO_2 and PM_{10} concentrations arising from road traffic sources and an industrial source operated by Tarmac in Ipswich.

The results of the NO_2 assessment indicated that the annual mean objective would be exceeded along most of the roads in the study area in 2005. Concentrations greater than 40 µg/m^3 were predicted to extend up to 50 m from the kerb. The area of exceedence would extend further if the standard deviation of the model had been taken into account.

The results of the PM_{10} study demonstrated that emissions from the main stack at the Tarmac site had very little impact on surrounding PM_{10} concentrations. However, the lack of PM_{10} monitoring data prevented a verification of the PM_{10} model results. It is possible therefore, that the model may have been under predicting concentrations of this pollutant.

Following the completion of the Detailed Assessment, three AQMAs were declared with regard to NO_2 pollution in April 2006[5]. The areas are:

- AQMA 1: Land in or around the junction of Norwich Road, Chevallier Street and Valley Road
- AQMA 2: Land in or around the junction of Crown Street with Fonnereau Road, St Margaret's Street and St Margaret's Plain.
- AQMA 3: Land in or around the junction of Grimwade Street with St Helens Street, Starr Lane gyratory system including Fore Street, Salthouse Street, Key Street, College Street, Bridge Street, Foundation Street and Slade Street.

Maps showing the AQMAs are reproduced in Appendix B. The boundaries of the AQMAs follow the 40 µg/m^3 NO_2 concentration contours.

Upon declaring an AQMA, the Review and Assessment process requires a Further Assessment to determine whether the locations and extent of the AQMAs were appropriate.

2.6 Report Structure

- Section 3 provides a background to the pollutants of concern (NO_2);
- Section 4 reviews the recent monitoring results;
- Section 5 details the assessment methodology that has been followed;
- Section 6 contains and analyses the results of the assessment;
- Section 7 concludes the assessment;
- Section 8 contains a list of references; and
- The Appendices contain additional information referred to within the report.

[4] Ipswich Borough Council (2003) USA [Online] Available from: http://www.ipswich.gov.uk/NR/rdonlyres/0FFFEC66-DF74-4655-8323-374520F02480/0/48hhakgpAirQualityUpdateScreeningAssessment.doc

[5] Ipswich Borough Council (2007) Air Quality Strategy and Local Air Quality Management [Online] Available from: http://www.ipswich.gov.uk/Services/Environmental+Protection/Air+Quality/Air+Quality.htm

3 Nitrogen Dioxide (NO_2)

3.1 Sources and Effects

Oxides of nitrogen (NO_X) are primarily comprised of nitric oxide (NO) and nitrogen dioxide (NO_2). A major source of NO_X is from motor vehicles, as NO_X is formed as a by-product of fuel combustion at high temperatures within the engine. The majority of NO_X emitted from vehicles is in the form of NO, a proportion of which is then oxidised in the air to produce NO_2. NO and NO_2 are grouped together in the term NO_X, because most anthropogenic NO_2 is derived from emissions of NO.

The health effects of NO_2 exposure can be chronic and/or acute. Studies of artificial exposure have shown that chronic effects of the upper range of possible exposure concentrations might include changes in lung structure, metabolism and reduced resistance of the lungs to bacterial infection. No clear link has been established between these effects and exposure to NO_2 from ambient air. Acute effects, including increased airway resistance and associated reduced pulmonary function, are experienced by some asthmatics, but there is no clear dose-response relationship. Studies in the UK have shown that exposure to NO_2 enhances response to allergens and may increase the prevalence of respiratory infections in children. There is also some evidence for long term effects of NO_2, although the evidence is weak.

Additionally, NO_X gases are recognised as indirect greenhouse gases, and are one of the main contributors to acid deposition. Direct exposure of vegetation to NO_X may result in leaf damage or make plants more susceptible to attack by pests and disease. The effects of NO_X can be greatly influenced by the presence of other pollutants. In particular, the combination of NO_X and sulphur dioxide can significantly reduce vegetation growth rates at higher concentrations.

3.2 Legislative Background

The Government and the Devolved Administrations have adopted two Air Quality Objectives for nitrogen dioxide (NO_2) to be achieved by the end of 2005:

- An annual mean concentration of 40 $\mu g/m^3$; and
- A 1-hour mean concentration of 200 $\mu g/m^3$, to be exceeded no more than 18 times per year.

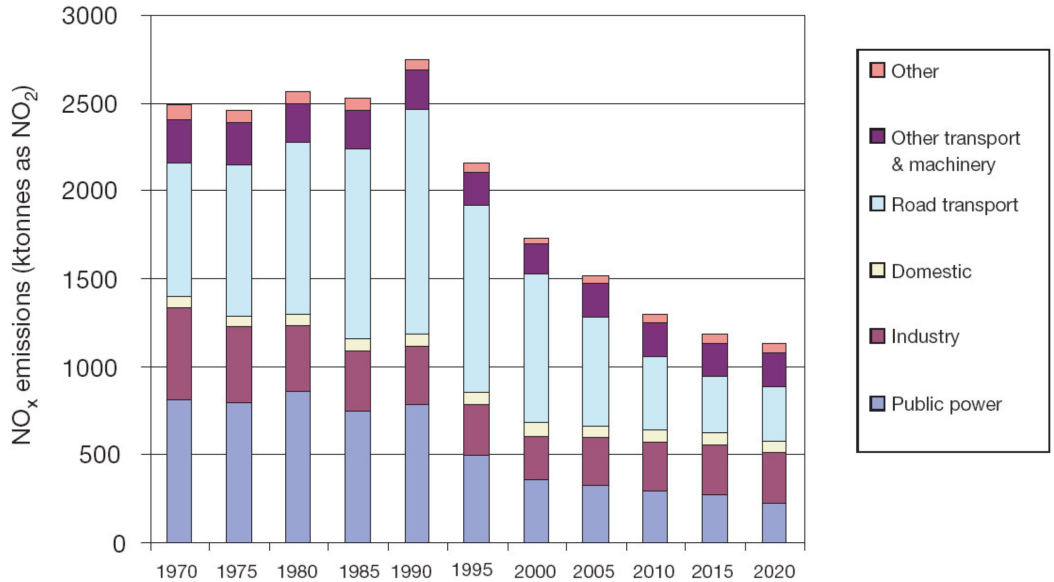
In practice, meeting the annual mean objective in 2005 is expected to be considerably more demanding than achieving the 1-hour objective. The EU First Daughter Directive also sets limit values for NO_2, to be achieved by 1st January 2010, which have been incorporated into UK legislation. The Directive includes a 1-hour limit value of 200 $\mu g/m^3$, not to be exceeded more than 18 times per year, and an annual mean limit value of 40 $\mu g/m^3$.

3.3 Recent Trends

As shown in Figure 1, estimates for 2005 show that road transport accounts for the largest proportion (~45%) of total UK NO_X emissions, with public power industries being the second largest contributor. The contribution of road transport to emissions has declined significantly in recent years as a result of various policy measures, and further reductions are expected up until 2010 and beyond. For example, road transport emissions are estimated to fall by about 50% between 2000 and 2010.

Emissions from industrial and public power sources have also declined significantly, due to the fitting of low NO_X burners, and the increased use of natural gas plant. Industrial sources generally make a very small contribution to annual mean NO_2 levels, although breaches of the hourly NO_2 objective may occur under rare meteorological conditions, due to emissions from these sources.

Figure 1: National Trend of NO_x Emissions (1970 – 2020)



Source: This figure has been reproduced from the Air Quality Expert Group (AQEG) Report on NO_2 in the UK[6].

The annual mean objective of 40 µg/m^3 is currently widely exceeded at roadside sites throughout the UK, with exceedences also reported at urban background locations in major conurbations. The number of exceedences of the 1-hour objective show considerable year-to-year variation, and are driven by meteorological conditions, which give rise to winter episodes of poor dispersion and summer oxidant episodes.

National studies have indicated that the annual mean objective is expected to be met at all background locations across the UK by 2010 but it is not expected to be met at all roadside locations under baseline conditions by 2020.

3.4 Atmospheric Chemistry of NO_x

Once released into the atmosphere NO is oxidised to form NO_2 in a reaction with ozone (O_3), and other hydrocarbon based oxidants. The availability of O_3 directly affects the ratio of NO to NO_2. Although motor vehicles are regarded as the primary source of NO, the diurnal variation of the NO_2 formed does not always vary in accordance with local traffic patterns. Nevertheless, measurements of NO_2 taken at kerbside and roadside monitoring sites typically show higher concentrations than those observed at background monitoring sites.

The Advisory Group on the Medical Aspects of Air Pollution Episodes [7] described NO_X chemistry in the following way:

During its atmospheric lifetime, the dominant oxide of nitrogen, NO, is progressively oxidised to NO_2, largely by reaction with O_3.

$NO + O_3 \rightarrow NO_2 + O_2$

The consequence of this reaction is that the amount of the total NO_X emitted which is oxidised to NO_2 is often limited by the availability of O_3. Close to NO_X sources, the fraction of NO_X present as NO_2 will generally be low. Further from the sources, in conditions of vigorous atmospheric mixing, the initial NO_X plume will be diluted with more O_3, and the proportion of NO_2 will be higher. The relationship between NO, NO_2 and O_3 is complicated by the photolytic reaction which occurs during daylight as NO_2 is photolysed by short wavelength light (> 400 nm), to reform NO and O_3.

$NO_2 + hv \rightarrow NO + O$

$O + O_2 \rightarrow O_3$

[6] Air Quality Expert Group (AQEG) (2004) Nitrogen Dioxide in the United Kingdom, Air Quality Expert Group.

[7] Department of Health Advisory Group on the Medical Aspects of Air Pollution Episodes. Oxides of Nitrogen - Third Report. HMSO, 1993)

The Quality of Urban Air Research Group[8] adds that, "In polluted atmospheres other reactions take place involving hydrocarbons, aldehydes, CO and other compounds".

Understanding the mechanisms that are responsible for the elevated levels of NO_2 that occur during the winter months is an ongoing topic of air quality research. Although NO_2 levels increased nationally by around 30% between 1986 and 1991, followed by a decrease to 2000, future trends associated with NO_2 remain unclear at present.

[8] Department of the Environment, Quality of Urban Air Research Group, Urban Air Quality in the UK, 1993

4 Monitoring Review

4.1 Local NO_2 Monitoring

The Council operates three continuous analysers and a current network of forty-nine diffusion tubes (increased from nineteen prior to 2007) to monitor NO_2 concentrations in Ipswich.

4.1.1 *Continuous Monitors*

Within Ipswich, there are three automatic monitoring stations measuring NO_2. The first continuous monitor at Ancaster Road is located outside the study area and was only in place for a short period of time. The two continuous monitors within the study area are located at Chevallier Street and St Margaret's Street (see Figure 4 Appendix C). The results from these continuous monitoring stations (where available) are detailed in Table 1.

Table 1: Nitrogen Dioxide Continuous Monitoring Results

Location	Site Type	Grid Reference		Annual Mean NO_2/µg/m^3	
				2006	2007
Chevallier Street	Roadside	615259	245350	36[a]	31
St Margaret's Street	Roadside	616578	244759	n/a	42

[a] Please note that data capture at Chevallier Street in 2006 was only 9.8%, therefore this result should be treated with extreme caution. This result has not been seasonally adjusted as insufficient data were recorded.

4.1.2 *Diffusion Tubes*

The table below (Table 2) gives the diffusion tube monitoring results from 2003 to 2007, where applicable. The results in italics are from tubes outside the study area. The locations of the tubes within the study area are given in Figure 4 Appendix C.

Table 2: NO_2 Diffusion Tube Results

Ref.	Site	OS Grid Reference		Type	Annual Mean NO_2/µg/m^3				
					2003[a]	2004[b]	2005[c]	2006[d]	2007[e]
1	Civic Drive	615999	244399	Kerbside	46.3	35.3	35.8	27.6	26.1
2	Civic Drive Co-locate 1	615999	244399	Kerbside	43.2	33.9	33.7	28.6	25.6
3	Stoke Bridge	616315	243934	Kerbside	48.0	39.1	37.1	27.7	29.3
4	*Wherestead Road*	*616258*	*242616*	*Kerbside*	*50.0*	*36.1*	*34.5*	26.5	28.1
5	Fore Street	616860	244147	Kerbside	73.6	50.2	50.5	40.6	42.0
6	*Kings Avenue*	*617299*	*244412*	*Background*	*42.7*	*24.1*	*22.1*	18.7	18.9
7	*Nacton Road*	*618971*	*242296*	*Kerbside*	*40.1*	*29.6*	*30.7*	23.6	25.4
8	*Nacton Rd/A14 junct*	*620076*	*241281*	*Kerbside*	*53.2*	*38.3*	*44.7*	36.5	36.2

Ref.	Site	OS Grid Reference		Type	Annual Mean NO_2/µg/m^3				
					2003[a]	2004[b]	2005[c]	2006[d]	2007[e]
9	*Nacton Rd/A14 junct*	*620076*	*241281*	*Kerbside*	*52.8*	*38.7*	*40.3*	37.3	37.9
10	*Woodbridge Rd East*	*619317*	*245127*	*Kerbside*	*53.2*	*39.0*	*46.4*	40.1	39.9
11	St Margarets Street	616578	244759	Kerbside	60.3	51.1	49.8	46.7	41.7
12	St Marg St Co-locate 1	616578	244759	Kerbside	64.3	52.4	49.3	44.5	41.8
19	St Marg St Co-locate 2	616578	244759	Kerbside	55.8	50.0	48.9	47.0	41.5
13	Valley/ Norwich Road	615342	245422	Kerbside	59.7	49.2	46.4	41.4	39.2[f]
14	Chevallier Street	615283	245391	Kerbside	66.7	55.1	53.5	46.6	46.7
15	Cornhill o/s No 17	616277	244641	Background	43.7	32.1	33.7	27.8	26.2
16	*Museum Street*	*616086*	*244571*	*Kerbside*	*42.8*	*38.2*	*n/a*	*n/a*	*n/a*
17	*Museum Street Co-locate 1*	*616086*	*244571*	*Kerbside*	*39.1*	*37.3*	*n/a*	*n/a*	*n/a*
18	*Museum Street Co-locate 2*	*616086*	*244571*	*Kerbside*	*32.7*	*37.6*	*n/a*	*n/a*	*n/a*
16	Valley/ Norwich Road	615342	245422	Kerbside	n/a	n/a	n/a	39.1	38.6[f]
17	Chevallier Street	615283	245391	Kerbside	n/a	n/a	n/a	45.2	47.2
18	*Norwich Road o/s 331*	*614997*	*245804*	*Kerbside*	*n/a*	*n/a*	*n/a*	36.3	34.6[f]

Key

[a] 2003 data adjusted using 1.36 bias adjustment factor

[b] 2004 data adjusted using 1.12 bias adjustment factor

[c] 2005 data adjusted using 1.11 bias adjustment factor

[d] 2006 adjusted using 1.04 bias adjustment factor

[e] 2007 bias adjusted using a local bias adjustment factor of 0.91.

[f] Data collected to November 2007 only

n/a No data collected or less than 6 months monitored

In 2007, diffusion tube monitoring began at an additional twenty sites. The results for November and December 2007 for these sites are given in Table 3.

Table 3: New NO_2 Diffusion Tubes / Locations (Added from November 2007)

Ref.	Site	OS Grid Reference		Type	11/07 to 12/07 Period Mean NO_2/µg/m^3 (Bias adjusted with local factor of 0.91)
13	Valley/Norwich Road	615361	245436	Kerbside	43.7
16	Valley/Norwich Road Co-locate 1	615361	245436	Kerbside	43.7
18	Norwich/Blenheim Road	615269	245460	Kerbside	34.6
20	St Margaret's Plain/Fonnereau Rd	616455	244824	Kerbside	36.8
21	St Margaret's Plain	616490	244806	Kerbside	34.8
22	St Margaret's Plain/Northgate St	616477	244790	Kerbside	43.3
23	St Margaret's Green/Street	616640	244741	Kerbside	37.4
24	St Margaret's Street	616659	244689	Kerbside	46.7
25	St Helen's Street	616750	244578	Kerbside	47.7
26	St Helen's St/Grimwade Street	616950	244517	Kerbside	43.1
27	St Helen's St/Argyle Street	616961	244536	Kerbside	44.5
28	St Helen's St/Dove Street	617023	244508	Kerbside	40.0
29	Fore Hamlet	617102	244077	Kerbside	37.3
30	Fore Street	616963	244106	Kerbside	50.6
31	Key Street	616699	244099	Kerbside	39.0
32	Key Street Co-locate 1	616699	244099	Kerbside	40.6
33	Key Street Co-locate 2	616699	244099	Kerbside	42.1
34	Key Street/Foundation Street	616502	244083	Kerbside	33.2
35	College Street	616341	244095	Kerbside	47.0
36	Star Lane/St Peter's Street	616307	244141	Kerbside	42.4

Ref.	**Site**	**OS Grid Reference**		**Type**	**11/07 to 12/07 Period Mean NO_2/µg/m^3 (Bias adjusted with local factor of 0.91)**
37	Lower Brook Street	616480	244163	Kerbside	32.5
38	Star Lane	616664	244177	Kerbside	45.9
39	Star Lane/Fore Street	616730	244246	Kerbside	50.2
40	Star Lane	616786	244260	Kerbside	44.2
41	Star Lane Co-locate 1	616786	244260	Kerbside	44.4
42	Star Lane Co-locate 2	616786	244260	Kerbside	44.0
43	Yarmouth Rd/Bramford Road	615107	245197	Kerbside	43.6
44	Bramford Road	615049	245234	Kerbside	44.5
45	Chevallier Street	615257	245349	Kerbside	38.6
46	Chevallier Street Co-locate 1	615257	245349	Kerbside	39.5
47	Chevallier Street Co-locate 2	615257	245349	Kerbside	40.7
48	Norwich Road/Anglesea Road	615397	245337	Kerbside	34.0
49	*St Matthew's Street*	*615803*	*244872*	*Kerbside*	48.1

5 Modelling Methodology

5.1 Scope of the Assessment

This assessment was required to determine whether local air quality management measures, such as the designation of the aforementioned AQMAs, were appropriate. This was accomplished by modelling the base year (2007) and objective year 2010 (based on the assumptions that no local actions are taken to address air quality). The traffic data used for modelling the Further Assessment have been updated since the Detailed Assessment to improve the accuracy of the model. The areas that were modelled included those that are within the three designated AQMAs in Ipswich and the areas immediately surrounding them. The bus station was modelled as an area source and congestion was modelled by reducing speeds at junctions. Source apportionment was undertaken to give an indication of the proportional contribution that each emissions source makes to the total NO_2 concentrations.

5.2 AAQuIRE

The AAQuIRE 6.1.1 regional air quality dispersion modelling package was used to predict concentrations of NO_2 arising from road traffic for the base year (2007) and future air quality objective year (2010).

The AAQuIRE regional dispersion model was developed by Faber Maunsell and has been used widely for the past 13 years. The model uses the dispersion algorithms, CALINE4 and AERMOD, which have been independently and extensively validated. A more detailed description of the AAQuIRE dispersion model is included in Appendix D.

AAQuIRE is capable of modelling the four main categories of air pollutant sources: road traffic sources; industrial sources (Part A and B processes); diffuse sources (e.g. domestic heating); and mobile sources (e.g. airports, rail and shipping). This study involved an assessment of NO_2 emissions from traffic on the main roads in Ipswich. Contributions from other pollutant sources were amalgamated into the background concentration (see Section 5.6).

The modelling procedure calculated the pollutant concentrations at a Cartesian grid of receptors that covered the study area. The receptors were evenly spaced at 10-metre intervals to ensure that a high level of spatial resolution was obtained. The results are presented as plots of pollutant concentration contours.

5.3 Meteorological Data

A meteorological dataset was compiled using 2007 data from Wattisham, which was considered by to be the most suitable site for the study area. Several recent years were studied, and 2007 was considered to give a good representation of typical meteorological conditions for the area in any one year, and also corresponds to the modelled base year.

The windrose for this location is shown in Appendix E along with further details about the methodology used to compile the meteorological data for the model.

5.4 Traffic Data

In order to determine emission rates of pollutants, the model requires annual average daily traffic (AADT) flows, vehicle speeds and the proportion of heavy goods vehicles (HGVs) for all the road links to be considered. It also takes into account future changes in exhaust emissions resulting from changes in legislation.

Traffic data were supplied by Ipswich Borough Council. These data took the form of AADTs, the percentage of HGVs and average speeds, and were based on 12-hour counts conducted at sixteen locations in Ipswich in 2007. The traffic data were converted to 24-flows using conversion factors supplied by Ipswich Borough Council. The Council calculated data for future years by applying a growth factor of 1% per annum. The traffic dataset is presented in Appendix F. Vehicle speeds were routinely reduced at junctions to account for stop/start traffic. Detailed traffic information was provided and incorporated into the modelling including the composition of the Ipswich bus fleet and use of the Tower Ramparts bus station on Crown Street.

The emission rates of some pollutants are higher when the engine is cold. Cars travel for about 3 minutes or 1.6 km before the engine is 'hot'. This engine warming was accounted for by using a variable vehicle composition profile for each road and for each year. Speed-related emission factors were taken from the National Atmospheric Emissions Inventory[9]. 'Cold' engines were modelled by assuming that 20% of all cars and 5% of HGVs were 'cold' . The emissions from 'cold' engines for different vehicle types were enhanced by the factors outlined in Table 4.

Table 4: Emissions Enhancement Factors for Cold Engines by Engine Type

Engine Type	NO_X
Petrol without Catalyst	1.0
Petrol with Catalyst	1.3
Diesel	1.2

5.5 Modelled Areas

As for previous air quality studies in the area, the modelling was focused on the three AQMAs declared in Ipswich and the areas immediately surrounding them. The study area was divided into three sections, defined as the designated AQMAs. Table 5 below outlines the three areas, the AQMAs they encompass and the main streets modelled within them.

Table 5: Areas Used for Modelling

Area No.	Area Name	AQMA Description	Main Roads
1	Chevallier Street	Ipswich AQMA 1	Norwich Road Chevallier Street Valley Road
2	Crown Street	Ipswich AQMA 2	Crown Street with Fonnereau Road St Margarets Street St Margarets Plain
3	Star Lane Gyratory	Ipswich AQMA 3	Grimwade Street St Helens Street Fore Street Key Street College Street Bridge Street Foundation Street

5.6 Background Concentrations

A large number of small sources of air pollutants exist, which individually may not be significant, but collectively, over a large area, need to be considered in the modelling process. The UK National Air Quality Information Archive[10] provides estimates of background NO_X concentrations nationwide, with a spatial resolution of 1 km^2. The background concentrations applied to the model are those listed for the grid square centred on (616500,244500) (Table 6). The concentrations for future years were determined by following the method outlined in Defra's Technical Guidance note, LAQM.TG(03)[11].

Table 6: Background Pollutant Concentrations (µg/m^3)

Pollutant	2007	2010
NO_X	32.6	29.1

As the local authority has some control over emissions of NO_X but little or no control over the atmospheric oxidants that oxidise NO to NO_2, it is more appropriate to review NO_2 by first modelling NO_X. It is for this reason that a NO_X background is applied to the modelled NO_X concentration before being converted to NO_2 (see Section 5.7).

[9] National Atmospheric Emissions Inventory (2007) NAEI [Online] Available from: http://www.naei.org.uk/
10 The UK National Air Quality Information Archive (2007) Air Quality [Online] Available from: http://www.airquality.co.uk/archive/index.php
11 Defra (2003) Local Air Quality Management, Technical Guidance, LAQM.TG(03)

5.7 Conversion of NO_X to NO_2

As explained in Section 5.6, the proportion of NO_2 in NO_X varies greatly with location and time according to a number of factors including the amount of ozone available and the distance from the emission source.

The Derwent-Middleton NO_2/NO_X relationship[12] (see Table 7) was used to convert the annual average NO_X concentrations generated by the model to annual average NO_2 concentrations. This relationship is based on data recorded at several London sites and is a good representation of the roadside ratio of NO_2 to NO_X. The relationship was used for both the base case and future year 2010. However, as NO_X concentrations are expected to decline in future years, NO_2 concentrations will not be limited as much by ozone. Consequently, it is possible that the future year NO_2/NO_X ratio will increase.

Table 7: NO_X to NO_2 Conversion

NO_X/µg/m^3	NO_2/ µg/m^3		NO_X/µg/m^3	NO_2/ µg/m^3		NO_X/µg/m^3	NO_2/ µg/m^3
0	0.0		170	65.3		340	80.4
10	7.1		180	66.8		350	80.9
20	14.4		190	68.2		360	81.4
30	21.0		200	69.5		370	81.9
40	26.7		210	70.6		380	82.3
50	31.8		220	71.7		390	82.8
60	36.4		230	72.7		400	83.2
70	40.5		240	73.7		410	83.6
80	44.1		250	74.6		420	84.0
90	47.5		260	75.4		430	84.5
100	50.5		270	76.1		440	84.9
110	53.2		280	76.9		450	85.3
120	55.7		290	77.5		460	85.7
130	58.0		300	78.2		470	86.1
140	60.0		310	78.8		480	86.5
150	61.9		320	79.4		490	87.0
160	63.7		330	79.9		500	87.4

5.8 Model Error and Verification

The results from the modelling study will be subject to error due to uncertainties in modelling dispersion algorithms and the input data. Therefore, it is imperative that the performance of any modelling study is verified by comparison with local monitoring data. See Section 6.2 for further detail on the verification process used.

5.9 Modelling Errors

Monitoring data are subject to error, as are the results generated by the AAQuIRE 6.1.1 regional air quality model. The systematic errors in model results are caused by many factors, such as uncertainties in vehicle flows, vehicle speeds and the composition of the vehicle fleet. The treatment of error is considered in more detail in the results section of this report.

[12] Derwent R.G. and Middleton D.R (1996) 'An empirical function for the ratio $[NO_2]:[NO_X]$', Clean Air, 26, 57-60..

6 Results and Discussions

6.1 Predicted Results

The results for each study area are detailed below. Contour plots indicating the predicted annual mean NO_2 concentrations are shown in Appendix G and are presented for 2007 and 2010 to indicate current and predicted future NO_2 concentrations. All the plots have contours for 36, 40 and 44 µg/m^3. These contours are selected to indicate where exceedences of the annual mean objective are possible, probable and likely, respectively. This 4 µg/m^3 buffer is used to represent ±1 standard deviation. This value of the model standard deviation is taken from work undertaken by the NSCA as detailed in Section 6.3 below[13].

Concentrations of NO_2 are predicted to decrease in all areas between 2007 and 2010 due to lower background concentrations and changes in vehicle fleet with the associated improvements in vehicle engine technology.

6.2 Model Verification

For an assessment such as this, it is necessary to consider and account for random errors, in both the modelling and the monitoring data. The modelling results discussed below were verified by a consideration of the errors associated with the modelling process and the model input data.

The systematic errors in modelling results can arise from many factors, such as uncertainties in vehicle flows, speeds and the composition of the vehicle fleet. Such errors can be addressed and corrected for by making comparisons with monitoring data.

The accuracy of the future year modelling results are relative to the accuracy of the base year results, therefore greater confidence can be placed in the future year concentrations if good agreement is found for the base year.

Initially, the AAQuIRE model did not accurately predict NO_2 concentrations at the St Margaret's Street and Chevallier Street continuous monitors or at various diffusion tubes in the area. Based on these results, two adjustment factors, F, were calculated. As Areas 2 and 3 are adjacent to each other, a single factor was determined for the two areas, and a separate factor was determined for Area 1, to adjust the modelled roadside NO_X in accordance with LAQM.TG(03) technical guidance. These factors were 2.8 for Area 1, and 1.5 for Areas 2 and 3. Only diffusion tubes for which full year annual mean NO_2 concentrations could be calculated were used in the model verification. The comparison between the monitored concentrations and the adjusted modelled results is shown in Table 8.

The steps in the adjustment procedure are described below:

$NO_{X\,[monitored,\ traffic\ contribution]} = NO_{X\,[monitored]} - NO_{X\,[background]}$

$NO_{X\,[modelled,\ traffic\ contribution]} = NO_{X\,[modelled]} - NO_{X\,[background]}$

Adjustment Factor, $F = NO_{X\,[monitored,\ traffic\ contribution]} / NO_{X\,[modelled,\ traffic\ contribution]}$

Monitored NO_X was calculated from the annual average monitored NO_2 as recorded by the continuous monitor in the study area, using the Derwent-Middleton NO_2/NO_X relationship. The adjustment factor was calculated and this factor was then applied according to the following equations.

$NO_{X\,[model\ adjusted,\ traffic\ contribution]} = NO_{X\,[modelled,\ traffic\ contribution]} \times F$

$NO_{X\,[model\ adjusted]} = NO_{X\,[model\ adjusted,\ traffic\ contribution]} + NO_{X\,[background]}$

Therefore, modelled NO_X traffic contributions were multiplied by the adjustment factor, F, and added to the background NO_X to give the adjusted NO_X concentrations ($NO_{X\,[model\ adjusted]}$). The

[13] NSCA, Air Quality Management Areas: Turning Reviews into Action.

adjusted NO_x concentrations were then converted to NO_2 using the Derwent-Middleton NO_2/NO_X relationship.

Table 8: Model Verification

Area	Site	Grid Reference		Type	Annual Mean NO_2/µg/m^3 2007			
					Monitored	Modelled	Modelled (Adjusted)	Factor
1	Chevallier Street CM	615259	245350	Continuous Monitor	31.4	29.2	38.9	2.8
	Valley/ Norwich Rd	615342	245422	Diffusion Tube	38.9	32.0	44.8	
	Chevallier Street	615283	245391	Diffusion Tube	47.0	28.6	37.7	
2	St Margaret's Street	616578	244759	Continuous Monitor	42.0	34.6	34.9	1.5
	St Margaret's Street	616578	244759	Diffusion Tube	40.5	34.6	34.9	
3	Stoke Bridge	616315	243934	Diffusion Tube	29.3	30.3	33.5	1.5
	Fore Street	616860	244147	Diffusion Tube	42.0	36.8	41.9	

Table 8 contains the monitored NO_2 concentrations at the sites which were used for the model verification, the modelled NO_2 concentrations both with and without model adjustment and the factors used for the adjustment.

6.3 Random Error of the Model

In addition to the systematic errors the model is still likely to predict concentrations slightly different to actual ambient values. This is termed random error, and must be considered. It is possible to account for the degree of random error, according to guidance provided by the NSCA.

'Stock U Values', figures provided by NSCA, allow the standard deviation of the model (SDM) to be calculated. The Stock U Value for NO_2 is between 0.1 and 0.2 for an annual mean (it is higher for shorter averaging periods). The SDM can be calculated according to:

$$SDM = U \times Co$$

Where Co is the air quality objective (40 µg/m^3 for the NO_2 UK annual mean objective).

Therefore:

$$SDM = 0.1 \times 40 = 4 \ \mu g/m^3$$

This calculation quantifies the uncertainty in the identification of areas where an exceedence of the air quality objective can be considered possible. This region, therefore, extends between 36 µg/m^3 to 44 µg/m^3 at 1 standard deviation from the objective.

The following terminology is used in conjunction with the modelling uncertainty results.

Table 9: Probability of Exceedence of Annual Mean NO_2 Objective

Probability of Exceedence	Uncertainty	Concentration Range (µg/m^3)
Very likely	> Mean + 2 SD	>48
Likely	Mean + 1 SD – Mean +2 SD	44 – 48
Probable	Mean - Mean + 1 SD	40 – 44
Possible	Mean - Mean – 1 SD	36 – 40
Unlikely	Mean - 1 SD – Mean - 2 SD	32 – 36
Very Unlikely	< Mean – 2 SD	< 32

6.4 NO_2 Modelling Results

6.4.1 *Area 1, Chevallier Street*

The modelling covered Chevallier Street from Waterloo Road to the junction with Norwich Road, Norwich Road from Beaufort Road in the south to All Saints' Road in the North and Valley Road from the junction with Norwich Road. The modelling predicts that exceedences of the 40 µg/m^3 UK annual mean NO_2 objective are probable at some properties at the junction of Norwich Road, Chevallier Street and Valley Road, and at some properties along Chevallier Street in 2007 according to the criteria in Table 9. At two properties, on the corner of Norwich Road and Valley Road and Norwich Road and Chevallier Street, the contour plots suggest that exceedences of this objective are likely. Additional exceedences of the annual mean objective in 2007 are possible at further properties along all three roads modelled in this area, especially Chevallier Street and the northern section of Norwich Road.

By 2010, the contour plots show that exceedences of this objective are probable at one property located immediately next to the junction. Additional, possible exceedences of the annual mean objective for NO_2 are predicted at a limited number of properties. It should however be noted that the contour plots represent concentrations at 1.5 m. Where the ground floor of properties is used for commercial purposes, the annual mean objective does not apply.

6.4.2 *Area 2, Crown Street*

The modelling covered Crown Street from the junction with the High Street past the Tower Ramparts Bus station, along St Margaret's Street and St Helen's Street past the junction with Grimwalde Street, Argyle Street and the northern section of Grimwalde Street. Modelling showed elevated concentrations of NO_2 in and around the bus station due to idling. However, exceedences of the annual mean objective for NO_2 are probable in 2007 at only a few properties, some of which appear to be commercial. Probable / likely exceedences of this objective were shown by the contour plots in 2007 at properties on the corner of Soane Street and St Margaret's Street with possible exceedences on the corner of Crown Street and Fonnereau Road. Exceedences may also be possible at further properties on Crown Street, Tower Ramparts and St Margaret's Street as concentrations are predicted to be in excess of 36 µg/m^3 at façades.

In 2010, it is possible that two properties near the bus station will be subjected to concentrations of NO_2 in excess of the 40 µg/m^3 annual mean objective, according to the criteria in Table 9. Contour plots also indicate that exceedences of this objective are possible at properties by the junction of St Margaret's Street and Soane Street.

6.4.3 *Area 3, Star Lane Gyratory*

The modelling covers the road network from Vernon Street, around the Star Lane gyratory, east along College Road and Star Lane, Key Street, the southern section of Grimwalde Street, and on to Fore Hamlet, Back Hamlet and Duke Street. The 2007 contour plots indicate that exceedences of the UK annual mean NO_2 objective are likely at a property on the corner of Grimwalde Street and Fore Street, and at two properties at the junction of Key Street and Fore Street. Exceedences of this objective are also predicted to be probable at the properties immediately surrounding the Fore Hamlet / Back Hamlet roundabout, along Fore Street, at the southern section of Grimwalde Street, the junction of Key Street and Fore Street and along Key Street. Additionally, possible exceedences of the annual mean objective have been modelled on Slade Street, Star Lane, properties on the Star Lane gyratory and on the northern section of Vernon Street.

In 2010, the contour plots indicate that exceedences of the annual mean NO_2 objective are probable at one property on the corner of Grimwalde Street and Fore Street, two properties on the Fore Hamlet roundabout and one on the corner of the junction of Key Street and Fore Street according to the criteria in Table 9. Exceedences of this objective are possible at properties along the southern section of Grimwalde Street after the junction with Star Lane, on the approach to the Fore Hamlet roundabout, on the approach to College Street roundabout and along Fore Street and Key Street.

6.5 Source Apportionment

Receptors were selected for each area and concentrations of NO_X and NO_2 were predicted for 2010 (the objective year) using the AAQuIRE dispersion modelling software. Receptors were selected to be properties where NO_2 concentrations were predicted to be greatest as indicated by the contour plots (see Appendix H). Traffic data were split into modes depending on whether they represented LGVs, HGVs or buses (including the bus station) and emission factors were defined for the modal split. Table 18 details receptor locations, and is provided in Appendix H along with Figures 11 and 12 showing the locations.

Table 10: Source Apportionment – Area 1

Receptor Number	Total NO_2 /µg/m^3	Total NO_X /µg/m^3	% Contribution to Total NO_X			
			Buses	Cars	HGVs	Background
1	36.5	60.2	4.7	21.8	25.2	48.3
2	39.2	66.8	9.0	20.5	25.5	45.0
3	41.3	72.1	11.0	21.8	24.0	43.1
4	35.9	58.8	6.9	17.9	20.7	54.6
Average			**7.9**	**20.5**	**23.8**	**47.8**

Table 11: Source Apportionment – Area 2

Receptor Number	Total NO_2 /µg/m^3	Total NO_X /µg/m^3	% Contribution to Total NO_X			
			Buses	Cars	HGVs	Background
5	37.7	63.0	47.8	3.1	2.9	46.2
6	40.4	69.9	41.6	8.3	7.1	43.1
7	35.8	58.6	28.8	9.4	8.7	53.1
8	41.2	72.0	41.6	7.2	6.6	44.6
9	42.9	76.5	42.2	7.5	7.0	43.2
10	42.4	75.0	41.7	6.6	6.2	45.5
Average			**40.6**	**7.0**	**6.4**	**45.9**
11	36.9	61.3	12.0	14.5	16.1	57.3

Note: Receptor 11 not included in the average for Area 2 as located some distance away from other receptors.

Table 12: Source Apportionment – Area 3

Receptor Number	Total NO_2 /µg/m^3	Total NO_X /µg/m^3	% Contribution to Total NO_X			
			Buses	Cars	HGVs	Background
12	37.5	62.7	7.3	20.1	26.1	46.4
13	35.0	56.9	8.7	14.1	24.2	52.9
14	39.7	68.0	12.8	16.3	25.2	45.7
15	42.5	75.5	13.8	17.1	26.5	42.5
16	37.4	62.3	10.4	16.8	19.7	53.1
17	46.0	85.4	12.7	19.9	27.4	39.9
18	40.8	70.9	11.6	16.6	22.3	49.5
19	42.5	75.5	12.2	16.6	23.4	47.8
Average			**11.2**	**17.2**	**24.4**	**47.2**

The results indicate that exceedences of the UK annual mean objective are either possible, probable or unlikely (according to the terminology in Table 9) at the receptor locations in all areas. In all three areas, the majority of the emissions were attributable to road traffic when the average of all receptors was taken. Results for Receptor 11 are presented separately as this receptor is located away from the main cluster of receptors in Area 2.

In Area 2, an average of 40.6% of NO_X concentrations was attributable to bus emissions from buses on the road network and from buses idling in the station. This was higher than Areas 1 and 3 at 7.9% and 11.2% respectively. This can be explained by the presence of the Tower Ramparts bus station in Area 2, through which the majority of the City's bus routes pass. In Areas 1 and 3, HGVs contributed the greatest percentage of roadside NO_X on average. Table 13 below indicates the source apportionment attributable to the bus station and buses on the local road network within Area 2. Receptors 5, 6 and 7 are more heavily influenced by the presence of the bus station than Receptors 8 to 10.

Table 13: Area 2 Breakdown of Bus Emissions

Receptor Number	% Contribution to Total NO_X		
	Buses	Bus Station	Total
5	4.7	43.2	47.8
6	12.1	29.5	41.6
7	14.9	13.9	28.8
8	40.3	1.3	41.6
9	40.9	1.3	42.2
10	40.6	1.2	41.7
Average	**25.6**	**15.1**	**40.6**

The key results can be summarised as follows:

- Cars were predicted to contribute between 3.1% (Receptor 5) and 21.8% (Receptors 1 and 3) of the total NO_X concentration at individual receptors.
- HGVs were predicted to contribute between 2.9% (Receptor 5) and 27.4 % (Receptor 17) of the total NO_X concentration at individual receptors.
- Buses were predicted to contribute between 4.7% (Receptor 1) and 47.8% (Receptor 5) of the total NO_X concentration at individual receptors.
- The majority of the emissions are attributable to traffic sources in all areas.
- In Area 2, buses are the predominant traffic source of NO_X emissions, particularly affecting Receptors 5-10.

Calculations were undertaken to determine the percentage NO_X reduction required to meet either 36 µg/m^3 or 40 µg/m^3 NO_2 concentrations based on the results in Tables 10 to 13. Only receptor locations where exceedences of the annual mean objective were predicted to be possible, probably or likely were used. An NO_2 concentration of 36 µg/m^3 was selected as a target concentration, as it is one standard deviation from 40 µg/m^3, the UK annual mean objective. Using the NO_2/NO_X relationship defined in Table 7, 36 µg/m^3 NO_2 equates to 59 µg/m^3 NO_X and 40 µg/m^3 NO_2 equates to 68 µg/m^3 NO_X . The reductions required have been presented for all sources and also for road transport sources only, excluding background contributions. Where no figure is given it is because no reduction is required. The data in Table 14 indicate the NO_x reductions necessary to reduce NO_x concentrations to meet a target of 36 µg/m^3 NO_2.

Table 14: NO_x Reduction required to meet 36 µg/m^3 NO_2

Area	Receptor Number	NO_X Reduction Required (%)to meet 36 µg/m^3 NO_2	
		All Sources (including Background)	All Traffic Sources
Area 1			
1	1	2.0	3.9
	2	11.7	21.3
	3	18.2	32.0
	4	-	-
Average Area 1		**10.7**	**19.1**
Area 2			
2	5	6.3	11.7
	6	15.6	27.4
	7	-	-
	8	18.0	32.5
	9	22.9	40.4
	10	21.3	39.1
Average Area 2		**16.8**	**30.2**
2	11	3.7	8.7
Area 3			
3	12	5.8	10.9
	13	-	-
	14	13.2	24.4
	15	21.8	38.0
	16	5.3	11.3
	17	30.9	51.5
	18	16.8	33.3
	19	21.9	41.9
Average Area 3		**16.5**	**30.2**

Note: Receptor 11 not included in the average for Area 2 as located some distance away from other receptors.

All areas require some reduction from sources to meet NO_2 concentrations of 36 µg/m^3 in 2010. The reduction required from all sources at an individual receptor throughout the study area varies between a maximum of 30.9% (Receptor 17) and a minimum of 2.0% (Receptor 1).

The results indicate that average NO_X reductions of between 10.7% (Area 1) and 16.8% (Area 2) are required to deliver NO_2 concentrations within one standard deviation of the 40 µg/m^3 annual mean objective. To achieve the objective through a reduction in traffic sources alone, an average decrease in traffic emissions of 19.1% for Area 1, 30.2 % for Area 2, and 30.2% for Area 3 would be required. However, there is variation between the areas, with the minimum average required reduction being 3.9% at Receptor 1 and the maximum being 51.5% at Receptor 17. Even within areas there is variation between required reductions, suggesting that individual roads should be targeted rather than whole areas.

The data in Table 15 indicate the NO_x reductions necessary to reduce NO_x concentrations to meet a target of 40 µg/m^3 NO_2.

Table 15: NO_x Reduction required to meet 40 µg/m^3 NO_2

Area	Receptor Number	NO_X Reduction Required (%)to meet 40 µg/m^3 NO_2	
		All sources (including background)	**All Traffic Sources**
Area 1			
1	1	-	-
	2	-	-
	3	4.8	8.4
	4	-	-
Average Area 1		**4.8**	**8.4**
Area 2			
2	5	-	-
	6	1.7	3.0
	7	-	-
	8	4.5	8.2
	9	10.3	18.1
	10	8.4	15.4
Average Area 2		**6.2**	**11.2**
2	11	-	-
Area 3			
3	12	-	-
	13	-	-
	14	-	-
	15	9.0	15.6
	16	-	-
	17	19.6	32.6
	18	3.1	6.2
	19	9.0	17.3
Average Area 3		**10.2**	**17.9**

Note: Receptor 11 not included in the average for Area 2 as located some distance away from other receptors.

All areas require some reduction from sources to meet NO_2 concentrations of 40 µg/m^3 in 2010 but obviously less reduction would be required to meet this less stringent target than to meet 36 µg/m^3. The average reduction required from all sources varies between a maximum of 10.2% (Area 3) and a minimum of 4.8% (Area 1). To achieve the objective through a reduction in traffic sources alone, an average decrease in traffic emissions of 8.4% for Area 1, 11.2% for Area 2, and 17.9% for Area 3 would be required.

7 Summary and Conclusions

7.1 **Summary**

Detailed dispersion modelling was undertaken in three areas of Ipswich that were highlighted in the Detailed Assessment 2005 for exceeding or being close to exceeding the annual mean NO_2 objective. Modelling was carried out for 2007 and 2010 and contour plots were produced showing the results. Source apportionment for each area was undertaken showing the contribution that background sources, HGVs, cars and buses make towards the overall NO_X concentrations. The necessary NO_X reductions required to meet an overall concentration of 36 µg/m^3(one standard deviation from the annual mean NO_2 objective) and also 40 µg/m^3 were calculated for 2010.

7.2 **Results**

The plots produced from this study suggest that the annual mean NO_2 objective is likely to be exceeded in all three areas in 2007. By 2010, exceedences are probable in Areas 1 and 3, and possible in Area 2.

Different sources contribute differing percentages of overall NO_X in the different areas. Background sources account for between 39.9% and 54.6% of total NO_X at the receptors examined. The remainder comes from traffic sources. Of the traffic sources, buses contributed the most NO_X as a percentage of the total in Area 2. HGVs were the biggest contributor of traffic NO_X in Area 1 and in Area 3.

Reductions in average NO_X are required in all areas to meet the annual mean objective for NO_2 at sensitive receptors in 2010. However, reduction requirements vary between and within areas.

7.3 **Modelling**

The modelling was undertaken with recent and accurate traffic count data for the roads in the study area. Detailed information has been provided regarding speeds and the composition of the current bus fleet, allowing accurate emissions data to be used.

For the model verification, the continuous monitors at St Margaret's Street and Chevallier Street and those diffusion tubes for which 9 to 12 months data were available were used. The extended diffusion tube monitoring program, which began in November 2007, will enable improved model verification in subsequent studies as more monitoring data will be available for each area.

7.4 **Conclusions**

The conclusions of the assessment were that the results are generally in good agreement with those from the Detailed Assessment undertaken in 2005. The concentrations of NO_2 within the designated AQMAs have decreased overall since the 2005 assessment and are likely to continue to decrease to 2010. Although the current modelled concentrations and those predicted for 2010 do not show sufficient improvement to revoke the AQMA designations, there is evidence to support a reduction in their extents. Exceedences of the annual mean objective at some locations in the areas modelled are either likely or probable in 2007 and should be considered for future air quality work.

7.5 **Recommendations**

Steps should be taken to further reduce the concentrations of NO_2 in the three areas studied. In order to reduce NO_X and therefore NO_2, all road transport emissions should be focused on, particularly cars and HGVs in Areas 1 and 3 and buses in Area 2.

It is recommended that all monitoring be continued and that further modelling incorporating the diffusion tube data from the new locations be undertaken when sufficient data are available.

Appendices

Appendix A: National Air Quality Objectives and EU Limit Values

Table 16: UK Air Quality Objectives

Pollutant	Air Quality Objectives		Date to be achieved by and maintained thereafter
	Concentration	Measured as	
Benzene All authorities	16.25 µg/m³	Running Annual Mean	31 December 2003
Benzene Authorities in England and Wales	5.0 µg/m³	Annual Mean	31 December 2010
1,3-Butadiene	2.25 µg/m³	Running Annual Mean	31 December 2003
Carbon Monoxide	10.0 mg/m³	Maximum Daily Running 8-hour Mean	31 December 2003
Lead	0.5 µg/m³	Annual Mean	31 December 2004
	0.25 µg/m³		31 December 2008
Nitrogen Dioxide	200 µg/m³ not to be exceeded more than 18 times a year	1 Hour Mean	31 December 2005
	40 µg/m³	Annual Mean	
Nitrogen Oxides (for the protection of vegetation)	30 µg/m³	Annual Mean	31 December 2000
Particles (PM_{10}) (gravimetric)	50 µg/m³ not to be exceeded more than 35 times a year	24 Hour Mean	31 December 2004
	40 µg/m³	Annual Mean	31 December 2004
Particles ($PM_{2.5}$) Exposure Reduction	25 µg/m³	Annual Mean	2020
Particles ($PM_{2.5}$) Exposure Reduction UK Urban Areas	Target of 15% reduction in concentrations at urban background [a]	Annual Mean	Between 2010 and 2020
Sulphur Dioxide	266 µg/m³ not to be exceeded more than 35 times a year	15 Minute Mean	31 December 2005
	350 µg/m³ not to be exceeded more than 24 times a year	1 Hour Mean	31 December 2004
	125 µg/m³ not to be exceeded more than 3 times a year	24 Hour Mean	31 December 2004

Note: a 25 µg/m³ is a cap to be seen in conjunction with 15% reduction.

Table 17: EU Limit Values

Pollutant	Objective	Measured as	Date to be achieved by and maintained thereafter
Benzene	5 µg/m^3	Annual Mean	1 January 2010
Carbon Monoxide	10.0 mg/m^3	Maximum Daily 8-Hour Mean updated hourly	1 January 2005
Lead	0.5 µg/m^3	Annual Mean	1 January 2005
Nitrogen Dioxide	200 µg/m^3 not to be exceeded more than 18 times per year	1 Hour Mean	1 January 2010
	40 µg/m^3	Annual Mean	
Nitrogen Oxides (assuming as nitrogen dioxide)	30 µg/m^3	Annual Mean	19 July 2001
Ozone(Target)	120 µg/m^3 not to be exceeded more than 25 times per year	Maximum Daily Running 8-hour Mean updated hourly	1 January 2010
Particles (PM_{10}) (gravimetric)	50 µg/m^3 not to be exceeded more than 35 times per year	24 Hour Mean	1 January 2005
	40 µg/m^3	Annual Mean	1 January 2005
Particles ($PM_{2.5}$) Exposure Reduction[a]	Target value 25 µg/m^3	Annual Mean	2010
Particles ($PM_{2.5}$) Exposure Reduction [a] UK urban areas	Target of 20% reduction in concentrations at urban background	Annual Mean	Between 2010 and 2020
Sulphur Dioxide	350 µg/m^3 not to be exceeded more than 24 times per year	1 Hour Mean	1 January 2005
	125 µg/m^3 not to be exceeded more than 3 times per year	24 Hour Mean	1 January 2005
	20 µg/m^3 (for the protection of vegetation)	Annual Mean	19 July 2001

Note: [a] The European Directive with proposals for $PM_{2.5}$ concentrations is currently subject to negotiation and final adoption.

Appendix B: Existing AQMA maps

Figure 2: Location of AQMA 1 with Annual Mean NO_2 ($\mu g/m^3$) Concentrations at the Norwich Road / Valley Road Junction in 2005

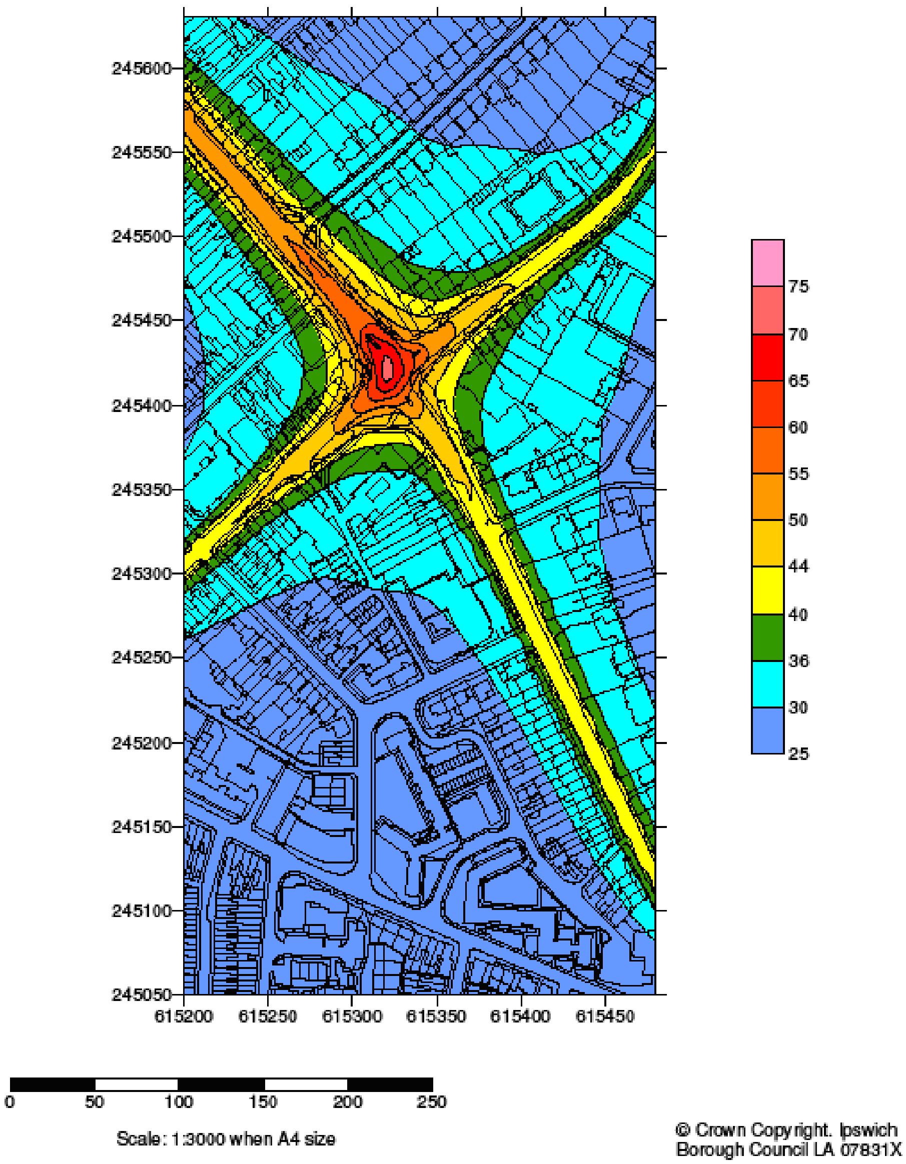


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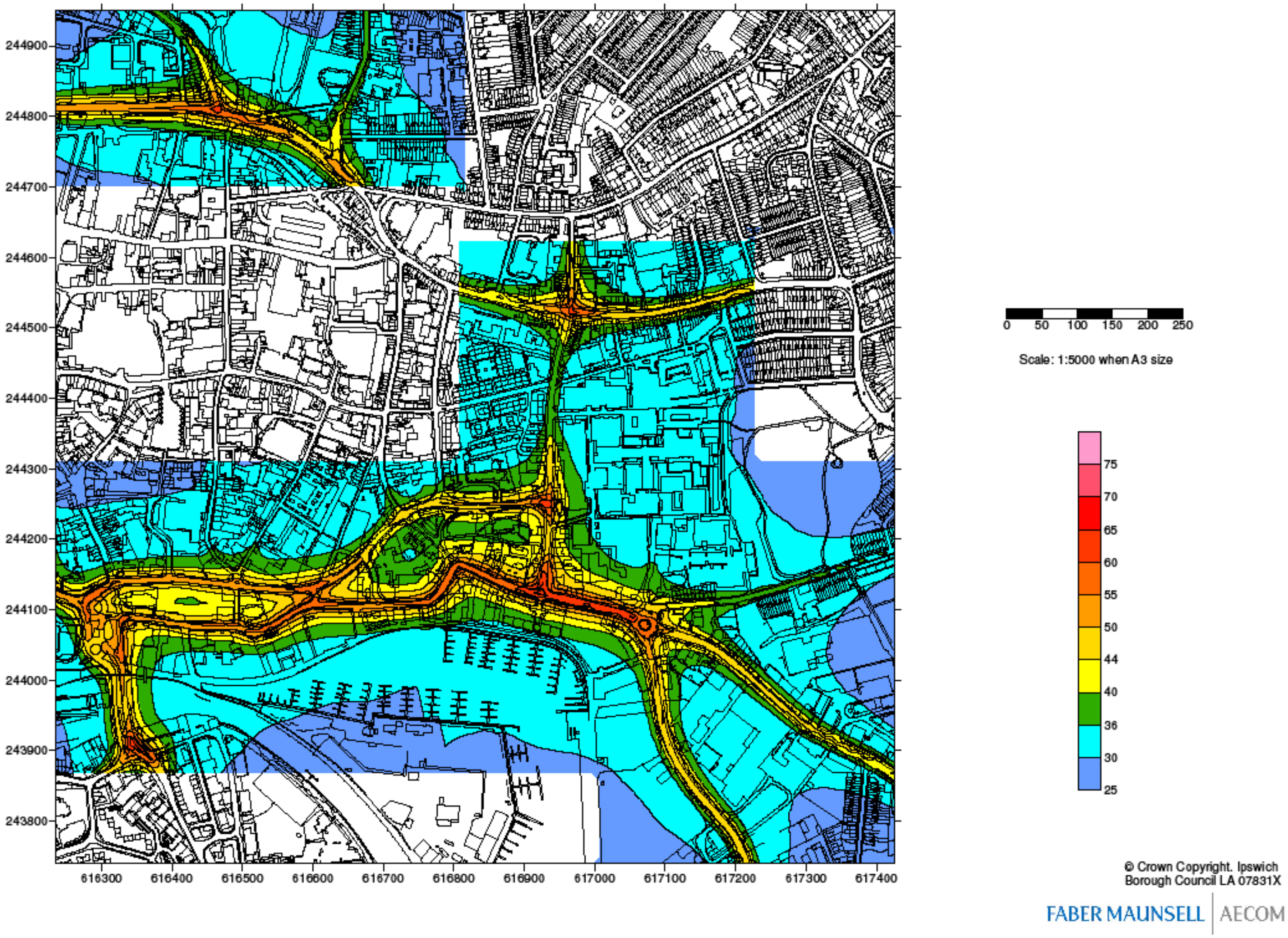
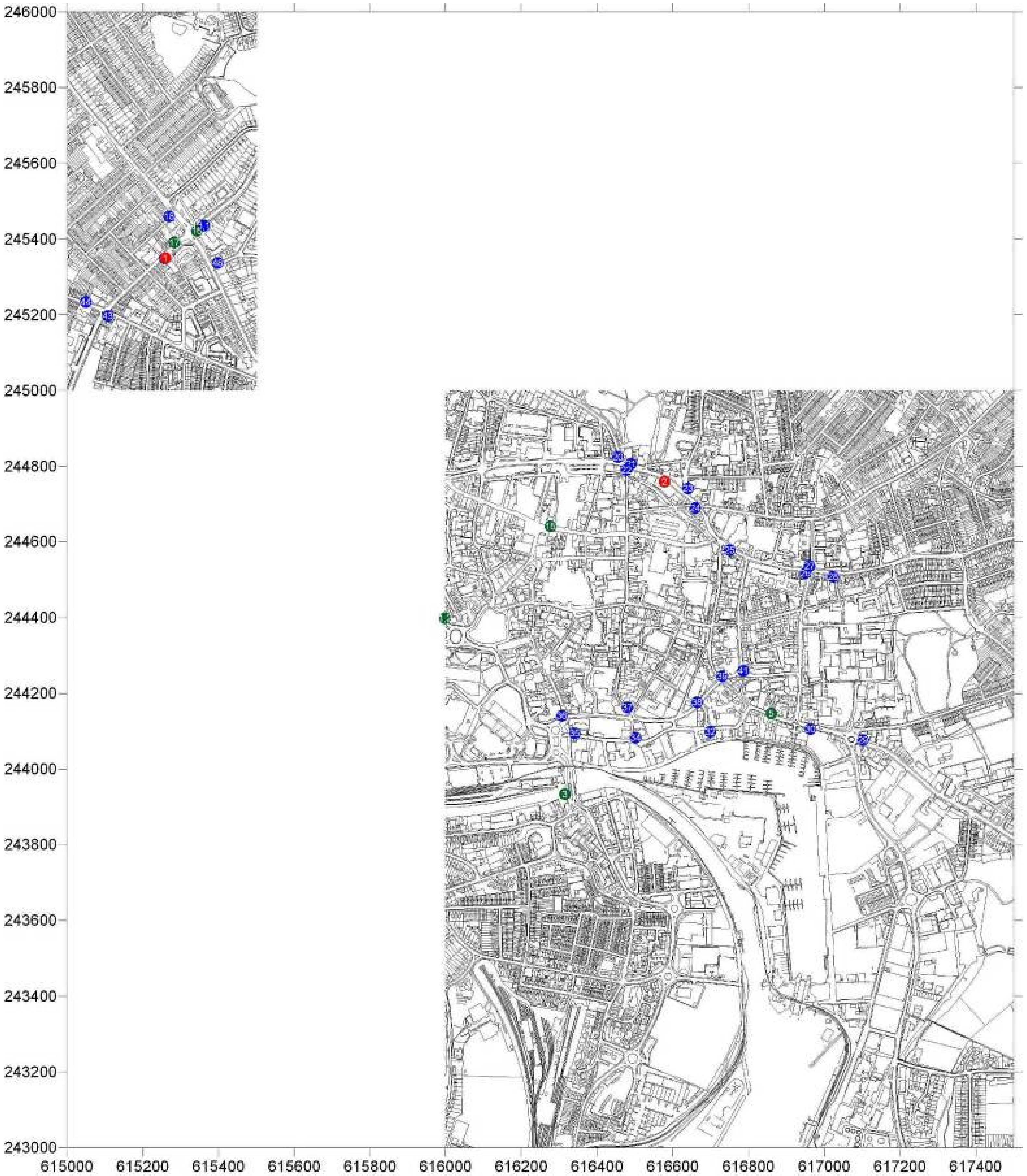
Figure 3: AQMA 2 (top) and AQMA 3 (below) with Annual Mean NO_2 (µg/m^3) Concentrations at the Norwich Road/Valley Road Junction 2005



Appendix C: Monitoring Locations

Figure 4: Continuous Monitor and Diffusion Tube Locations



Ipswich Further Assessment

Location of Continuous Monitors (Red), Diffusion Tubes (Green) and New Diffusion Tube Locations (Blue) Within or Close to Study Area

Client:
Ipswich Borough Council

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Appendix D: AAQuIRE 6.1.1 Modelling Software

The AAQuIRE 6.1.1 software is a system that predicts Ambient Air Quality in Regional Environments and comprises a regional air quality model and statistical package.

AAQuIRE was developed by Faber Maunsell Ltd to meet three requirements in predictive air quality studies. The first requirement was an immediate need for a system that produced results that could be interpreted easily by non-air quality specialists to allow for proper informed inclusion of air quality issues in wider fora, the main example being to allow consideration of air quality issues in planning processes. This was achieved by allowing results to be generated over a sufficiently large study area, and at an appropriate resolution, for the issue being considered. The results are also presented in a relevant format, which is normally a statistic directly comparable with an air quality criterion or set of measured data being considered. For example, the AQS PM_{10} 24-hour objective level of 50 µg/m^3 is expressed as a 90th percentile of hourly means. AAQuIRE can also produce results directly comparable with all ambient air quality standards.

The second requirement was for a system to be based, initially, on existing and well-accepted and validated dispersion models. This has two advantages. The primary one is that it avoids the need to prove a new model against the accepted models and therefore enhances acceptability. The second advantage is that when appropriate new models are developed they can be included in AAQuIRE and be compared directly with the existing models, and sets of measured data, using the most appropriate statistics.

The final primary requirement for AAQuIRE was a consideration of quality assurance and control. An important aspect of modelling is proper record keeping ensuring repeatability of results. This is achieved within AAQuIRE by a set of log files, which record all aspects of a study and allow model runs to be easily repeated.

The ways in which AAQuIRE and the models currently available within it operate are discussed below.

The operation of AAQuIRE can be divided into five main stages. These are:
- the preparation of the input data;
- the generation of model input files;
- dispersion modelling;
- the statistical treatment of dispersion modelling results; and
- the presentation of results.

The first step in operating AAQuIRE is to prepare the input data. The following data are needed for the year and pollutant to be modelled:
- meteorological data expressed as occurrence frequencies for specified combinations of wind speed, direction, stability and boundary layer height;
- road system layout and associated traffic data within and immediately surrounding the study area;
- industrial stack locations and parameters; and
- a grid of model prediction locations (receptors).

The modelling is always carried out to give annual average results from which appropriate shorter period concentrations can be derived.

The second stage is the generation of the model input files required for the study. All the data collated in the first stage can be easily input into AAQuIRE, using the worksheets, drop down boxes and click boxes in the Data Manager section of the software. Data from spreadsheets can be easily pasted into worksheets, so that any complicated procedures required for data manipulation can be achieved before entry into AAQuIRE. Several diurnal and seasonal profiles can be defined for each separate source. The relevant meteorological data can also be specified at this stage.

The third stage is executing the models. The study area will usually be divided up into manageable grids and run separately using the Run Manager in AAQuIRE. The results from the separate files can be combined at a later stage. Pollutant concentrations are determined for each receptor point and each meteorological category and are subsequently combined.

The fourth stage is the statistical processing of the raw dispersion results to produce results in the relevant averaging period. Traffic sources and industrial sources can be combined at this stage provided the same receptor grid has been used for both. Background concentrations should also be incorporated at this stage.

The final stage is presentation of results. Currently the result files from the statistical interpretation are formatted to be used directly by the Surfer package produced by Golden Software Inc. Alternative formats are available to permit interfacing with other software packages. On previous projects the results have been imported into a GIS (e.g. ArcView and Map Info).

Currently AAQuIRE uses the CALINE4 model for the dispersion of road-traffic emissions and AERMOD for all other sources. Both these models are fully validated and have been extensively used worldwide. These are relatively complex models designed for detailed studies of local areas, which are used within AAQuIRE for both local and larger scale studies. This is considered necessary because of the frequent importance of local effects, such as traffic junctions, in properly assessing ‘regional’ effects.

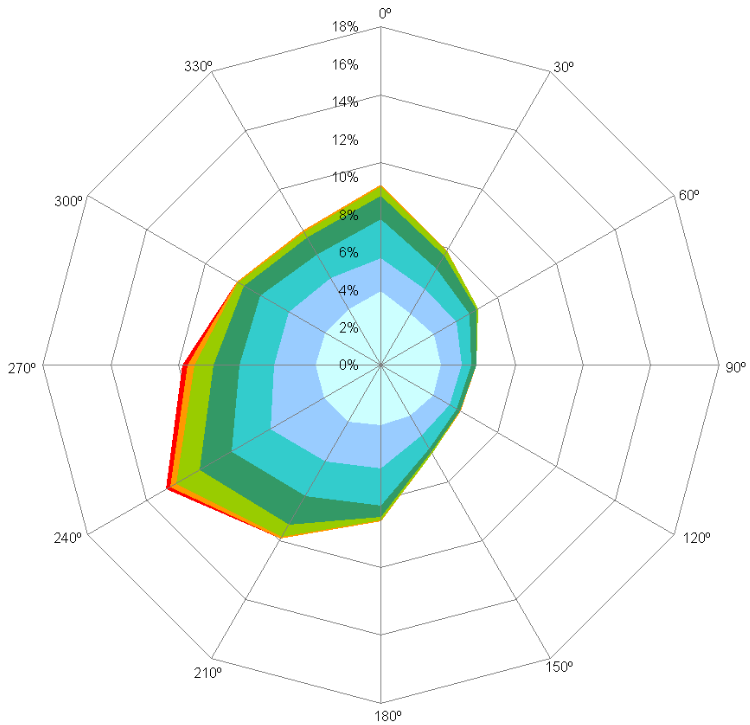
Appendix E: Meteorological Data

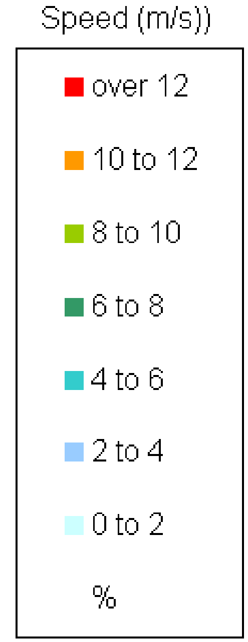
Meteorological data measured at Wattisham in 2007 were used for this modelling study. The data consisted of the frequencies of occurrence of wind speed 0 – 2, 2 – 4, 4 – 6, 6 – 10, 10+ m/s), wind direction (30° resolution) and Pasquill stability classes. Pasquill stability classes categorise the stability of the atmosphere from A (very unstable) through D (neutral) to G (very stable).

The meteorological data were used to produce a wind/stability rose. The rose consisted of 12 wind direction sectors of 30°, 5 wind speed bands and 3 stability classes. Calm winds were distributed evenly between the wind direction sectors in the 1 m/s category. The stability classes used were C, D and E where all of the unstable classes (A-C) were grouped in C and all of the stable classes (E-G) in E. The windrose is shown in the figure below.

Interpretation of Windroses

Each windrose bar is designed to illustrate three wind properties: the direction the wind is coming from; the relative number of hours the wind is from this direction; and the magnitude of the wind speeds.





Appendix F: Traffic Data

Table 18: Traffic Data Used in the Assessment

Road	AADT		% HGV		Average Speed (kph)
	2007	2010	2007	2010	
1 Norwich Road N	24616	25355	6.7	6.7	43
2 Norwich Road South	15191	15647	6.9	6.9	40
3 Valley Road	16108	16592	5.0	5.0	44
4 Chevallier Street	15561	16028	5.4	5.4	36
5 Fonnereau Road	4490	4625	1.8	1.8	25
6 Crown Street	16049	16530	8.0	8.0	36
7 St Margarets Street	14101	14524	7.6	7.6	22
8 Bolton Lane	5648	5818	4.9	4.9	27
9 St Margarets/St Helens Street One Way	11452	11796	8.3	8.3	25
10 St Helens Street Two Way	8613	8872	8.3	8.3	25
11 Argyle Street	12874	13261	5.2	5.2	10
12 St Helens St East	13354	13754	7.6	7.6	17
13 Grimwade St North	8685	8946	4.4	4.4	22
14 Star Lane East	13087	13480	6.4	6.4	28
15 Grimwade Street South	24642	25381	5.4	5.4	17
16 Grimwade St SW	6723	6925	6.2	6.2	17
17 Grimwade St SE	17919	18456	5.0	5.0	17
18 Fore St Central	19380	19961	6.3	6.3	20
19 Fore St West	26103	26886	6.3	6.3	20
20 Fore St East	33809	34824	6.6	6.6	20
21 Duke St	12209	12575	11.1	11.1	36
22 Fore Hamlet	15613	16082	5.1	5.1	28
23 College Street to Bridge Street	5920	6097	6.4	6.4	8
24 Bridge Street Rbt C	5204	5360	6.8	6.8	8
25 Back Hamlet	8420	8673	2.6	2.6	28
26 Long Street	2196	2262	1.9	1.9	8
27 Greyfriars Rbt to Grafton Rbt	9584	9872	5.5	5.5	8
28 Greyfriars rbt E	15615	16083	5.3	5.3	8
29 Greyfriars rbt A	24480	25214	4.7	4.7	8
30 Fore St rbt A	16923	17431	6.7	6.7	8
31 Fore St rbt B	18248	18796	6.1	6.1	8
32 Fore St rbt C	17668	18198	6.2	6.2	8
33 Fore St rbt D	18835	19400	6.2	6.2	8
34 Bridge Street Rbt D	17762	18295	5.5	5.5	8
35 Bridge Street Rbt E	20273	20882	5.3	5.3	8
36 Bridge Street Rbt A	2614	2692	4.3	4.3	8
37 Bridge Street Rbt B	12198	12564	5.3	5.3	8
38 Star Lane Fore St to Waterworks St	18357	18908	5.2	5.2	28
39 Star Ln East Lower Orwell St to Slade St	17315	17834	4.4	4.4	28
40 Fore St. North to Orwell Pl	8595	8853	18.8	18.8	20
41 Key St East	25608	26376	5.2	5.2	28
42 Star Ln Slade St to Fore St	20059	20661	6.0	6.0	28
43 Slade St	1778	1831	2.8	2.8	8
44 Key St Central	23831	24545	5.1	5.1	28
45 Star Ln Central	18822	19387	4.5	4.5	28
46 Foundation St South	467	481	2.6	2.6	24

Road	AADT		% HGV		Average Speed (kph)
	2007	2010	2007	2010	
47 College St East	20743	21366	5.2	5.2	28
48 College St to Bridge St Dock St	6407	6599	5.1	5.1	28
49 College St to greyfriars rbt	8416	8669	4.3	4.3	28
50 Greyfriars rbt to Bridge St Dock St	7547	7773	5.9	5.9	8
51 Bridge St East to Dock St	13954	14373	5.5	5.5	16
52 Bridge St Dock St Vernon St	8928	9196	7.4	7.4	16
53 Vernon St	19139	19713	7.6	7.6	16
54 Burrel Road	1260	1297	17.8	17.8	16
55 Burrell Rd Stoke St	14913	15360	4.2	4.2	16
56 Bridge St D heading to Stoke St	6494	6689	2.7	2.7	16
57 Bridge St West (South)	16111	16594	5.0	5.0	16
58 Grafton Way to Greyfriars rbt	20273	20882	4.6	4.6	8
59 Greyfriars Road	21385	22027	3.4	3.4	16
60 Greyfriars Rd East	8865	9131	3.5	3.5	8
61 Greyfriars Rd West	12520	12896	3.4	3.4	8
62 Greyfriars rbt B	3664	3774	4.1	4.1	8
63 Greyfriars rbt C	8416	8669	4.3	4.3	8
64 Star Ln West	20815	21440	4.8	4.8	28
65 Lower Brook St	1390	1432	3.3	3.3	20
66 Foundation St	2578	2655	2.9	2.9	24
67 Star Ln to Lower Brook St and Foundation St	2258	2326	3.2	3.2	28
68 Lower Brook St and Foundation St to Star Ln	1015	1045	2.6	2.6	24
69 Greyfriars rbt D	26522	27318	4.5	4.5	8
70 Star Ln West right of St peters st	17965	18504	4.7	4.7	28
71 St Peters St	3555	3662	1.5	1.5	20
72 Greyfriars rbt South to Bridge St rbt	3664	3774	4.1	4.1	8
73 Grafton Way	14531	14967	5.6	5.6	28
74 Key St West	24837	25582	5.2	5.2	28
75 Lower Orwell Street (Star Lane to Key Street)	1007	1037	7.7	7.7	20
76 Vernon Street One Way North	10211	10518	7.8	7.8	20
77 Stoke Street to Bridge Street	7159	7374	17.8	17.8	16
78 Vernon Street ro Bridge Street	8952	9220	3.2	3.2	20
79 Bridge St West (Central)	15141	15595	6.4	6.4	16
80 Bridge St West (North)	14171	14596	5.0	5.0	16
81 Grafton Way (one way east)	7715	7946	5.0	5.0	8
82 Grafton Way (one way west)	6816	7020	5.0	5.0	8
83 St Margarets Plain	20321	20931	6.7	6.7	13
84 Dove Street	479	494	3.3	3.3	20
85 Northgate Street	1651	1701	47.5	47.5	20
86 Northgate Street (North)	2331	2401	34.4	34.4	20
87 Fore St North to Star Ln	495	510	3.5	3.5	20

Please note that where additional traffic speed data were provided, such as speeds at junctions, these were included in the model.

Appendix G: Contour Plots

Figure 5: Area 1 – Chevallier Street NO_2 Contour Plot 2007

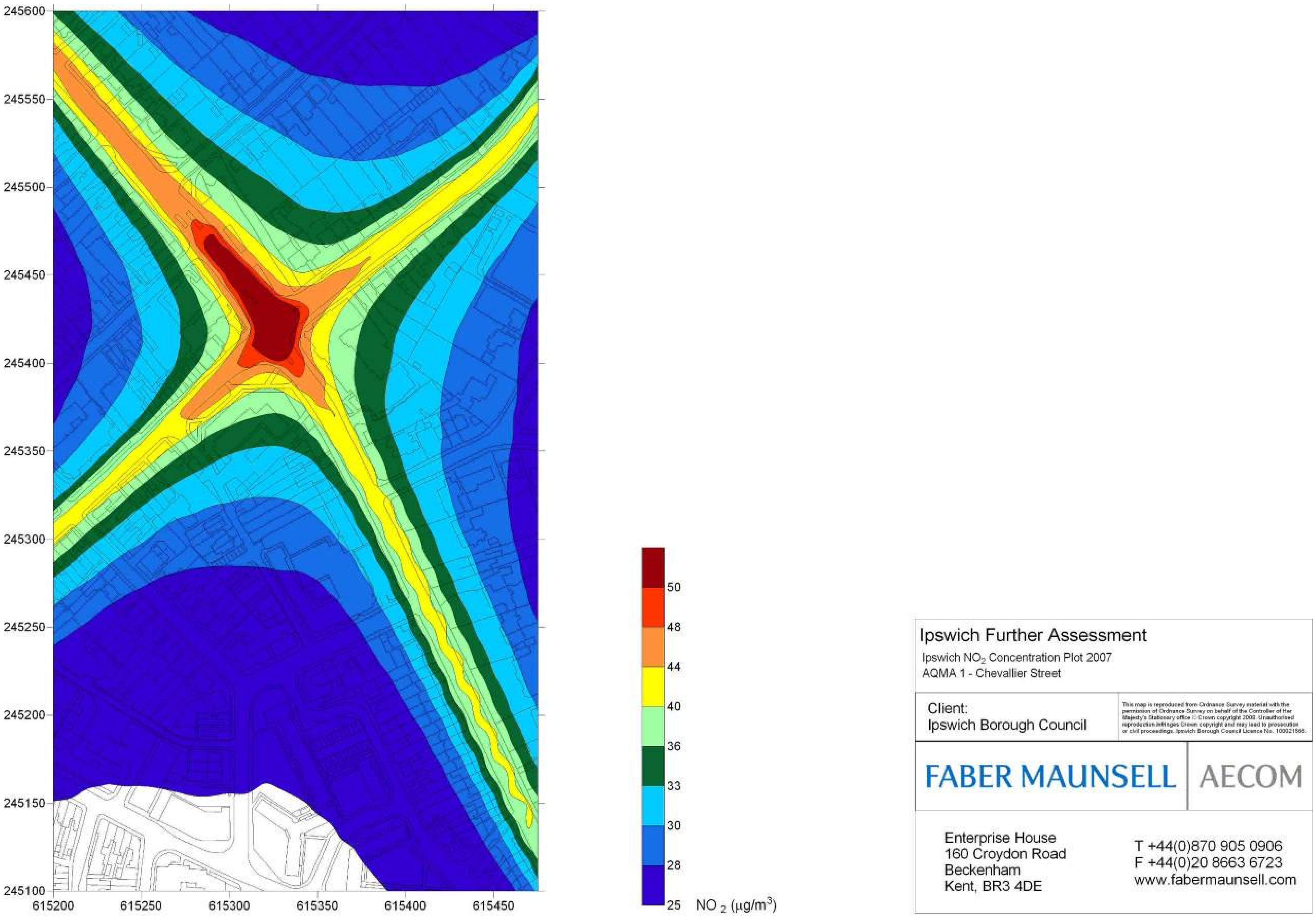
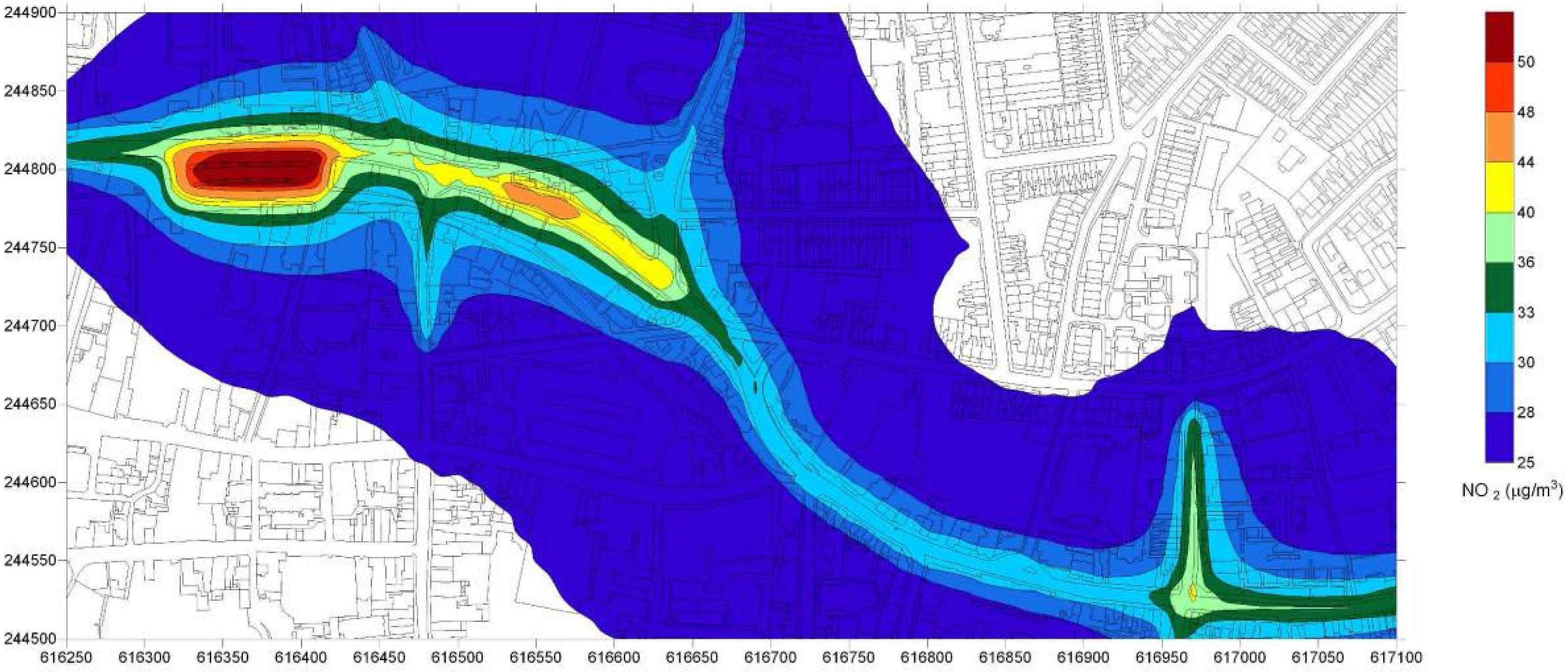


Figure 6: Area 2 – Crown Street NO_2 Contour Plot 2007



Ipswich Further Assessment

Ipswich NO_2 Concentration Plot 2007

AQMA 2 - Crown Street

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Ipswich Borough Council

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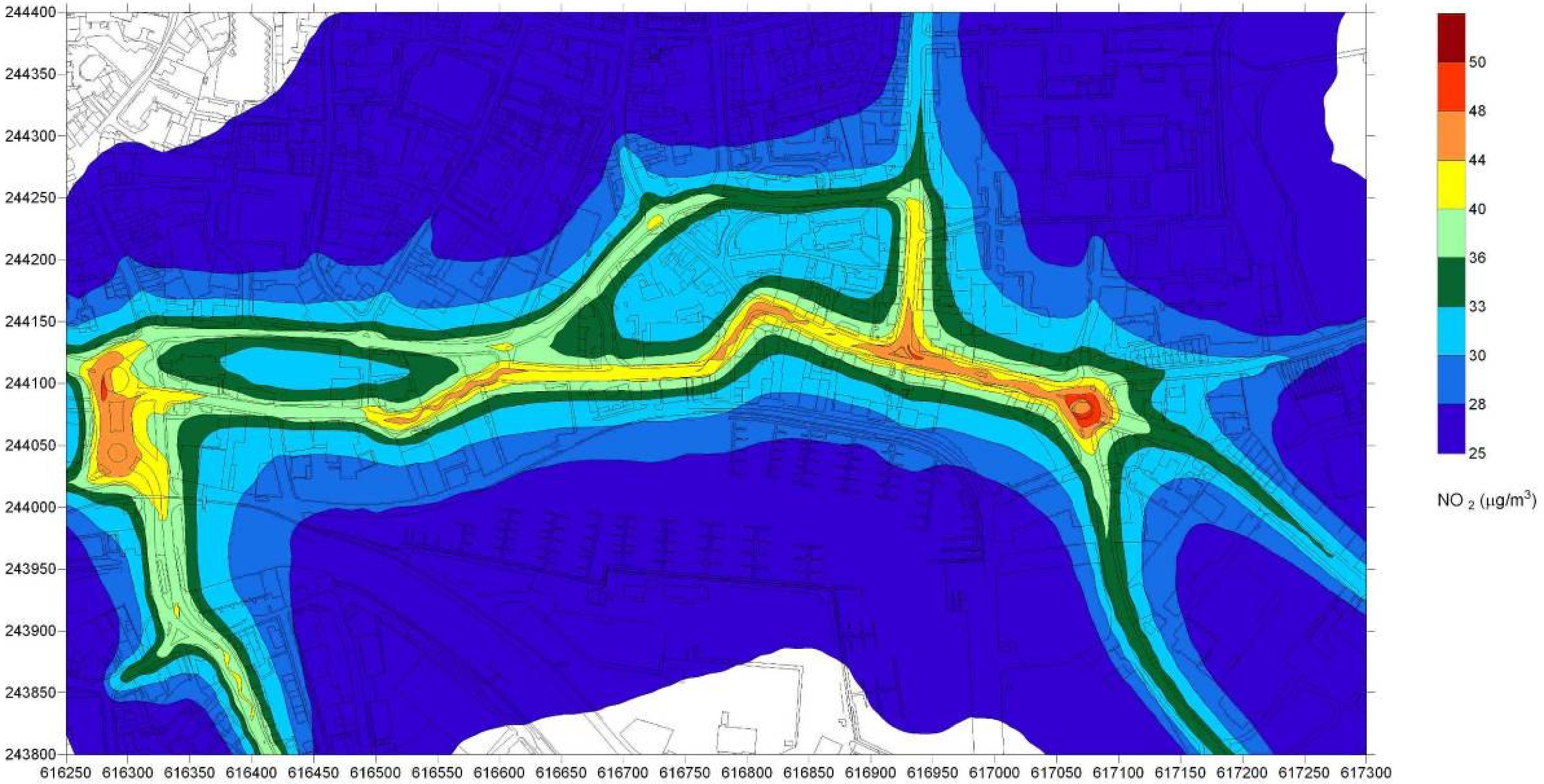
Figure 7: Area 3 – Star Lane Gyratory NO_2 Contour Plot 2007



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AQMA 3- Star Lane Gyratory

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Figure 8: Area 1 – Chevallier Street NO_2 Contour Plot 2010

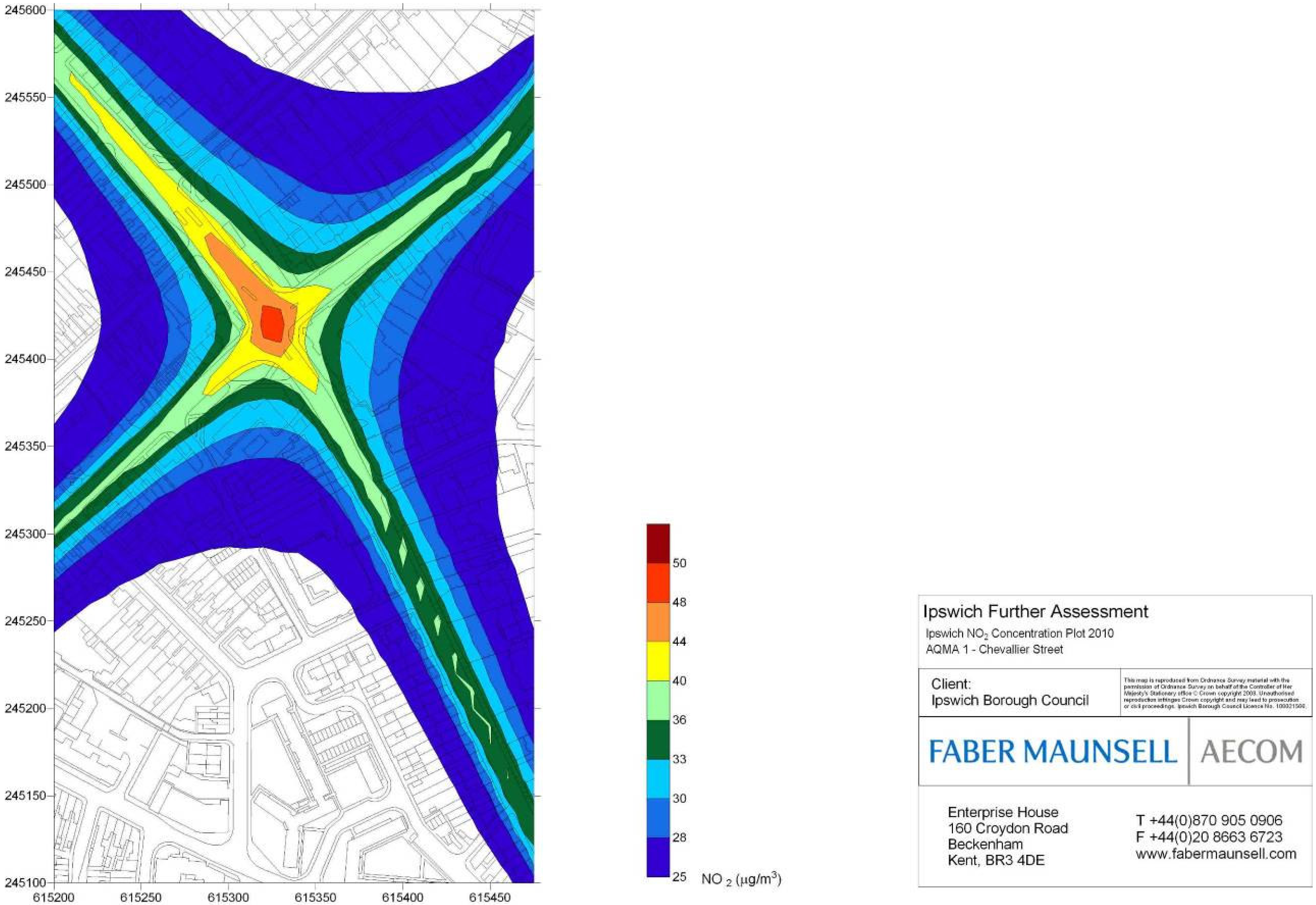
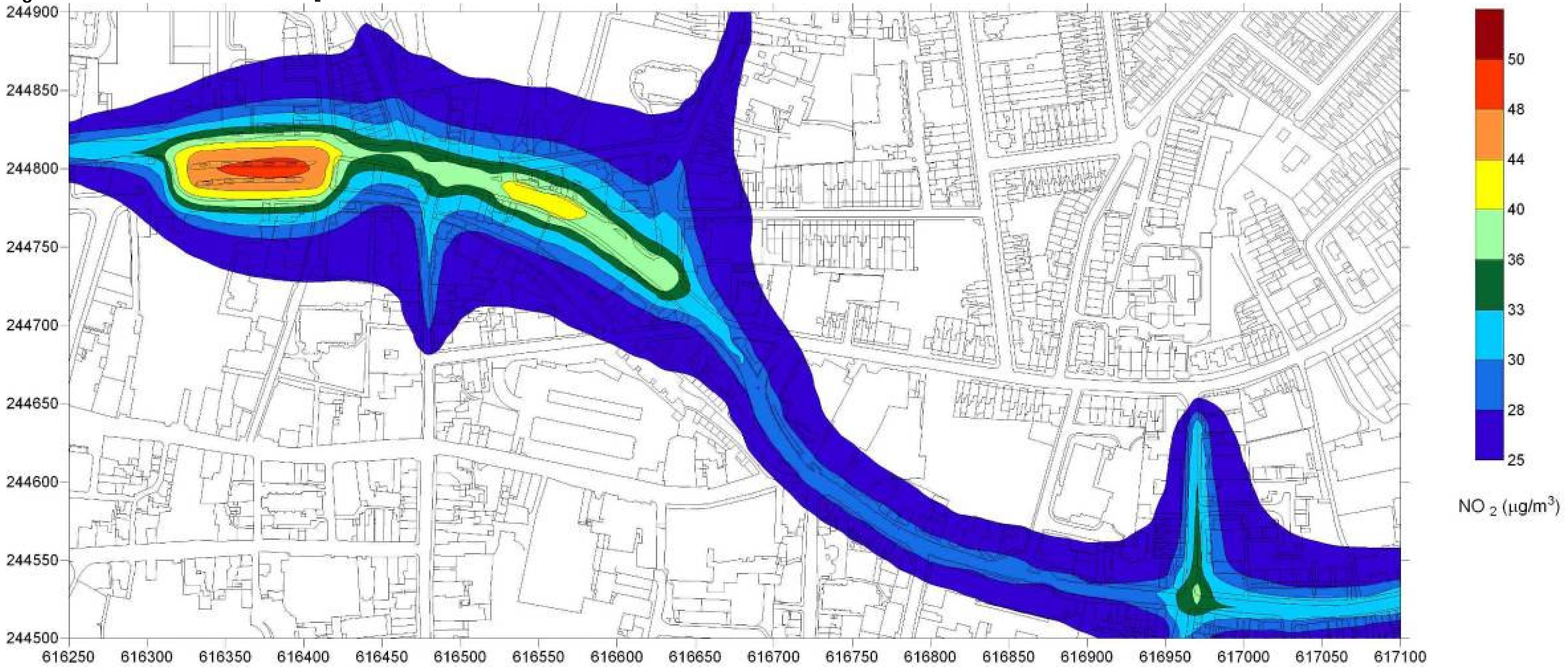


Figure 9: Area 2 – Crown Street NO_2 Contour Plot 2010



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Ipswich NO_2 Concentration Plot 2010
AQMA 2 - Crown Street

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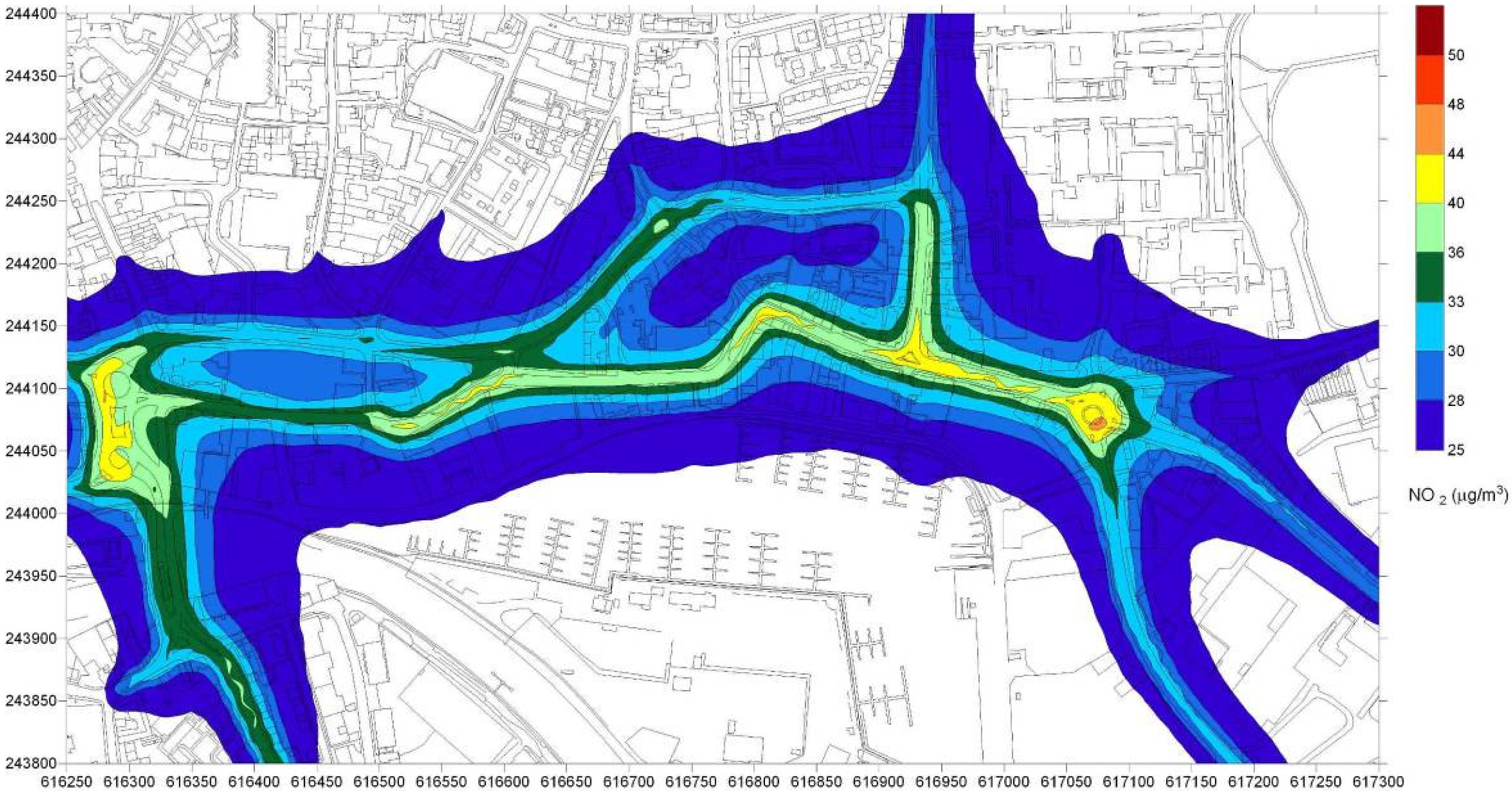
Figure 10: Area 3 – Star Lane Gyratory NO_2 Contour Plot 2010



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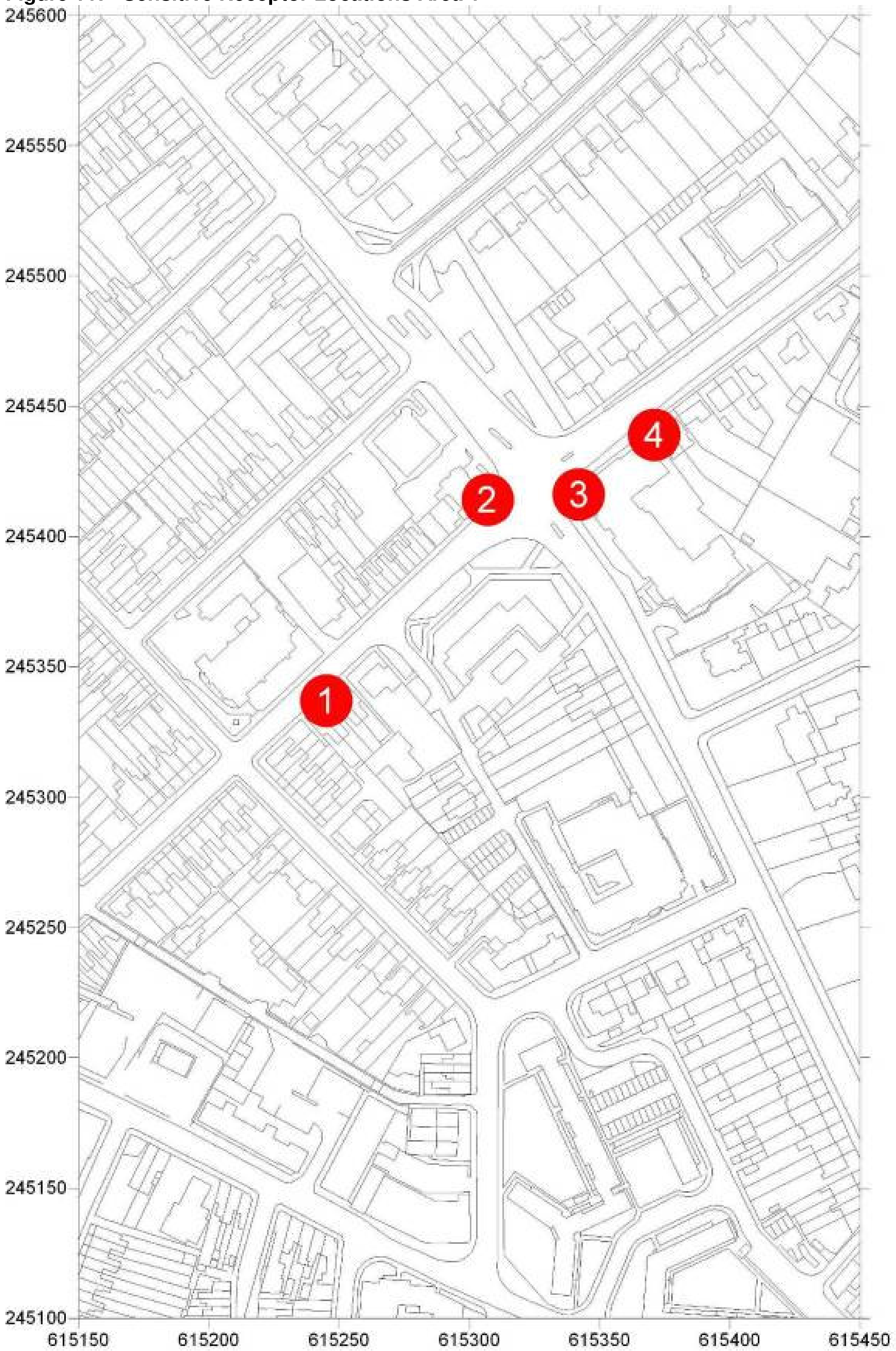
Appendix H: Receptor Locations

Table 19: Receptor Grid References

Receptor Number	Grid Reference	
	x	y
1	615245	245337
2	615307	245414
3	615342	245416
4	615371	245439
5	616373	244778
6	616422	244805
7	616434	244819
8	616536	244778
9	616536	244791
10	616550	244788
11	616969	244517
12	616337	244084
13	616410	243822
14	616676	244111
15	616810	244156
16	616927	244205
17	616939	244125
18	617048	244081
19	617092	244083

Figure 11: Sensitive Receptor Locations Area 1



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Receptor Locations - Area 1

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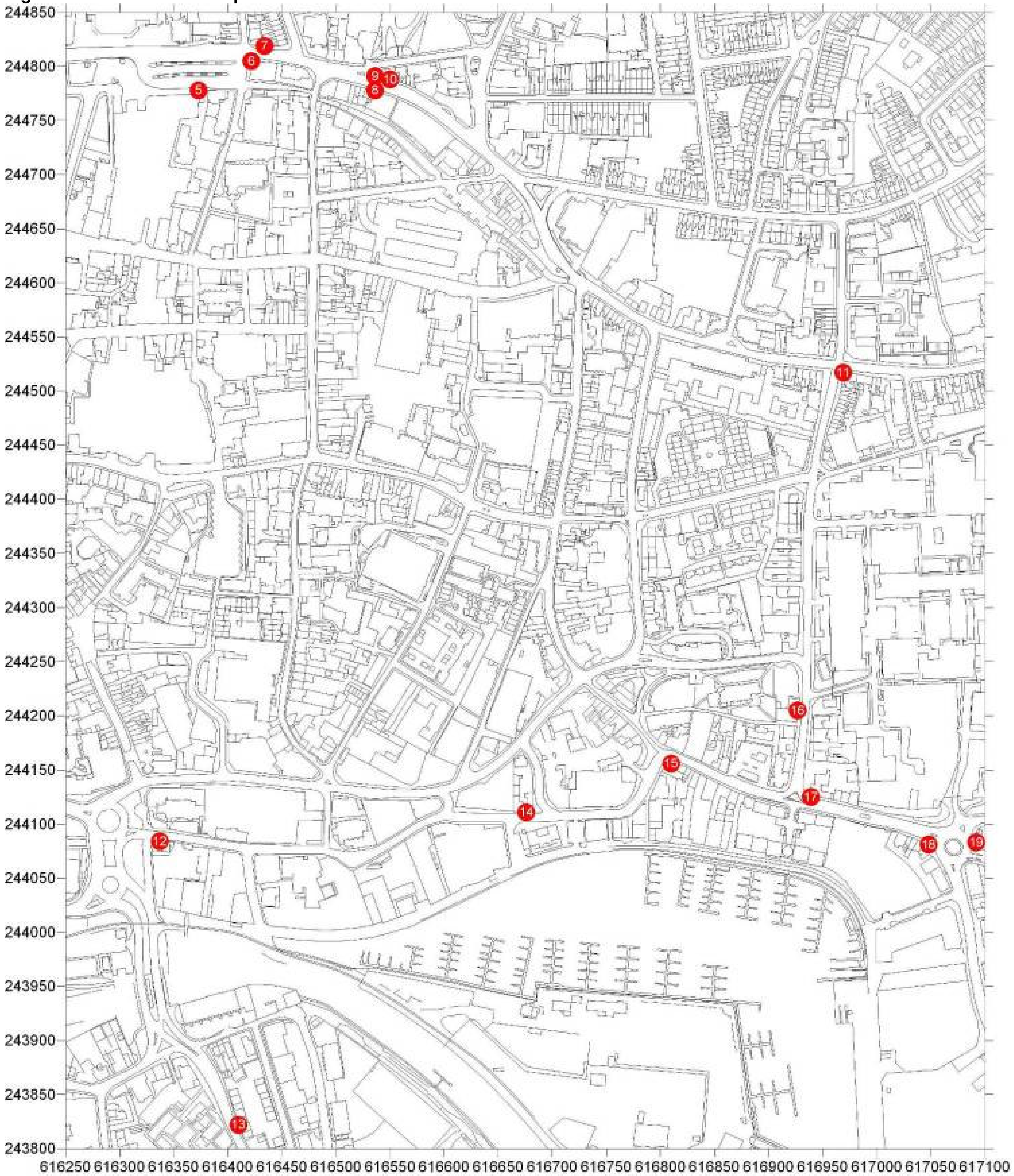
Figure 12: Sensitive Receptor Locations Areas 2 and 3



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Receptor Locations - Areas 2 and 3

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