

DETAILED AIR QUALITY MODELLING STUDY

FINAL REPORT

EAST HERTFORDSHIRE COUNCIL

February 2005

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TABLE OF CONTENTS

1. Introduction.....	2
2. Literature Review.....	4
2.1. Overview of Recent Air Quality Legislation and Policy.....	4
2.2. National Air Quality Objectives	4
2.3. The Phased Approach to Review and Assessment	4
2.4. East Hertfordshire Council's Updating and Screening Assessment	5
3. Nitrogen Dioxide.....	7
3.1. National Air Quality Objectives	7
3.2. UK Emissions	7
3.3. Health Impacts.....	7
3.4. Atmospheric Chemistry of NO _x	8
3.5. Local NO ₂ Monitoring.....	8
4. Modelling Methodology.....	13
4.1. AAQuIRE.....	13
4.2. Traffic Data and Emission Factors.....	13
4.3. Background Concentrations	14
4.4. Conversion of NO _x TO NO ₂	14
4.5. Meteorological Data.....	15
4.6. Modelling Errors	15
4.7. Model Verification	15
5. Results	17
5.1. Model Results.....	17
5.2. Model Verification and Errors	17
6. Summary and Conclusions.....	21
7. References	23
Appendix A Model Results	24
Appendix B UK National Air Quality Objectives.....	29
Appendix C AAQuIRE Description.....	32
Appendix D Traffic Data	35
Appendix E Meteorological Data	37
Table 1 Calculation of Bias Correction Factors.....	9
Table 2 Diffusion Tube Results	9
Table 3 Calculation of Short-Term Monitoring Adjustment Factors.....	10
Table 4 Continuous Analyser Results.....	11
Table 5 Ratio of Emissions from Cold Engines Relative to Hot Engines.....	14
Table 6 Background Concentrations	14
Table 7 NO _x /NO ₂ Relationship (NO _x expressed as NO ₂ equivalent)	15
Table 8 Model Verification	18
Table 9 UK Air Quality Objectives set in Regulations	30
Table 10 UK Air Quality Objectives not set in Regulations	31
Table 11 Traffic Data, Bishop's Stortford.....	36
Table 12 Traffic Data, Ware	36
Figure 1 National Trend of Oxides of Nitrogen Emissions (MT/yr) (1970 – 2001).....	7
Figure 2 The Diurnal Variations in Traffic Flows in Bishop's Stortford and Ware	14
Figure 3 Annual Mean NO ₂ Concentrations (µg/m ³) and Monitor Locations, Bishop's Stortford (2004) Error! Bookmark not defined.	
Figure 4 Annual Mean NO ₂ Concentrations (µg/m ³), Bishop's Stortford (2005).....	Error!
Bookmark not defined.	
Figure 5 Annual Mean NO ₂ Concentrations (µg/m ³) and Monitor Locations, Ware (2004) Error! Bookmark not defined.	
Figure 6 Annual Mean NO ₂ Concentrations (µg/m ³), Ware (2005).....	Error! Bookmark not defined.
Figure 7 Wind Rose and Data for Stansted, 1995	39

1 INTRODUCTION



1. Introduction

FaberMaunsell was commissioned by East Hertfordshire Council to undertake a detailed air quality modelling study. This assessment forms part of the second round of the local authority review and assessment process.

The aim of this study was to determine whether there are any locations in the East Hertfordshire area that are likely to fail to meet the UK National Air Quality Objectives. The first round of the review and assessment process identified that two pollutants, nitrogen dioxide (NO₂) and particulate matter (PM₁₀), were of concern and consequently, an Air Quality Management Area (AQMA) was designated with respect to PM₁₀^[Ref 1]. The AQMA has since been revoked in the light of new monitoring and modelling data; however, NO₂ pollution continues to be a potential problem. This assessment investigates NO₂ pollution at two locations in the East Hertfordshire area.

2 LITERATURE REVIEW



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)^[Ref 2] and the Air Quality (England) (Amendment) Regulations 2002^[Ref 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 Objectives

The NAQS identifies eight 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 seven pollutants that are associated with local air quality. These objectives aim to reduce the health impacts of the pollutants to negligible levels.

The standards stated in the Air Quality Regulations are listed in Appendix B. The new and revised objectives for benzene, carbon monoxide and particulate matter (PM₁₀), as detailed in the Air Quality (England)(Amendment) Regulations 2002, are included.

2.3. The Phased Approach to Review and Assessment

The second round of the review and assessment process has been split into two phases: an Updating and Screening Assessment, and a Detailed Assessment.

The first phase, the Updating and Screening Assessment, has been designed to review the changes in air quality issues that have occurred within each local authority since the first round of review and assessment. Therefore, it should cover:

- new monitoring data
- new objectives
- new sources of pollution
- significant changes to existing sources of pollution.

These changes are assessed using appropriate screening methods.

The Updating and Screening Assessment also re-examines locations and sources, e.g. road junctions, bus stations, domestic burning, fugitive sources, etc., that have been highlighted as issues during the previous round of review and assessment.

Where the Updating and Screening Assessment has identified a risk that an air quality objective may be exceeded, 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.

2.4. East Hertfordshire Council's Updating and Screening Assessment

East Hertfordshire Council completed their Updating and Screening Assessment in 2004 ^[Ref 4]. This study concluded that no further assessments were required for carbon monoxide, 1,3-butadiene, lead, benzene, sulphur dioxide and particulate matter (PM₁₀). In particular, the report confirmed the recommendation of the previous Stage 4 report to revoke the AQMA declared with respect to PM₁₀. However, the Updating and Screening Assessment detailed the results of a diffusion tube survey conducted in 2002, which indicated that exceedences of the objectives relating to nitrogen dioxide (NO₂) were possible at two locations: near the junction of the London Road (A1184) with Hockerill Street (A1250) in Bishop's Stortford, and Viaduct Road (A1170) in Ware. Thus the report concluded that a detailed assessment of NO₂ pollution was necessary in these two areas.

3 NITROGEN DIOXIDE



3. Nitrogen Dioxide

3.1. National Air Quality Objectives

In an attempt to reduce ambient nitrogen dioxide (NO₂) levels, the Government and the Devolved Administrations have adopted two Air Quality Objectives to be achieved by the end of 2005:

- an annual mean concentration of 40 µg/m³ (21 ppb)
- a 1-hour mean concentration of 200 µg/m³ (105 ppb) not to be exceeded more than 18 times per year (equivalent to a 99.8th percentile).

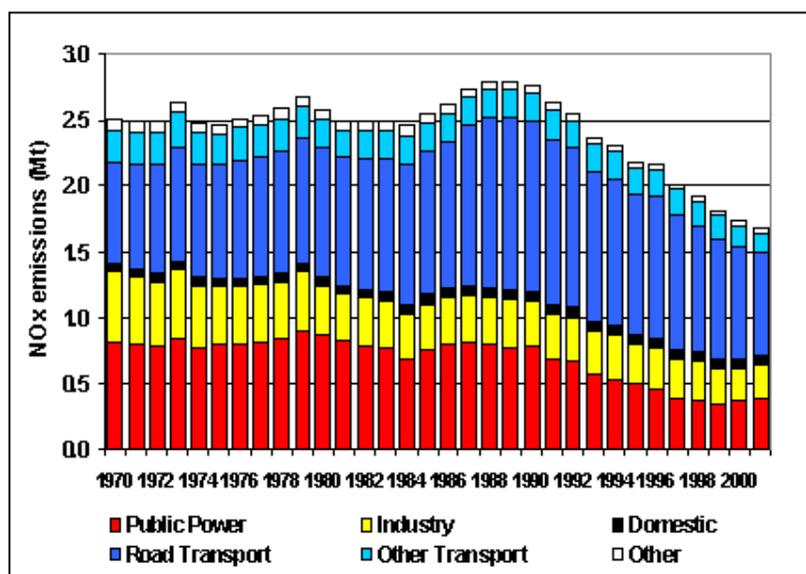
In practice, meeting the annual mean objective in 2005 is expected to be considerably more demanding than achieving the 1-hour objective. Thus, if the annual mean objective is not exceeded, it can be assumed that the 1-hour objective will be met.

3.2. UK Emissions

NO₂ is one of the members of a family of pollutants called the oxides of nitrogen (NO_x), the other member being nitric oxide (NO). A major source of NO_x is motor vehicle exhausts as it is formed as a by-product of the high-temperature combustion processes in 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 NO₂. The conversion of NO to NO₂ takes place in the atmosphere via reactions with chemically active species, such as ozone (O₃).

As shown in Figure 1, estimates for 2001 show that road transport accounts for 42% of the total UK emissions of NO_x, with the energy industry accounting for a further 29%. 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, urban traffic NO_x emissions are estimated to fall by about 20% between 2000 and 2005, and by 46% between 2000 and 2010.

Figure 1 National Trend of Oxides of Nitrogen Emissions (MT/yr) (1970 – 2001)



3.3. Health Impacts

The health effects of NO₂ exposure can be chronic and/or acute. Studies of artificial exposure have shown that the chronic effects of the upper range of possible exposure concentrations might include changes in lung structure and metabolism, and reduced resistance of the lungs to bacterial infection. No clear link has been established between these effects and exposure to

NO₂ 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. Exposure to NO₂ may also increase reactivity to natural allergens.

NO_x gases are also 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, NO_x and sulphur dioxide can significantly reduce vegetation growth rates at higher concentrations.

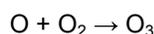
3.4. Atmospheric Chemistry of NO_x

Once released into the atmosphere, NO is oxidised to form NO₂ in a reaction with O₃ and other hydrocarbon-based oxidants. The availability of O₃ directly affects the ratio of NO to NO₂. Although motor vehicles are regarded as the primary source of NO, the diurnal variation of the NO₂ formed does not always vary in accordance with local traffic patterns. Nevertheless, measurements of NO₂ 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 ^[Ref 5] describe NO_x chemistry in the following way. In the atmosphere, the dominant oxide of nitrogen, NO, is progressively oxidised to NO₂, largely by reaction with ozone.



A consequence of this reaction is that the amount of the total NO_x emitted that is present as NO₂ is often limited by the availability of ozone. Close to NO_x sources, the fraction of NO_x present as NO₂ will generally be low. Further from the sources, in conditions of vigorous atmospheric mixing, the initial NO_x plume will be diluted with more O₃, and thus the proportion of NO₂ will be higher. The relationship between NO, NO₂ and O₃ is complicated by a photolytic reaction that occurs during daylight, whereby NO₂ is photolysed by short wavelength light (greater than 400 nm), to reform NO and O₃.



The Quality of Urban Air Research Group ^[Ref 6] add 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 NO₂ that occur during the winter months is an ongoing topic of air quality research. NO₂ levels increased nationally by around 30% between 1986 and 1991, and then decreased up until 2000. Future trends associated with NO₂ remain unclear at present.

3.5. Local NO₂ Monitoring

3.5.1. Diffusion Tube Monitoring

The Council operate a network of diffusion tubes throughout the East Hertfordshire area, four of which are in the study areas. However, before discussing the NO₂ concentrations measured at these sites, it is important to consider the adjustments made to diffusion tube results.

3.5.1.1 Bias Correction Factors

Diffusion tube results often differ from those generated by a more sophisticated monitoring technique such as a continuous analyser. Defra's Technical Guidance Note LAQM.TG(03) ^[Ref 7] states that an adjustment should be made to account for these differences. This adjustment takes the form of a bias correction factor, which is derived by comparing the NO₂ concentrations measured by a continuous analyser and co-located diffusion tubes. East Hertfordshire Council have co-located one diffusion tube (EHDC13) with a continuous analyser at Edens Mount in Sawbridgeworth (EH2). The bias correction factor for 2002 was calculated by netcen; the factors for 2003 and 2004 were calculated by FaberMaunsell, see Table 1.

Table 1 Calculation of Bias Correction Factors

Year	Annual Mean NO ₂ Concentration ^b /µg/m ³		Bias Correction Factor
	EH2 (continuous analyser)	EHDC13 (co-located diffusion tube)	
2003	24.1	23.4	1.03
2004	20.0 ^a	24.8	0.80

Notes: ^a – these data have not yet been fully ratified; ^b – the 2003 annual mean concentrations do not include data for May and the 2004 annual mean concentrations do not include data for April or December.

When calculating bias correction factors, it is important to take account of the data capture during the year in question. In the case of 2003, the diffusion tube measurement for May is not available; therefore this period of data has also been removed from the continuous analyser dataset. The resulting correction factor, 1.03, when applied to the diffusion tube results, increases the annual mean concentrations by 3%. In the case of 2004, diffusion tube data were not available for April and December. (Note that the data for December were not available as the tube had not yet been analysed). After removing the corresponding periods of data from the continuous analyser dataset, a correction factor of 0.80 was derived, which reduces the diffusion tube measurements by 20%.

Note that the continuous analyser data for 2004 are provisional. When the dataset has been fully ratified, and the diffusion tube result for December is available, it is likely that the bias correction factor, and consequently the diffusion tube results, for 2004 will change. The new data will be analysed in a forthcoming progress report.

3.5.1.2 Diffusion Tube Results

Details of the four diffusion tubes located in the study areas are presented in Table 2 and Figures 3 and 5 in Appendix A. The annual mean concentrations measured in 2002, 2003 and 2004 are listed in the table. Note that the 2004 results are preliminary, as discussed in the previous section.

Table 2 Diffusion Tube Results

Site Ref	Site Type	Location	Grid Ref	Annual Mean NO ₂ Concentration ^a /µg/m ³		
				2002	2003	2004 ^b
EHDC12	KS	Hockerill St, Bishop's Stortford	549154, 221242	28.2	31.3	27.6
EHDC18	KS	Stansted Rd, Bishop's Stortford	549301, 221314	36.1	45.7	34.0
EHDC19	KS	London Rd, Bishop's Stortford	549247, 221193	46.5	53.0	35.9
EHDC22	RS	Viaduct Rd, Ware	536099, 214091	44.5	45.2	34.1

Notes: KS – kerbside; RS – roadside; ^a – all measurements have been adjusted for bias; ^b – the 2004 results are preliminary.

The 2002 results were presented in the previous Updating and Screening Assessment (USA) ^[Ref 4]. It can be seen that the annual mean NO₂ concentrations measured at EHDC19 and EHDC22 are above the objective of 40 µg/m³. As sensitive receptors are located at these sites, the USA concluded that a detailed assessment was required.

The 2003 results confirm that the two areas identified in the USA are of concern, as concentrations continue to exceed the annual mean objective. Furthermore, the NO₂ concentrations measured at EH18 increased in 2003 to greater than 40 µg/m³.

The 2004 results suggest that there has been an improvement in air quality, particularly at sites EHDC18, EHDC19 and EHDC22, where the annual mean NO₂ concentrations have dropped to

below the air quality objective. As previously stated, these results are preliminary, and when the full dataset is available, they will be re-analysed in a forthcoming progress report.

It should be noted that the high levels of NO₂ recorded in 2003 were possibly the result of the unusual meteorological conditions experienced that year.

3.5.2. Continuous Monitoring

The Council operate several continuous analysers in the East Hertfordshire area. There are two permanent analysers and, between August and December 2004, two temporary analysers were also in operation. These temporary analysers were installed in response to the recommendations of the previous Updating and Screening Assessment (USA) ^[Ref 4], which had identified the possibility of exceedences of the NO₂ objective at two locations in East Hertfordshire. As the temporary analysers were only in use for part of 2004, it is necessary to adjust the data in order to obtain annual mean concentrations. These adjustments are discussed in the following section.

3.5.2.1 Short-Term Monitoring Adjustment Factors

The methodology defined in Technical Guidance Note LAQM.TG(03) ^[Ref 7] was used to convert the short-term monitoring data collected at the two temporary sites into annual mean concentrations. The four AURN background sites used in the adjustment were Thurrock, Southend-on-Sea, London Brent and Northampton. Data were collected at the temporary sites between 26/08/04 and 09/12/04. The mean concentrations recorded at the four AURN sites during this period were calculated and then compared with the annual mean concentrations to derive adjustment factors. The average of these factors was then applied to the data collected at the temporary sites to determine annual mean values. Further details of these calculations are presented in Table 3.

Table 3 Calculation of Short-Term Monitoring Adjustment Factors

Site	Mean NO ₂ Concentration/µg/m ³		Adjustment Factor
	26/08/04 to 09/12/04	01/01/04 to 31/12/04	
Thurrock	34.0	34.6	0.981
Southend-on-Sea	23.5	25.8	0.909
London Brent	30.2	31.1	0.969
Northampton	20.0	25.4	0.789
		Average Factor	0.912

The resulting adjustment factor, 0.912, produces an annual mean concentration that is about 9% lower than the average concentration recorded at the temporary sites. This effect is in agreement with the general observation that NO₂ levels peak in the winter months.

Note that the data collected at both the temporary and AURN sites have not yet been fully ratified; therefore it is likely that the adjustment factor will change. These changes will be discussed in the progress report.

3.5.2.2 Continuous Analyser Results

Details of the continuous analysers located in East Hertfordshire are listed in Table 4 and Figures 3 and 5 in Appendix A. The annual mean concentrations measured in 2003 and 2004 are presented in the table. Note that the 2004 results for sites EH4 and EH5 are preliminary, as discussed in the previous section. The 2004 results for sites EH2 and EH3 are also preliminary, as the data have not yet been fully ratified.

It can be seen that there were no exceedences of the hourly mean of 200 µg/m³ at all four sites in 2003 and 2004.

There were also no exceedences of the NO₂ annual mean objective at sites EH2 and EH3 in both 2003 and 2004. The 2004 annual mean NO₂ concentration derived for temporary site EH4 in Ware is below the objective too. This result is in general agreement with the average concentration measured at the nearby diffusion tube site EHDC22, although it should be noted that the two measurements differ by nearly 5 µg/m³. The 2004 annual mean concentration

recorded at temporary site EH5 in Bishop's Stortford exceeds the objective. This result differs to that of nearby diffusion tube EHDC19, which measured an annual mean concentration that was more than $7 \mu\text{g}/\text{m}^3$ lower. The discrepancies between continuous analyser and diffusion tube data could be the result of the preliminary nature of the data and the corrections applied, or perhaps 'local effects', such as bus stops or taxi ranks, are responsible.

Table 4 Continuous Analyser Results

Site Ref	Site Type	Location	Grid Ref	Annual Mean NO ₂ Concentration / $\mu\text{g}/\text{m}^3$		No. of Exceedences of the Hourly Mean	
				2003	2004 ^a	2003	2004 ^a
EH2	UB permanent	Edens Mount, Sawbridgeworth	549600, 215700	23.4	21.5	0	0
EH3	RS permanent	Cutforth Road, Sawbridgeworth	548250, 215400	36.0	31.1	0	0
EH4	RS temporary	Viaduct Road, Ware	536115, 214050	N/A	29.3 ^b	N/A	0
EH5	RS temporary	London Road, Bishop's Stortford	549239, 221162	N/A	43.1 ^b	N/A	0

Notes: UB – urban background; RS – roadside; ^a – the 2004 results are preliminary; ^b – these annual mean concentrations have been calculated by adjusting short-term monitoring data.

4 MODELLING METHODOLOGY



4. Modelling Methodology

4.1. AAQuIRE

The AAQuIRE 6.1.1 regional air quality model was used to predict concentrations of NO₂ in the two study areas for the base year (2004) and the future air quality objective year (2005 for NO₂).

The AAQuIRE regional dispersion model was developed by FaberMaunsell and has been used widely for the past 12 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 C.

There are 4 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 emissions from traffic on the main roads in the two study areas (near the junction of the London Road (A1184) with Hockerill Street (A1250) in Bishop's Stortford, and Viaduct Road (A1170) in Ware). Contributions from the other pollutant sources were amalgamated into the background concentration (see Section 4.3).

The modelling procedure calculated the NO₂ 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 NO₂ concentration contours.

4.2. Traffic Data and Emission Factors

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 Hertfordshire Highways. These data took the form of 12-hour or 24-hour traffic flows and the percentage of HGVs, based on traffic counts conducted in 2003 and 2004. The 2003 data were converted to 2004 (base case) data, which in turn were converted to 2005 (future case) data, using National Road Traffic Forecasts growth factors ^[Ref 8]. As vehicle speed data were not available, these were estimated.

The traffic dataset is listed in Appendix D and examples of the daily variations in traffic flows are presented in Figure 2. Note that the am peak hour (8 – 9 am) flow is normalised to 1.

Road transport represents the major source of pollution in the study areas and it was therefore imperative that the emission data were as accurate as possible. Speed-related emission factors for NO₂ were derived from the latest factors supplied on the National Atmospheric Emissions Inventory website ^[Ref 9].

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. This information was taken from the first report by the Quality of Urban Air Research Group ^[Ref 6]. The enhancement of pollutant emissions resulting from cold starts is shown in Table 5. This table summarises the results of vehicle emissions testing, which has demonstrated, for example, that a Light Duty Vehicle (LDV) with a cold catalyst will emit 1.3 times the quantity of NO_x as the same LDV once the catalyst has warmed up. It has been assumed that 20% of LDVs are running 'cold' on all the roads in the network.

Figure 2 The Diurnal Variations in Traffic Flows in Bishop's Stortford and Ware

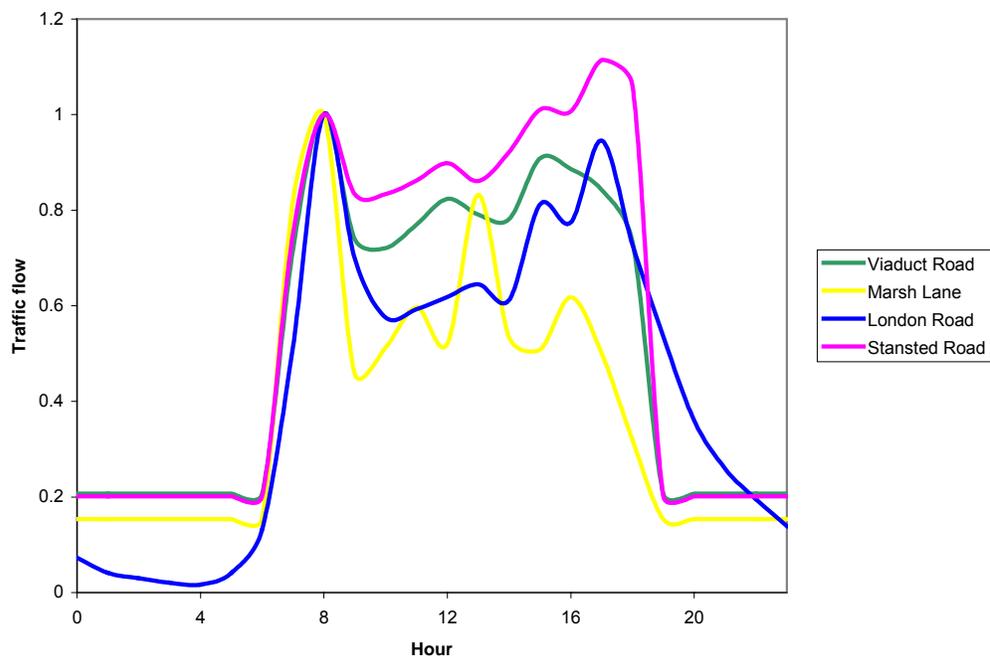


Table 5 Ratio of Emissions from Cold Engines Relative to Hot Engines

LDV Category	NO _x
Non catalyst petrol	1.0
Catalyst petrol	1.3
Diesel	1.2

4.3. 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 background concentrations of NO_x applied to the model were based on measurements made by the continuous analyser at Edens Mount in Sawbridgeworth (background site EH2) in 2004. The annual mean concentration for the future case (2005) was determined from the base case (2004) data according to the method outlined in Defra's Technical Guidance note, LAQM.TG(03)^[Ref 7]. The background concentrations used are listed in Table 6. It should be noted that the 2004 data have not yet been fully ratified.

Table 6 Background Concentrations

Year	Annual Mean NO _x Concentration /µg/m ³
2004	32.4
2005	31.4

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 NO₂, it is more appropriate to review NO₂ 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 NO₂ (see the next section).

4.4. Conversion of NO_x to NO₂

The proportion of NO₂ 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 NO₂/NO_x relationship (see Table 7) was used to convert annual average NO_x concentrations to annual average NO₂ concentrations in this study. This relationship is based on data recorded at several London sites and is a good representation of the roadside ratio of NO₂ to NO_x. The relationship was used for both the base case and future years. However, as NO_x concentrations are expected to decline in future years, NO₂ concentrations will not be limited as much by ozone. Consequently, it is possible that the future year NO₂/NO_x ratio will increase.

Table 7 NO_x/NO₂ Relationship (NO_x expressed as NO₂ equivalent)

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

It should be noted that although NO₂ and NO_x concentrations were measured at the two temporary analysers in Bishop's Stortford and Ware, a NO_x/NO₂ relationship was not derived from these data for application to the model results, as only three and a half months of data were collected. The Derwent-Middleton relationship was applied instead as it represents the changes in the NO_x/NO₂ relationship that occur throughout the year.

4.5. Meteorological Data

After consultation with the Meteorological Office, a meteorological dataset was compiled using data from the nearest suitable station: Stansted. Wind roses from the most recent years available were analysed and the most typical year (1995) was selected. The wind rose for Stansted is presented in Appendix E, along with further details of the methodology used.

4.6. 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 are the result of 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.

4.7. Model Verification

Model verification involves a comparison of the model results with local monitoring data. In this study, verification of the model has been undertaken using data collected by the continuous analysers and the diffusion tubes. This procedure is discussed further in the results section of this report.

5 RESULTS



5. Results

5.1. Model Results

This assessment considers the annual mean and hourly air quality standards as detailed in UKNAQS (see Appendix B). For NO₂, the standards to be achieved by the end of 2005 are an annual mean of 40 µg/m³ (21 ppb), and an hourly mean of 200 µg/m³ (105 ppb) to be exceeded no more than 18 times per year (equivalent to 99.8th percentile). It is generally considered that the annual mean objective is more stringent, and so if it is met, it can be assumed that the hourly objective will also be met.

Emphasis in the Review and Assessment guidance has been placed on non occupational, near ground-level, outdoor locations where the public might be exposed to air pollutants for a substantial part of the day. These locations include:

- residential properties
- schools, hospitals, libraries, etc.

An exceedence of an air quality objective is only considered to have occurred if the pollutant concentration breaches the objective at such a location.

The model results are presented in Appendix A as plots of NO₂ concentration contours. There are contours 4 µg/m³ above and below the 2005 annual mean Air Quality Objective (40 µg/m³): their significance is explained in the model verification section below.

5.1.1. Bishop's Stortford

Figures 3 and 4 in Appendix A show the predicted annual mean NO₂ concentrations for the base year (2004) and the objective year (2005), respectively.

In the 2004 simulation, high concentrations of NO₂ are predicted along all of the roads included in the study, with the junction being the area of greatest concern. Indeed, concentrations greater than 40 µg/m³ extend up to 38 m from the kerb of the junction. Sensitive locations are found along all of the roads included in the study.

Pollutant levels for the objective year are generally predicted to be slightly lower than the levels in 2004. Such changes are mainly a consequence of reductions in the background concentrations of NO₂, and greater vehicle emission controls. Increased pollution resulting from increases in traffic flows tend to be offset by these two factors.

Despite the reduction, the predicted concentrations for 2005 still exceed the annual mean objective along all of the roads, with NO₂ levels greater than 40 µg/m³ extending up to 35 m from the kerb of the junction.

5.1.2. Ware

Figures 5 and 6 in Appendix A show the annual mean NO₂ concentrations predicted to occur in Ware for the base year (2004) and the objective year (2005), respectively. The pollution levels in this area differ significantly from those in Bishop's Stortford.

In the 2004 simulation, the highest concentrations (37µg/m³) occur at the junctions of Viaduct Road with Amwell End and the London Road. In the 2005 simulation, NO₂ levels have generally reduced slightly for the reasons discussed in section 5.1.1, with concentrations at the junctions of Viaduct Road with Amwell End and the London Road dropping to 36 µg/m³. This concentration is below the NO₂ annual mean objective.

5.2. Model Verification and Errors

For an assessment such as this it is necessary that systematic and random errors, in both the modelling and the monitoring data, are considered and accounted for. The modelling results discussed above and presented in Appendix A were verified by a consideration of the errors associated with the modelling process and the model input data.

5.2.1. Verification of Model Results

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.

The model results for the 2004 simulation were compared with 2004 monitoring data collected at sites in the two study areas (see Table 8).

Table 8 Model Verification

Site Ref	Site Type	Location	2004 Annual Mean NO ₂ Concentration /µg/m ³		
			Monitored ^a	Modelled (uncorrected)	Modelled (corrected)
EH4 ^{ca}	RS	Viaduct Road, Ware	29.3	30.5	
EHDC22 ^{dt}	RS	Viaduct Road, Ware	34.1	30.4	
EH5 ^{ca}	RS	London Road, Bishop's Stortford	43.1	28.8	43.0
EHDC12 ^{dt}	KS	Hockerill St, Bishop's Stortford	27.6	28.0	41.1
EHDC18 ^{dt}	KS	Stansted Rd, Bishop's Stortford	34.0	29.7	45.4
EHDC19 ^{dt}	KS	London Rd, Bishop's Stortford	35.9	31.0	48.6

Notes: KS – kerbside; RS – roadside; ^a – the 2004 monitoring results are preliminary; ^{ca} – continuous analyser; ^{dt} – diffusion tube.

In the case of Ware, there is good agreement between the monitoring and modelling data for the continuous analyser site, whereas agreement between the data for the diffusion tube site is less good. The diffusion tube is located directly opposite the junction of Viaduct Road with Station Road, which leads to Ware train station. Traffic data for this road were not available and therefore, could not be included in the model. It is possible that the discrepancy between the monitoring and modelling data at the diffusion tube site is caused by the omission of these data. Alternatively, errors in the monitoring data may be the cause, as discussed in section 3.5.2.2.

Model results are generally corrected with respect to continuous analyser measurements in preference to diffusion tube results. As agreement between the monitoring and modelling data for the continuous analyser site is good, the Ware model results were not corrected.

The model results for Bishop's Stortford do not agree so well with the monitoring results, with the exception of the data relating to diffusion tube site EHDC12. The greatest discrepancy between the results occurs at the continuous analyser location. It was decided to correct the model for the apparent systematic errors, in order to more accurately predict NO₂ concentrations for the objective year.

The first step in this process was to subtract the background concentrations of NO_x from the modelled and monitored results to obtain the concentrations produced solely by traffic. Comparison of these figures allowed a linear scaling factor to be calculated, which was then applied to the modelled traffic contributions. Finally, the background concentration was added to the corrected modelled traffic contributions to produce the corrected modelled concentrations.

It can be seen that following correction, agreement between the modelling and monitoring data for the continuous analyser site is much improved. However, the model over predicts concentrations at the diffusion tube locations. This situation is inevitable considering the discrepancy between the continuous analyser and diffusion tube monitoring results (as

discussed in section 3.5.2.2), and that the traffic dataset did not detail higher traffic flows or 'local effects', such as taxi ranks or bus stops, in the vicinity of any of the monitoring sites.

5.2.2. Random Errors

Random errors in modelling and monitoring data also contribute to discrepancies between the two datasets. It is possible to account for the degree of random error in dispersion model results according to guidance provided by the NSCA ^[Ref 10].

'Stock U Values' allow the standard deviation of the model (SDM) to be calculated. The Stock U Value (U) for the NO₂ annual mean objective is between 0.1 and 0.2. The SDM can be calculated according to:

$$\text{SDM} = U \times C_o$$

where C_o is the air quality objective. Thus:

$$\text{SDM} = 0.1 \times 40 = 4 \mu\text{g}/\text{m}^3.$$

This calculation quantifies the uncertainty in the identification of areas where an exceedence of the air quality objective can be considered likely. For this reason, the plots presented in Appendix A have marked on them concentration contours at 36, 40 and 44 $\mu\text{g}/\text{m}^3$.

Taking the above SDM value into account, the area of exceedence in Bishop's Stortford is extended along all of the roads in the study area to the 36 $\mu\text{g}/\text{m}^3$ contour.

6 SUMMARY AND CONCLUSIONS



6. Summary and Conclusions

FaberMaunsell was commissioned by East Hertfordshire Council to undertake a detailed modelling study of NO₂ concentrations arising from road traffic at two locations: near the junction of the London Road (A1184) with Hockerill Street (A1250) in Bishop's Stortford, and Viaduct Road (A1170) in Ware. The model was run for the base year (2004) and the future air quality objective year (2005).

The assessment was performed using the AAQuIRE 6.1.1 regional dispersion model, which has been independently and extensively validated, and widely used for the past 12 years. Traffic and meteorological data, and background concentrations of the pollutant of concern were input to the model to produce NO₂ concentration plots for the required years.

The results of the Bishop's Stortford assessment indicate that the annual mean objective will be exceeded along all of the roads in the study area in 2005. Concentrations greater than 40 µg/m³ are predicted to extend up to 35 m from the kerb of the junction. The area of exceedence extends further if the standard deviation of the model is taken into account.

The results of the Ware model indicate that the annual mean objective will be met at all locations in the study area in 2005.

The model results for 2004 were compared with monitoring data in order to verify the model performance. The results of the Ware study were in good to reasonable agreement with the monitoring data whereas the model results for Bishop's Stortford did not agree so well. Thus the Bishop's Stortford model results were corrected; however, a comparison of the corrected results with monitoring data indicated that the model was over predicting NO₂ concentrations at several locations in the study area. Possible causes of the inconsistencies, such as the preliminary nature of the monitoring data, 'local effects' (taxi ranks, bus stops, etc.) and omissions in the traffic dataset were identified.

Based on the monitoring and modelling data, East Hertfordshire Council are recommended to declare an Air Quality Management Area (AQMA) with regard to NO₂ pollution in Bishop's Stortford. The council may consider the following options:

- declare an AQMA according to the 40 µg/m³ contour in the concentration plot of Bishop's Stortford
- delay declaration on the basis of the preliminary nature of the monitoring dataset for 2004. When a fully ratified and complete monitoring dataset is available, the model results can be re-verified and if necessary, the concentration plots re-calculated.

With regard to monitoring of NO₂, the council are also recommended to:

- continue operating the continuous analysers at the temporary site in Bishop's Stortford
- co-locate three diffusion tubes, not just one, with the continuous analyser in Sawbridgeworth, as recommended by Technical Guidance Note LAQM.TG(03) ^[Ref 7].

7 REFERENCES



7. References

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Appendix A Model Results

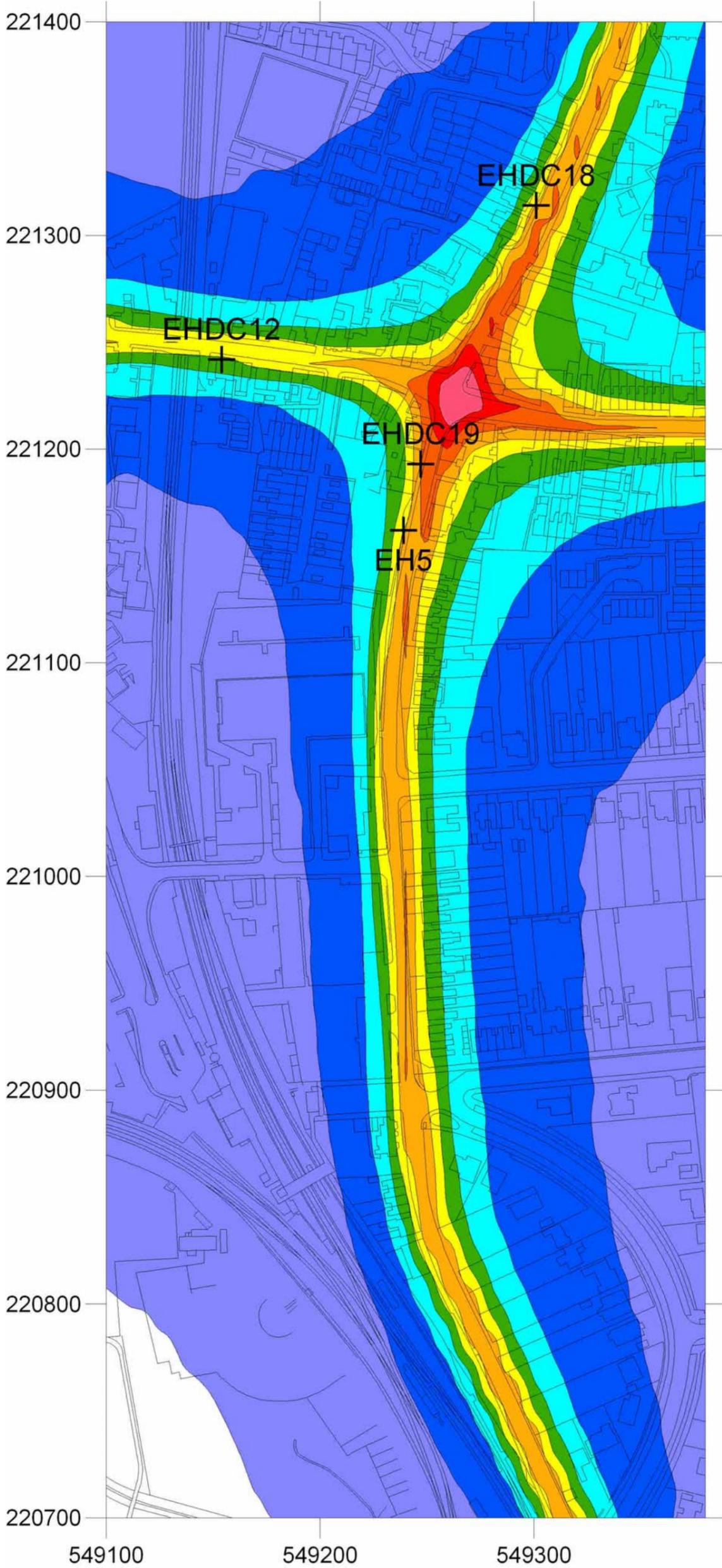
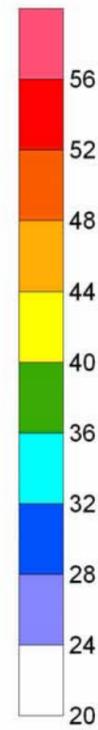


Figure 3: Annual Mean NO₂ Concentrations ($\mu\text{g}/\text{m}^3$) and Monitor Locations, Bishop's Stortford (2004)

Scale: 1:5000 when A3 size



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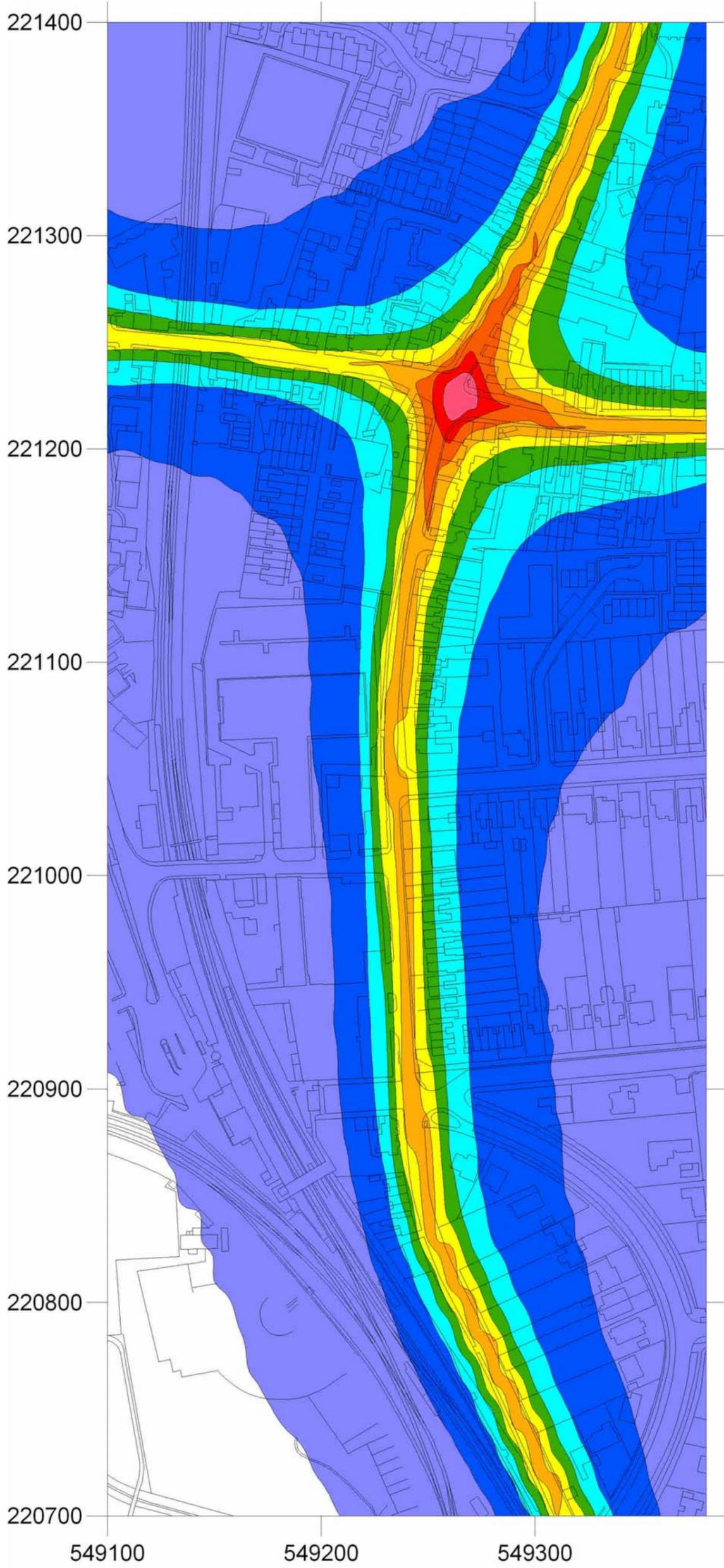
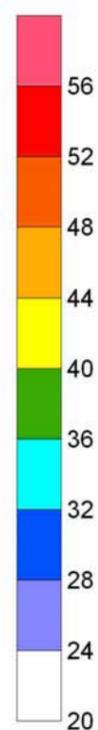


Figure 4: Annual Mean NO₂ Concentrations (µg/m³), Bishop's Stortford (2005)

Scale: 1:5000 when A3 size



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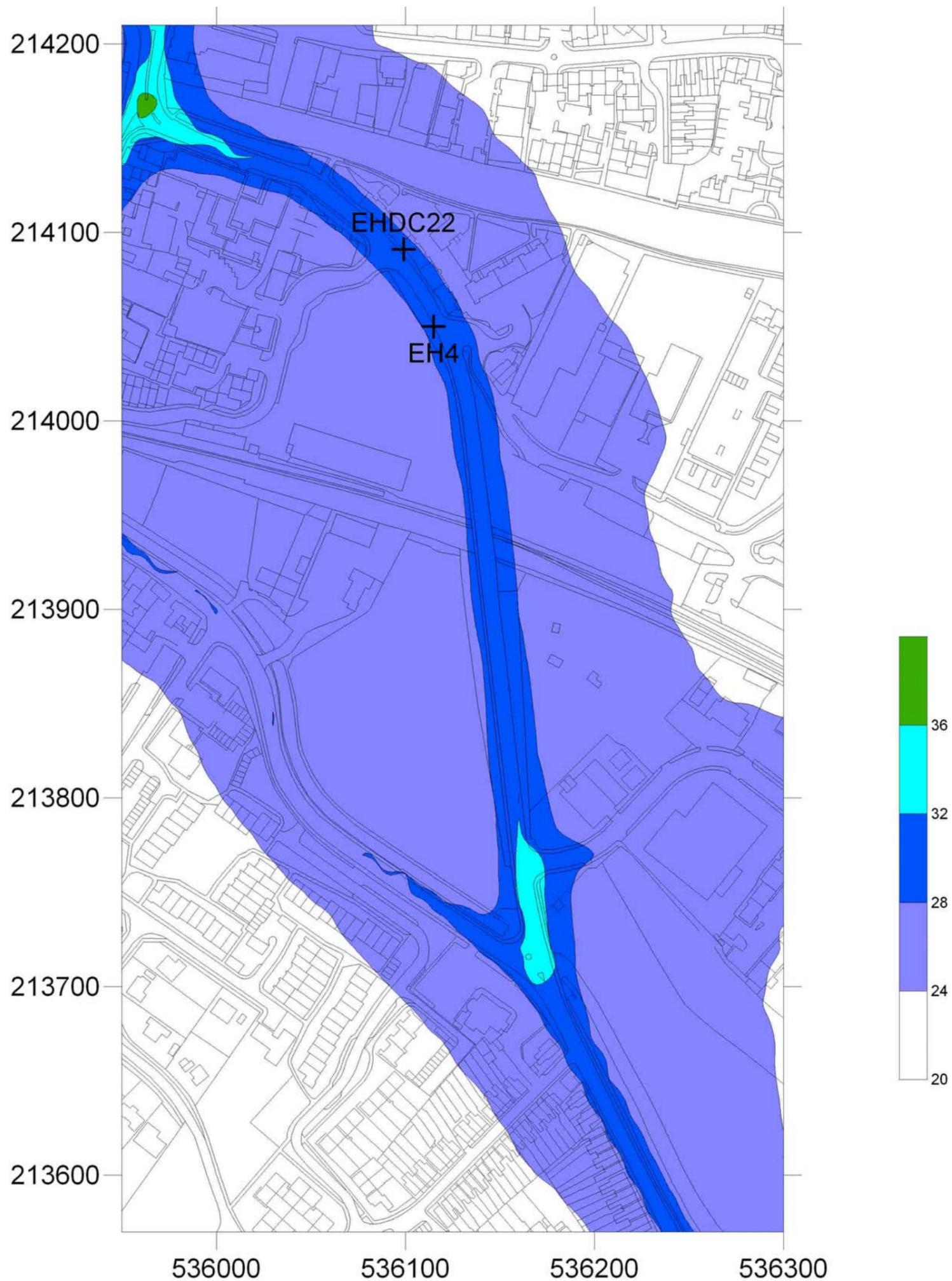


Figure 5: Annual Mean NO₂
Concentrations (µg/m³) and Monitor Locations,
Ware (2004)

Scale: 1:5000 when A3 size

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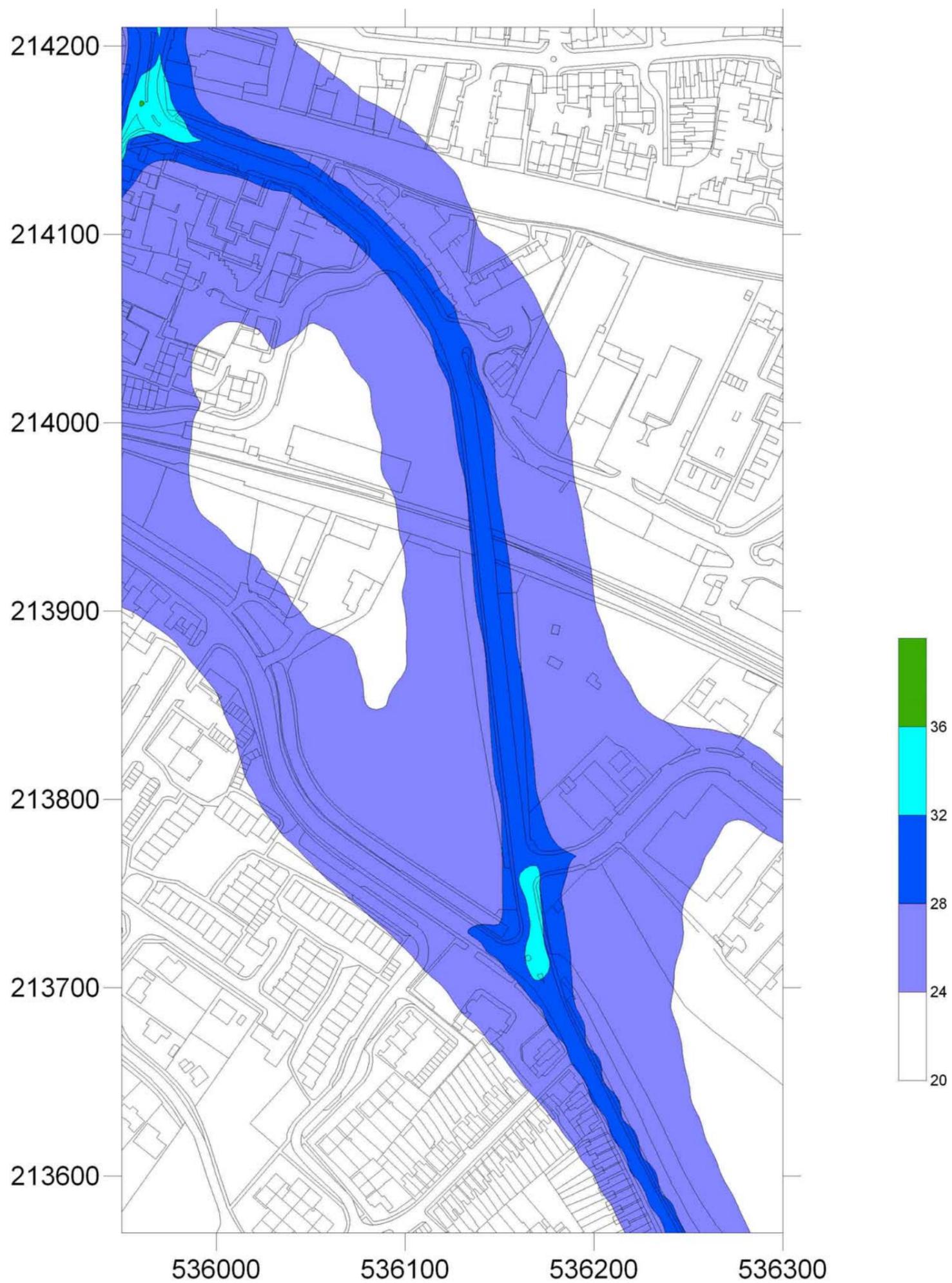


Figure 6: Annual Mean NO₂
Concentrations ($\mu\text{g}/\text{m}^3$), Ware (2005)

Scale: 1:5000 when A3 size

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Appendix B UK National Air Quality Objectives

Table 9 UK Air Quality Objectives set in Regulations

Pollutant	Applies	Objective		Compliance	EU Objectives	
		Concentration	Measured as		Concentration	Date
Benzene	All UK	16.25 µg/m ³ (5 ppb)	Running annual mean	Dec 31, 2003	5 µg/m ³	2010
	England & Wales	5 µg/m ³ (1.5 ppb)	Annual mean	Dec 31, 2003		
	Scotland	3.25 µg/m ³ (1 ppb)		Dec 31, 2010		
1,3-Butadiene	All UK	2.25 µg/m ³ (1 ppb)	Running annual mean	Dec 31, 2010	n/a	n/a
Carbon monoxide	All UK	10 mg/m ³ (8.6 ppm)	Maximum daily running 8 hour mean	Dec 31, 2003	10 mg/m ³	2005
Lead	All UK	0.5 µg/m ³	Annual mean	Dec 31, 2004	0.5 µg/m ³	2005
		0.25 µg/m ³	Annual mean	Dec 31, 2008		
Nitrogen dioxide	All UK	200 µg/m ³ (105 ppb)	1 hour, 18 exceedences	Dec 31, 2005	200 µg/m ³ (18 exceedences)	2010
		40 µg/m ³ (21 ppb)	Annual mean	Dec 31, 2005	40 µg/m ³	2010
Particles (PM ₁₀) (gravimetric)	All UK	50 µg/m ³	24hr mean, 35 exceedences	Dec 31, 2004	50 µg/m ³	2005
		40 µg/m ³	Annual mean	Dec 31, 2004	40 µg/m ³	2005
	Scotland	50 µg/m ³	24hr mean, 7 exceedences	Dec 31, 2010	40 µg/m ³	2010
		18 µg/m ³	Annual mean	Dec 31, 2010	20 µg/m ³	2010
Sulphur dioxide	All UK	350 µg/m ³ (132 ppb)	1 hour, 24 exceedences	Dec 31, 2004	350 µg/m ³ (24 exceedences)	2005
		125 µg/m ³ (47 ppb)	24 hour mean, 3 exceedences	Dec 31, 2004	125 µg/m ³ (18 exceedences)	2005
		266 µg/m ³ (100 ppb)	15 min mean, 35 exceedences	Dec 31, 2005	n/a	n/a

Table 10 UK Air Quality Objectives not set in Regulations

Pollutant	Applies	Objective		Compliance	Notes
		Concentration	Measured as		
Polycyclic aromatic hydrocarbons (PAHs)	All UK	0.25 ng/m ³	Annual mean	Dec 31, 2010	To be set in future regulations, 2005.
Ozone	All UK	100 µg/m ³	8 hour mean, 10 exceedences	Dec 31, 2005	Ozone is a national rather than local authority problem.
Particles (PM₁₀) (gravimetric)	London	50 µg/m ³ (provisional)	24 hour mean, 10 exceedences	Dec 31, 2010	These particle objectives may be set in regulations once the EU has decided its new limit value.
		23 µg/m ³ (provisional)	Annual mean	Dec 31, 2010	
		20 µg/m ³ (provisional)	Annual mean	Dec 31, 2015	
	Rest of England & Wales	50 µg/m ³ (provisional)	24 hour mean, 7 exceedences	Dec 31, 2010	
		20 µg/m ³ (provisional)	Annual mean	Dec 31, 2010	
Nitrogen oxides	All UK	30 µg/m ³ (16 ppb)	Annual mean	Dec 31, 2000	Vegetative based directives kept out of regulations as national problem. Targets have been met.
Sulphur dioxide	All UK	20 µg/m ³ (8 ppb)	Annual mean	Dec 31, 2000	
		20 µg/m ³ (8 ppb)	Winter mean (October – March)	Dec 31, 2000	

Appendix C AAQuIRE Description

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 FaberMaunsell 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 UKNAQS PM₁₀ 24-hour objective level of 50 µg/m³ is expressed as a 90th percentile of hourly means. AAQuIRE can also produce results directly comparable with all ambient air quality standards, including:

- the annual average objective for nitrogen dioxide of 40 µg/m³
- the 90th percentile of 24-hour means for PM₁₀ of 50 µg/m³
- the 99.9th percentile of 15-minute means for sulphur dioxide of 266 µg/m³
- the nitrogen dioxide 1-hour mean objective of 200 µg/m³, not to be exceeded more than 18 times a year.

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
- the presentation of results.

The first step in operating AAQuIRE is to prepare the input data. Data are needed on:

- 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
- grid of model prediction locations (receptors)

for the year and pollutant to be modelled. 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. The modelling uncertainty for AAQuIRE is approximately $\pm 20\%$, which is well within the recommendations in technical guidance note LAQM.TG(03)^[Ref 7].

Appendix D Traffic Data

Table 11 Traffic Data, Bishop's Stortford

Road	AADT flows			% HGV (all years)
	2003	2004	2005	
A1184 London Road	16537	16816	17101	4.1
A1250 Hockerill Street	14827	15078	15332	2.1
B1383 Stansted Road	18526	18839	19157	3.2
A1250 Dunmow Road	14265	14506	14751	4.4

Table 12 Traffic Data, Ware

Road	AADT flows			% HGV (all years)
	2003	2004	2005	
A1170 Viaduct Road	18210	18518	18831	3.9
A1170 Viaduct Road	18433	18745	19061	3.9
Marsh Lane	2157	2193	2231	13.0
A1170 London Road	9752	9917	10084	3.9
A1170 London Road	14565	14811	15061	3.9
A1170 High Street	18210	18518	18831	3.9
A1170 Amwell End	16547	16827	17111	3.9

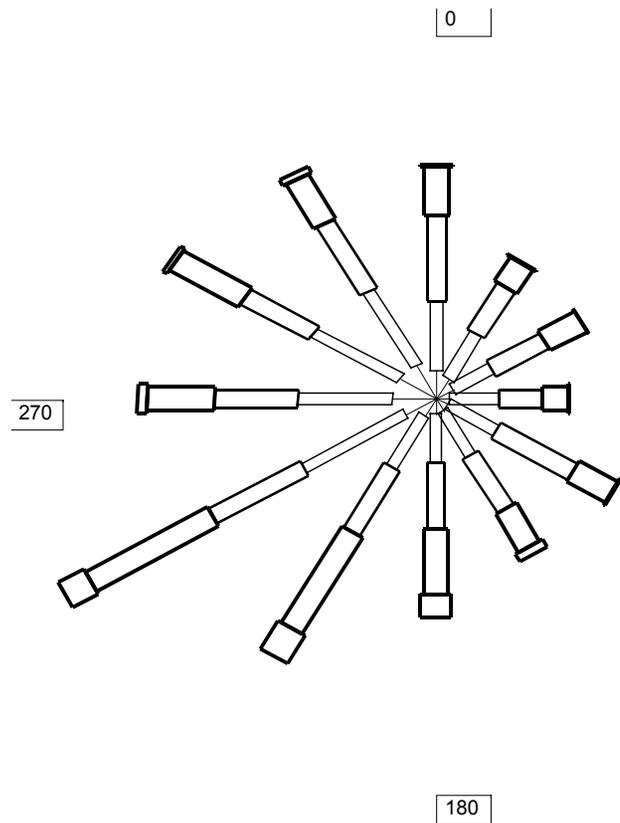
Appendix E Meteorological Data

Meteorological data measured at Stansted were used in 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).

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 were grouped in C and all of the stable classes in E.

The meteorological data were used to produce a wind/stability rose: see the figure on the following page. Each wind rose 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. These data are also tabulated to show the total number of hours and the wind speed split for each wind direction sector.

Figure 3 Wind Rose and Data for Stansted, 1995



	Wind <= 2 m/s	Wind <= 4 m/s	Wind <= 6 m/s	Wind <= 10 m/s	Wind > 10 m/s
D >= 345 or D < 15	91	223	269	154	6
15 <= D < 45	71	165	176	87	3
45 <= D < 75	60	128	180	121	2
75 <= D < 105	43	144	125	77	2
105 <= D < 135	40	163	261	128	5
135 <= D < 165	48	159	199	138	27
165 <= D < 195	49	157	208	205	74
195 <= D < 225	65	187	236	354	100
225 <= D < 255	105	339	306	410	85
255 <= D < 285	128	276	243	192	31
285 <= D < 315	120	291	231	233	14
315 <= D < 345	118	275	252	160	21
Total	938	2507	2686	2259	370

