# Borough Council of Kings Lynn & West Norfolk

*Air Quality Modelling Report*

*December 2017*

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## Document Control Sheet

| Issue/Revision | Issue 1 | Issue 2 |
|---|---|---|
| Remarks | Draft for comment | Final |
| Date | December 2017 | January 2018 |
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# Executive Summary

The Borough Council of King's Lynn and West Norfolk current Air Quality Action Plan (AQAP) was published in 2015 however, a source apportionment exercise has not been carried out since 2008. Therefore, the Council have commissioned Bureau Veritas to undertake an update of the Councils source apportionment dispersion modelling, with a view of informing an air quality action plan update. The Town Centre and Gaywood Clock AQMAs have both been included in the modelling assessment.

This report has been undertaken in accordance with the methodology agreed with the Council. The area was modelled using the advanced atmospheric dispersion model ADMS-Roads (Version 4.0) and using the latest emissions from the Emissions Factors Toolkit (Version 8.0).

Annual mean $NO_2$ concentrations were predicted at 80 residential receptors around the main roads links of concern, representative of worst-case exposure. Annual mean nitrogen dioxide ($NO_2$) concentrations were not found to be exceeding the 40µg/m$^3$ annual mean Air Quality Strategy (AQS) objective at any modelled receptor location. Only one location (66) was predicted to be within 10% of the AQS for $NO_2$.

The gridded receptors highlighted predicted exceedances located within both existing AQMAs. With regards to the Town Centre AQMA, exceedances were predicted along Southgates Roundabout, which is not located within the AQMA. The exceedances appear to remain within the roadway and the closest residential property is approximately 35m away. Therefore, at this time there is no immediate requirement to extend the AQMA to cover the roundabout. Small exceedances were also predicted outside the AQMA along Littleport Street. Nonetheless, diffusion tube monitoring carried out in this area has confirmed concentrations to be within the AQS objective at relevant exposure.

In regards to the Gaywood Clock AQMA, exceedances can be seen along the majority of the roads covered by the AQMA. There are also exceedances predicted outside the AQMA further along Lynn Road. Modelled receptors and monitored concentrations along this stretch of road report $NO_2$ concentrations below the annual mean AQS objective. This suggests that the exceedances are localised along the roadway. Continued monitoring at sensitive areas along Lynn Road is recommended to ensure the concentrations remain below the AQS objective at potential areas of exposure. It is not recommended that the Gaywood Clock AQMA should be revoked or amended at this stage.

To inform decisions around testing of action plan measures a source apportionment exercise has been undertaken considering apportionment of road $NO_x$ concentrations averaged across the following different selections of the modelled receptors:

- All modelled receptors;
- At the receptor where the maximum $NO_x$ concentration was predicted.

The source apportionment exercise highlighted the slight differences in traffic composition between the two AQMAs. It can be seen that the background $NO_x$ concentration is relatively consistent between the two areas. However, the $NO_x$ contribution from HGVs and buses/coaches is greater in the Town Centre AQMA whereas the contribution from cars is greater in the Gaywood Clock AQMA. With regards to $NO_2$, a greater proportion of the overall $NO_2$ is derived from the background, particularly in the Town Centre AQMA. Although cars are the greatest vehicle contributor to emissions in both AQMAs, the spread across all vehicle sectors is more pronounced within the Town Centre AQMA. Understanding the source apportionment will help to ensure measures implemented in the AQAP are focused to the specific issues associated with each AQMA.

Overall, the dispersion modelling assessment has determined that no current changes are required to the boundaries of the Town Centre and Gaywood Clock AQMAs. However, it has highlighted areas where monitoring should continue to ensure the pollutant concentrations do not worsen in

these areas. The information provided in this assessment should be used to inform the update of the AQAP.

# 1 Introduction

## 1.1 Scope of Project

The Borough Council of King's Lynn & West Norfolk commissioned Bureau Veritas to undertake an update of the Councils source apportionment dispersion modelling, which was last undertaken in 2008, with a view of informing an air quality action plan update.

The Council have declared Air Quality Management Areas (AQMAs) at two locations for exceedances of the annual mean $NO_2$ air quality objective. The AQMAs are located within the Town Centre and at Gaywood Clock. Both AQMAs were included in the previous 2008 source apportionment dispersion modelling assessment however it was deemed necessary for an update of the model to be carried out to ascertain whether any changes in traffic composition have occurred since 2008.

Bureau Veritas UK Ltd has therefore been commissioned by the Council to undertake dispersion modelling using the latest available traffic data and 2016 air quality monitoring data.

An outline of the main tasks involved in undertaking the assessment is provided below:

1. Collate information required for the air quality dispersion modelling;
2. Input of the information into the model, including sensitive receptors and a receptor grid for concentration contours;
3. Model run;
4. Model verification using 2016 local monitoring information;
5. Mapping and contours; and
6. Submission of Draft Modelling Report outlining, if necessary, any recommended changes to the AQMA boundary.

## 1.2 Scope of this Report

This report represents the modelling of the current AQMAs, which takes into account monitoring carried out since the AQMA was declared to inform the subsequent action plan update.

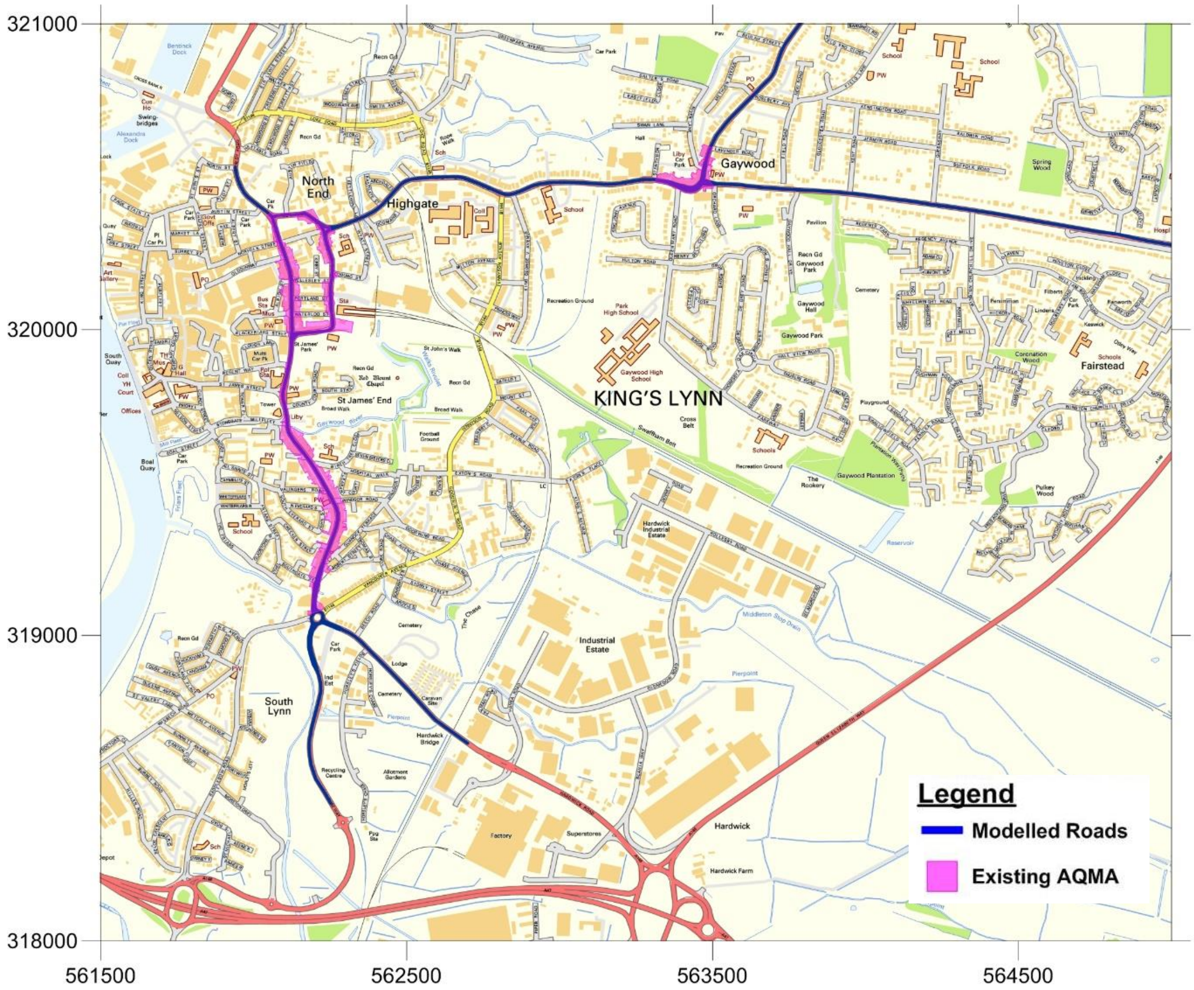
The area considered as part of this study is illustrated in Figure 1.1. The following are the main objectives of the assessment:

- To assess the air quality at selected locations ("receptors") at the façades of the existing residential units, representative of worst-case exposure, based on modelling of emissions from road traffic on the local road network for 2016;
- To determine the geographical extent of any potential exceedance of the annual mean Air Quality Strategy (AQS) objective for $NO_2$; and
- To put forward recommendations as to the extent of any changes to the AQMA boundary.

The approach adopted in this assessment of the impact of road traffic emissions on air quality utilised the atmospheric dispersion model ADMS Roads version 4.0.1, focusing on emissions of oxides of nitrogen ($NO_x$).

In order to provide consistency with the Council's own work on air quality, the guiding principles for air quality assessments as set out in the latest guidance and tools provided by Defra for air quality assessment (LAQM.TG(16)[1]) have been used.

**Figure 1.1– Modelled Area**






1 Local Air Quality Management Technical Guidance LAQM.TG(16). April 2016. Published by Defra in partnership with the Scottish Government, Welsh Assembly Government and Department of the Environment Northern Ireland.

# 2 Air Quality – Legislative Context

## 2.1 Air Quality Strategy

The importance of existing and future pollutant concentrations can be assessed in relation to the national air quality standards and objectives established by Government. The Air Quality Strategy[2] (AQS) provides the over-arching strategic framework for air quality management in the UK and contains national air quality standards and objectives established by the UK Government and Devolved Administrations to protect human health. The air quality objectives incorporated in the AQS and the UK Legislation are derived from Limit Values prescribed in the EU Directives transposed into national legislation by Member States.

The CAFE (Clean Air for Europe) programme was initiated in the late 1990s to draw together previous directives into a single EU Directive on air quality. The CAFE Directive[3] has been adopted and replaces all previous air quality Directives, except the 4th Daughter Directive[4]. The Directive introduces new obligatory standards for $PM_{2.5}$ for Government but places no statutory duty on local government to work towards achievement of these standards.

The Air Quality Standards (England) Regulations[5] 2010 came into force on 11 June 2010 in order to align and bring together in one statutory instrument the Government's obligations to fulfil the requirements of the new CAFE Directive.

The objectives for ten pollutants – benzene ($C_6H_6$), 1,3-butadiene ($C_4H_6$), carbon monoxide (CO), lead (Pb), nitrogen dioxide ($NO_2$), sulphur dioxide ($SO_2$), particulate matter - $PM_{10}$ and $PM_{2.5}$, ozone ($O_3$) and Polycyclic Aromatic Hydrocarbons (PAHs), have been prescribed within the AQS[2].

The EU Limit Values are considered to apply everywhere with the exception of the carriageway and central reservation of roads and any location where the public do not have access (e.g. industrial sites).

The AQS objectives apply at locations outside buildings or other natural or man-made structures above or below ground, where members of the public are regularly present and might reasonably be expected to be exposed to pollutant concentrations over the relevant averaging period. Typically these include residential properties and schools/care homes for long-term (i.e. annual mean) pollutant objectives and high streets for short-term (i.e. 1-hour) pollutant objectives. Table 2.1 taken from LAQM.TG(16)[1] provides an indication of those locations that may or may not be relevant for each averaging period.

This assessment focuses on $NO_2$ as this is the pollutant for which the AQMAs are delcared in reference to. Moreover, as a result of traffic pollution the UK has failed to meet the EU Limit Values for $NO_2$ by the 2010 target date. As a result, the Government has had to submit time extension applications for compliance with the EU Limit Values. Continued failure to achieve these limits may lead to EU fines. The AQS objectives for these pollutants are presented in Table 2.2.

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[2] The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (2007), Published by Defra in partnership with the Scottish Executive, Welsh Assembly Government and Department of the Environment Northern Ireland

[3] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

[4] Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic hydrocarbons in ambient air.

[5] The Air Quality Standards Regulations (England) 2010, Statutory Instrument No 1001, The Stationary Office Limited.

### Table 2.1 – Examples of where the Air Quality Objectives should apply

| Averaging Period | Objectives should apply at: | Objectives should generally not apply at: |
|---|---|---|
| Annual mean | All locations where members of the public might be regularly exposed<br>Building facades of residential properties, schools, hospitals, care homes etc. | Building facades of offices or other places of work where members of the public do not have regular access.<br>Hotels, unless people live there as their permanent residence.<br>Gardens of residential properties.<br>Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term |
| 24-hour mean and 8-hour mean | All locations where the annual mean objectives would apply, together with hotels<br>Gardens or residential properties[1] | Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term. |
| 1-hour mean | All locations where the annual mean and 24 and 8-hour mean objectives would apply.<br>Kerbside sites (e.g. pavements of busy shopping streets).<br>Those parts of car parks, bus stations and railway stations etc. which are not fully enclosed, where the public might reasonably be expected to spend one hour or more.<br>Any outdoor locations at which the public may be expected to spend one hour or longer. | Kerbside sites where the public would not be expected to have regular access. |
| 15-minute mean | All locations where members of the public might reasonably be expected to spend a period of 15 minutes or longer. | |

Note [1] For gardens and playgrounds, such locations should represent parts of the garden where relevant public exposure is likely, for example where there is seating or play areas. It is unlikely that relevant public exposure would occur at the extremities of the garden boundary, or in front gardens, although local judgement should always be applied.

### Table 2.2 – Relevant AQS Objectives for the Assessed Pollutants in England

| Pollutant | AQS Objective | Concentration Measured as: | Date for Achievement |
|---|---|---|---|
| **Nitrogen dioxide ($NO_2$)** | 200µg/m³ not to be exceeded more than 18 times per year | 1-hour mean | 31 December 2005 |
| | 40µg/m³ | Annual mean | 31 December 2005 |

## 2.2 Local Air Quality Management (LAQM)

Part IV of the Environment Act 1995 places a statutory duty on local authorities to periodically Review and Assess the current and future air quality within their area, and determine whether they are likely to meet the AQS objectives set down by Government for a number of pollutants – a process known as Local Air Quality Management (LAQM). The AQS objectives that apply to LAQM are defined for seven pollutants: benzene, 1,3-butadiene, carbon monoxide, lead, nitrogen dioxide, sulphur dioxide and particulate matter.

Where the results of the Review and Assessment process highlight that problems in the attainment of health-based objectives for air quality will arise, the authority is required to declare an Air Quality Management Area (AQMA) – a geographic area defined by high concentrations of pollution and exceedances of health-based standards.

Where an authority has declared an AQMA, and development is proposed to take place either within or near the declared area, further deterioration to air quality resulting from a proposed development can be a potential barrier to gaining consent for the development proposal. Similarly, where a development would lead to an increase of the population within an AQMA, the protection of residents against the adverse long-term impacts of exposure to existing poor air quality can provide the barrier to consent. As such, following an increased number of declarations across the UK, it has become standard practice for planning authorities to require an air quality assessment to be carried out for a proposed development (even where the size and nature of the development indicates that a formal Environmental Impact Assessment (EIA) is not required).

One of the objectives of the LAQM regime is for local authorities to enhance integration of air quality into the planning process. Current LAQM Policy Guidance[1] clearly recognises land-use planning as having a significant role in terms of reducing population exposure to elevated pollutant concentrations. Generally, the decisions made on land-use allocation can play a major role in improving the health of the population, particularly at sensitive locations – such as schools, hospitals and dense residential areas.

# 3 Review and Assessment of Air Quality Undertaken by the Council

## 3.1 Local Air Quality Management

Between 1999 and 2003, the Borough Council of King's Lynn & West Norfolk undertook its First Round of Review and Assessment of air quality, which concluded that $PM_{10}$ and $NO_2$ concentrations were likely to exceed the AQS objectives at a number of locations in King's Lynn. As a result, the Council declared two AQMAs, one in South Quay (for $PM_{10}$) in April 2002, and another one in Railway Road (for $NO_2$) in November 2003. The South Quay AQMA was revoked in June 2006 following the effective implementation of an AQAP for the area.

The Second Round of Review and Assessment began with an Updating and Screening Assessment (USA), completed in 2003. The report concluded that there had been no significant changes since the First Round and that it was not necessary to carry out a Detailed Assessment at that time. However, the subsequent Progress Report (2004) recommended proceeding to a Detailed Assessment for $NO_2$, following new monitored exceedances of the annual mean objective outside the AQMA in King's Lynn. The Detailed Assessment (2005) confirmed that exceedances were likely to occur at several sites outside the AQMA, and as a result, made the recommendation to extend the AQMA to encompass properties along Railway Road, Blackfriars Road and London Road.

The Third Round of Review and Assessment began with the USA, completed in 2006. The report provided an update with respect to air quality issues within the Borough since the previous round. Having considered each pollutant, the USA concluded that the AQS objectives were still being met and that no further assessment was required. The report also recommended (following the conclusions of the Detailed Assessment 2005) that monitoring of $NO_2$ be continued in the Borough to validate the proposal to extend the Railway Road AQMA in King's Lynn.

The Council approved a variation order (February 2007) to extend the AQMA, which now includes all of Railway Road, Austin Street, Blackfriars Road, St James Road and London Road.

Modelling undertaken by a neighbouring Local Authority, Fenland District Council, also predicted potential exceedances of the $NO_2$ annual mean AQS objective along Elm High Road in Wisbech. The area lies on the border of the Borough of King's Lynn & West Norfolk; therefore, both local authorities deployed additional diffusion tubes in the area to confirm the modelling results. Subsequent monitoring for Elm High Road, Wisbech, showed compliance with the annual mean objective for $NO_2$ and demonstrated that there is no requirement to declare an AQMA.

The Progress Report carried out in 2007 confirmed that $NO_2$ concentrations were still exceeding the objective at the majority of the monitoring sites in the AQMA; justifying its extension. It also concluded that a Detailed Assessment for $NO_2$ in Wisbech was not required, as new monitoring results were below the AQS objective. However, new available $NO_2$ monitoring results showed an exceedance of the objective at the 'Wootton Road 2' diffusion tube in the Gaywood Clock area of King's Lynn. This site is located about 1km east of the extended AQMA in the town centre; therefore, it was recommended that a Detailed Assessment be carried out in this area.

The Detailed Assessment, which also included the Further Assessment of the Railway Road AQMA, was completed in 2008. The report concluded that a new AQMA in the Gaywood Clock area was required, as both updated monitoring data and predicted $NO_2$ concentrations confirmed that the AQS annual mean objective was likely to be exceeded. The new AQMA was declared in April 2009, for an area encompassing properties at the junction of Wootton Road, Gayton Road and Lynn Road.

The Further Assessment confirmed that the extended Railway Road AQMA in King's Lynn Town Centre was still valid and should remain, as both monitoring and modelling confirmed exceedances of the AQS objective. The source apportionment results showed that cars are the main contributors with respect to high levels of $NO_2$ in the AQMA, followed by buses, HGVs and LGVs, while background pollution levels also contribute significantly.

The 2009 USA concluded that although exceedances of $NO_2$ were still recorded in the Borough, these were confined to the existing AQMAs. Pollutant concentrations outside the AQMAs met the objectives and no Detailed Assessment was required. The 2010 and 2011 Annual Progress Reports concluded that no new Detailed Assessment were required as there were no new exceedances recorded outside the existing AQMAs.

The 2012 Updating and Screening Assessment found that a Detailed Assessment was required in the Page Stair Lane area due to potential exceedances of the annual mean and 24-hour mean with regards to $PM_{10}$. The 2012 USA also identified two new developments on Hardwick Road, which modelling had predicted to increase $NO_2$ concentrations on Hardwick Road. Both applications had highway improvements as part of the application and developments. It was advised that the Borough Council of King's Lynn & West Norfolk continue to monitor at this location in order to assess the impact of the development.

The 2013 and 2014 Progress Reports found no exceedances of the $NO_2$ objectives outside of existing AQMAs. The monitoring site at Hardwick Road showed that the annual mean $NO_2$ concentrations were generally reducing (based on the 2012 and 2013 diffusion tube results, both of which were below 2011 levels). From this data it would appear that the two developments have not lead to increases in $NO_2$ concentrations as predicted. With regards to $PM_{10}$, the 2012 and 2013 results from an Osiris monitoring site in Stoke Ferry showed compliance of the annual mean and 24-hour mean objectives by 2013. However, $PM_{10}$ monitoring at Stoke Ferry, Page Stair Lane and King's Lynn were continued to assess whether a Detailed Assessment with regards to $PM_{10}$ in this area was still required.

The 2015 Updating and Screening Assessment and the 2016 and 2017 Annual Status Reports demonstrated that exceedances of the $NO_2$ air quality objective were still being reported within the Town Centre AQMA. However, no exceedances at relevant exposure were observed outside the AQMA. Furthermore, the $PM_{10}$ annual mean and 24-hour mean objectives continued to be met at all locations.

## 3.2 Council Monitoring Data

The Council operates seven automatic air quality monitoring stations, two for $NO_2$ and five for $PM_{10}$. The two automatic stations measuring $NO_2$ are located at roadside locations within the two declared AQMAs. Details of all the automatic monitoring stations are summarised in Table 3.1 and Table 3.2.

Annual mean $PM_{10}$ concentrations are well below the 40µg/m$^3$ AQS objective at all monitoring stations, justifying the omission of the pollutant from this assessment.

**Table 3.1 – LAQM Automatic Monitoring Undertaken in the Council area – Annual Mean**

| Site | Site Name | Site Type | OS Grid Ref | Pollutants Monitored | Annual Mean Concentration (µg/m$^3$) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2012 | 2013 | 2014 | 2015 | 2016 |
| Southgates | Southgates Park | Roadside | 562225, 319191 | $NO_2$ | 25 | 26 | 21 | 21 | 25 |
| Gaywood | Gaywood | Roadside | 563437, 320472 | $NO_2$ | 33 | 39 | 36 | **42** | **45** |
| North Lynn | North Lynn | Industrial | 562086, 321325 | $PM_{10}$ | - | 23 | 18 | 18 | 18 |
| Page Stair Lane | Page Stair Lane | Industrial | 561527, 320437 | $PM_{10}$ | 23 | 20 | 19 | 19 | 21 |
| Stoke Ferry, Furlong Road | Furlong Road, | Industrial | 570339, 300083 | $PM_{10}$ | **70** | 17 | 18 | 16 | 21 |
| Estuary Road | Estuary Road | Industrial | 561593, 321466 | $PM_{10}$ | - | 18 | 16 | 20 | 15 |

| Site | Site Name | Site Type | OS Grid Ref | Pollutants Monitored | Annual Mean Concentration (µg/m³) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2012 | 2013 | 2014 | 2015 | 2016 |
| Stoke Ferry, Wretton Road | Wretton Road, Stoke Ferry | Industrial | 570438, 299905 | $PM_{10}$ | - | - | - | - | 16 |
| In **Bold**, exceedance of the annual mean $NO_2$ AQS objective of 40µg/m³ | | | | | | | | | |

**Table 3.2 – LAQM Automatic Monitoring Undertaken in the Council area – Short-term $NO_2$**

| Site | Site Name | Site Type | OS Grid Ref | Exceedances of Short-term objective (Hourly mean > 200 µg/m³ for $NO_2$, | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 2012 | 2013 | 2014 | 2015 | 2016 |
| Southgates | Southgates Park, King's Lynn | Roadside | 562225, 319191 | 0 | 0 | 0 | 0 | 0 |
| Gaywood | Gaywood, King's Lynn | Roadside | 563437, 320472 | 0 | 0 | 0 | 0 | 0 |

Annual mean $NO_2$ concentrations are observed to be below the 40µg/m³ AQS objective at the Southgates Park automatic monitoring site for years 2012 to 2016. However, the Gaywood automatic monitoring station observed exceedances of the annual mean AQS in 2015 and 2016. Furthermore, in 2013, whilst not exceeding the annual mean $NO_2$ concentration, the Gaywood site was observed to be 36µg/m³, within 10% of the AQS objective.

Neither of the sites have exceeded the 18 allowed exceedances of the 200µg/m³ 1-hour $NO_2$ AQS objective during the last five years, with no exceedances reported between 2012 to 2016 at either site.

In addition to the automatic monitoring stations, the Council carries out passive monitoring for $NO_2$ at 61 locations within the local authority area. Figure 3.1 shows the locations of both the automatic and passive $NO_2$ monitoring locations within close proximity of the declared AQMAs. Recent results for all the passive monitoring sites in the local authority area are shown in Table 3.3.**Table 3.3 – LAQM Passive Diffusion Tube Monitoring undertaken for $NO_2$**

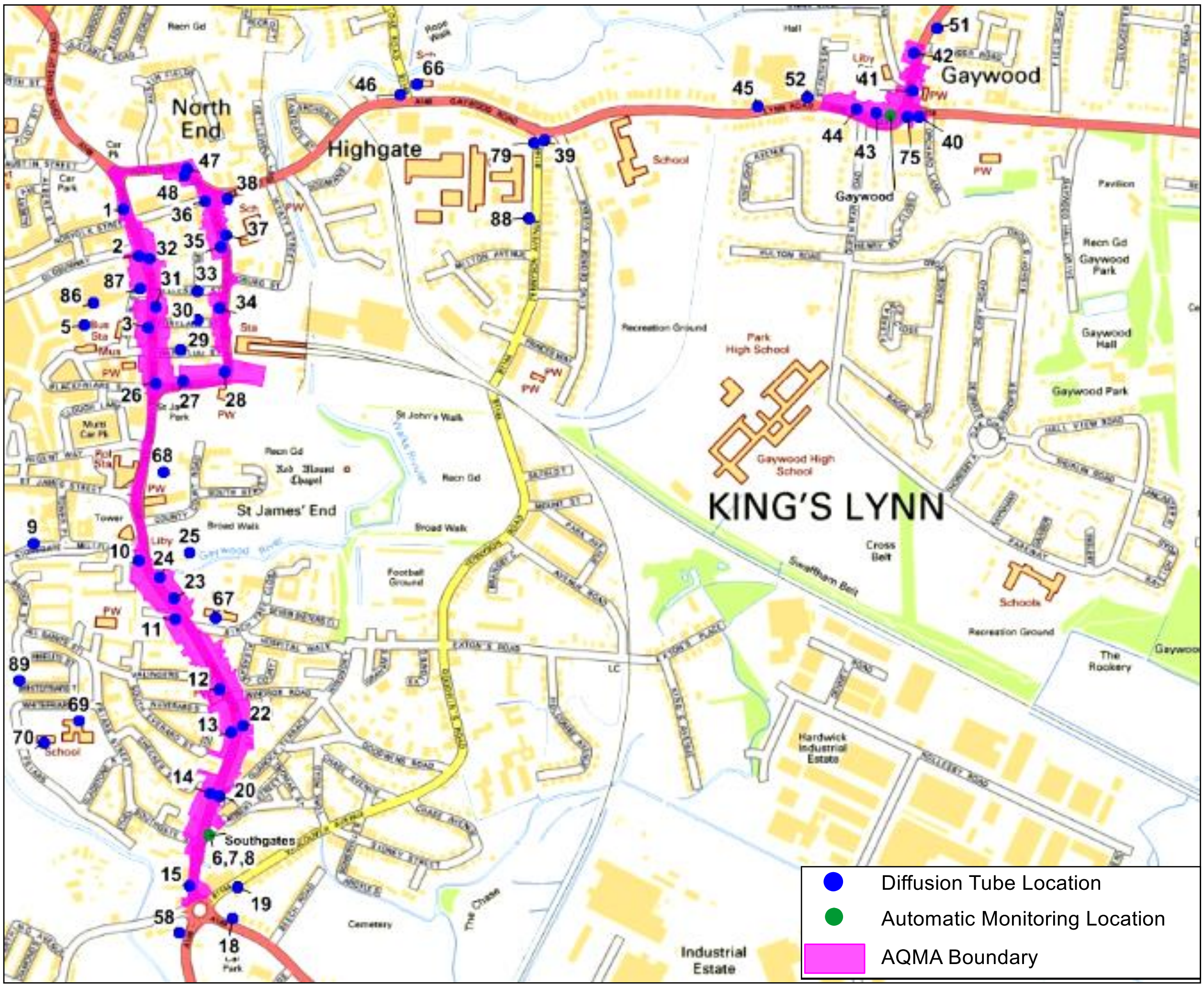
| Site | Site Name | Site Type | OS Grid Ref | Distance to Road (m) | Located In AQMA | Annual Mean $NO_2$ Concentration (µg/m³)* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2012 (Bias 0.84) | 2013 (Bias 0.90) | 2014 (Bias 0.73) | 2015 (Bias 0.88) | 2016 (Bias 0.85) |
| 1 | Railway Road 1 | RS | 562073,320304 | 2 | YES | **40.3** | 37.1 | 38.2 | 36.6 | 35.5 |
| 2 | Railway Road 4 | RS | 562100,320222 | 2 | YES | **45.1** | **47.1** | **47** | **46.6** | **44.6** |
| 3 | Railway Road 5 | RS | 562117,320095 | 1.5 | YES | **40.6** | **42.2** | 39.7 | 36.9 | 38.6 |
| 5 | Bus Station - Shelters, Bay D | RS | 562003,320099 | N/A | NO | **43.6** | **43.9** | **46** | **53** | 32.4 |
| 6,7,8 | Southgates Monitoring Station | RS | 562226,319191 | 5 | YES | 24.6 | 26.2 | 26.7 | 25.2 | 24.6 |
| 9 | Mill Fleet | RS | 561912,319711 | 4 | NO | 20 | 22.9 | 21.2 | 20.3 | 20.8 |
| 10 | London Road 1 | RS | 562101,319679 | 3 | YES | 38.6 | 35.1 | 36.7 | 37.8 | 36.3 |
| 11 | London Road 2 | RS | 562165,319575 | 3 | YES | 30 | 28.4 | 30.4 | 28.5 | 27.9 |
| 12 | London Road 3 | RS | 562243,319452 | 3 | YES | 32.8 | 33.5 | 34.7 | 33.1 | 32 |
| 13 | London Road 4 | RS | 562264,319375 | 4.5 | YES | 31.7 | 30.8 | 31.5 | 30.3 | 31 |
| 14 | London Road 5 | RS | 562227,319266 | 4 | YES | **50.4** | 34.4 | 35 | 33.1 | 33.1 |
| 15 | Southgates | RS | 562190,319102 | 0.5 | YES | 37.4 | 36.7 | 38.4 | 37.2 | 35.4 |
| 18 | Hardwick Rd | RS | 562266,319043 | 7 | NO | 26.4 | 26.4 | 26.5 | 25.8 | 24.5 |

| Site | Site Name | Site Type | OS Grid Ref | Distance to Road (m) | Located In AQMA | Annual Mean $NO_2$ Concentration (µg/m$^3$)* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2012 (Bias 0.84) | 2013 (Bias 0.90) | 2014 (Bias 0.73) | 2015 (Bias 0.88) | 2016 (Bias 0.85) |
| 19 | Vancover Avenue | RS | 562277,319098 | 6 | NO | 25 | 24.8 | 23.6 | 23.7 | 23 |
| 20 | London Road 10 | RS | 562244,319261 | 3.5 | YES | 29.5 | 33.5 | 33.1 | 30.8 | 30.6 |
| 22 | London Road 6 | RS | 562285,319386 | 5 | YES | 32.1 | 33.3 | 34.2 | 31.4 | 32.6 |
| 23 | London Road 7 | RS | 562162,319614 | 4.5 | YES | 32.7 | 36.2 | 35.3 | 31.6 | 32.5 |
| 24 | London Road 8 | RS | 562136,319651 | 5.5 | YES | 31.4 | 32.5 | 32 | 28.7 | 28.9 |
| 25 | The Walks | RS | 562191,319695 | 75 | NO | 17.4 | 16.4 | 16.3 | 15 | 14.4 |
| 26 | Railway Road 7 | RS | 562131,319996 | 2 | YES | 36.7 | 37.2 | 36 | 33.8 | 31.5 |
| 27 | St John's Terrace | RS | 562178,319999 | 2 | YES | 31.3 | 30.4 | 30 | 27.5 | 28.5 |
| 28 | St John's Terrace/Blackfriar's | RS | 562253,320015 | 1.5 | YES | 29.5 | 32.1 | 30 | 30.2 | 30 |
| 29 | Waterloo Street | KS | 562175,320055 | 1 | NO | 21.6 | 21.8 | 19.1 | 18.6 | 18.3 |
| 30 | Portland Street | KS | 562204,320108 | 1 | NO | 22.9 | 22.8 | 21.3 | 21.4 | 20.4 |
| 31 | Railway Road 2 | RS | 562129,320132 | 2 | YES | 36 | 32.7 | 30.9 | 30.4 | 28.2 |
| 32 | Railway Road 3 | RS | 562119,320216 | 2 | YES | 30.7 | 30.6 | 30.9 | 27.7 | 29 |
| 33 | Wellsley Street | RS | 562203,320159 | 0.5 | NO | 28.3 | 26.9 | 29.7 | 27.4 | 26.1 |
| 34 | Blackfriars 2 | RS | 562244,320129 | 2.5 | YES | 31.4 | 31.3 | 32.1 | 30.1 | 28.7 |
| 35 | Blackfriars 1 | RS | 562245,320238 | 1.5 | YES | 30.6 | 29.9 | 29 | 28.5 | 27.2 |
| 36 | Norfolk Street | RS | 562219,320319 | 2 | YES | 31.1 | 28.6 | 29.2 | 27.9 | 27.3 |
| 37 | Blackfriars 3 | RS | 562254,320259 | 2 | YES | 29 | 35.2 | 33.1 | 27.3 | 26.5 |
| 38 | Littleport Street | RS | 562257,320323 | 2.5 | YES | 35.7 | 31.7 | 35.1 | 32.5 | 31.5 |
| 39 | Gaywood Road 2 | RS | 562822,320427 | 7 | NO | 26 | 27.5 | 26.8 | 24.3 | 24.1 |
| 40 | The Swan (1) Gayton Road | RS | 563490,320469 | 2 | YES | 34.2 | 31.7 | 32.8 | 31.2 | 30.2 |
| 41 | Wootton Road 2 | RS | 563478,320515 | 2 | YES | 33.7 | 37.1 | 35.2 | 31.2 | 32.2 |
| 42 | Wootton Road 1 | RS | 563480,320582 | 3 | YES | 32.3 | 30.8 | 29.7 | 29.8 | 29.3 |
| 43 | Lynn Road 1 | RS | 563412,320477 | 5 | YES | 30.6 | 30.6 | 30.9 | 28.7 | 30 |
| 44 | Lynn Road 2 | RS | 563377,320484 | 2 | YES | 34.3 | 35.5 | 36.6 | 31.8 | 32.8 |
| 45 | Gaywood Road 3 | RS | 563202,320488 | 4.5 | NO | 29.9 | 31.5 | 26.8 | 26 | 27 |
| 46 | Gaywood Road 1 | RS | 562565,320509 | 6.5 | NO | 24.4 | 26.3 | 26.2 | 23.8 | 24 |
| 47 | Austin Street 1 | RS | 562186,320376 | 1 | YES | 35.5 | 33.9 | 34.9 | 29.6 | 30.3 |
| 48 | Austin Street 2 | RS | 562180,320365 | 2 | YES | 30.6 | 30.2 | 32.1 | 28.4 | 26.8 |
| 51 | Wootton Road 3 | RS | 563521,320628 | 1.5 | NO | 19.7 | 19.6 | 19 | 17.3 | 18.3 |
| 52 | Lynn Road 3 | RS | 563289,320504 | 1 | NO | 30 | 29.4 | 28.7 | 27.2 | 27.3 |
| 58 | NORR | RS | 562171,319019 | 2 | NO | 24.8 | 30.1 | 28.9 | 26.7 | 28.2 |
| 66 | Gaywood Road | UB | 562595,320527 | N/A | NO | 22.6 | 22.3 | 22.6 | 20.9 | 20.4 |
| 67 | Greyfriars , London Road | UB | 562236,319579 | N/A | NO | 18.2 | 18.2 | 16.8 | 16.4 | 15.7 |
| 68 | Nursery, London Road | UB | 562143,319838 | N/A | NO | 22.9 | 21 | 19.4 | 18.8 | 19 |
| 69 | Whitefriars 1, Whitefriars Road | UB | 561994,319395 | N/A | NO | 15.3 | 13.8 | 14.1 | 12.8 | 12.7 |
| 70 | Whitefriars 2, Whitefriars Road | UB | 561930,319355 | N/A | NO | 12.4 | 12.5 | 13.9 | 12.4 | 12.3 |
| 75 | The Swan (2) Gayton Road | RS | 563469,320469 | 2 | YES | 34.1 | 34.8 | 35.1 | 33 | 32.2 |
| 76 | Hardwick Road | RS | 562597,318740 | 8 | NO | - | 20.1 | 20.8 | 18.8 | 18.2 |
| 79 | Tennyson Ave | RS | 562804,320423 | 2 | NO | - | 35.2 | 34.7 | 34 | 34.6 |
| 86 | Bus Station - Taxi Rank | Other | 562019,320139 | N/A | NO | - | - | - | 27.6 | 27.7 |

| Site | Site Name | Site Type | OS Grid Ref | Distance to Road (m) | Located In AQMA | Annual Mean $NO_2$ Concentration (µg/m$^3$)* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2012 (Bias 0.84) | 2013 (Bias 0.90) | 2014 (Bias 0.73) | 2015 (Bias 0.88) | 2016 (Bias 0.85) |
| 87 | Albion Street | RS | 562103,320164 | 2.6 | NO | - | - | - | 28.7 | 30.5 |
| 88 | Tennyson Avenue (2) | RS | 562795,320290 | 7.4 | NO | - | - | - | 18.9 | 18.3 |
| 89 | Whitefriars Terrace | RS | 561888,319467 | 1 | NO | - | - | - | 13.3 | 13 |
| 90 | Spenser Road | RS | 563366,322065 | 8 | NO | - | - | - | - | 14.0 |
| 91 | Reid Way | RS | 563255,321613 | 8 | NO | - | - | - | - | 13.6 |
| 92 | Garden Court | RS | 563256,321589 | 16 | NO | - | - | - | - | 12.9 |
| 93 | Front Way | RS | 563213,321283 | 9.7 | NO | - | - | - | - | 13.1 |

In **bold**, exceedance of the annual mean $NO_2$ AQS objective of 40µg/m$^3$
*Bias Adjustment Factors listed with relevant year, RS = Roadside; KS = Kerbside; UB = Urban Background;

### Figure 3.1 – Local Monitoring Locations within King's Lynn

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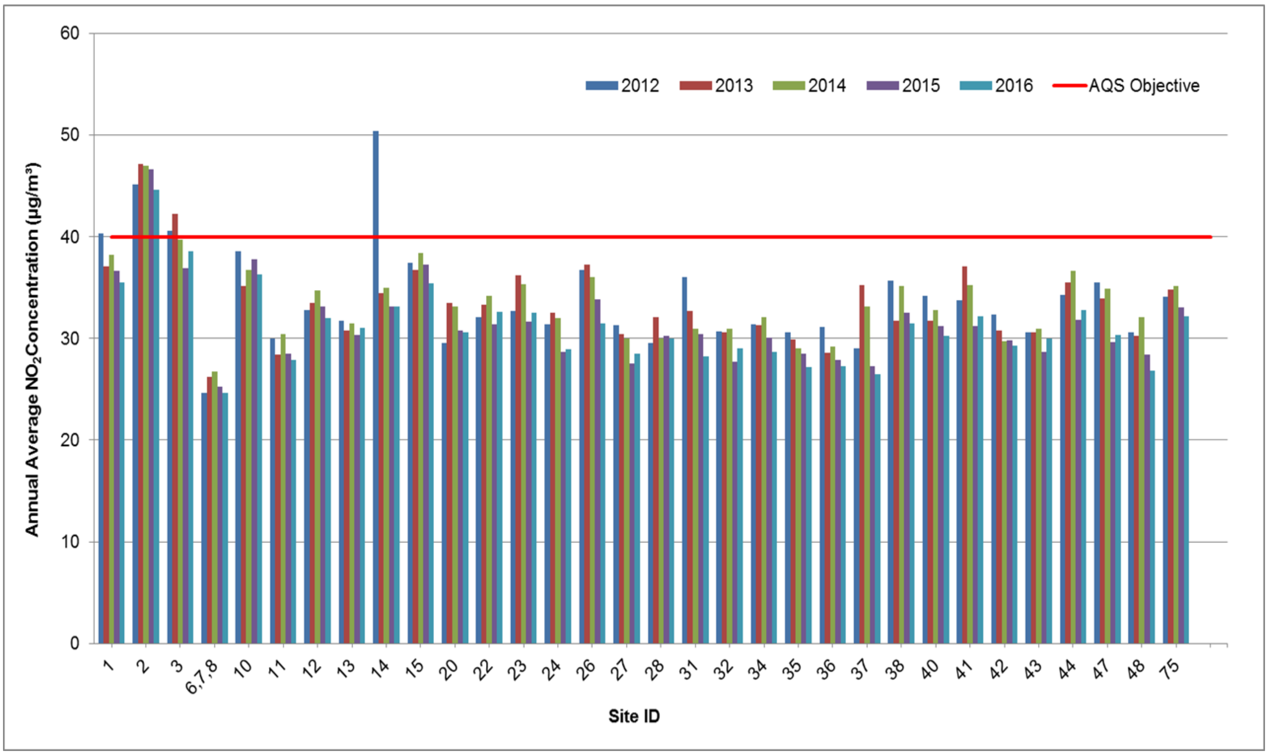
Only one of the 61 monitoring sites was observed to exceed the annual mean 40µg/m$^3$ AQS objective in 2016. The diffusion tube was located on Railway Road, within the Town Centre AQMA, and represented relevant exposure at this location.

Figure 3.2 shows the trend in annual mean $NO_2$ concentrations at monitoring locations within the AQMA for years 2012 to 2016. There are no obvious trends across the period, with some sites observed to increase and some decrease over the 5 year period.

**Figure 3.2 – Annual Mean $NO_2$ Concentrations at Passive Monitoring Locations within the Two Declared AQMAs from 2012 to 2016**




## 3.3 Background Mapped Concentration Estimates

Defra maintains a nationwide model of existing and future background air quality concentrations at a 1km grid square resolution. The data sets include annual average concentration estimates for $NO_x$, $NO_2$, $PM_{10}$ and $PM_{2.5}$, using a base year of 2015. The model used is semi-empirical in nature; it uses the national atmospheric emissions inventory (NAEI) emissions to model-predict the concentrations of pollutants at the centroid of each 1km grid square, calibrating these concentrations in relation to actual monitoring data.

Annual mean background concentrations have been obtained from the Defra published background maps[6] for consideration in the assessment, based on the 1km grid squares which cover the modelled area and the affected road network. The Defra mapped background concentrations for 2016 are presented in Table 3.4.

**Table 3.4 – Background Pollutant Concentrations (Defra Background Maps)**

| Grid Square (E,N) | 2016 Annual Mean Concentration (µg/m$^3$) | |
|---|---|---|
| | $NO_2$ | $NO_x$ |
| 564500, 321500 | 10.0 | 15.1 |
| 563500, 321500 | 9.6 | 18.4 |

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

| Grid Square (E,N) | 2016 Annual Mean Concentration (µg/m$^3$) | |
|---|---|---|
| | $NO_2$ | $NO_x$ |
| 563500, 320500 | 11.5 | 18.5 |
| 562500, 320500 | 10.8 | 21.6 |
| 561500, 320500 | 7.6 | 19.9 |
| 562500, 319500 | 14.7 | 21.4 |
| **AQS objective** | **40.0** | **-** |

These mapped background concentrations are below the respective annual mean AQS objectives. Annual mean background concentrations of $NO_2$ used in this study have been derived using the Defra background map concentration in which each specific receptor is located in.

# 4 Assessment Methodology

To predict pollutant concentrations of road traffic emissions the atmospheric dispersion model ADMS Roads version 4.0 was utilised, focusing on emissions of $NO_x$. A single scenario has been modelled reflecting $NO_2$ concentrations as were in 2016.

In order to provide consistency with the Council's own work on air quality, the guiding principles for air quality assessments as set out in the latest guidance and tools provided by Defra for air quality assessment (LAQM.TG(16)[1]) have been used.

The approach used in this assessment has been based on the following:

- Prediction of ambient $NO_2$ concentrations, to which existing receptors may be exposed and comparison with the relevant AQS objectives; and
- Determination of the geographical extent of any potential exceedances with a view to possible amendment of the boundary of the AQMA.

## 4.1 Traffic Inputs

The traffic data for this assessment has been taken from the Department for Transport (DfT) Traffic Counts website[7].

Details of the traffic flows used in this assessment are provided in Table 4.1.

**Table 4.1 – Traffic Data Inputs (2016 Base)**

| Road | AADT | % Car | % LGV | % HGV | % Bus and Coach | % Motorcycle |
|---|---|---|---|---|---|---|
| Austin Street | 14434 | 80 | 16.5 | 1 | 2 | 0.5 |
| Blackfriars Road | 12266 | 81 | 12.3 | 1 | 5 | 0.2 |
| Gayton Road | 16413 | 84 | 12.4 | 1 | 2 | 0.4 |
| Gaywood Road | 19695 | 86 | 11.5 | 1 | 2 | 0.6 |
| Hardwick Road | 20537 | 86 | 11.1 | 2 | 1 | 0.5 |
| John Kennedy Road | 15597 | 83 | 13.5 | 1 | 2 | 0.5 |
| Littleport Street | 19695 | 86 | 11.5 | 1 | 2 | 0.6 |
| London Road | 20481 | 83 | 13.5 | 1 | 2 | 0.5 |
| Lynn Road | 19695 | 86 | 11.5 | 1 | 2 | 0.6 |
| Nar Ouse Way | 12125 | 80 | 16.3 | 3 | 1 | 0.3 |
| Railway Road | 16759 | 86 | 10.8 | 1 | 2 | 0.4 |
| St James' Road | 20481 | 83 | 13.4 | 1 | 2 | 0.6 |
| Wootton Road | 13073 | 87 | 11.0 | 0 | 1 | 1.0 |
| Data taken from Department for Transport Traffic Counts Website http://www.dft.gov.uk/traffic-counts/ (2016 data) | | | | | | |

## 4.2 Emissions Estimates and Bus Fleet Composition

Using the traffic data presented in Table 4.1, emissions from road traffic have been estimated using version 8 of the Emissions Factors Toolkit (EFT)[8].

---

[7] Department for Transport Traffic Counts website - http://www.dft.gov.uk/traffic-counts/

[8] EFT_v8 available at - http://laqm.defra.gov.uk/review-and-assessment/tools/emissions-factors-toolkit.html

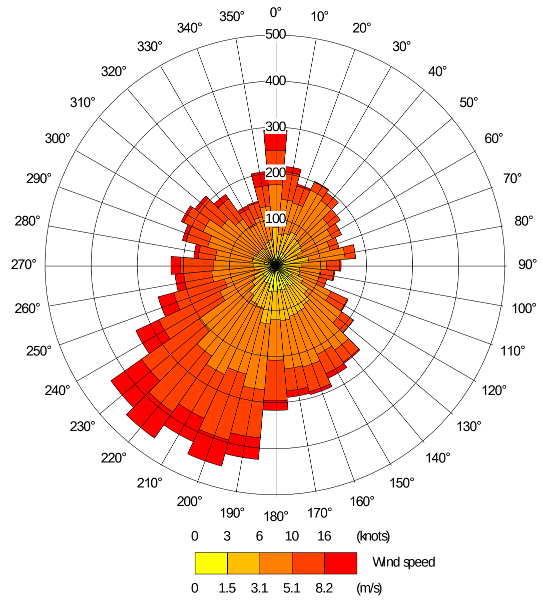
The EFT v8 used to calculate emissions from road traffic in this assessment assumes a default proportion of vehicles of each vehicle type are a certain Euro emissions standard. This is based on forecasts from 2015 base fleet composition data, as calculated by Ricardo-AEA's fleet turnover model (used for the development of the NAEI), which is based upon:

- The implementation dates of new emission standards and advice from DfT on the early penetration of sales of vehicles meeting these standards in the UK fleet;
- Assumed survival rates of vehicles in the fleet derived from historic licensing data and estimates of projected new vehicle sales. Projections are from a 2015 base year taking into account the current economic downturn;
- Advice from DfT on future sales of cars and LGVs by conventional and alternative vehicle technologies (i.e. hybrid and electric vehicles);
- Traffic growth assumptions according to the TfL's traffic growth factors for London and DfT's Road Traffic Forecast for the rest of the UK provided in June 2016; and
- Evidence from DfT's Automatic Number Plate Recognition data (2007-2011) on the age mix of vehicles on the road across the country.

## 4.3 Meteorological Data

2016 meteorological data from Marham weather station, located approximately 15km to the southwest of the modelled area, has been used in this assessment. A wind rose for this site for the year 2016 is shown in Figure 4.1.

**Figure 4.1 – Wind Rose for Marham Meteorological Data 2016**




Dispersion of air pollutants is difficult for computational models to calculate under calm conditions. Consequently, ADMS-Roads treats calm wind conditions by setting the minimum wind speed to 0.75m/s. It is recommended in LAQM.TG(16)[1] that the meteorological data file be tested within a dispersion model and the relevant output log file checked, to confirm the number of missing and calm hours that cannot be used by the dispersion model. This is important when considering predictions of high percentiles and the number of exceedances. LAQM.TG(16)[1] recommends that if there is less than 85% of meteorological data available over a year, modelled short-term concentrations should be expressed as percentiles, rather than as number of exceedances. 2016 meteorological data from Marham includes 8,494 lines of usable hourly data out of the total 8,760 for the year, i.e. 96.7% usable data. This is therefore suitable for the dispersion modelling exercise.

## 4.4 Sensitive Receptors

A total of 80 receptors are considered in the assessment of emissions from road traffic and their location is illustrated in Figure 4.2 and Figure 4.3 and detailed in Appendix 3 – Location of Discrete Receptors.

**Figure 4.2 – Receptor Locations considered in the Assessment of Emissions from Road Traffic – Town Centre AQMA**

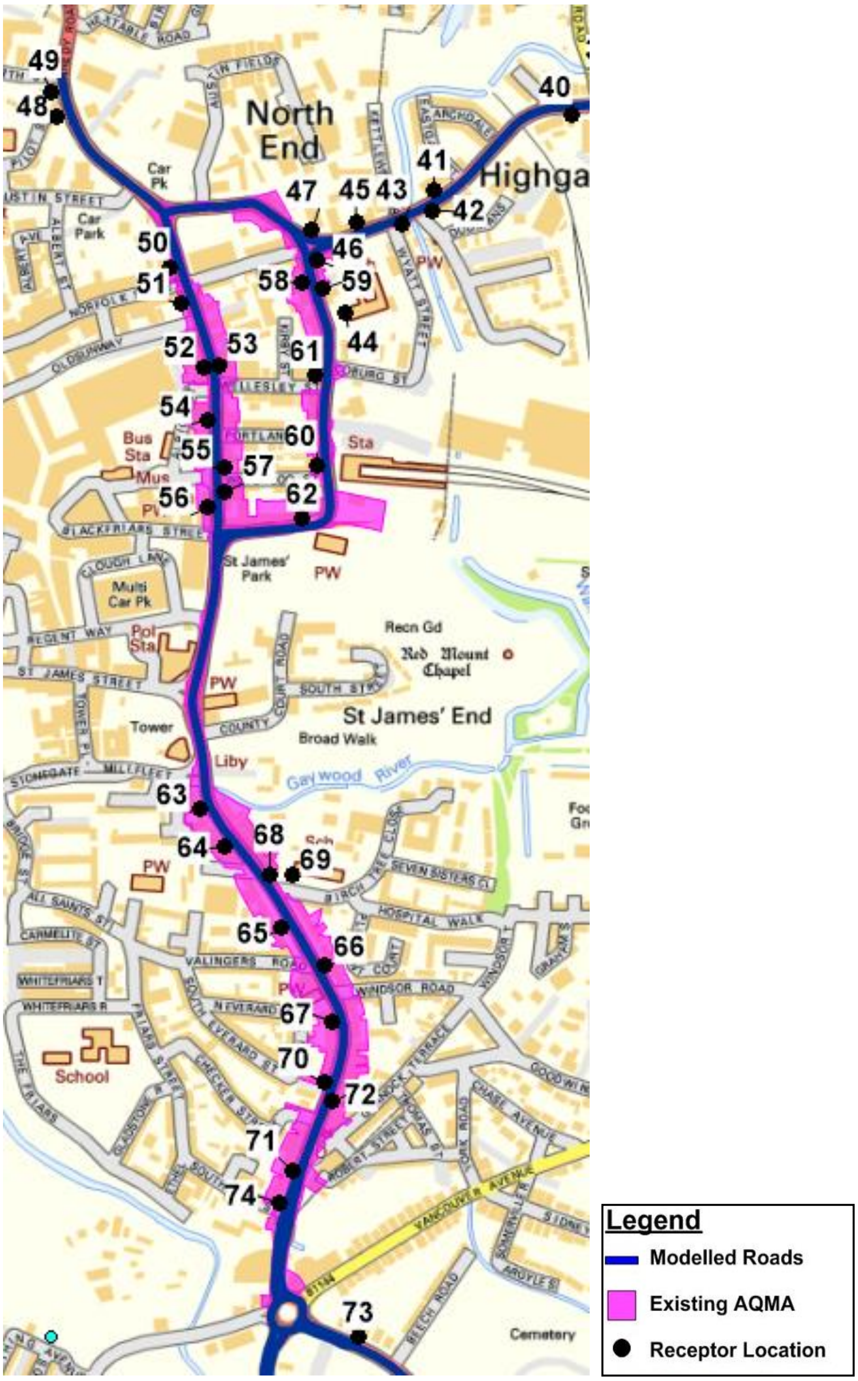
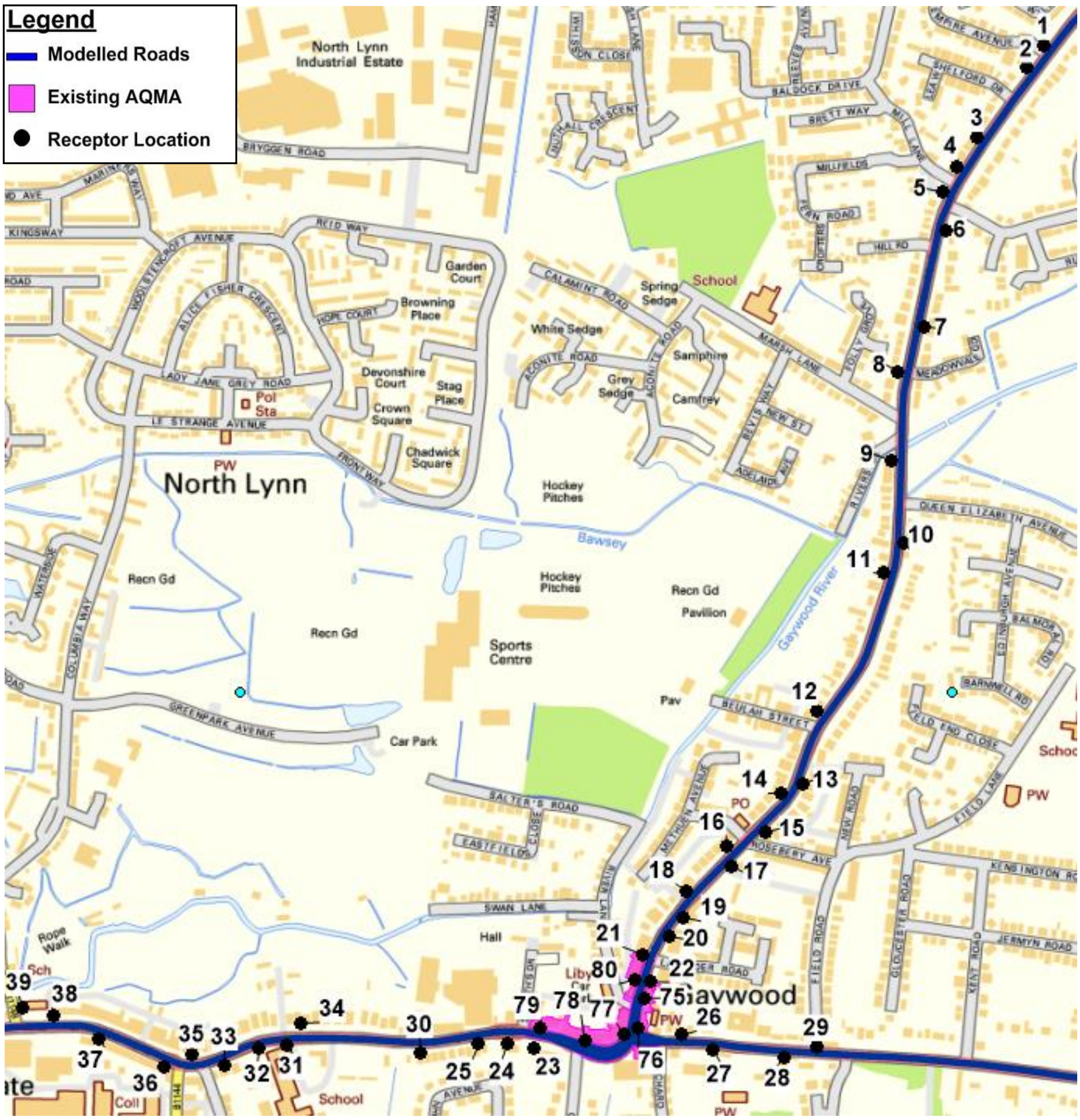


**Figure 4.3 – Receptor Locations considered in the Assessment of Emissions from Road Traffic – Gaywood Clock AQMA**






## 4.5 Model Outputs

The monitored background $NO_2$ concentration has been used in conjunction with the emissions from road traffic calculated in the ADMS-Roads model to calculate predicted total annual mean concentrations of $NO_x$ and $NO_2$.

For the prediction of annual mean $NO_2$ concentrations for the modelled scenarios, the output of the ADMS-Roads model for $NO_x$ has been converted to $NO_2$ following the methodology in LAQM.TG(16)[1] and using the $NO_x$ to $NO_2$ conversion tool developed on behalf of Defra. This tool also utilises the total background $NO_x$ and $NO_2$ concentrations. This assessment has utilised version 6.1 (October 2016) of the $NO_x$ to $NO_2$ conversion tool. The road contribution is then added to the appropriate $NO_2$ background concentration value to obtain an overall total $NO_2$ concentration.

Verification of the ADMS assessment has been undertaken using those local authority monitoring locations that are located adjacent to the affected road network. All $NO_2$ results presented in the assessment are those calculated following the process of model verification, using a factor of 1.146 around the Town Centre AQMA and a factor of 1.612 around the Gaywood Clock AQMA. Full details of the model verification can be found in Appendix 2 – ADMS Model Verification.

## 4.6 Uncertainty in $NO_x$ and $NO_2$ Trends

Recent studies have identified analyses of historical monitoring data within the UK that show a disparity between measured concentration data and the projected decline in concentrations associated with emission forecasts for future years[9]. The report identifies that trends in ambient concentrations of $NO_x$ and $NO_2$ in many urban areas of the UK have generally shown two characteristics; a decrease in concentration from about 1996 to 2002-2004, followed by a period of more stable concentrations from 2002-2004 up until 2009. This trend of more stable recent years is expected to continue in more recent years. Trends in more rural, less densely trafficked areas, tend to show downward trend in either $NO_x$ or $NO_2$, which are more in line with those expected.

The reason for this disparity is thought to be related to the actual on-road performance of vehicles, in particular diesel cars and vans, when compared with calculations based on the Euro emission standards. Preliminary studies suggest the following:

- NOx emissions from petrol vehicles appear to be in line with current projections and have decreased by 96% since the introduction of 3-way catalysts in 1993;
- NOx emissions from diesel cars, under urban driving conditions, do not appear to have declined substantially, up to and including Euro 5. There is limited evidence that the same pattern may occur for motorway driving conditions; and
- NOx emissions from Heavy Duty Vehicles (HDVs) equipped with Selective Catalytic Reduction (SCR) are much higher than expected when driving at low speeds.

This disparity in the historical national data highlights the uncertainty of future year projections of both $NO_x$ and $NO_2$.

Defra and the Devolved Administrations have investigated these issues and have since published an updated version of the Emissions Factors Toolkit (EFT Version 8) utilising COPERT 5 emission factors, which go some way to address this disparity. This assessment has utilised the latest EFT version 8 and associated tools published by Defra to help minimise any associated uncertainty when forming conclusions from this assessment.

[9] Carslaw, D, Beevers, S, Westmoreland, E, Williams, M, Tate, J, Murrells, T, Steadman, J, Li, Y, Grice, S, Kent, A and Tsagatakis, I. 2011. Trends in $NO_x$ and $NO_2$ emissions and ambient measurements in the UK. Prepared for DEFRA, 18th July 2011

# 5 Air Quality Modelling Results

## 5.1 Total Annual Mean $NO_2$

This assessment has considered emissions of $NO_2$ from road traffic at 80 existing receptor locations and across a generic output grid covering the modelled area. The intelligent gridding option was also applied to the ADMS model, meaning further points were added at locations close to roads for greater output resolution.

Table 5.1 provides a summary of the modelled annual mean $NO_2$ concentrations at each receptor. It can be seen that there are no predicted exceedances of the annual mean $NO_2$ 40µg/m³ AQS objective at any of the existing receptors within or close to both AQMAs. Furthermore, there was only 1 location (Receptor 66) which predicted concentrations within 10% of the annual mean AQS objective.

**Table 5.1 – Summary of Modelled Receptor Results**

| Receptor | Annual Mean (µg/m³) | | Receptor | Annual Mean (µg/m³) | |
|---|---|---|---|---|---|
| | AQS | 2016 | | AQS | 2016 |
| 1 | 40 | 17.5 | 41 | 40 | 24.6 |
| 2 | 40 | 17.5 | 42 | 40 | 24.4 |
| 3 | 40 | 19.7 | 43 | 40 | 24.5 |
| 4 | 40 | 19.2 | 44 | 40 | 19.4 |
| 5 | 40 | 18.8 | 45 | 40 | 23.9 |
| 6 | 40 | 19.3 | 46 | 40 | 26.0 |
| 7 | 40 | 19.6 | 47 | 40 | 25.5 |
| 8 | 40 | 18.5 | 48 | 40 | 18.8 |
| 9 | 40 | 19.1 | 49 | 40 | 18.4 |
| 10 | 40 | 19.8 | 50 | 40 | 23.2 |
| 11 | 40 | 19.2 | 51 | 40 | 21.7 |
| 12 | 40 | 18.8 | 52 | 40 | 23.1 |
| 13 | 40 | 19.5 | 53 | 40 | 28.5 |
| 14 | 40 | 19.6 | 54 | 40 | 23.0 |
| 15 | 40 | 18.6 | 55 | 40 | 25.9 |
| 16 | 40 | 18.9 | 56 | 40 | 24.5 |
| 17 | 40 | 19.1 | 57 | 40 | 26.0 |
| 18 | 40 | 20.1 | 58 | 40 | 22.6 |
| 19 | 40 | 20.3 | 59 | 40 | 24.0 |
| 20 | 40 | 21.3 | 60 | 40 | 25.1 |
| 21 | 40 | 22.2 | 61 | 40 | 23.3 |
| 22 | 40 | 23.4 | 62 | 40 | 25.4 |
| 23 | 40 | 22.3 | 63 | 40 | 23.9 |
| 24 | 40 | 23.2 | 64 | 40 | 23.1 |
| 25 | 40 | 25.3 | 65 | 40 | 23.2 |
| 26 | 40 | 25.0 | 66 | 40 | 36.7 |
| 27 | 40 | 21.4 | 67 | 40 | 28.0 |
| 28 | 40 | 21.1 | 68 | 40 | 32.6 |
| 29 | 40 | 24.3 | 69 | 40 | 19.9 |
| 30 | 40 | 20.4 | 70 | 40 | 26.0 |
| 31 | 40 | 24.5 | 71 | 40 | 30.0 |
| 32 | 40 | 25.4 | 72 | 40 | 32.7 |
| 33 | 40 | 22.9 | 73 | 40 | 24.0 |
| 34 | 40 | 21.8 | 74 | 40 | 25.1 |
| 35 | 40 | 26.1 | 75 | 40 | 25.5 |
| 36 | 40 | 24.3 | 76 | 40 | 35.0 |
| 37 | 40 | 23.4 | 77 | 40 | 35.5 |
| 38 | 40 | 24.1 | 78 | 40 | 33.4 |
| 39 | 40 | 22.0 | 79 | 40 | 33.1 |
| 40 | 40 | 26.1 | 80 | 40 | 23.6 |

*Red = Receptors within the Town Centre AQMA
*Blue = Receptors within the Gaywood Clock AQMA

Figure 5.1 and Figure 5.2 show annual mean $NO_2$ concentration isopleths for the gridded receptors covering the Town Centre and Gaywood Clock AQMAs respectively. Areas shaded red represent annual mean $NO_2$ concentrations above the 40µg/m$^3$ AQS objective and areas shaded black represent annual mean $NO_2$ concentrations within 10% of the 40µg/m$^3$ AQS objective.

**Figure 5.1 – Annual Mean $NO_2$ concentration isopleths showing areas predicted to be exceeding or close to exceeding the 40µg/m$^3$ AQS objective in the Town Centre AQMA**

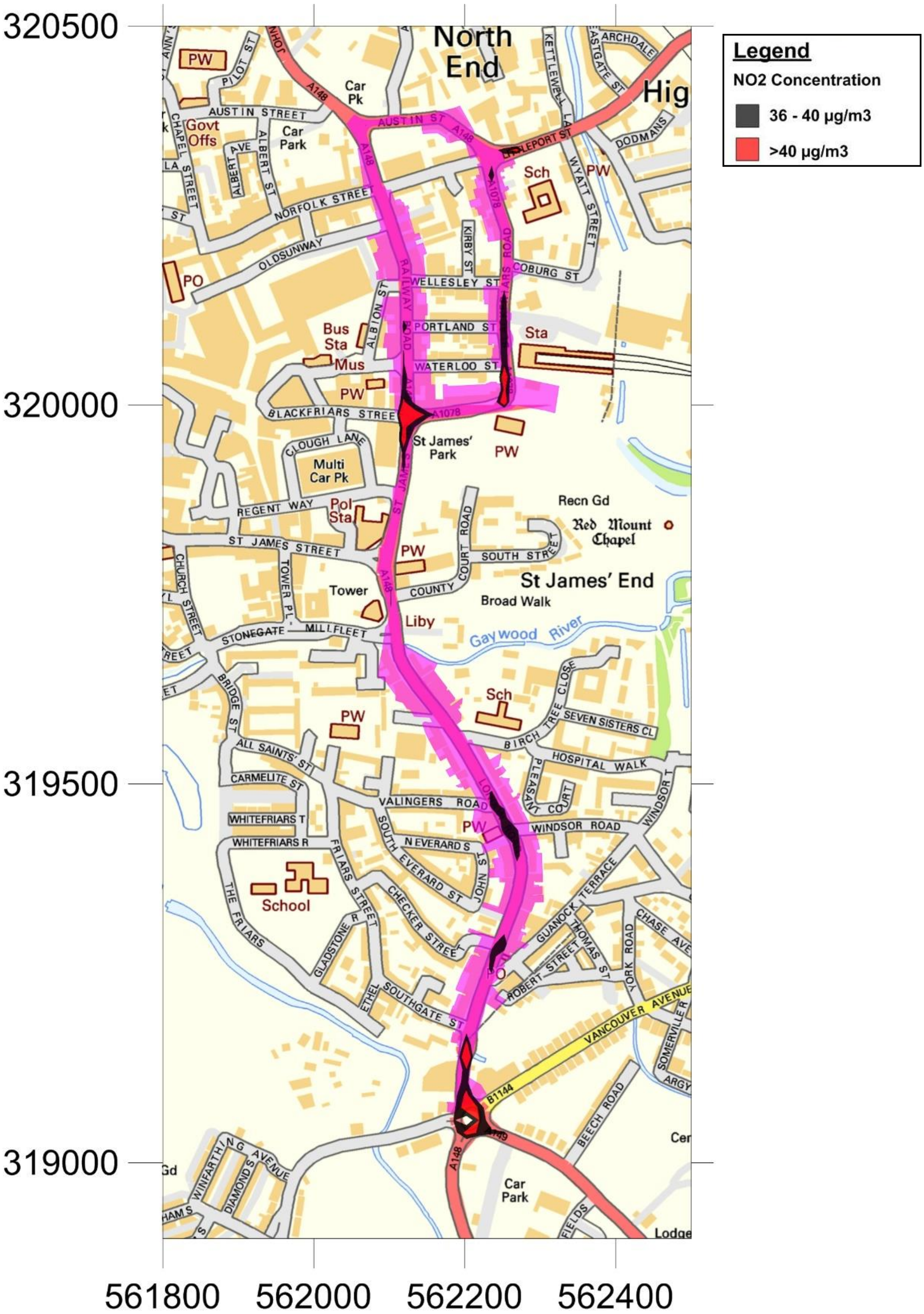



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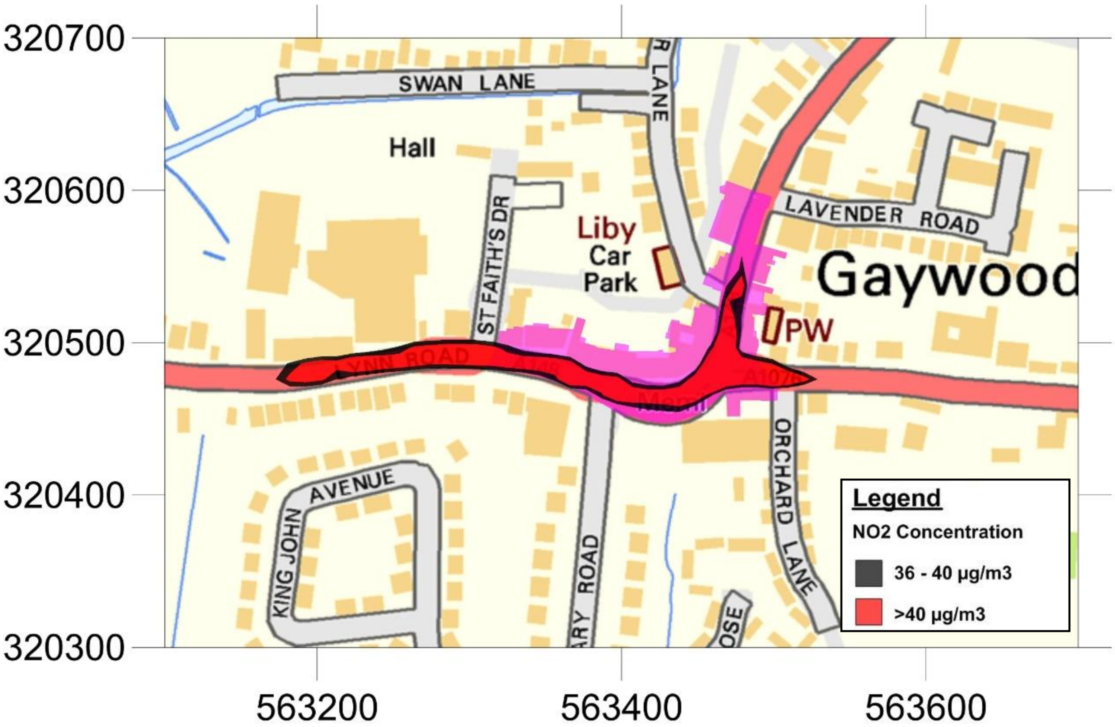
**Figure 5.2 – Annual Mean $NO_2$ concentration isopleths showing areas predicted to be exceeding or close to exceeding the 40µg/m³ AQS objective in the Gaywood Clock AQMA**

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Predicted exceedances are located within both existing AQMAs. With regards to the Town Centre AQMA, the exceedances are largely localised along parts of Blackfriars Road, the junction of St James' Road and Railway Road and the Southgates Roundabout. The Southgates Roundabout is not located within the AQMA and exceedances appear to remain within the roadway. The closest residential property to the roundabout is approximately 35m away and has reported concentrations below the annual mean $NO_2$ AQS objective. Therefore, at this time there is no immediate requirement to extend the AQMA to cover the roundabout. The contour map also highlights a small exceedance on Littleport Street outside the AQMA. Diffusion tube monitoring and modelled receptors on residential properties close to Littleport Street report concentrations below the annual mean $NO_2$ AQS objective and therefore, although the area should continue to be monitored, there is no immediate need to extend the AQMA along Littleport Street.

It should also be noted that it is likely the modelled concentrations along Railway Road are slightly under predicting due to limited traffic data availability for the roads feeding into Railway Road. This includes Wellesley Street, Portland Street and Waterloo Street. Diffusion tube monitoring in this area shows exceedances are being reported and therefore the AQMA should not be removed or adjusted along this stretch.

In regards to the Gaywood Clock AQMA, exceedances can be seen along the majority of the roads covered by the AQMA. There are also exceedances predicted outside the AQMA further along Lynn Road. Modelled receptors and monitored concentrations along this stretch of road report $NO_2$ concentrations below the annual mean AQS objective. This suggests that the exceedances are localised along the roadway and concentrations drop before reaching areas of exposure. Continued monitoring at sensitive areas along Lynn Road is recommended to ensure the concentrations remain below the AQS objective at potential areas of exposure. It is not recommended that the Gaywood Clock AQMA should be revoked or amended at this stage.

## 5.2 Source Apportionment

To help inform decisions about what action plan measures could be considered, source apportionment of the different road traffic categories has been undertaken. The source apportionment was carried out for the following vehicle categories:

- Cars
- Light goods vehicles (LGVs)
- Heavy goods vehicles (HGVs)
- Buses and coaches
- Motorcycles

Source apportionment results shown below are for two different selections of the modelled receptors:

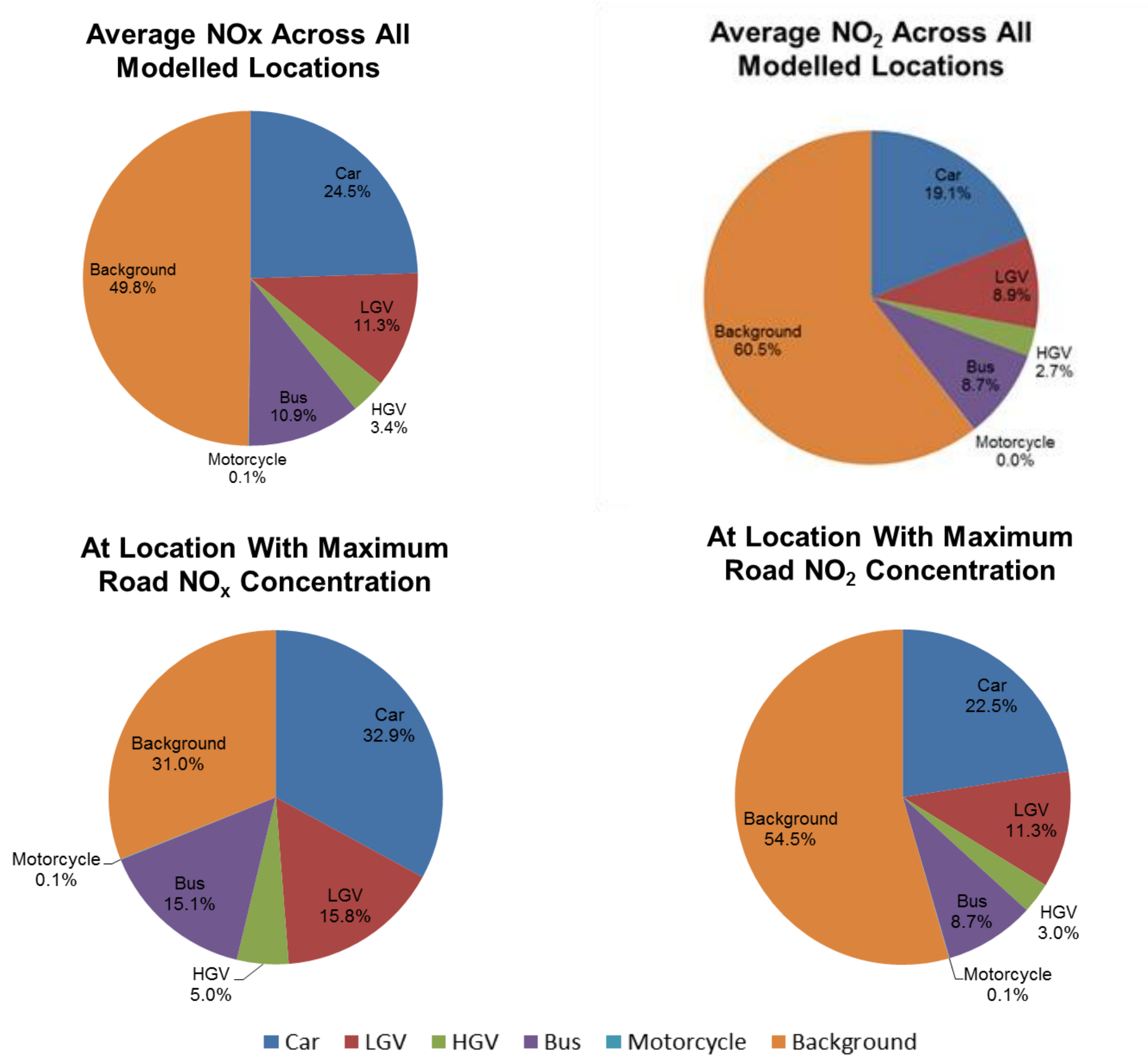
- Average across all modelled receptors ($NO_x$ and $NO_2$) – This provides an average at all modelled receptors and so is useful when considering possible action plan measure to test and adopt. It will however understate road NOx/$NO_2$ concentrations in problem areas;
- At the receptor with maximum road NOx and $NO_2$ concentration - Provides the NOx/$NO_2$ source apportionment at the receptor with the highest predicted road NOx/$NO_2$ concentration. This is likely to be in the area of most concern and so a good place to test and adopt action plan measures. Any gains predicted by action plan measures are however likely to be greatest at this location and so would not represent gains across the whole modelled area.

Table 5.2 and Figure 5.3 show results for the source apportionment exercise for the Town Centre AQMA and Figure 5.4 and Table 5.3 show results for the Gaywood Clock AQMA.

**Table 5.2 – Source Apportionment Results for the Town Centre AQMA**

| Results | All Vehicles | Car | LGV | HGV | Bus | Motorcycle | Background |
|---|---|---|---|---|---|---|---|
| **Average across all modelled receptors** | | | | | | | |
| **$NO_x$ Concentration (µg/m$^3$)** | 21.6 | 10.5 | 4.9 | 1.5 | 4.7 | 0.0 | 21.4 |
| **Percentage of Total $NO_x$** | 50.2 | 24.5 | 11.3 | 3.4 | 10.9 | 0.1 | 49.8 |
| **Percentage Road Contribution $NO_x$** | 100.0 | 48.8 | 22.5 | 6.8 | 21.8 | 0.1 | - |
| **$NO_2$ Concentration (µg/m$^3$)** | 7.8 | 3.8 | 1.8 | 0.5 | 1.7 | 0.0 | 12.0 |
| **Percentage of Total $NO_2$** | 39.5 | 19.1 | 8.9 | 2.7 | 8.7 | 0.0 | 60.5 |
| **Percentage Road Contribution $NO_2$** | 100.0 | 48.5 | 22.5 | 6.8 | 22.2 | 0.1 | - |
| **At Receptor with maximum road $NO_x$ Concentration** | | | | | | | |
| **$NO_x$ Concentration (µg/m$^3$)** | 47.5 | 22.7 | 10.9 | 3.4 | 10.4 | 0.0 | 21.4 |
| **Percentage of Total $NO_x$** | 69.0 | 32.9 | 15.8 | 5.0 | 15.1 | 0.1 | 31.0 |
| **Percentage Road Contribution $NO_x$** | 100.0 | 47.7 | 22.9 | 7.3 | 22.0 | 0.1 | - |
| **$NO_2$ Concentration (µg/m$^3$)** | 12.3 | 6.1 | 3.0 | 0.8 | 2.4 | 0.0 | 14.7 |
| **Percentage of Total $NO_2$** | 45.5 | 22.5 | 11.3 | 3.0 | 8.7 | 0.1 | 54.5 |
| **Percentage Road Contribution $NO_2$** | 100.0 | 49.5 | 24.7 | 6.5 | 19.2 | 0.1 | - |

**Figure 5.3 – Pie Charts showing Source Apportionment Results for the Town Centre AQMA**




When considering the average $NO_x$ concentration across all modelled receptors for the Town Centre AQMA, road traffic accounts for 21.6µg/m³ (50.2%) of 43µg/m³. Of this 43µg/m³, Cars account for the most (24.5%) of any of the vehicle types. Buses account for 4.7µg/m³ of $NO_x$ representing 10.9% of the overall predicted $NO_x$ concentration. In regards to the average $NO_2$ concentration across all modelled receptors for the Town Centre AQMA, road traffic accounts for 7.8µg/m² (39.5%) of 18.6µg/m³. Of this, Cars account for the most (19.1%) of any vehicle types.

At the receptor with the maximum road $NO_x$ concentration, road traffic accounts for 47.5µg/m³ (69%) of 68.9µg/m³. Of this 68.9µg/m³, Cars account for the most (32.9%) of any of the vehicle types. Buses account for 10.4µg/m³ of $NO_x$ representing 15.1% of the overall predicted $NO_x$ concentration. In regards to the receptor with the maximum $NO_2$ concentration, road traffic accounts for 12.3µg/m³ (45.5%) of 23.8µg/m³. Cars account for the most (22.5%) of any of the vehicle types.

**Figure 5.4 – Pie Charts showing Source Apportionment Results for the Gaywood Clock AQMA**

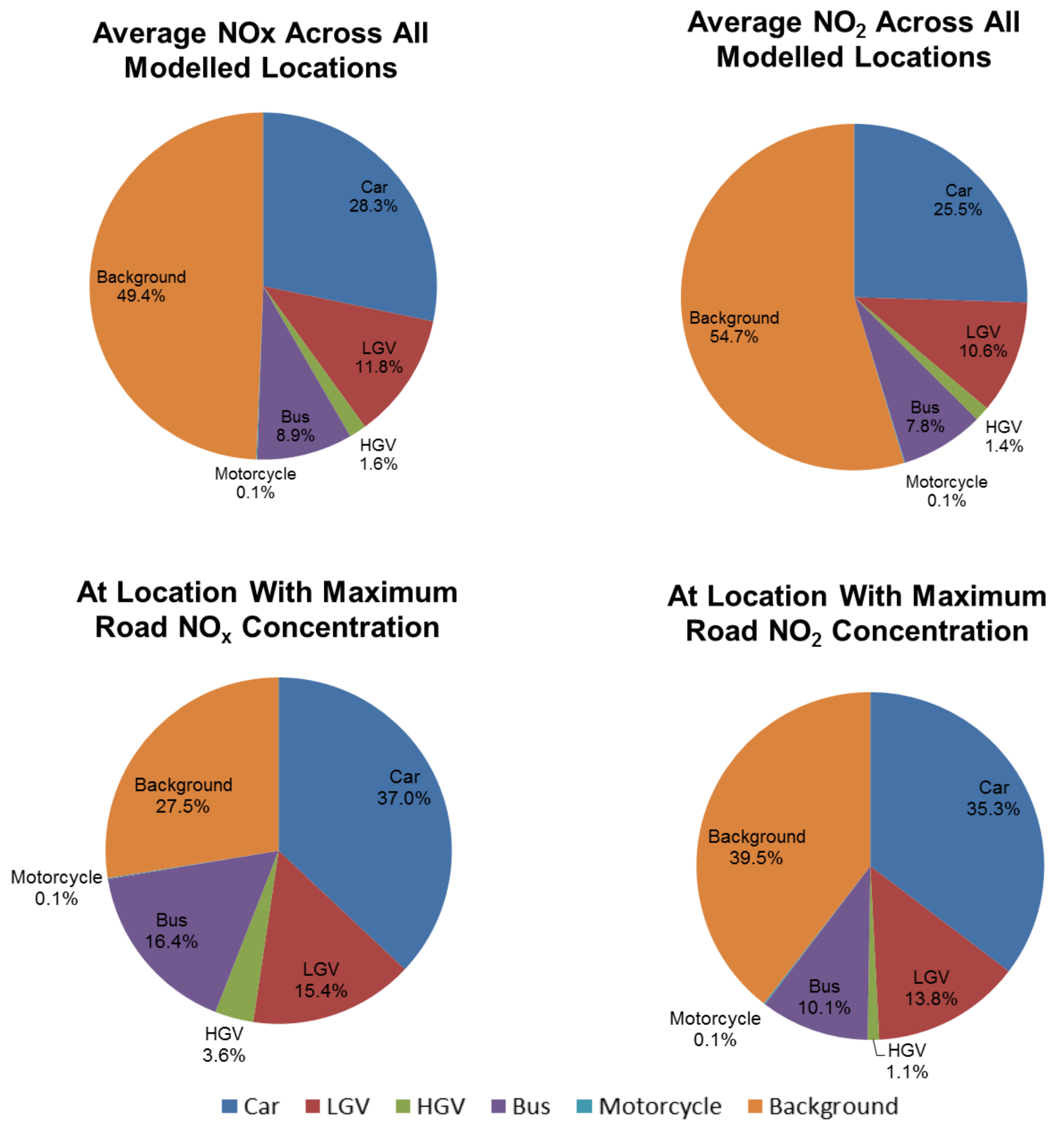



**Table 5.3 – Source Apportionment Results for the Gaywood Clock AQMA**

| Results | All Vehicles | Car | LGV | HGV | Bus | Motorcycle | Background |
|---|---|---|---|---|---|---|---|
| **Average across all modelled receptors** | | | | | | | |
| **$NO_x$ Concentration (µg/m$^3$)** | 19.5 | 10.9 | 4.5 | 0.6 | 3.4 | 0.0 | 19.0 |
| **Percentage (%)** | 50.6 | 28.3 | 11.8 | 1.6 | 8.9 | 0.1 | 49.4 |
| **Percentage Road Contribution (%)** | 100.0 | 55.8 | 23.2 | 3.2 | 17.6 | 0.2 | - |
| **$NO_2$ Concentration (µg/m$^3$)** | 9.0 | 5.1 | 2.1 | 0.3 | 1.6 | 0.0 | 10.9 |
| **Percentage of Total $NO_2$** | 45.3 | 25.5 | 10.6 | 1.4 | 7.8 | 0.1 | 54.7 |
| **Percentage Road Contribution $NO_2$** | 100.0 | 56.2 | 23.4 | 3.0 | 17.2 | 0.2 | - |
| **At Receptor with maximum road $NO_x$ Concentration** | | | | | | | |
| **$NO_x$ Concentration (µg/m$^3$)** | 48.7 | 24.9 | 10.3 | 2.4 | 11.0 | 0.1 | 18.5 |
| **Percentage (%)** | 72.5 | 37.0 | 15.4 | 3.6 | 16.4 | 0.1 | 27.5 |

| Results | All Vehicles | Car | LGV | HGV | Bus | Motorcycle | Background |
|---|---|---|---|---|---|---|---|
| **Percentage Road Contribution (%)** | 100.0 | 51.1 | 21.2 | 5.0 | 22.7 | 0.1 | - |
| **$NO_2$ Concentration (µg/m$^3$)** | 17.6 | 10.3 | 4.0 | 0.3 | 2.9 | 0.0 | 11.5 |
| **Percentage of Total $NO_2$** | 60.5 | 35.3 | 13.8 | 1.1 | 10.1 | 0.1 | 39.5 |
| **Percentage Road Contribution $NO_2$** | 100.0 | 58.4 | 22.9 | 1.8 | 16.7 | 0.2 | - |

When considering the average $NO_x$ concentration across all modelled receptors for the Gaywood Clock AQMA, road traffic accounts for 19.5µg/m$^3$ (50.6%) of 48.7µg/m$^3$. Of this 48.7µg/m$^3$, Cars account for the most (28.3%) of any of the vehicle types. Buses account for 3.4µg/m$^3$ of $NO_x$ representing 8.9% of the overall predicted $NO_x$ concentration. In regards to the average $NO_2$ concentration across all modelled receptors for the Gaywood Clock AQMA, road traffic accounts for 9µg/m$^2$ (45.3%) of 19.8µg/m$^3$. Of this, Cars account for the most (25.5%) of any vehicle types.

At the receptor with the maximum road $NO_x$ concentration, road traffic accounts for 48.7µg/m$^3$ (72.5%) of 48.7µg/m$^3$. Of this 48.7µg/m$^3$, Cars account for the most (37%) of any of the vehicle types. Buses account for 11µg/m$^3$ of $NO_x$ representing 16.4% of the overall predicted $NO_x$ concentration. In regards to the receptor with the maximum $NO_2$ concentration, road traffic accounts for 17.6µg/m$^3$ (60.5%) of 28.4µg/m$^3$. Cars account for the most (35.3%) of any of the vehicle types.

In comparison between the source apportionment study for the Town Centre AQMA and Gaywood Clock AQMA, it can be seen that the background $NO_x$ concentration is relatively consistent between the two areas. However, the $NO_x$ contribution from HGVs and buses/coaches is greater in the Town Centre AQMA whereas the contribution from cars is greater in the Gaywood Clock AQMA. With regards to $NO_2$, a greater proportion of the overall $NO_2$ is derived from the background, particularly in the Town Centre AQMA. Although cars are the greatest vehicle contributor to emissions in both AQMAs, the spread across all vehicle sectors is more pronounced within the Town Centre AQMA. This suggests measures targeting all vehicle types will have a greater impact in the Town Centre AQMA.

# 6 Conclusions and Future Project Actions

Bureau Veritas UK Ltd has been commissioned by the Borough of King's Lynn & West Norfolk to undertake dispersion modelling of the current AQMAs to take into account latest available traffic data and 2016 air quality monitoring data, and carry out a source apportionment exercise to inform the subsequent new action plan.

## 6.1 Air Quality Modelling Conclusions

The ADMS-Roads dispersion model (version 4.0) has been used to determine the likely $NO_2$ concentrations at existing receptor locations in the area around the Town Centre and Gaywood Clock AQMAs.

Annual mean $NO_2$ concentrations were predicted at 80 residential receptors around the main road links of concern, representative of worst-case exposure. Annual mean $NO_2$ concentrations were found to be below the 40µg/m$^3$ annual mean AQS objective at all locations and only one receptor (60) predicted concentrations within 10% of the annual mean AQS objective.

The gridded receptors highlighted predicted exceedances located within both existing AQMAs. With regards to the Town Centre AQMA, exceedances were predicted along Southgates Roundabout, which is not located within the AQMA. The exceedances appear to remain within the roadway and the closest residential property is approximately 35m away. Therefore, at this time there is no immediate requirement to extend the AQMA to cover the roundabout. Small exceedances were also predicted outside the AQMA along Littleport Street. Nonetheless, diffusion tube monitoring carried out in this area has confirmed concentrations to be within the AQS objective at relevant exposure.

In regards to the Gaywood Clock AQMA, exceedances can be seen along the majority of the roads covered by the AQMA. There are also exceedances predicted outside the AQMA further along Lynn Road. Modelled receptors and monitored concentrations along this stretch of road report $NO_2$ concentrations below the annual mean AQS objective. This suggests that the exceedances are localised along the roadway and concentrations drop before reaching areas of potential exposure on the roadside. Continued monitoring at sensitive areas along Lynn Road is recommended to ensure the concentrations remain below the AQS objective at potential areas of exposure. It is not recommended that the Gaywood Clock AQMA should be revoked or amended at this stage.

The source apportionment exercise highlighted the slight differences in traffic composition between the two AQMAs. It can be seen that the background $NO_x$ concentration is relatively consistent between the two areas. However, the $NO_x$ contribution from HGVs and buses/coaches is greater in the Town Centre AQMA whereas the contribution from cars is greater in the Gaywood Clock AQMA. With regards to $NO_2$, a greater proportion of the overall $NO_2$ is derived from the background, particularly in the Town Centre AQMA. Although cars are the greatest vehicle contributor to emissions in both AQMAs, the spread across all vehicle sectors is more pronounced within the Town Centre AQMA. Understanding the source apportionment will help to ensure measures implemented in the AQAP are focused to the specific issues associated with each AQMA.

Overall, the dispersion modelling assessment has determined that no current changes are required to the boundaries of the Town Centre and Gaywood Clock AQMAs. However, it has highlighted areas where monitoring should continue to ensure the pollutant concentrations do not worsen in these areas. The information provided in this assessment should be used to inform the update of the AQAP.

# Appendices

## Appendix 1 – Background to Air Quality

Emissions from road traffic contribute significantly to ambient pollutant concentrations in urban areas. The main constituents of vehicle exhaust emissions, produced by fuel combustion are carbon dioxide ($CO_2$) and water vapour ($H_2O$). However, combustion engines are not 100% efficient and partial combustion of fuel results in emissions of a number of other pollutants, including carbon monoxide (CO), particulate matter (PM), Volatile Organic Compounds (VOCs) and hydrocarbons (HC). For HC, the pollutants of most concern are 1,3 - butadiene ($C_4H_6$) and benzene ($C_6H_6$). In addition, some of the nitrogen (N) in the air is oxidised under the high temperature and pressure during combustion; resulting in emissions of oxides of nitrogen ($NO_x$). $NO_x$ emissions from vehicles predominately consist of nitrogen oxide (NO), but also contain nitrogen dioxide ($NO_2$). Once emitted, NO can be oxidised in the atmosphere to produce further $NO_2$.

The quantities of each pollutant emitted depend upon a number of parameters; including the type and quantity of fuel used, the engine size, the vehicle speed, and the type of emissions abatement equipment fitted. Once emitted, these pollutants disperse in the air. Where there is no additional source of emission, pollutant concentrations generally decrease with distance from roads, until concentrations reach those of the background.

This air quality assessment focuses on $NO_2$ as this pollutant is least likely to meet the respective Air Quality Strategy (AQS) objectives near roads. This has been confirmed over recent years by the outcome of the Local Air Quality Management (LAQM) regime. The most recent statistics[10] regarding Air Quality Management Areas (AQMAs) show that, 655 AQMAs have been declared in the UK, of which 618 include $NO_2$ and 91 include $PM_{10}$ (a number of AQMAs have been declared for both pollutants). The majority (94%) of existing AQMAs have been declared in relation to road traffic emissions.

In line with these results, the reports produced by the Council under the LAQM regime have confirmed that road traffic within their administrative area is the main issue in relation to air quality.

An overview of $NO_2$, describing briefly the sources and processes influencing the ambient concentrations, is presented below.

### Nitrogen Oxides ($NO_x$)

NO and $NO_2$, collectively known as $NO_x$, are produced during the high temperature combustion processes involving the oxidation of N. Initially, $NO_x$ are mainly emitted as NO, which then undergoes further oxidation in the atmosphere, particularly with ozone ($O_3$), to produce secondary $NO_2$. Production of secondary $NO_2$ could also be favoured due to a class of compounds, VOCs, typically present in urban environments, and under certain meteorological conditions, such as hot sunny days and stagnant anti-cyclonic winter conditions.

Of $NO_x$, it is $NO_2$ that is associated with health impacts. Exposure to $NO_2$ can bring about reversible effects on lung function and airway responsiveness. It may also increase reactivity to natural allergens, and exposure to $NO_2$ puts children at increased risk of respiratory infection and may lead to poorer lung function in later life.

In the UK, emissions of NOx have decreased by 62% between 1990 and 2010. For 2010, $NO_x$ (as $NO_2$) emissions were estimated to be 1,106kt. The transport sector remained the largest source of $NO_x$ emissions with road transport contribution 34% to $NO_x$ emissions in 2010.

[10] Statistics from the UK AQMA website available at http://aqma.defra.gov.uk – Figures as of June 2017

# Appendix 2 – ADMS Model Verification

The ADMS-Roads dispersion model has been widely validated for this type of assessment and is specifically listed in the Defra's LAQM.TG(16)[1] guidance as an accepted dispersion model.

Model validation undertaken by the software developer (CERC) will not have included validation in the vicinity of the modelled area. It is therefore necessary to perform a comparison of modelled results with local monitoring data at relevant locations. This process of verification attempts to minimise modelling uncertainty and systematic error by correcting modelled results by an adjustment factor to gain greater confidence in the final results.

The predicted results from a dispersion model may differ from measured concentrations for a large number of reasons, including uncertainties associated with:

- Background concentration estimates;
- Source activity data such as traffic flows and emissions factors;
- Monitoring data, including locations; and
- Overall model limitations.

Model verification is the process by which these and other uncertainties are investigated and where possible minimised. In reality, the differences between modelled and monitored results are likely to be a combination of all of these aspects.

Model setup parameters and input data were checked prior to running the models in order to reduce these uncertainties. The following were checked to the extent possible to ensure accuracy:

- Traffic data;
- Distance between sources and monitoring as represented in the model;
- Speed estimates on roads;
- Background monitoring and background estimates; and
- Monitoring data.

Traffic data was obtained from the DfT traffic count website[7] as detailed in Section 4.1. The Borough Council of Kings Lynn & West Norfolk, as part of its LAQM commitments, undertakes monitoring at 44 locations in close proximity to the modelled road network. Details of the 38 passive and 2 automatic LAQM monitoring sites used for the purposes of model verification are presented in Table A1.

Details of all the automatic and passive monitoring sites that are located in close proximity to the Site are provided in Section 3.2. Not all of monitoring sites have been used to verify the model, as per LAQM.TG(16) guidance[7] only Roadside monitoring sites that are located on modelled road links within the assessment have been used.

The following four diffusion tube locations were not used due to various reasons:

- DT2 – Adjacent road not included in the model
- DT25 – Located 75m from the kerb
- DT39 – Adjacent road not included in the model
- DT46 – Adjacent road not included in the model

### Table A1 – Local Monitoring Data Suitable for Model Verification

| Site | Site Name | Site Type [a] | OS Grid Ref | 2016 Annual Mean $NO_2$ Concentration (µg/m$^3$) (Bias 0.85*) |
|---|---|---|---|---|
| DT1 | Railway Road 1 | RS | 562073,320304 | 35.5 |
| DT3 | Railway Road 5 | RS | 562117,320095 | 38.6 |
| DT6 | Southgates Monitoring Station | RS | 562226,319191 | 24.6 |
| DT10 | London Road 1 | RS | 562101,319679 | 36.3 |
| DT11 | London Road 2 | RS | 562165,319575 | 27.9 |
| DT12 | London Road 3 | RS | 562243,319452 | 32 |
| DT13 | London Road 4 | RS | 562264,319375 | 31 |
| DT14 | London Road 5 | RS | 562227,319266 | 33.1 |
| DT15 | Southgates | RS | 562190,319102 | 35.4 |
| DT18 | Hardwick Rd | RS | 562266,319043 | 24.5 |
| DT20 | London Road 10 | RS | 562244,319261 | 30.6 |
| DT22 | London Road 6 | RS | 562285,319386 | 32.6 |
| DT23 | London Road 7 | RS | 562162,319614 | 32.5 |
| DT24 | London Road 8 | RS | 562136,319651 | 28.9 |
| DT26 | Railway Road 7 | RS | 562131,319996 | 31.5 |
| DT27 | St John's Terrace | RS | 562178,319999 | 28.5 |
| DT28 | St John's Terrace/Blackfriar's | RS | 562253,320015 | 30 |
| DT31 | Railway Road 2 | RS | 562129,320132 | 28.2 |
| DT32 | Railway Road 3 | RS | 562119,320216 | 29 |
| DT34 | Blackfriars 2 | RS | 562244,320129 | 28.7 |
| DT35 | Blackfriars 1 | RS | 562245,320238 | 27.2 |
| DT36 | Norfolk Street | RS | 562219,320319 | 27.3 |
| DT37 | Blackfriars 3 | RS | 562254,320259 | 26.5 |
| DT38 | Littleport Street | RS | 562257,320323 | 31.5 |
| DT40 | The Swan (1) Gayton Road | RS | 563490,320469 | 30.2 |
| DT41 | Wootton Road 2 | RS | 563478,320515 | 32.2 |
| DT42 | Wootton Road 1 | RS | 563480,320582 | 29.3 |
| DT43 | Lynn Road 1 | RS | 563412,320477 | 30 |
| DT44 | Lynn Road 2 | RS | 563377,320484 | 32.8 |
| DT45 | Gaywood Road 3 | RS | 563202,320488 | 27 |
| DT47 | Austin Street 1 | RS | 562186,320376 | 30.3 |
| DT48 | Austin Street 2 | RS | 562180,320365 | 26.8 |
| DT51 | Wootton Road 3 | RS | 563521,320628 | 18.3 |
| DT52 | Lynn Road 3 | RS | 563289,320504 | 27.3 |
| DT58 | NORR | RS | 562171,319019 | 28.2 |
| DT75 | The Swan (2) Gayton Road | RS | 563469,320469 | 32.2 |
| DT76 | Hardwick Road | RS | 562597,318740 | 18.2 |
| | Gaywood Automatic Site | RS | 563437,320472 | **45** |
| | Southgates Automatic Site | RS | 562226,319191 | 25 |

In **bold**, exceedance of the annual mean $NO_2$ AQS objective of 40µg/m$^3$
[a] RS = Roadside (sites with sample inlets between 1m and 5m of the kerbside)
*Bias Adjustment Factors listed with relevant year
*Red = Monitoring sites used for verification of the Town Centre AQMA
*Blue = Monitoring sites used for verification of the Gaywood Clock AQMA

## Verification calculations

The verification of the modelling output was performed in accordance with the methodology provided in Annex 3 of LAQM.TG(16)[1]. Verification was carried out separately for the Town Centre AQMA and the Gaywood Clock AQMA.

## Town Centre AQMA

For the verification and adjustment of NOx/$NO_2$, the LAQM monitoring data was used as shown in Table A1 (highlighted in red). Data capture for 2016 at all sites was above the 75% threshold. Table A2 shows an initial comparison of the monitored and unverified modelled $NO_2$ results for the year 2016, in order to determine if verification and adjustment was required.

**Table A2 – Comparison of Unverified Modelled and Monitored $NO_2$ Concentrations (Town Centre AQMA)**

| Site ID | Site Type [a] | Background $NO_2$ | Monitored total $NO_2$ (µg/m$^3$) | Modelled total $NO_2$ (µg/m$^3$) | % Difference (modelled vs. monitored) |
|---|---|---|---|---|---|
| **DT1** | RS | 14.1 | 35.5 | 23.4 | -34.0 |
| **DT3** | RS | 14.1 | 38.6 | 30.4 | -21.4 |
| **DT6** | RS | 14.3 | 24.6 | 20.4 | -17.2 |
| **DT10** | RS | 14.3 | 36.3 | 29.5 | -18.6 |
| **DT11** | RS | 14.3 | 27.9 | 23.4 | -16.3 |
| **DT12** | RS | 14.3 | 32.0 | 33.1 | 3.5 |
| **DT13** | RS | 14.3 | 31.0 | 28.3 | -8.7 |
| **DT14** | RS | 14.3 | 33.1 | 31.5 | -4.9 |
| **DT15** | RS | 14.3 | 35.4 | 35.7 | 0.8 |
| **DT18** | RS | 14.3 | 24.5 | 23.6 | -3.7 |
| **DT20** | RS | 14.3 | 30.6 | 31.2 | 2.0 |
| **DT22** | RS | 14.3 | 32.6 | 23.2 | -29.0 |
| **DT23** | RS | 14.3 | 32.5 | 26.1 | -19.7 |
| **DT24** | RS | 14.3 | 28.9 | 22.5 | -22.0 |
| **DT26** | RS | 14.3 | 31.5 | 29.4 | -6.6 |
| **DT27** | RS | 14.3 | 28.5 | 26.1 | -8.3 |
| **DT28** | RS | 14.1 | 30.0 | 33.6 | 11.9 |
| **DT31** | RS | 14.1 | 28.2 | 22.9 | -18.7 |
| **DT32** | RS | 14.1 | 29.0 | 24.9 | -14.0 |
| **DT34** | RS | 14.1 | 28.7 | 31.9 | 11.0 |
| **DT35** | RS | 14.1 | 27.2 | 22.6 | -16.8 |
| **DT36** | RS | 14.1 | 27.3 | 21.1 | -22.6 |
| **DT37** | RS | 14.1 | 26.5 | 22.0 | -16.8 |
| **DT38** | RS | 14.1 | 31.5 | 28.6 | -9.2 |
| **DT47** | RS | 14.1 | 30.3 | 24.3 | -19.9 |
| **DT48** | RS | 14.1 | 26.8 | 21.5 | -19.7 |
| **DT58** | RS | 14.3 | 28.2 | 21.9 | -22.3 |
| **DT76** | RS | 13.7 | 18.2 | 18.5 | 1.4 |
| **Southgates** | RS | 14.3 | 25.0 | 21.9 | -12.4 |

[a] RS = Roadside (sites with sample inlets between 1m and 5m of the kerbside)

The model was observed to be under predicting at 23 locations and over predicting at 6 locations. No further improvement of the modelled results could be obtained on this occasion. Therefore adjustment of modelled results was necessary. The relevant data was gathered to allow the adjustment factor to be calculated.

Model adjustment needs to be undertaken based on $NO_x$ and not $NO_2$. For the diffusion tube monitoring results used in the calculation of the model adjustment, $NO_x$ was derived from $NO_2$; these calculations were undertaken using a spreadsheet tool available from the LAQM website[11].

Table A3 provides the relevant data required to calculate the model adjustment based on regression of the modelled and monitored road source contribution to $NO_x$.

[11] http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html#NOxNO2calc

### Table A3 – Data Required for Adjustment Factor Calculation (Town Centre AQMA)

| Site ID | Monitored total $NO_2$ (µg/m³) | Monitored total $NO_x$ (µg/m³) | Background $NO_2$ (µg/m³) | Background $NO_x$ (µg/m³) | Monitored road contribution $NO_2$ (total - background) (µg/m³) | Monitored road contribution $NO_x$ (total - background) (µg/m³) | Modelled road contribution $NO_x$ (excludes background) (µg/m³) |
|---|---|---|---|---|---|---|---|
| **DT1** | 35.5 | 63.7 | 14.1 | 19.6 | 21.4 | 44.1 | 18.1 |
| **DT3** | 38.6 | 71.0 | 14.1 | 19.6 | 24.5 | 51.4 | 32.6 |
| **DT6** | 24.6 | 40.0 | 14.3 | 19.8 | 10.3 | 20.2 | 11.7 |
| **DT10** | 36.3 | 65.5 | 14.3 | 19.8 | 22.0 | 45.7 | 30.6 |
| **DT11** | 27.9 | 46.9 | 14.3 | 19.8 | 13.6 | 27.1 | 17.7 |
| **DT12** | 32.0 | 55.8 | 14.3 | 19.8 | 17.7 | 36.0 | 38.4 |
| **DT13** | 31.0 | 53.6 | 14.3 | 19.8 | 16.7 | 33.8 | 27.9 |
| **DT14** | 33.1 | 58.2 | 14.3 | 19.8 | 18.8 | 38.4 | 34.8 |
| **DT15** | 35.4 | 63.4 | 14.3 | 19.8 | 21.1 | 43.6 | 44.3 |
| **DT18** | 24.5 | 39.8 | 14.3 | 19.8 | 10.2 | 20.0 | 18.2 |
| **DT20** | 30.6 | 52.7 | 14.3 | 19.8 | 16.3 | 32.9 | 34.2 |
| **DT22** | 32.6 | 57.1 | 14.3 | 19.8 | 18.3 | 37.3 | 17.3 |
| **DT23** | 32.5 | 56.9 | 14.3 | 19.8 | 18.2 | 37.1 | 23.3 |
| **DT24** | 28.9 | 49.0 | 14.3 | 19.8 | 14.6 | 29.2 | 16.0 |
| **DT26** | 31.5 | 54.7 | 14.3 | 19.8 | 17.2 | 34.9 | 30.3 |
| **DT27** | 28.5 | 48.2 | 14.3 | 19.8 | 14.2 | 28.4 | 23.4 |
| **DT28** | 30.0 | 51.5 | 14.1 | 19.6 | 15.9 | 31.9 | 39.8 |
| **DT31** | 28.2 | 47.6 | 14.1 | 19.6 | 14.1 | 28.0 | 17.1 |
| **DT32** | 29.0 | 49.3 | 14.1 | 19.6 | 14.9 | 29.7 | 21.1 |
| **DT34** | 28.7 | 48.7 | 14.1 | 19.6 | 14.6 | 29.1 | 36.0 |
| **DT35** | 27.2 | 45.5 | 14.1 | 19.6 | 13.1 | 25.9 | 16.4 |
| **DT36** | 27.3 | 45.7 | 14.1 | 19.6 | 13.2 | 26.1 | 13.4 |
| **DT37** | 26.5 | 44.0 | 14.1 | 19.6 | 12.4 | 24.4 | 15.3 |
| **DT38** | 31.5 | 54.8 | 14.1 | 19.6 | 17.4 | 35.1 | 28.9 |
| **DT47** | 30.3 | 52.1 | 14.1 | 19.6 | 16.2 | 32.5 | 19.8 |
| **DT48** | 26.8 | 44.7 | 14.1 | 19.6 | 12.7 | 25.0 | 14.3 |
| **DT58** | 28.2 | 47.5 | 14.3 | 19.8 | 13.9 | 27.7 | 14.8 |
| **DT76** | 18.2 | 27.4 | 13.7 | 18.8 | 4.5 | 8.6 | 9.1 |
| **Southgates** | 25.0 | 40.9 | 14.3 | 19.8 | 10.7 | 21.0 | 14.8 |

Figure A1 provides a comparison of the Monitored Road $NO_x$ Contribution versus the Unverified Modelled Road $NO_x$ and the equation of the trend line based on linear regression through zero. The Total Monitored $NO_x$ concentration has been derived by back-calculating $NO_x$ from the $NO_x/NO_2$ empirical relationship using the spreadsheet tool available from Defra's website[6]. The equation of the trend lines presented in Figure A1 gives an adjustment factor for the modelled results of 1.228.

**Figure A1 – Comparison of the Unverified Modelled Road Contribution $NO_x$ versus Monitored Road Contribution $NO_x$ (Town Centre AQMA)**

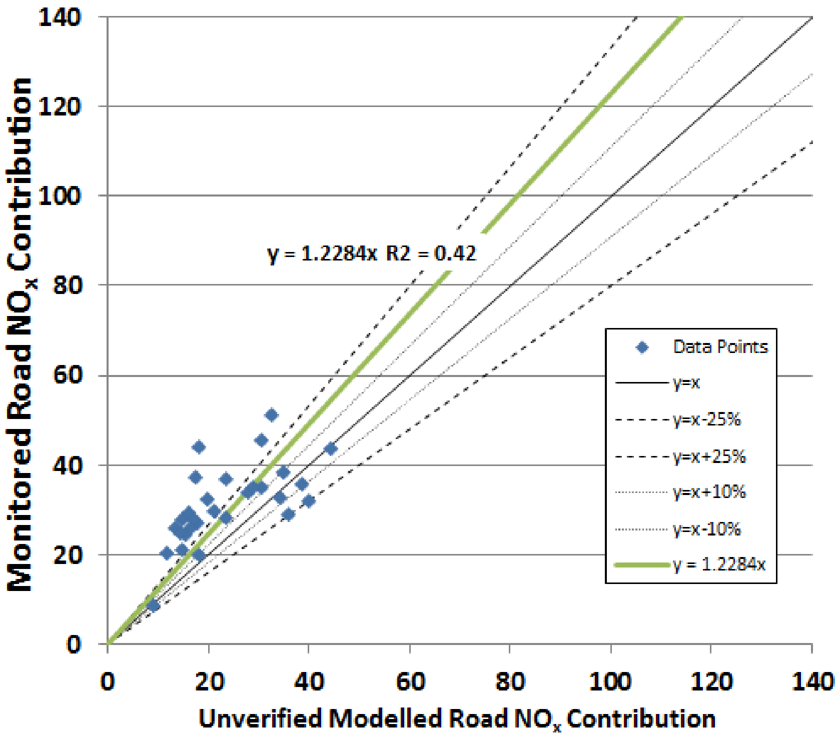



Figure A1 and Table A4 show the ratios between monitored and modelled $NO_2$ for each monitoring location. LAQM.TG(16)[1] states that:

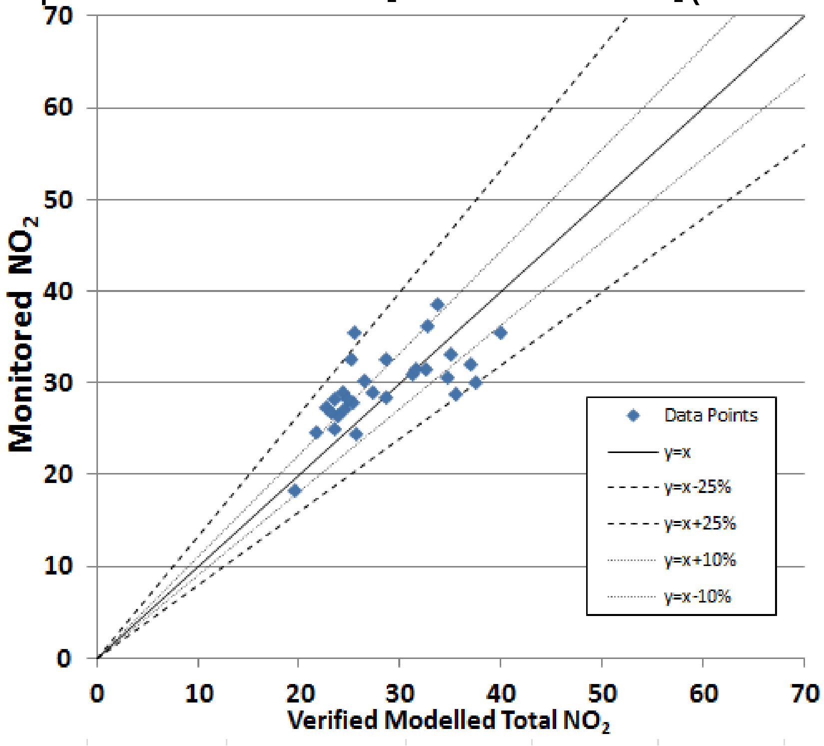
> *"In order to provide more confidence in the model predictions and the decisions based on these, the majority of results should be within 25% of the monitored concentrations, ideally within 10%."*

Table A4 and Figure A2 show the ratios between monitored and modelled $NO_2$ for each monitoring locations in the verification. All sites, apart from DT1 and DT28, show acceptable agreement between the ratios of monitored and modelled $NO_2$, being ±25%. DT1 is under predicting by 28.3% and DT28 is over predicting by 25.1%. No further improvements were possible. A verification factor of 1.228 was therefore deemed acceptable to be used to adjust the model results. A factor of 1.228 reduces the Root Mean Square Error (RMSE) from a value of 5.1 to 4.2.

### Table A4 – Model Verification (Town Centre AQMA)

| Site ID | Ratio of monitored road contribution $NO_x$ / modelled road contribution $NO_x$ | Adjustment factor for modelled road contribution $NO_x$ | Adjusted modelled road contribution $NO_x$ (µg/m$^3$) | Adjusted modelled total $NO_x$ (including background $NO_x$) (µg/m$^3$) | Modelled total $NO_2$ (based upon empirical $NO_x$ / $NO_2$ relationship) (µg/m$^3$) | Monitored total $NO_2$ (µg/m$^3$) | % Difference (adjusted modelled $NO_2$ vs. monitored $NO_2$) |
|---|---|---|---|---|---|---|---|
| DT1 | 2.44 | 1.228 | 22.2 | 41.8 | 25.5 | 35.5 | -28.3 |
| DT3 | 1.57 | | 40.1 | 59.7 | 33.7 | 38.6 | -12.6 |
| DT6 | 1.73 | | 14.4 | 34.2 | 21.7 | 24.6 | -11.8 |
| DT10 | 1.49 | | 37.6 | 57.4 | 32.7 | 36.3 | -9.8 |
| DT11 | 1.53 | | 21.7 | 41.5 | 25.3 | 27.9 | -9.2 |
| DT12 | 0.94 | | 47.2 | 67.0 | 37.0 | 32.0 | 15.5 |
| DT13 | 1.21 | | 34.3 | 54.1 | 31.3 | 31.0 | 0.8 |
| DT14 | 1.10 | | 42.8 | 62.6 | 35.0 | 33.1 | 5.9 |
| DT15 | 0.99 | | 54.4 | 74.2 | 40.0 | 35.4 | 12.9 |
| DT18 | 1.10 | | 22.3 | 42.1 | 25.6 | 24.5 | 4.6 |
| DT20 | 0.96 | | 42.0 | 61.9 | 34.7 | 30.6 | 13.4 |
| DT22 | 2.16 | | 21.2 | 41.0 | 25.1 | 32.6 | -23.0 |
| DT23 | 1.59 | | 28.6 | 48.4 | 28.6 | 32.5 | -12.0 |
| DT24 | 1.83 | | 19.7 | 39.5 | 24.3 | 28.9 | -15.8 |
| DT26 | 1.15 | | 37.3 | 57.1 | 32.6 | 31.5 | 3.5 |
| DT27 | 1.21 | | 28.7 | 48.5 | 28.7 | 28.5 | 0.6 |
| DT28 | 0.80 | | 48.9 | 68.5 | 37.5 | 30.0 | 25.1 |
| DT31 | 1.64 | | 21.0 | 40.6 | 24.8 | 28.2 | -12.0 |
| DT32 | 1.40 | | 26.0 | 45.6 | 27.2 | 29.0 | -6.1 |
| DT34 | 0.81 | | 44.2 | 63.8 | 35.5 | 28.7 | 23.8 |
| DT35 | 1.57 | | 20.2 | 39.8 | 24.5 | 27.2 | -10.0 |
| DT36 | 1.94 | | 16.5 | 36.1 | 22.7 | 27.3 | -17.0 |
| DT37 | 1.60 | | 18.8 | 38.4 | 23.8 | 26.5 | -10.3 |
| DT38 | 1.22 | | 35.5 | 55.1 | 31.7 | 31.5 | 0.5 |
| DT47 | 1.64 | | 24.3 | 43.9 | 26.5 | 30.3 | -12.7 |
| DT48 | 1.75 | | 17.5 | 37.1 | 23.2 | 26.8 | -13.6 |
| DT76 | 1.87 | | 18.2 | 38.0 | 23.6 | 28.2 | -16.3 |
| DT58 | 0.95 | | 11.2 | 30.0 | 19.5 | 18.2 | 7.3 |
| Southgates | 1.42 | | 18.1 | 38.0 | 23.6 | 25.0 | -5.6 |

**Figure A2 – Comparison of the Modelled $NO_2$ versus Monitored $NO_2$ (Town Centre AQMA)**




The adjustment factor 1.228 was applied to the road-$NO_x$ concentrations predicted by the model to arrive at the final $NO_2$ concentrations. $NO_2$ results presented and discussed for the Town Centre AQMA herein are those calculated following the process of model verification using an adjustment factor of 1.228.

## Gaywood Clock AQMA

For the verification and adjustment of NOx/$NO_2$, the LAQM monitoring data was used as shown in Table A1 (highlighted in blue). Data capture for 2016 at all sites was above the 75% threshold. Table A5 shows an initial comparison of the monitored and unverified modelled $NO_2$ results for the year 2016, in order to determine if verification and adjustment was required.

**Table A5 – Comparison of Unverified Modelled and Monitored $NO_2$ Concentrations (Gaywood Clock AQMA)**

| Site ID | Site Type [a] | Background $NO_2$ | Monitored total $NO_2$ (µg/m$^3$) | Modelled total $NO_2$ (µg/m$^3$) | % Difference (modelled vs. monitored) |
|---|---|---|---|---|---|
| **DT40** | RS | 12.4 | 30.2 | 20.7 | -31.4 |
| **DT41** | RS | 12.4 | 32.2 | 25.9 | -19.5 |
| **DT42** | RS | 12.4 | 29.3 | 21.1 | -28.0 |
| **DT43** | RS | 12.4 | 30.0 | 19.8 | -34.0 |
| **DT44** | RS | 12.4 | 32.8 | 27.2 | -17.1 |
| **DT45** | RS | 12.4 | 27.0 | 24.4 | -9.8 |
| **DT51** | RS | 12.4 | 18.3 | 17.0 | -7.1 |
| **DT52** | RS | 12.4 | 27.3 | 23.4 | -14.2 |
| **DT75** | RS | 12.4 | 32.2 | 21.3 | -33.9 |
| **Gaywood** | RS | 12.4 | 45.0 | 31.7 | -29.7 |

[a] RS = Roadside (sites with sample inlets between 1m and 5m of the kerbside)

The model was observed to be under predicting at all 10 locations. No further improvement of the modelled results could be obtained on this occasion. Therefore adjustment of modelled results was necessary. The relevant data was gathered to allow the adjustment factor to be calculated.

Model adjustment needs to be undertaken based on $NO_x$ and not $NO_2$. For the diffusion tube monitoring results used in the calculation of the model adjustment, $NO_x$ was derived from $NO_2$; these calculations were undertaken using a spreadsheet tool available from the LAQM website[12].

Table A6 provides the relevant data required to calculate the model adjustment based on regression of the modelled and monitored road source contribution to $NO_x$.

**Table A6 – Data Required for Adjustment Factor Calculation (Gaywood Clock AQMA)**

| Site ID | Monitored total $NO_2$ (µg/m³) | Monitored total $NO_x$ (µg/m³) | Background $NO_2$ (µg/m³) | Background $NO_x$ (µg/m³) | Monitored road contribution $NO_2$ (total - background) (µg/m³) | Monitored road contribution $NO_x$ (total - background) (µg/m³) | Modelled road contribution $NO_x$ (excludes background) (µg/m³) |
|---|---|---|---|---|---|---|---|
| **DT40** | 30.2 | 52.7 | 12.4 | 16.9 | 17.8 | 35.9 | 16.1 |
| **DT41** | 32.2 | 57.2 | 12.4 | 16.9 | 19.8 | 40.3 | 26.7 |
| **DT42** | 29.3 | 50.8 | 12.4 | 16.9 | 16.9 | 33.9 | 16.8 |
| **DT43** | 30.0 | 52.3 | 12.4 | 16.9 | 17.6 | 35.4 | 14.2 |
| **DT44** | 32.8 | 58.5 | 12.4 | 16.9 | 20.4 | 41.6 | 29.4 |
| **DT45** | 27.0 | 45.9 | 12.4 | 16.9 | 14.6 | 29.0 | 23.4 |
| **DT51** | 18.3 | 28.2 | 12.4 | 16.9 | 5.9 | 11.3 | 8.8 |
| **DT52** | 27.3 | 46.5 | 12.4 | 16.9 | 14.9 | 29.6 | 21.5 |
| **DT75** | 32.2 | 57.2 | 12.4 | 16.9 | 19.8 | 40.3 | 17.2 |
| **Gaywood** | 45.0 | 87.8 | 12.4 | 16.9 | 32.6 | 70.9 | 39.1 |

Figure A3 provides a comparison of the Monitored Road $NO_x$ Contribution versus the Unverified Modelled Road $NO_x$ and the equation of the trend line based on linear regression through zero. The Total Monitored $NO_x$ concentration has been derived by back-calculating $NO_x$ from the $NO_x/NO_2$ empirical relationship using the spreadsheet tool available from Defra's website[6]. The equation of the trend lines presented in Figure A3 gives an adjustment factor for the modelled results of 1.689.

[12] http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html#NOxNO2calc

**Figure A3 – Comparison of the Unverified Modelled Road Contribution $NO_x$ versus Monitored Road Contribution $NO_x$ (Gaywood Clock AQMA)**

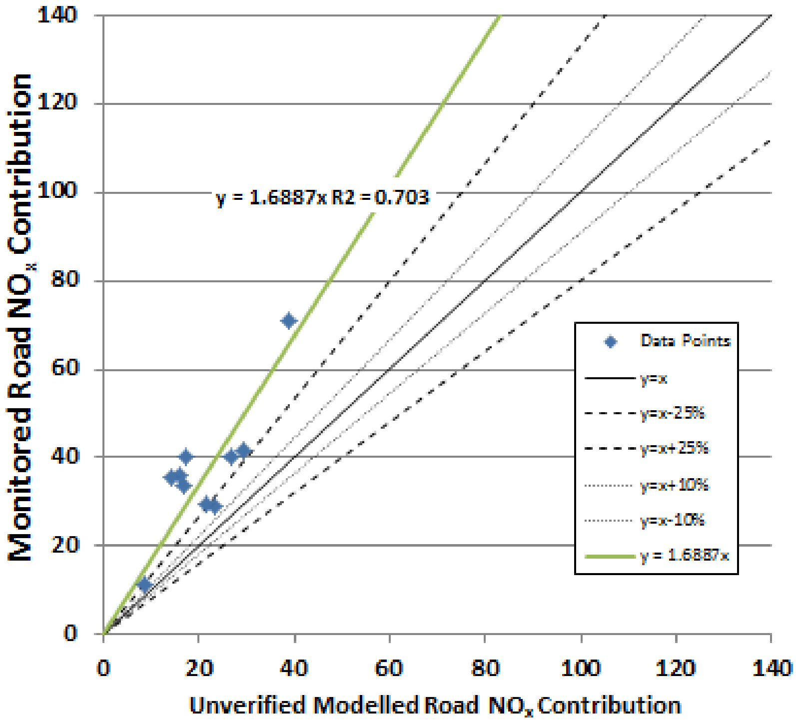
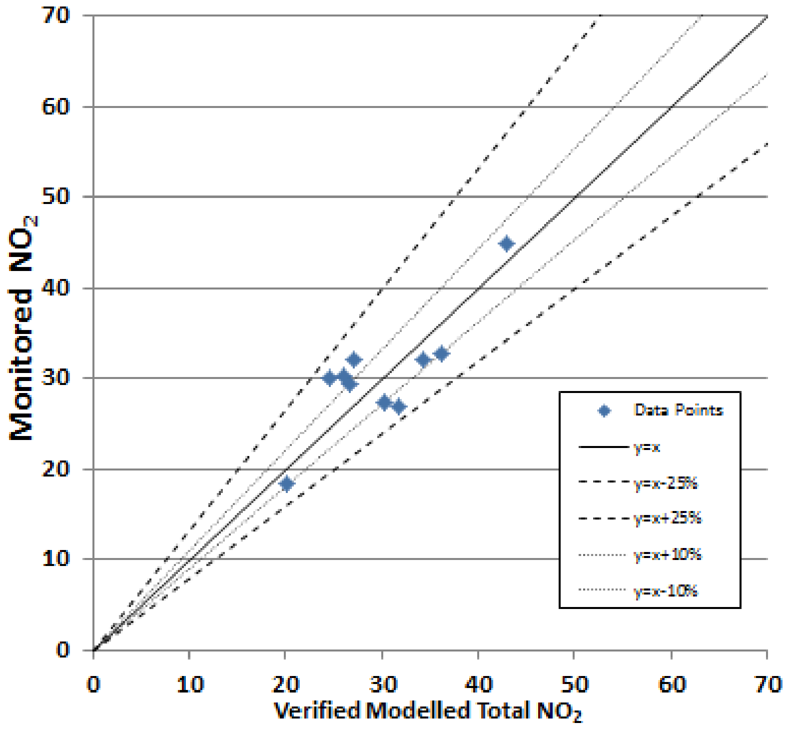



Figure A4 and Table A4 show the ratios between monitored and modelled $NO_2$ for each monitoring location. Table A7 and Figure A4 show the ratios between monitored and modelled $NO_2$ for each monitoring locations in the verification. All sites show acceptable agreement between the ratios of monitored and modelled $NO_2$, all being ±25%. A verification factor of 1.689 was therefore deemed acceptable to be used to adjust the model results. A factor of 1.689 reduces the Root Mean Square Error (RMSE) from a value of 8.1 to 3.7.

**Table A7 – Model Verification (Gaywood Clock AQMA)**

| Site ID | Ratio of monitored road contribution $NO_x$ / modelled road contribution $NO_x$ | Adjustment factor for modelled road contribution $NO_x$ | Adjusted modelled road contribution $NO_x$ (µg/m$^3$) | Adjusted modelled total $NO_x$ (including background $NO_x$) (µg/m$^3$) | Modelled total $NO_2$ (based upon empirical $NO_x$ / $NO_2$ relationship) (µg/m$^3$) | Monitored total $NO_2$ (µg/m$^3$) | % Difference (adjusted modelled $NO_2$ vs. monitored $NO_2$) |
|---|---|---|---|---|---|---|---|
| **DT40** | 2.23 | 1.689 | 27.1 | 44.0 | 26.1 | 30.2 | -13.5 |
| **DT41** | 1.51 | | 45.1 | 62.0 | 34.3 | 32.2 | 6.6 |
| **DT42** | 2.02 | | 28.4 | 45.2 | 26.7 | 29.3 | -8.8 |
| **DT43** | 2.49 | | 24.0 | 40.9 | 24.6 | 30.0 | -17.9 |
| **DT44** | 1.42 | | 49.6 | 66.5 | 36.3 | 32.8 | 10.6 |
| **DT45** | 1.24 | | 39.6 | 56.4 | 31.9 | 27.0 | 18.0 |
| **DT51** | 1.29 | | 14.8 | 31.7 | 20.1 | 18.3 | 9.7 |
| **DT52** | 1.38 | | 36.3 | 53.2 | 30.4 | 27.3 | 11.3 |
| **DT75** | 2.35 | | 29.0 | 45.9 | 27.0 | 32.2 | -16.1 |
| **Gaywood** | 1.82 | | 66.0 | 82.8 | 43.0 | 45.0 | -4.4 |

**Figure A4 – Comparison of the Modelled $NO_2$ versus Monitored $NO_2$ (Town Centre AQMA)**




The adjustment factor 1.689 was applied to the road-$NO_x$ concentrations predicted by the model to arrive at the final $NO_2$ concentrations. $NO_2$ results presented and discussed for the Gaywood Clock AQMA herein are those calculated following the process of model verification using an adjustment factor of 1.689.

# Appendix 3 – Location of Discrete Receptors

### Table A8 – Discrete Receptor Locations

| Receptor | X(m) | Y(m) | Z(m) | Approximate Location |
|---|---|---|---|---|
| 1 | 564061 | 321915 | 1.5 | 294 Wootton Road |
| 2 | 564036 | 321882 | 1.5 | 303 Wootton Road |
| 3 | 563965 | 321782 | 1.5 | 275 Wootton Road |
| 4 | 563936 | 321740 | 1.5 | 263 Wootton Road |
| 5 | 563914 | 321703 | 1.5 | 257 Wootton Road |
| 6 | 563920 | 321648 | 1.5 | 216 Wootton Road |
| 7 | 563889 | 321509 | 1.5 | 196 Wootton Road |
| 8 | 563849 | 321444 | 1.5 | 212 Wootton Road |
| 9 | 563842 | 321315 | 1.5 | 199 Wootton Road |
| 10 | 563860 | 321196 | 1.5 | 166 Wootton Road |
| 11 | 563829 | 321154 | 1.5 | 165 Wootton Road |
| 12 | 563734 | 320954 | 1.5 | 129 Wootton Road |
| 13 | 563713 | 320849 | 1.5 | 78 Wootton Road |
| 14 | 563682 | 320836 | 1.5 | 99 Wootton Road |
| 15 | 563660 | 320779 | 1.5 | 64 Wootton Road |
| 16 | 563603 | 320759 | 1.5 | 87 Wootton Road |
| 17 | 563610 | 320730 | 1.5 | 62 Wootton Road |
| 18 | 563544 | 320694 | 1.5 | 61 Wootton Road |
| 19 | 563540 | 320656 | 1.5 | 44 Wootton Road |
| 20 | 563519 | 320629 | 1.5 | 46 Wootton Road |
| 21 | 563483 | 320602 | 1.5 | 19 Wootton Road |
| 22 | 563493 | 320563 | 1.5 | 30 Wootton Road |
| 23 | 563325 | 320468 | 1.5 | 44 Lynn Road |
| 24 | 563286 | 320473 | 1.5 | 38 Lynn Road |
| 25 | 563245 | 320473 | 1.5 | 28 Lynn Road |
| 26 | 563538 | 320486 | 1.5 | 3 Gayton Road |
| 27 | 563584 | 320464 | 1.5 | 10 Gayton Road |
| 28 | 563686 | 320454 | 1.5 | 24 Gayton Road |
| 29 | 563733 | 320469 | 1.5 | 45 Gayton Road |
| 30 | 563162 | 320460 | 1.5 | 4 Lynn Road |
| 31 | 562967 | 320472 | 1.5 | 127 Gaywood Road |
| 32 | 562928 | 320467 | 1.5 | 119 Gaywood Road |
| 33 | 562878 | 320442 | 1.5 | 124 Gaywood Road |
| 34 | 562987 | 320503 | 1.5 | 125 Gaywood Road |
| 35 | 562831 | 320459 | 1.5 | 115 Gaywood Road |
| 36 | 562791 | 320440 | 1.5 | 108 Gaywood Road |
| 37 | 562696 | 320481 | 1.5 | 72 Gaywood Road |
| 38 | 562631 | 320515 | 1.5 | 35 Gaywood Road |
| 39 | 562586 | 320525 | 1.5 | Highgate Infant School |
| 40 | 562547 | 320485 | 1.5 | The College of West Anglia |
| 41 | 562382 | 320396 | 1.5 | 2a Gaywood Road |
| 42 | 562381 | 320371 | 1.5 | 4 Gaywood Road |
| 43 | 562344 | 320354 | 1.5 | 2 Gaywood Road |
| 44 | 562277 | 320249 | 1.5 | Eastgate Academy |
| 45 | 562289 | 320356 | 1.5 | 17 Littleport Street |
| 46 | 562244 | 320312 | 1.5 | 2 Littleport Street |
| 47 | 562237 | 320348 | 1.5 | 5 Littleport Street |
| 48 | 561934 | 320482 | 1.5 | 30 Pilot Street |

| | | | | |
|---|---|---|---|---|
| 49 | 561926 | 320512 | 1.5 | 409 North Street |
| 50 | 562068 | 320302 | 1.5 | 96 Norfolk Street |
| 51 | 562082 | 320260 | 1.5 | 1a Railway Road |
| 52 | 562108 | 320184 | 1.5 | 10 Railway Road |
| 53 | 562127 | 320186 | 1.5 | 48 Railway Road |
| 54 | 562112 | 320122 | 1.5 | 21 Railway Road |
| 55 | 562132 | 320066 | 1.5 | 39 Railway Road |
| 56 | 562113 | 320018 | 1.5 | 32a Railway Road |
| 57 | 562133 | 320036 | 1.5 | 34 Railway Road |
| 58 | 562225 | 320285 | 1.5 | 14 Blackfriars Road |
| 59 | 562250 | 320278 | 1.5 | 17 Blackfriars Road |
| 60 | 562243 | 320068 | 1.5 | The Fenman, Blackfriars Road |
| 61 | 562241 | 320175 | 1.5 | 18 Blackfriars Road |
| 62 | 562226 | 320005 | 1.5 | 12 Blackfriars Road |
| 63 | 562104 | 319658 | 1.5 | 103 London Road |
| 64 | 562133 | 319613 | 1.5 | 126 London Road |
| 65 | 562200 | 319517 | 1.5 | 104 London Road |
| 66 | 562252 | 319473 | 1.5 | 23 London Road |
| 67 | 562262 | 319406 | 1.5 | 91 London Road |
| 68 | 562187 | 319580 | 1.5 | 12 London Road |
| 69 | 562214 | 319581 | 1.5 | Greyfriars Primary School |
| 70 | 562251 | 319333 | 1.5 | 88 London Road |
| 71 | 562213 | 319229 | 1.5 | 66 London Road |
| 72 | 562261 | 319310 | 1.5 | 57 London Road |
| 73 | 562293 | 319031 | 1.5 | Deganwy, Hardwick Road |
| 74 | 562197 | 319190 | 1.5 | 61 London Road |
| 75 | 563485 | 320539 | 1.5 | 14 Lynn Road |
| 76 | 563476 | 320496 | 1.5 | 4 Lynn Road |
| 77 | 563454 | 320488 | 1.5 | 1 Lynn Road |
| 78 | 563398 | 320478 | 1.5 | 69 Lynn Road |
| 79 | 563334 | 320497 | 1.5 | 31 Lynn Road |
| 80 | 563470 | 320566 | 1.5 | 1a Wootton Road |