St Albans City & District Council

Instantaneous Emissions Modelling Study

February 2018

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Table of Contents

List of Figures

List of Tables

Executive Summary

As part of a study part funded by a Defra Air Quality Grant, St Albans City & District Council commissioned Bureau Veritas to undertake a dispersion modelling study which attempts to consider a second-by-second “virtual” representation of the “real” traffic network on the area around the St Albans AQMA No.1.

The two key aims of the project were:

- To undertake an assessment of the suitability of an instantaneous emissions dispersion modelling approach to the wider LAQM process; and
- To undertake advanced quantitative appraisal of the impacts of two intervention measures.

The study was undertaken with assistance from a number of project partners. Hertfordshire Highways and their transport consultants (Aecom) provided the following traffic inputs to the project:

- Traffic surveys at Peahen Junction;
- ANPR Survey data collection; and
- Paramics traffic model output for the baseline and intervention scenarios.

Further details of the methodology applied to derive the required traffic data is provided in Appendix 1 – Transport Technical Note.

The Institute for Transport Studies at the University of Leeds have assisted by providing instantaneous emissions information for model scenarios using Passenger car and Heavy duty Emission Model (PHEM). Further details of the methodology applied to derive the required instantaneous emissions data is provided in Appendix 2 – Instantaneous Emissions Modelling.

Different Model Approaches

In order to undertake the assessment into instantaneous emissions three different modelling approaches were undertaken. Briefly this can be described as follows:

- V1 – Emissions used in the dispersion modelling have been calculated using Defra’s Emissions Factors Toolkit
- V2 – Emissions used in the dispersion modelling have been calculated using Defra’s Emissions Factors Toolkit with the addition of the use of a local diurnal profile; and
- V3 – Emissions used in the dispersion modelling have been calculated using output from PHEM which has been calculated assuming instantaneous variation in traffic flows.

An assessment of model performance for the three modelling approaches inevitably lends itself to an appraisal of the model verification results obtained for each approach. The following verification factors for each of the three modelling approaches were obtained:

- V1 - 1.22;
- V2 – 1.33; and
- V3 – 0.81.

Approaches V1 and V2 therefore lead to an under-prediction of NO_2 road contributions, which is typical of dispersion models, whilst approach V3 leads to an over-prediction. Without detailed source apportionment of emissions outputs for the V3 approach it is difficult to draw any conclusions as to why this has been observed.

The ratios between monitored and modelled NO_2 concentrations would imply that modelling using either of approaches V1 or V2 would represent the most consistent approaches across the modelled area with all six verification points being well inside the ±25% criteria. It should be noted that the RMSE remained high for approach V3 post model verification relative to V1 and V2, which is an indicator that overall the model is performing less well than these other methods.

NO_2 concentrations predicted by method V2 appears to provide the best fit against the 2013 monitoring data. It is concluded therefore that the effort required to distil the additional information required for method V3 does not appear to be justified. It is noted however, that this may be due to the limitations of the V3 instantaneous emissions dataset, which only covered the am and pm peak periods (07.30 to 08.30 and 16.30 to 17.30 respectively) due to the constraints of the Paramics traffic model that also only covered these periods - the data for this period had to be scaled back to 24-hour based emissions estimates so as to be modelled, which will have introduced a higher level of uncertainty in the V3 predictions. It would be of interest to revisit this modelling comparison should an interpeak Paramics model be developed at some future point.

Quantitative Appraisal of Bus Gating Scheme

Exceedences of the NO_2 40µg/m^3 annual mean AQS objective were predicted in both the BC and GC scenarios. The number of predicted exceedences either decreased or stayed the same when comparing BC the GC scenarios for each respective model approach. At least 25% of receptors were found to exceed in all the modelled scenarios and approaches.

Following adoption of the GC scenario adverse impact descriptor are predicted at two receptors for all three scenarios whilst beneficial impact descriptors are predicted at 23 receptors for approaches V1 and V2, and 24 receptors for approach V3. In accordance to EPUK guidance it can therefore be concluded that for each of the three model approaches an overall beneficial impact descriptor is observed following adoption of the GC scenarios.

The annual mean NO_2 concentration was predicted to be above 60µg/m^3 at two receptors for each of the GC scenarios indicating that there is a possibility that the 1-hour mean NO_2 AQS objective is being exceeded. The two receptors which exceed are located at the junction of High Street (A5183), London Road (A1081), Holywell Hill (A5183) and Chequer Street (A1081) just outside the boundary of St Albans AQMA No. 1.

The bus gating scenario was shown to marginally improve air quality in the study area in terms of a net impact. However, some areas were predicted to worsen and exceedences of the annual mean NO_2 AQS objective were still predicted to persist with the bus gating (based on 2013 model verification). The benefits of proceeding with the bus gating intervention may therefore be further considered as part of a package of measures as opposed to a single measure that will remove all exceedences.

Quantitative Appraisal of CAZ Implementation

Preliminary consideration of CAZ based interventions shows significant reductions in NO_x emissions and therefore NO_2 concentrations may be realised, but direct comparison to the BC and GC scenarios is problematic given the assumed base year of 2020 and the limited emissions data available (i.e. only available for the instantaneous method). It has therefore not been possible to quantify the NO_2 concentration impacts of the CAZ feasibility scenarios.

However, with respect to the available NO_x emissions data alone this would suggest that a CAZ with a focus comparable to the London ULEZ would bring forwards the most significant reductions in NO_x emissions relative to a 2020 base scenario with a 40% reduction, whilst a HDV only focus would translate to an 18% reduction. A Bus only CAZ focus would give rise to a 9% reduction in NO_x emissions; by way of comparison, introduction of the bus gating measure in 2020 will give rise to an estimated 6% NO_x emissions.

Further consideration to CAZ feasibility studies is therefore warranted as part of further work and is likely to bring forwards more significant air quality improvements when compared to the more vigorously tested bus gating scenario.

NO_x Source Apportionment

Source apportionment of NO_x shows the greater impact that HGV and bus emissions have to the overall road traffic NO_x contribution, relative to the proportion of these vehicles within the observed fleet.

Consideration should be given to intervention strategies/measures that preferentially target reductions in HGV and bus emissions sources, in order to provide the greatest cost-benefit to realising the overall objective of reducing NO_2 concentrations at receptor locations.

1 Introduction

1.1 Scope of Study

Newly emerging detailed, integrated traffic-vehicle emission modelling approaches are considered to represent a step-change in the capability of traffic-vehicle emission modelling methods and the validity of vehicle emission assessments. Most current dispersion models rely on emission factors based on average vehicle speed which, whilst useful, do not take account of factors such as gear change patterns, thermal behaviours of engines and catalysts and all driving resistances, including gradient.

In 2004, St Albans City & District Council declared an AQMA (AQMA 1) in the city centre at the Peahen Junction including London Road, Holywell Hill and Chequer Street in relation to exceedences of the NO_2 annual mean objective. At the Peahen junction the following local traffic conditions have been observed which are likely to cause increased traffic emissions and so result in elevated pollutant concentrations:

- Very slow moving congested traffic;
- Continuous traffic idling at signals;
- Street canyons along Chequer Street, Holywell Hill, London Road and High Street;
- Steep roads;
- Large number of slow moving buses;
- Large number of slow moving heavy goods vehicles (HGVs);
- Large number of taxis; and
- Idling taxis and buses.

Therefore, as part of a study part funded by a Defra Air Quality Grant, St Albans City & District Council commissioned Bureau Veritas to undertake a dispersion modelling study which attempts to consider a second-by-second “virtual” representation of the “real” traffic network. The area to be considered is AQMA 1 and the surrounding road network.

The two key aims of the project were:

- To undertake an assessment of the suitability of an instantaneous emissions dispersion modelling approach to the wider LAQM process; and
- To undertake advanced quantitative appraisal of the impacts of two intervention measures.

The study was undertaken with assistance from a number of project partners. Hertfordshire Highways and their transport consultants (Aecom) provided the following traffic inputs to the project:

- Traffic surveys at Peahen Junction;
- ANPR Survey data collection; and
- Paramics traffic model output for the baseline and intervention scenarios.

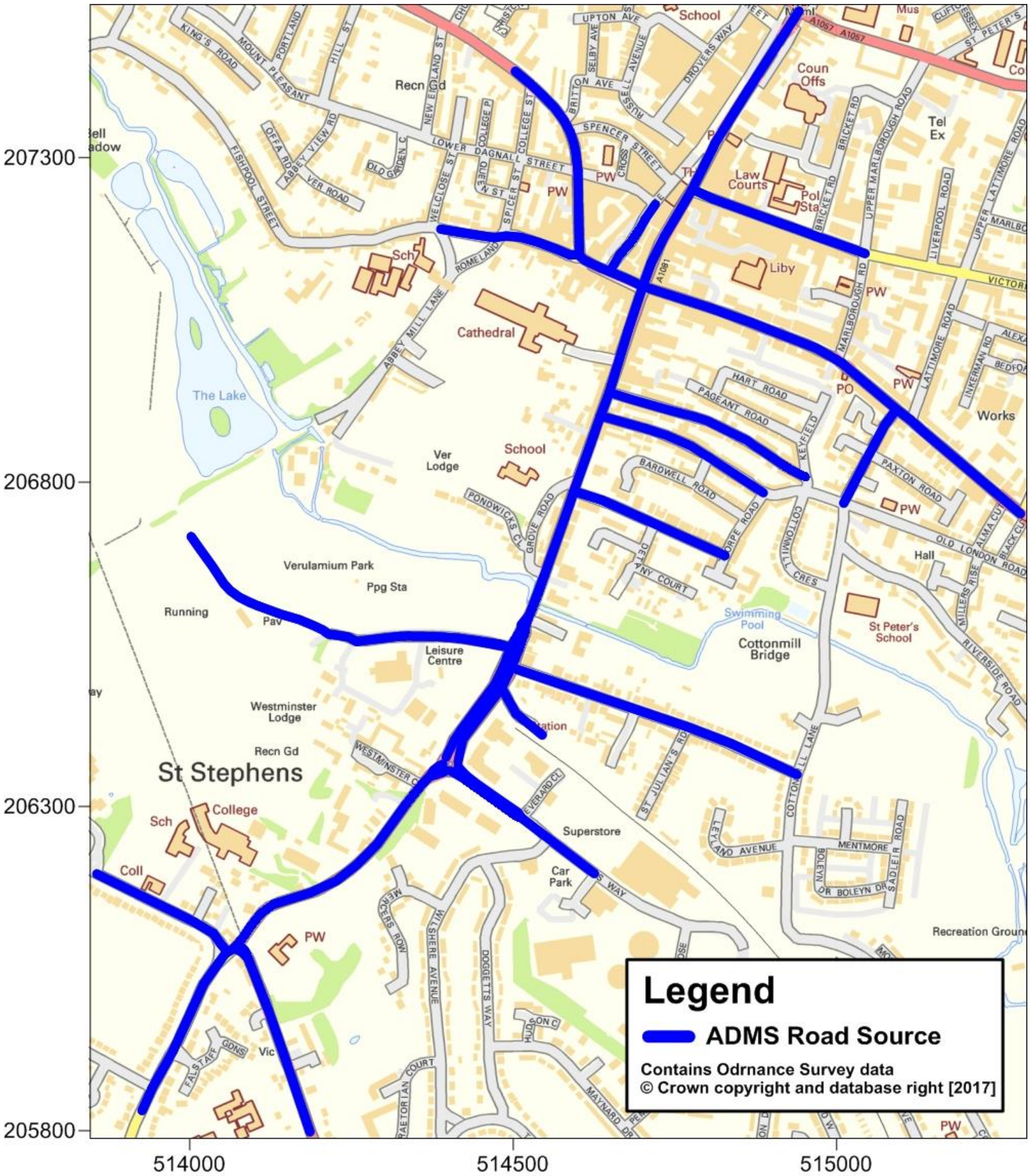
Further details of the methodology applied to derive the required traffic data is provided in Appendix 1 – Transport Technical Note.

The Institute for Transport Studies at the University of Leeds have assisted by providing instantaneous emissions information for model scenarios using Passenger car and Heavy duty

Emission Model (PHEM). Further details of the methodology applied to derive the required instantaneous emissions data is provided in Appendix 2 – Instantaneous Emissions Modelling.

The area considered in the air quality model is based around the A5183 running through St Albans from The Marlborough Science Academy in the south to the junction with the A1057 (Hatfield Road) to the north. Figure 1 shows the extent of the air quality dispersion model area.

Figure 1 - Modelled Area



Appendix 3 – Background to Air Quality provides for a brief introduction to the key pollutants of interest to this particular study.

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[1] (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[2] has been adopted and replaces all previous air quality Directives, except the 4th Daughter Directive[3]. 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[4] 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 1 taken from LAQM.TG(16)[5] 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 in St Albans are declared 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 and more recently has had to outline their immediate priorities to improve concentrations of NO_2 across the UK as part of an updated NO_2 plan. Continued failure to achieve these limits may lead to EU fines. The AQS objectives for NO_2 are presented in Table 2.

[1] 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

[2] 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.

[3] 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.

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

[5] LAQM 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.

Guidance from the UK Government and Devolved Administrations makes clear that exceedences of the health based objectives should be assessed at outdoor locations where members of the general public are regularly present over the averaging time of the objective. Table 1, taken from LAQM TG(16), provides an indication of those locations that may or may not be relevant for each averaging period.

Table 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 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. Hotels, unless people live there as their permanent residence. Gardens of residential properties. 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 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. Kerbside sites (e.g. pavements of busy shopping streets). 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. 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 - Relevant AQS Objectives for the Assessed Pollutants

Pollutant	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 First and Second Rounds of Review and Assessment

Air pollution is associated with a number of adverse health impacts. It is recognised as a contributing factor in the onset of heart disease and cancer. Additionally, air pollution particularly affects the most vulnerable in society: children and older people, and those with heart and lung conditions. There is also often a strong correlation with equality issues, because areas with poor air quality are also often the less affluent areas.

The annual health cost to society of the impacts of particulate matter alone in the UK is estimated to be around £16 billion[6].

The main source of air pollution within St Albans City and District Council is vehicle emissions, the main pollutants of concern being NO_2, PM_{10} and $PM_{2.5}$. A number of main roads pass through the District in addition to smaller roads serving the main population centres. There are three designated AQMAs currently in force, these have been declared due to exceedences of the NO_2 annual mean AQS objective and all the AQMA boundaries are either close to, or have busy roads within them. Details of which are provided in Table 3. This study incudes the area covered by St Albans AQMA No. 1.

Table 3 - Declared Air Quality Management Areas in St Alban City and District Council area

AQMA Name	Pollutant and Air Quality Objectives	Description
St Albans AQMA No. 1	NO_2 annual mean	The area comprising of odd numbers 1-7 London Road, 1-11c Holywell Hill and even numbers 2-38 London Road, St Albans.
St Albans AQMA No. 2	NO_2 annual mean	The area comprising of Beechtree Cottages, Hemel Hempstead Road, St Albans (adjacent to junction of M1 (J7) and M10).
St Albans AQMA No. 7	NO_2 annual mean	An area encompassing a number of domestic properties in Frogmore on Radlett Road and Colney Street in the vicinity of the M25.

An Air Quality Action Plan (AQAP) was completed in 2003 and was subsequently updated in 2010. The AQAP measures are outlined within the plan in order to meet the annual mean objective for NO_2 thus improving air quality within the AQMAs and therefore the District as a whole. The AQAP is currently in the process of being updated and there are a number of projects that are ongoing that will provide steer for the updated measures included.

3.2 Council Monitoring Data

St Albans City & District Council do not currently undertake continuous automatic monitoring at any sites. The council operates a network of 39 non-automatic (passive) monitoring sites for NO_2 using diffusion tubes. Table 4 provides details of the 11 monitoring sites which are located within the model area. The locations of the monitoring sites are illustrated on Figure 4.

[6] Defra. Abatement cost guidance for valuing changes in air quality, May 2013.

Table 4 - LAQM Diffusion Tube Monitoring undertaken for NO_2 in modelled area

ID	Site	Site Name	Site Type*	OS Grid Ref	Annual Mean NO_2 Concentration (µg/m^3)		
					2013	2014	2015
A	**SA101**	Museum, Hatfield Road, St Albans	Ro	515105, 207476	34	33.2	27.9
B	**SA132**	Westminster Lodge, Holywell Hill, St Albans	B	514317, 206453	25	22.7	21.5
C	**SA133**	Belmont Hill, St Albans	K	514606, 206801	**48.8**	30.9	33.9
D	**SA134**	Albert Street, St Albans	K	514648, 206919	36	**42.3**	30.9
E	**SA135**	Watsons Walk, St Albans	K	515096, 206921	**40.2**	**43.2**	30.9
F	**SA136**	St Peters Street, St Albans	K	514883, 207422	**62.9**	**60**	38.8
G	**SA137**	High Street, St Albans	K	514664, 207125	**46.3**	**47.9**	**40.2**
H	**SA138**	Peahen PH, Holywell Hill, St Albans	K	514701, 207082	**48.8**	**55.5**	**42.4**
I	**SA139**	Civic Centre, St Peters Street, St Albans	B	514921, 207391	24	26	28.5
J	**SA140**	Lattimore Road, St Albans	K	515185, 207070	30	30	26.8
K	**SA141**	Town Hall, St Albans	B	514741, 207245	29.6	30.8	22.1
In **Bold**, exceedence of the annual mean NO_2 objective of 40µg/m^3 * UI = Urban Industrial, RS = Roadside, KS = Kerbside, UB = Urban Background							

Exceedences of the 40µg/m^3 annual mean NO_2 objective were observed at two of the 11 monitoring locations in 2015, locations SA137 and SA138. The data shows an improvement from the monitored data for 2013 and 2014 when five of the 11 monitoring locations were observed to exceed the objective value. As the year of the modelling study is 2013, monitoring data from this year has therefore been used for model verification purposes.

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 and PM_{10}. 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, but then calibrates these concentrations in relation to actual monitoring data.

The current data set of background maps has been calculated using a base year of 2015. As the modelling undertaken in this study has used a year of 2013 it is necessary to make use of previous versions of the background maps, hence those with a base year of 2013 have been considered.

Annual mean background concentrations have been obtained from the Defra published background maps[7] 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 annual mean concentrations for mapped background concentrations for 2013 (using the 2013 based background maps) and 2015 (using the 2015 based background maps) are presented in Table 5.

[7] https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html

Table 5 - Background Pollutant Concentrations (Defra Background Maps)

Grid Square (E,N)	2013 Annual Mean Concentration (µg/m^3) (2013-based background maps)		2015 Annual Mean Concentration (µg/m^3) (2015-based background maps)	
	NO_2	NO_x	NO_2	NO_x
514500, 207500	18.6	28.1	16.4	23.0
514500, 206500	17.4	26.0	15.3	21.2
515500, 206500	18.7	28.4	17.0	24.0
513500, 206500	16.4	24.4	14.3	19.6
514500, 205500	17.5	26.3	15.5	21.4
AQS objective	***40.0***	**-**	***40.0***	**-**

These mapped background concentrations are all well below the respective annual mean objective. The background maps concentrations for both NO_x and NO_2 are observed to be lower for 2015 than 2013 at all grid squares covered by the model area. This is as expected as pollutant concentrations are generally assumed to reduce in future as road transport becomes cleaner.

3.4 Background Concentrations used in the Assessment

It is generally preferable to use background data from appropriate local monitoring where available and provided there is good data capture. Mapped concentrations are estimates of background pollution and include inherent errors associated with large scale modelling. LAQM TG(16)[5] states that if mapped background concentrations are to be used, these should be "*compared against local monitoring data to confirm there is good agreement*".

Three background monitoring sites are located within the modelled area SA132, SA139 and SA141. All three of these sites were below the NO_2 annual mean objective for all years from 2013 to 2015. Data capture in 2013 at SA132, SA139 and SA141 was 25%, 58% and 42% respectively.

Due to this low data capture Defra background mapped concentration estimates have been used for pollutant background values in this assessment.

4 Assessment Methodology

To assess the impact of road traffic emissions on air quality and to quantify the impacts of the various modelled scenarios, the atmospheric dispersion model ADMS Roads version 3.4 was utilised, focusing on emissions of 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)[5]) have been used.

As detailed previously the two key aims of the project were to undertake:

- An assessment of the suitability of an instantaneous emissions dispersion modelling approach to the wider LAQM process; and
- Advanced quantitative appraisal of the impacts of two intervention scenarios.

In order to undertake the assessment into instantaneous emissions three different modelling approaches have been undertaken. Briefly this can be described as follows:

- V1 – Emissions used in the dispersion modelling have been calculated using Defra's Emissions Factors Toolkit making use of 24 hour Annual Average Daily Traffic figures. This would be classed as an industry standard approach and would assume a continuous NO_x emission form all modelled roads for the entire modelled year;
- V2 – Emissions used in the dispersion modelling have been calculated using Defra's Emissions Factors Toolkit making use of 24 hour Annual Average Daily Traffic figures but emissions have then been varied to take into account of diurnal variation on an hourly basis. This would be classed as an advanced industry approach and assumes NO_x emissions vary on an hourly basis over a 24 hour period for all modelled roads for the entire modelled year; and
- V3 – Emissions used in the dispersion modelling have been calculated using output from PHEM which has been calculated assuming instantaneous variation in traffic flows. This emission rate has then been further varied across the 24 hour period to take into account diurnal variation on an hourly basis using the diurnal profiles calculated for approach V2.

More detail on the three modelling approaches follows with a description of the traffic inputs which have been utilised.

4.1 Assessment Scenarios

For each of the modelling approaches detailed the following two scenarios were assessed.

- 2013 Base Case – Base case representing the current air quality at the study area; and
- 2013 Gating Case – Traffic flows taking into account a proposed bus gating measure on Holywell Hill (A5183).

In addition, for the V3 modelling approach several potential Clean Air Zone (CAZ) intervention scenarios have been considered, in line with the minimum classes and standards for CAZs as specified by Defra's CAZ Framework:

- Class A – Buses and coaches to meet Euro VI Euro standard;

- Class B – Buses, coaches and HGVs to meet Euro VI Euro standard; and
- Class D – Buses, coaches and HGVs to meet Euro VI Euro standard. LGVs and cars to meet Euro 6 (diesel) and Euro 4 (petrol). This is comparable to the London Ultra Low Emission Zone (ULEZ).

4.2 V1 Methodology

Assessing the air quality effects of a proposal that affects local traffic flows is typically carried out by using an atmospheric dispersion model to calculate pollutant concentrations at sensitive human receptors, based on the vehicle exhaust emissions, having due regard to their spatial distribution.

Emissions of NO_x for the V1 modelling approach were calculated using traffic data provided on behalf of the Council by AECOM. Traffic data was provided in 24-hour Annual Average Daily Traffic (AADT) format with a percentage split between Cars, LDVs, HDVs, double decker Buses (BUS DD) and single decker Buses (BUS Sprinter). In addition to the AADT counts the for modelled road links, speed data was also provided.

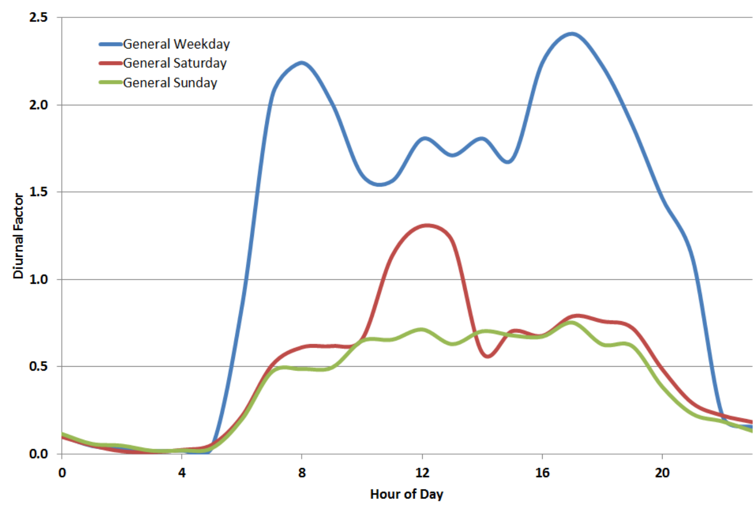
Vehicle emissions for different road links were then calculated using Defra's Emissions Factors Toolkit (EFT) v6.0.2. It is recognised that this is no longer the most up to date version of the EFT however this represents the most up to date version when this aspect of the study was undertaken and aligns with the study year of 2013.

4.3 V2 Methodology

The model input for the V2 modelling approach were identical to that for the V1 approach except for the inclusion of a diurnal profile which was applied to the emission rate as used in the V1 approach.

Local hourly traffic patterns were represented in the model using traffic data from monitored hourly traffic counts. Traffic monitoring was undertaken at 32 different links in the model. A full 24-hour survey was not undertaken at all locations, with data recorded at some locations only representing peak hours. Where data was incomplete, for the hours which were not monitored an average ratio of those hours from monitoring locations where the full 24-hours were monitored was assumed. For model links where no monitoring was undertaken, an average diurnal profile was applied, based on the average ratios for all locations where a full 24-hours data was available; this was noted as the general profile, as shown in Figure 2. On the weekday profile, am and pm peaks can clearly be seen; reduced flows can be seen in the interpeak periods and on the weekend profiles.

Figure 2 - General Diurnal Profile as used in V2 Model Scenarios



Full details of the traffic data can be found in Appendix 5 – Traffic Data.

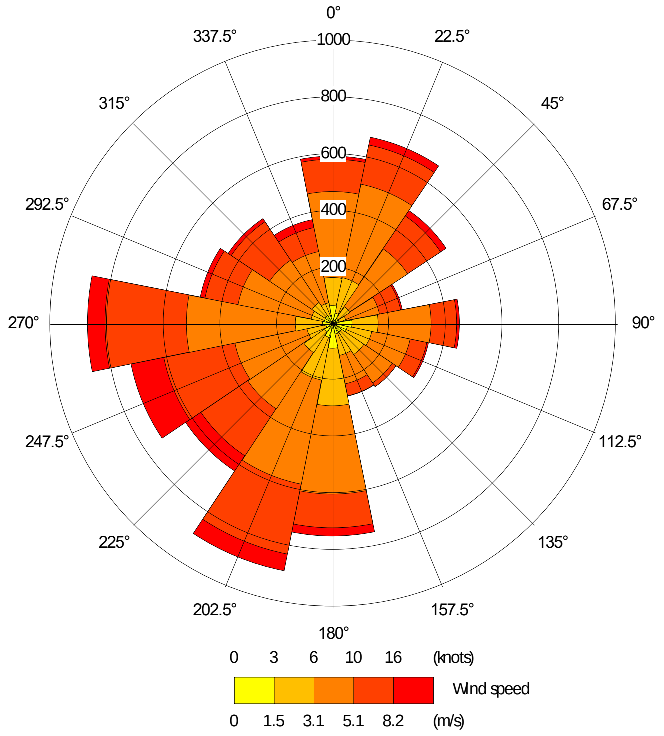
4.4 V3 Methodology

Modelled vehicle emissions for the V3 approach were provided by The Institute for Transport Studies at the University of Leeds. Output from the Passenger car and Heavy duty Emission Model (PHEM) which took account of the instantaneous variation in emissions over the observed time period, which was then adapted to take into account the known diurnal variation (as used in approach V2) to provide an estimate of instantaneous emissions over a 24-hour period.

4.5 Meteorological Data

2013 meteorological data from Luton weather station, located approximately 14km to the south, has been used in this assessment. A wind rose for data collected at the site for the year 2013 is shown in Figure 3.

Figure 3 - Luton 2013 Meteorological Data

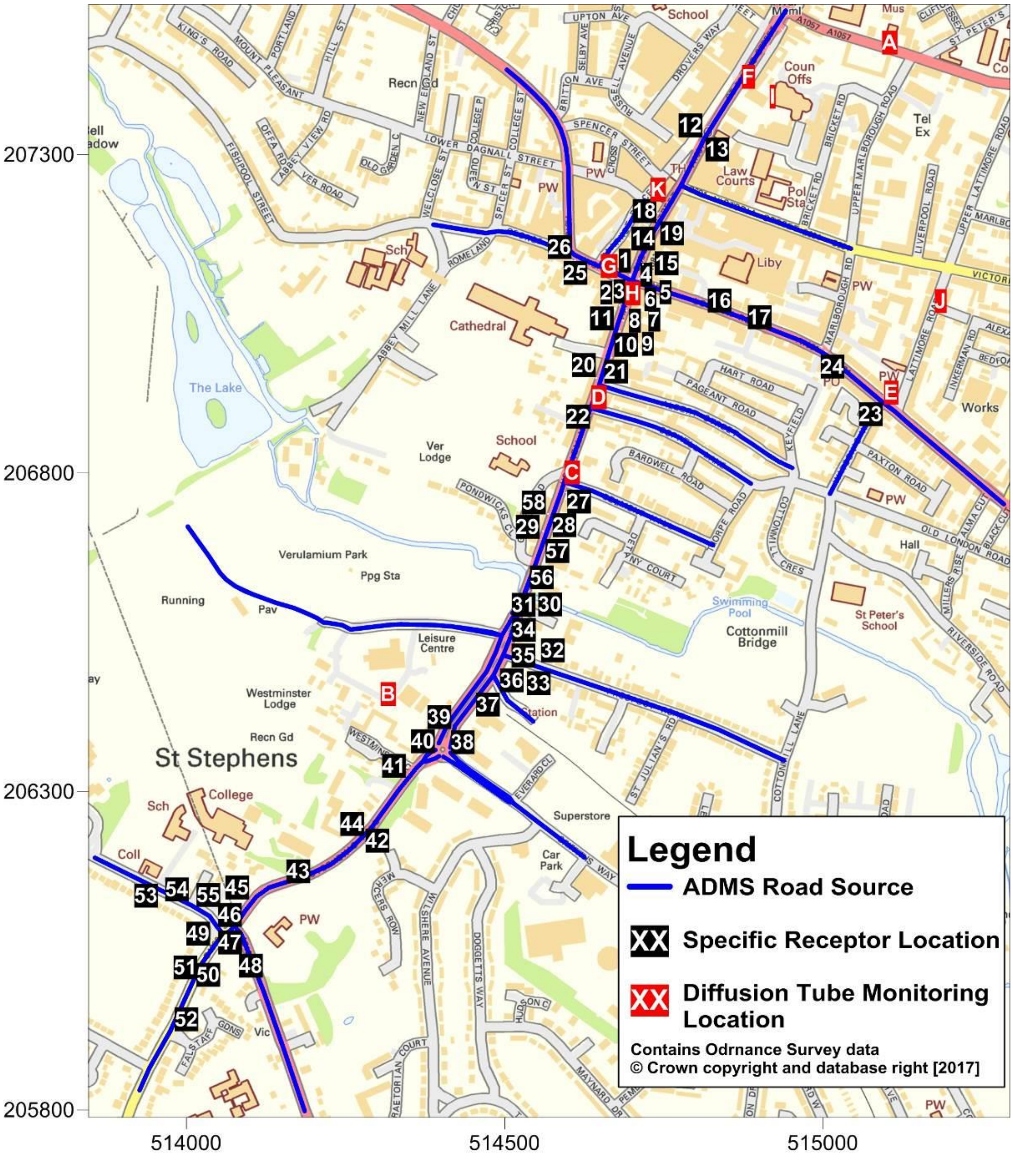


Most dispersion models do not use meteorological data if they relate to calm winds conditions, as dispersion of air pollutants is more difficult to calculate in these circumstances. ADMS-Roads treats calm wind conditions by setting the minimum wind speed to 0.75m/s. It is recommended in LAQM.TG(16)[5] that the meteorological data file be tested within a dispersion model and the relevant output log file checked, to confirm the number of missing hours and calm hours that cannot be used by the dispersion model. This is important when considering predictions of high percentiles and the number of exceedences. LAQM.TG(16)[5] recommends that meteorological data should only be used if the percentage of usable hours is greater than 75%, and preferably 90%. 2013 meteorological data from Luton includes 8,497 lines of usable hourly data out of the total 8,760 for the year, i.e. 97.0% usable data. This is therefore suitable for the dispersion modelling exercise.

4.6 Sensitive Receptors

A total of 58 discrete receptor locations are considered in the assessment of emissions from road traffic and their location is illustrated in Figure 4 and detailed in Table A1. In addition to the discrete receptors, pollutant concentrations were also output across a regular gridded area and at additional receptor points added close to the modelled road links, through application of the intelligent gridding option in ADMS-Roads.

Figure 4 - Receptor and Monitoring Locations considered in the Assessment



4.7 Model Outputs

The monitored background NO_2 concentration has been used in conjunction with the contribution 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)[5] 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 4.1 (June 2014) of the NO_x to NO_2 conversion tool.

It is recognised that the version of the NO_x to NO_2 conversion tool used is not the most recently published version. Version 4.1 has been used however as this was the current tool when most of the modelling work was undertaken. Additionally as some of the model inputs relate to years prior to 2015 the most recently published set of LAQM tools cannot be used.

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 1.22 for modelling approach V1, 1.33 for modelling approach V2 and 0.81 for approach V3. Full details of the model verification are presented in Section 5.1.

4.8 Significance Criteria

Although no formal procedure exists for classifying the magnitude and significance of air quality effects from a new development, guidance issued by Environmental Protection UK and Institute of Air quality Management (EPUK and IAQM, 2015)[8] suggests an impact matrix for assessing air quality impacts at individual receptors, as shown in Table 6.

These criteria are based on the change in concentration brought about by a new development as a percentage of the AQS objectives in combination with the overall resultant pollutant concentration. The impact descriptors set out in Table 6 are not, themselves, a clear and unambiguous guide to reaching a conclusion on significance. These impact descriptors are intended for application at a series of individual receptors. Whilst it may be that there are ‘slight’, ‘moderate’ or ‘substantial’ impacts at one or more receptors, the overall effect may not necessarily be judged as being significant in some circumstances.

Table 6 - Impact Descriptors for Individual Receptors

Long term Average Concentration at Receptor in assessment year	% Change in Concentration relative to Air Quality Assessment Level (AQAL)			
	1	2-5	6-10	>10
75% or less of AQAL	Negligible	Negligible	Slight	Moderate
76-94% of AQAL	Negligible	Slight	Moderate	Moderate
95-102% of AQAL	Slight	Moderate	Moderate	Substantial
103-109% of AQAL	Moderate	Moderate	Substantial	Substantial
110 or more of AQAL	Moderate	Substantial	Substantial	Substantial

Notes:
AQAL = Air Quality Assessment Level, which may be an AQS objective, EU limit or target value, or an Environment Agency ‘Environmental Assessment Level (EAL)’.
Changes of 0%, i.e. less than 0.5% will be described as Negligible.
Rounding to whole numbers has been completed by .5 (.45) rounding up, and .4 (.44) rounding down.

Additionally the factors in Table 7 should be considered in the determination of an overall significance, based on professional judgement, whilst other factors may also be relevant in individual cases.

[8] EPUK & IAQM Land-Use Planning & Development Control: Planning For Air Quality (2015).

Table 7 - Factors to Judge Significance

Factors
The existing and future air quality in the absence of the development.
The extent of current and future population exposure to the impacts.
The influence and validity of any assumptions adopted when undertaking the prediction of impacts.

The EPUK/IAQM criteria has been applied in this assessment to provide a description of the significance of the air quality effects due to road traffic emissions associated with the proposed development.

4.9 Comparison with AQS Objectives

Annual mean NO_2 concentrations have been predicted based on dispersion modelling, and compared to the annual mean NO_2 AQS objective. Short-term concentrations (1-hour mean for NO_2) have also been considered in the assessment. The 1-hour mean NO_2 AQS objective is 200µg/m^3 with 18 allowed exceedences per year. Analysis of UK continuous NO_2 monitoring data has shown that it is unlikely that the 1-hour mean objective would be exceeded where the annual mean objective is below 60µg/m^3 [9]. Therefore, potential exceedences of the 1-hour mean objective have been identified based on this criterion.

[9] AEAT (May 2008) - Analysis of the relationship between annual mean nitrogen dioxide concentration and exceedences of the 1-hour mean AQS Objective. A report produced for Defra, the Scottish Government, the Welsh Assembly Government and the Department of the Environment in Northern Ireland.

5 Assessment Results

5.1 Assessment of Different Model Approaches

An assessment of model performance for the three modelling approaches inevitably lends itself to an appraisal of the model verification results obtained for each approach. Whilst 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)[5] guidance as an accepted dispersion model, model validation undertaken by the software developer (CERC) will not have included validation in the vicinity of the proposed development site. 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 better a particular modelling method performs, the less uncertainty there will be in the model predictions and a better fit will be observed between the model predictions and actual observed monitoring data.

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 Council and project partners as detailed in Section 4.2. Separation distances between road sources and receptors were checked using electronic OS mapping data.

NO_2 Verification

St Albans City and District Council operates an extensive network of passive NO_2 monitoring as part of its LAQM commitment. Details of the six LAQM monitoring sites located within the vicinity of the modelled road network are presented in Table 8.

Whilst urban background sites are useful for giving an indication of background values, they are not useful for the purpose of model verification. Model verification has therefore been undertaken using only the kerbside and roadside sites listed in Table 8.

Table 8 - Local Monitoring Data Available for Model Verification

ID		Site Name	Site Type*	OS Grid Ref	2013 Annual Mean NO_2 Concentration (µg/m^3) [a]
C	SA133	Belmont Hill, St Albans	K	514606, 206801	**48.8**
D	SA134	Albert Street, St Albans	K	514648, 206919	36
E	SA135	Watsons Walk, St Albans	K	515096, 206921	**40.2**
F	SA136	St Peters Street, St Albans	K	514883, 207422	**62.9**
G	SA137	High Street, St Albans	K	514664, 207125	**46.3**
H	SA138	Peahen PH, Holywell Hill, St Albans	K	514701, 207082	**48.8**

In **bold**, exceedence of the annual mean NO_2 AQS objective of 40µg/m^3
*K = Kerbside
[a] Monitoring undertaken by St Albans City and District Council as part of LAQM commitments

Verification Calculations

The verification of the modelling output was performed in accordance with the methodology provided in Annex 3 of LAQM.TG(16)[5].

For the verification and adjustment of NO_x/NO_2, the LAQM diffusion tube monitoring data was used as shown in Table 8. Data capture for 2013 at four of the kerbside sites was less than 75%, annual average values have therefore been annualised to account of seasonal variation. Table 9 shows an initial comparison of the monitored and unverified modelled NO_2 results for the year 2013, in order to determine if verification and adjustment was required.

Table 9 - Comparison of Unverified Modelled and Monitored NO_2 Concentrations

Site ID	Site Type	Background NO_2	Monitored total NO_2 (µg/m^3)	Modelled total NO_2 (µg/m^3)	% Difference (modelled vs. monitored)
V1					
C	K	17.4	48.8	40.4	-17.1
D	K	17.4	36.0	33.8	-6.2
E	K	18.7	40.2	39.8	-1.2
F	K	18.6	62.9	56.7	-10.0
G	K	18.6	46.3	37.5	-19.1
H	K	18.6	48.8	47.0	-3.7
V2					
C	K	17.4	48.8	38.3	-21.5
D	K	17.4	36.0	31.8	-11.7
E	K	18.7	40.2	37.5	-6.8
F	K	18.6	62.9	55.4	-12.1
G	K	18.6	46.3	35.6	-23.2
H	K	18.6	48.8	44.6	-8.7
V3					
C	K	17.4	48.8	34.9	-28.4
D	K	17.4	36.0	38.2	6.2
E	K	18.7	40.2	49.2	22.3
F	K	18.6	62.9	61.1	-3.0
G	K	18.6	46.3	54.8	18.4
H	K	18.6	48.8	64.0	31.0

For V1 the model was observed to be under predicting at all receptors by as much as 19.1% and no further improvement of the modelled results could be obtained through changing the model inputs. For V2 the model was observed to be under predicting at all receptors by as much as 23.2% and no further improvement of the modelled results could be obtained through changing the model inputs. For V3 the model was observed to be under predicting by as much as 28.4% and over predicting by as much as 31.0%.

Therefore adjustment of modelled results was necessary for all three modelling approaches. 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[10].

Table 10 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 10 - Data Required for NO_2 Adjustment Factor Calculation for the Three Modelling Approaches

Site ID	Monitored total NO_2 (µg/m^3)	Monitored total NO_x (µg/m^3)	Background NO_2 (µg/m^3)	Background NO_x (µg/m^3)	Monitored road contribution NO_2 (total - background) (µg/m^3)	Monitored road contribution NO_x (total - background) (µg/m^3)	Modelled road contribution NO_x (excludes background) (µg/m^3)
V1							
C	48.8	100.8	17.4	26.0	31.4	74.8	52.1
D	36.0	66.9	17.4	26.0	18.6	40.8	35.4
E	40.2	77.1	18.7	28.4	21.6	48.7	47.4
F	62.9	146.7	18.6	28.1	44.4	118.6	97.3
G	46.3	93.6	18.6	28.1	27.7	65.5	41.9
H	48.8	100.9	18.6	28.1	30.3	72.8	67.6
V2							
C	48.8	100.8	17.4	26.0	31.4	74.8	46.6
D	36.0	66.9	17.4	26.0	18.6	40.8	30.7
E	40.2	77.1	18.7	28.4	21.6	48.7	41.7
F	62.9	146.7	18.6	28.1	44.4	118.6	93.0
G	46.3	93.6	18.6	28.1	27.7	65.5	37.2
H	48.8	100.9	18.6	28.1	30.3	72.8	60.6
V3							
C	48.8	100.8	17.4	26.0	31.4	74.8	38.2
D	36.0	66.9	17.4	26.0	18.6	40.8	46.4
E	40.2	77.1	18.7	28.4	21.6	48.7	73.7
F	62.9	146.7	18.6	28.1	44.4	118.6	112.0
G	46.3	93.6	18.6	28.1	27.7	65.5	91.3
H	48.8	100.9	18.6	28.1	30.3	72.8	122.2

Figure 5 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 for the three modelling approaches. The Total Monitored NO_x concentration has been derived by back-calculating NOx from the NO_x/NO_2 empirical relationship using the spreadsheet tool available from Defra's website. The equation of the trend lines presented in Figure 5 gives an adjustment factor for the modelled results of 1.22 for V1, 1.33 for V2 and 0.81 for V3.

Figure 5 and Table 11 show the ratios between monitored and modelled NO_2 for each monitoring location.

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

Figure 5 - Comparison of the Modelled Road Contribution NO_x versus Monitored Road Contribution NO_x for all Monitoring Locations for the Three Modelling Approaches

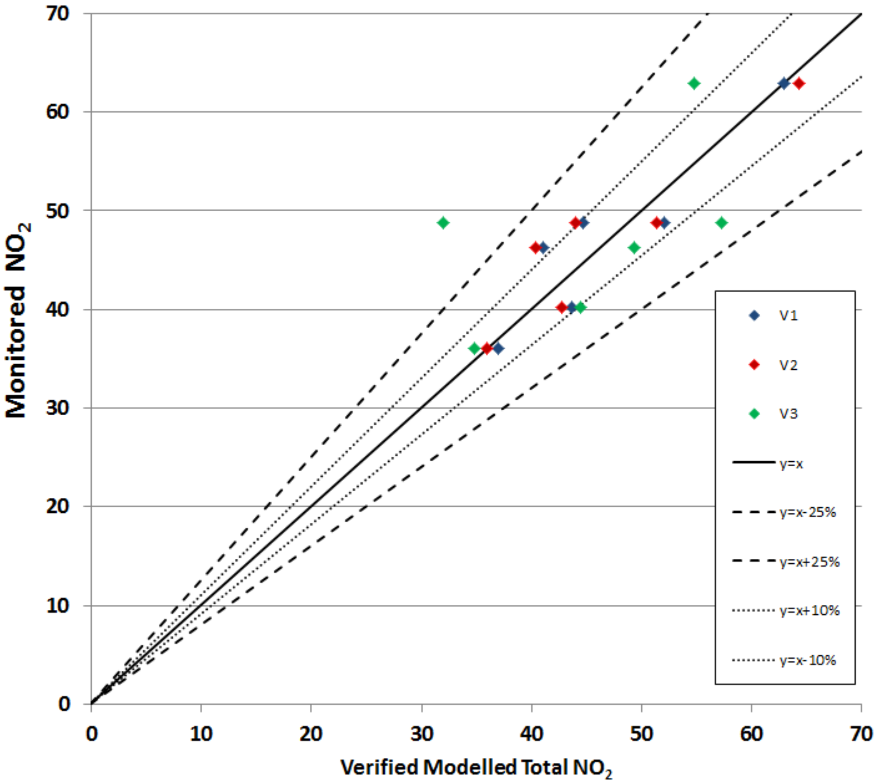
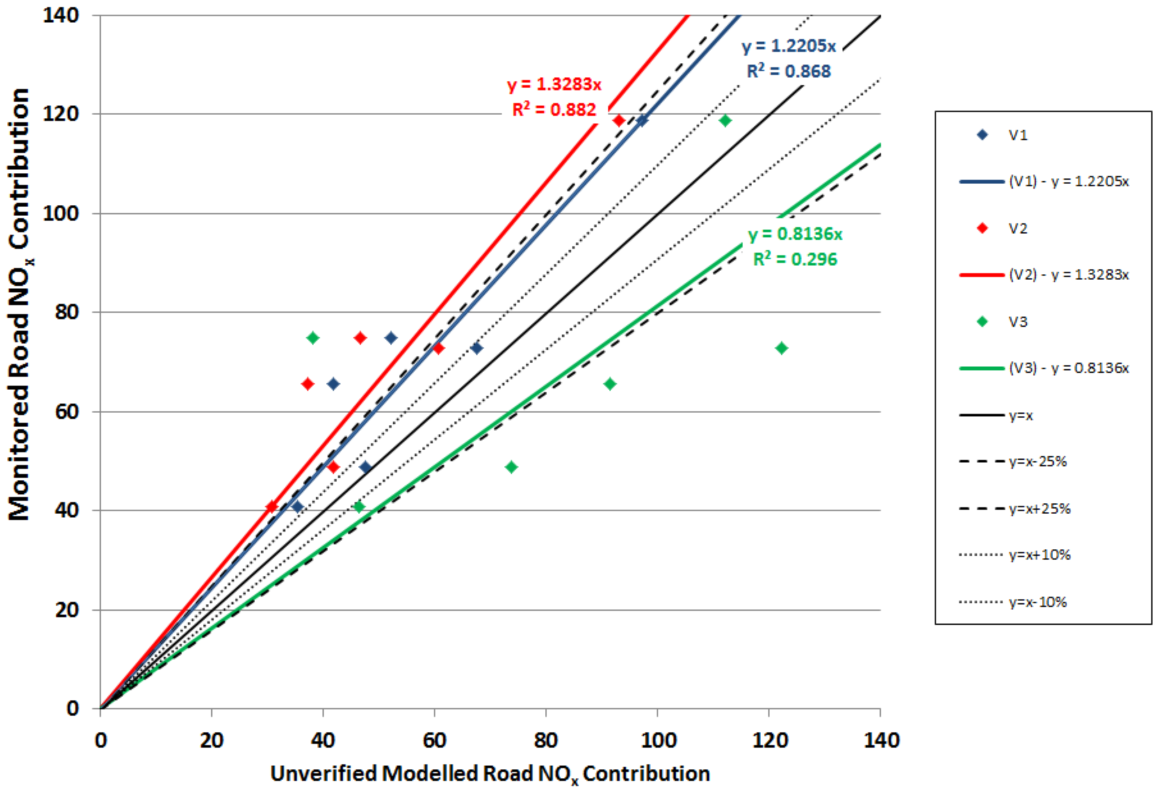


Table 11 - Model NO_2 Verification for all Monitoring Locations for the Three Modelling Approaches

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)
V1							
C	1.44	1.22	63.6	89.6	44.6	48.8	-8.5
D	1.15		43.2	69.2	36.9	36.0	2.6
E	1.03		57.9	86.3	43.7	40.2	8.5
F	1.22		118.8	146.9	63.0	62.9	0.1
G	1.56		51.1	79.2	41.1	46.3	-11.3
H	1.08		82.5	110.6	52.0	48.8	6.5
V2							
C	1.61	1.33	61.9	87.9	44.0	48.8	-9.7
D	1.33		40.8	66.8	36.0	36.0	-0.1
E	1.17		55.4	83.8	42.8	40.2	6.2
F	1.28		123.5	151.6	64.3	62.9	2.2
G	1.76		49.4	77.5	40.4	46.3	-12.7
H	1.20		80.5	108.6	51.4	48.8	5.2
V3							
C	1.96	0.81	31.1	57.1	31.9	48.8	-34.5
D	0.88		37.8	63.8	34.8	36.0	-3.4
E	0.66		60.0	88.3	44.4	40.2	10.4
F	1.06		91.2	119.3	54.8	62.9	-13.0
G	0.72		74.3	102.4	49.3	46.3	6.5
H	0.60		99.4	127.5	57.3	48.8	17.4

Figure 6 provide a comparison of the Modelled Road Contribution NO_x versus Monitored Road Contribution NO_x, and the equations of the trend line based on linear regression through zero for the monitoring locations using the three modelling approaches. The equation of the trend lines presented in Figure 6 gives an adjustment factor of 1.22 for V1, 1.33 for V2 and 0.81 for V3.

Figure 6 - Comparison of the Modelled Road Contribution NO_x versus Monitored Road Contribution NO_x for the Three Modelling Approaches



NO_2 results presented and discussed below have used the following verification factors for each of the three modelling approaches:

- V1 - 1.22;
- V2 – 1.33; and
- V3 – 0.81.

Approaches V1 and V2 therefore lead to an under-prediction of NO_2 road contributions, which is typical of dispersion models, whilst approach V3 leads to an over-prediction. Without detailed source apportionment of emissions outputs for the V3 approach it is difficult to draw any conclusions as to why this has been observed.

Table 11 and Figure 6 show the ratios between monitored and modelled NO_2 for each monitoring locations for each of the three modelling approaches. All sites considered for approaches V1 and V2 show acceptable agreement between the ratios of monitored and modelled NO_2 all being ±25%.

A verification factor of 1.22 was therefore used to adjust the model results assuming approach V1. A factor of 1.22 for V1 reduces the Root Mean Square Error (RMSE) from a value of 5.713 to 3.357. A verification factor of 1.33 was therefore used to adjust the model results assuming approach V2. A factor of 1.33 for V2 reduces the Root Mean Square Error (RMSE) from a value of 7.372 to 3.468.

The ratios between monitored and modelled NO_2 in Table 11 and Figure 6 would imply that modelling using either of approaches V1 or V2 would represent the most consistent approaches across the modelled area with all six verification points being well inside the ±25% criteria. Whilst the adjustment factor for V2 is slightly higher than V1, modelled concentrations result marginally lower for approach V2.

For modelling approach V3 one of the monitoring sites (Site C) was found to not show acceptable agreement between the ratios of monitored and modelled values. Ordinarily it may therefore be appropriate to remove this site when calculating the adjustment factor for approach V3 however in order to allow direct comparison with the other two model approaches Site C has remained included. A verification factor of 0.81 was therefore used to adjust the model results assuming approach V3. A factor of 0.81 for V3 reduces the Root Mean Square Error (RMSE) from a value of 9.856 to 8.663. It should be noted however that the RMSE remains high for V3 post model verification relative to V1 and V2, which is an indicator that overall the model is performing less well than these other methods.

5.2 Quantitative Appraisal of Bus Gating Scheme

Table 12 provides a summary of the NO_2 results for the BC and GC scenarios using the three modelling approaches.

Table 12 - NO_2 Results Summary

<table>
<tr><th colspan="2" rowspan="2">Descriptor</th><th colspan="2">V1</th><th colspan="2">V2</th><th colspan="2">V3</th></tr>
<tr><th>BC</th><th>GC</th><th>BC</th><th>GC</th><th>BC</th><th>GC</th></tr>
<tr><td rowspan="3">Summary Statistics (µg/m³)</td><td>Min</td><td>20.1</td><td>19.4</td><td>20.1</td><td>19.3</td><td>18.6</td><td>19.4</td></tr>
<tr><td>Max</td><td>65.5</td><td>64.5</td><td>64.2</td><td>63.3</td><td>75.7</td><td>72.3</td></tr>
<tr><td>Average</td><td>34.7</td><td>33.8</td><td>34.1</td><td>33.3</td><td>33.9</td><td>32.6</td></tr>
<tr><td rowspan="4">Number of Receptors with NO₂ concentration relative to 100%, 90% and 75% of the 40µg/m³ AQS Objective</td><td><30µg/m³</td><td>26</td><td>28</td><td>26</td><td>31</td><td>31</td><td>35</td></tr>
<tr><td>30-36µg/m³</td><td>11</td><td>10</td><td>11</td><td>8</td><td>9</td><td>5</td></tr>
<tr><td>36-40µg/m³</td><td>2</td><td>2</td><td>3</td><td>1</td><td>1</td><td>3</td></tr>
<tr><td>>=40µg/m³</td><td>19</td><td>18</td><td>18</td><td>18</td><td>17</td><td>15</td></tr>
<tr><td rowspan="4">Percentage of Receptors with NO₂ concentration relative to 100%, 90% and 75% of the 40µg/m³ AQS Objective</td><td><30µg/m³</td><td>44.8%</td><td>48.3%</td><td>44.8%</td><td>53.4%</td><td>53.4%</td><td>60.3%</td></tr>
<tr><td>30-36µg/m³</td><td>19.0%</td><td>17.2%</td><td>19.0%</td><td>13.8%</td><td>15.5%</td><td>8.6%</td></tr>
<tr><td>36-40µg/m³</td><td>3.4%</td><td>3.4%</td><td>5.2%</td><td>1.7%</td><td>1.7%</td><td>5.2%</td></tr>
<tr><td>>=40µg/m³</td><td>32.8%</td><td>31.0%</td><td>31.0%</td><td>31.0%</td><td>29.3%</td><td>25.9%</td></tr>
<tr><td rowspan="7">EPUK Impact Descriptor</td><td>Substantial Beneficial</td><td rowspan="7">N/A</td><td>12</td><td rowspan="7">N/A</td><td>10</td><td rowspan="7">N/A</td><td>15</td></tr>
<tr><td>Moderate Beneficial</td><td>9</td><td>11</td><td>7</td></tr>
<tr><td>Slight Beneficial</td><td>2</td><td>2</td><td>3</td></tr>
<tr><td>Negligible</td><td>33</td><td>33</td><td>32</td></tr>
<tr><td>Slight Adverse</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>Moderate Adverse</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>Substantial Adverse</td><td>1</td><td>1</td><td>0</td></tr>
</table>

Exceedences of the NO_2 40µg/m^3 annual mean AQS objective were predicted for all scenarios. The number of predicted exceedences either decreased or stayed the same when comparing BC the GC scenarios for each respective model approach. At least 25% of receptors were found to exceed in all the modelled scenarios and approaches.

Following adoption of the GC scenario adverse impact descriptor are predicted at two receptors for all three scenarios whilst beneficial impact descriptors are predicted at 23 receptors for approaches V1 and V2, and 24 receptors for approach V3. In accordance to EPUK guidance it can therefore be concluded that for each of the three model approaches an overall beneficial impact descriptor is observed following adoption of the GC scenarios.

The annual mean NO_2 concentration was predicted to be above 60µg/m^3 at two receptors for each of the GC scenarios indicating that there is a possibility that the 1-hour mean NO_2 AQS objective is being exceeded. The two receptors which exceed are located at the junction of High Street (A5183), London Road (A1081), Holywell Hill (A5183) and Chequer Street (A1081) just outside the boundary of St Albans AQMA No. 1.

Figure A1 of Appendix 7 – Concentration Isopleths provides concentration isopleths for annual mean NO_2 for the V1 BC scenario. Areas shown in blue represent NO_2 concentrations predicted to be above 36µg/m^3 (within 10% of the NO_2 annual mean AQS objective) and areas shown in red represent NO_2 concentrations predicted to be above 40µg/m^3 (above the NO_2 annual mean AQS objective).

Figure A2 provides concentration isopleths for annual mean NO_2 for the V1 GC scenario, although the differences are present from the V1 BC scenario they are difficult distinguish across the two figures.

Figure A3 has therefore been included to illustrate the differences in then annual mean NO_2 concentrations between the BC and GC scenarios. In Figure A3 areas shaded green represent a reduction in NO_2 concentrations (an improvement in air quality) from the V1 BC to V1 GC scenario, whilst areas show in red represent an increase in NO_2 concentrations (a worsening in air quality) from the V1 BC to V1 GC scenario. It can be observed in Figure A3 that NO_2 concentrations are predicted to improve along Chequer Street and Holywell Hill from Victoria Street to North to Prospect Road in the south. Along Holywell Hill improvements of over 2µg/m^3 are predicted. Additional areas of NO_2 improvements occur to the South of the modelled area around King Harry Lane and Watling Street. A worsening in NO_2 concentrations between the V1 BC and V1 GC scenarios is observed to the North of the modelled area, North of Victoria Street and along Holywell Hill between Prospect Road and St Stephens College.

Figure A4 of Appendix 7 – Concentration Isopleths provides concentration isopleths for annual mean NO_2 for the V2 BC scenario and Figure A5 provides concentration isopleths for annual mean NO_2 for the V2 GC scenario, although the differences are present from the V2 BC scenario they are difficult distinguish across the two figures.

Figure A6 has therefore been included to illustrate the differences in then annual mean NO_2 concentrations between the BC and GC scenarios. Figure A6 shows very similar isopleths to those in the equivalent figure for approach V1 with NO_2 concentrations predicted to improve along Chequer Street and Holywell Hill from Victoria Street to North to Prospect Road in the south. Again similar to the equivalent Figure for V1 a worsening in the NO_2 concentrations between the V2 BC and V2 GC scenarios is observed to the North of the modelled area, North of Victoria Street and along Holywell Hill between Prospect Road and St Stephens College.

Figure A7 of Appendix 7 – Concentration Isopleths provides concentration isopleths for annual mean NO_2 for the V3 BC scenario and Figure A8 provides concentration isopleths for annual mean NO_2 for the V3 GC scenario.

Figure A9 illustrates the differences in then annual mean NO_2 concentrations between the BC and GC scenarios for modelling approach V3. Figure A9 shows a greater area of difference than the equivalent figures for approaches V1 and V2, it also shows more localised variation between areas of improvement and areas worsening NO_2 concentrations.

A complete set of results for all receptors can be found in Appendix 6 – Air Quality Model Results.

5.3 Quantitative Appraisal of CAZ Implementation

Table 13 provides a summary of the NO_x emissions for the CAZ implementation scenarios, relative to 2020 BC and 2020 GC scenarios. The emissions summary is provided only for the instantaneous V3 modelling approach, as comparable traffic data was not made available for either of the V1 or V2 methodologies. All comparisons are made relative to a 2020 base case and are representative of the net change in total NO_x emissions across all roads included in the model domain (see Figure 1).

Table 13 - Predicted NO_x Emissions Reduction

	Bus Gating	CAZ Class A	CAZ Class B	CAZ Class D
NO_x Emissions Reduction relative to a 2020 BC	6%	9%	18%	40%

CAZ Class D brings forward the most significant reduction in emissions, with a 40% reduction relative to a 2020 BC. This is expected given the additional vehicle types that this targets with more stringent minimum Euro classes and standards. A Class B CAZ scenario is predicted to give rise to an 18% reduction in NO_x emissions across the assessment area. Inclusion of additional emissions controls for LDVs (i.e. LGVs and cars) therefore more than doubles the estimated NO_x emissions reductions. A Class A CAZ scenario is anticipated to give rise to a 9% reduction in NO_x emissions relative to a 2020 BC, which is comparable to the predicted emissions reduction associated with a bus gating scheme in 2020 (6%).

Owing to the constraints of the year for which the V3 emissions data was provided (i.e. 2020), it has not been possible to determine the resultant NO_2 concentrations for the above CAZ implementation scenarios without a significant amount of additional modelling which is outside of the scope of this study (all modelling was originally undertaken on the basis of a 2013 baseline year).

Whilst therefore it has not been possible to predict the direct air quality improvements geographically within the study area as a function of the various options for CAZ implementation. Nevertheless, this quantitative appraisal of NO_x emissions associated with CAZ implementation options has provided good evidence that further consideration to CAZ feasibility studies is warranted as part of further work, as a CAZ of an appropriate class is likely to bring forwards more significant air quality improvements when compared to the more vigorously tested bus gating scenario.

A complete set of emissions results for all scenarios, as determined by the V3 modelling methodology, are provided in Appendix 2 – Instantaneous Emissions Modelling.

5.4 NO_x Source Apportionment

A source apportionment exercise was undertaken for the NO_x/NO_2 concentration results obtained for the V2 BC and V2 GC scenarios.

The source apportionment was carried out for the following vehicle classes, which represent the same resolution as the traffic data inputs used in the dispersion modelling exercise:

- Cars;
- Light Goods Vehicles (LGVs);
- Mid-Range Heavy Goods Vehicles (HGVs).
- Buses (Double-Deckers); and
- Buses (Sprinters).

Figure 7 presents source apportionment results for V2 BC NO_x concentrations for three different selections of the modelled receptors:

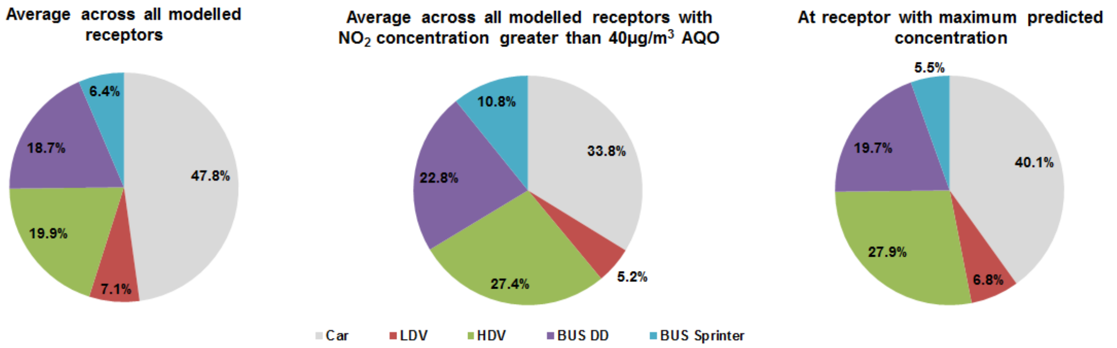
- **Average across all modelled receptors**. This provides useful information when considering possible AQAP measure to test and adopt. It will however understate road NO_x concentrations in problem areas;

- **Average across all receptors with NO_2 Concentration greater than 40µg/m^3**. This provides an indication of source apportionment in areas known to be a problem (i.e. only where the AQS objective is exceeded). As such, this information should be considered with more scrutiny when testing and adopting AQAP measures; and

- **At the Receptor with maximum road NO_x Concentration**. This is likely to be in the area of most concern and so a good place to test and adopt AQAP measures. Any gains predicted by AQAP measures are however likely to be greatest at this location and so would not represent gains across the whole modelled area.

Figure 7 illustrates the source apportionment of the various road traffic emissions sources as a proportion of the road traffic NOx/NO_2 concentrations (i.e. excluding background contributions to total NO_x/NO_2), as averaged across the 58 receptor locations of relevant exposure, for the V2 BC and V2 GC scenarios.

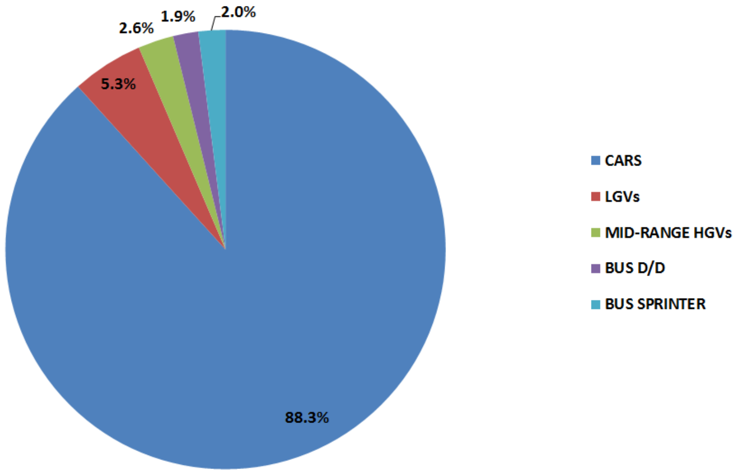
Figure 7 - Pie Charts showing NO_x Source Apportionment for V2 BC



On average, cars account for almost half of the road traffic NO_x contribution at the 58 assessed receptors. Double-decker buses and mid-range HGVs each account for approximately a fifth of road traffic NO_x contributions, whilst sprinter buses and LGVs each make up around 7% of road traffic NO_x at the assessed receptor locations.

Vehicle fleet composition, as averaged across all road links included within the dispersion model, is shown in Figure 8.

Figure 8 - Average Vehicle Fleet Composition for the V2 BC scenario



It can be seen that cars make up almost 90% of vehicles on the roads included within the model, with each of mid-range HGVs, double-decker buses and sprinter buses accounting for around 2% of the vehicles considered in the model, whilst LGVs comprise approximately 5% on average.

Comparison of the average NO_x source apportionment (Figure 7) relative to the average fleet split (Figure 8) highlights the far greater impact that buses and HGVs have in comparison to cars with regards to NO_x concentrations at the assessed receptor locations. This suggests merit in exploring intervention strategies/measures that target emissions from buses and HGVs, as these are more likely to lead to reductions in NO_x concentrations than alternative strategies that target cars or LGVs.

6 Conclusions

As part of a study part funded by a Defra air quality grant, St Albans City & District Council commissioned Bureau Veritas to undertake a dispersion modelling study which attempts to consider a second-by-second “virtual” representation of the “real” traffic network on the area around the St Albans AQMA No.1.

The two key aims of the project were:

- To undertake an assessment of the suitability of an instantaneous emissions dispersion modelling approach to the wider LAQM process; and
- To undertake advanced quantitative appraisal of the impacts of two intervention measures.

The study was undertaken with assistance from a number of project partners. Hertfordshire Highways and their transport consultant (Aecom) provided the following traffic inputs to the project:

- Traffic surveys at Peahen Junction;
- ANPR Survey data collection; and
- Paramics traffic model output for the baseline and intervention scenarios.

The Institute for Transport Studies at the University of Leeds have assisted by providing instantaneous emissions information for model scenarios using Passenger car and Heavy duty Emission Model (PHEM).

In order to undertake the assessment into instantaneous emissions three different modelling approaches were undertaken. Briefly this can be described as follows:

- V1 – Emissions used in the dispersion modelling have been calculated using Defra’s Emissions Factors Toolkit;
- V2 – Emissions used in the dispersion modelling have been calculated using Defra’s Emissions Factors Toolkit with the addition of the use of a local diurnal profile; and
- V3 – Emissions used in the dispersion modelling have been calculated using output from PHEM which has been calculated assuming instantaneous variation in traffic flows.

For each of the modelling approaches the following two scenarios were assessed.

- 2013 Base Case – base case representing the current air quality at the study area; and
- 2013 Gating Case – traffic flows taking into account the proposed bus gating measure on Holywell Hill (A5183).

In addition, for the V3 modelling approach several potential CAZ intervention scenarios have been considered, in line with the minimum classes and standards for CAZs as specified by Defra’s CAZ Framework:

- Class A – Buses and coaches to meet Euro VI Euro standard;
- Class B – Buses, coaches and HGVs to meet Euro VI Euro standard; and

Class D – Buses, coaches and HGVs to meet Euro VI Euro standard. LGVs and cars to meet Euro 6 (diesel) and Euro 4 (petrol). This is comparable to the London ULEZ.

6.1 Conclusion of Different Model Approaches

NO_2 results presented and discussed herein have used the following verification factors for each of the three modelling approaches:

- V1 - 1.22;
- V2 – 1.33; and
- V3 – 0.81.

Approaches V1 and V2 therefore lead to an under-prediction of NO_2 road contributions, which is typical of dispersion models, whilst approach V3 leads to an over-prediction. Without detailed source apportionment of emissions outputs for the V3 approach it is difficult to draw any conclusions as to why this has been observed.

The ratios between monitored and modelled NO_2 in Table 11 and Figure 6 would imply that modelling using either of approaches V1 or V2 would represent the most consistent approaches across the modelled area with all six verification points being well inside the ±25% criteria. Whilst the adjustment factor for V2 is slightly higher than V1, modelled concentrations result marginally lower for approach V2.

For modelling approach V3 one of the monitoring sites (Site C) was found to not show acceptable agreement between the ratios of monitored and modelled values. Ordinarily it may therefore be appropriate to remove this site when calculating the adjustment factor for approach V3 however in order to allow direct comparison with the other two model approaches Site C has remained included. A verification factor of 0.81 was therefore used to adjust the model results assuming approach V3. A factor of 0.81 for V3 reduces the RMSE from a value of 9.856 to 8.663. It should be noted however that the RMSE remains high for V3 post model verification relative to V1 and V2, which is an indicator that overall the model is performing less well than these other methods.

NO_2 concentrations predicted by method V2 appears to provide the best fit against the 2013 monitoring data. It is concluded therefore that the effort required to distil the additional information required for method V3 does not appear to be justified. It is noted however, that this may be due to the limitations of the V3 instantaneous emissions dataset, which only covered the am and pm peak periods (07.30 to 08.30 and 16.30 to 17.30 respectively) due to the constraints of the Paramics traffic model that also only covered these periods - the data for this period had to be scaled back to 24-hour based emissions estimates so as to be modelled, which will have introduced a higher level of uncertainty in the V3 predictions. It would be of interest to revisit this modelling comparison should an interpeak Paramics model be developed at some future point.

6.2 Conclusion of Quantitative Appraisal of Bus Gating Scheme

Exceedences of the NO_2 40µg/m^3 annual mean AQS objective were predicted in both the BC and GC scenarios. The number of predicted exceedences either decreased or stayed the same when comparing BC the GC scenarios for each respective model approach. At least 25% of receptors were found to exceed in all the modelled scenarios and approaches.

Following adoption of the GC scenario adverse impact descriptor are predicted at two receptors for all three scenarios whilst beneficial impact descriptors are predicted at 23 receptors for approaches V1 and V2, and 24 receptors for approach V3. In accordance to EPUK guidance it can therefore be concluded that for each of the three model approaches an overall beneficial impact descriptor is observed following adoption of the GC scenarios.

The annual mean NO_2 concentration was predicted to be above 60µg/m^3 at two receptors for each of the GC scenarios indicating that there is a possibility that the 1-hour mean NO_2 AQS objective is being exceeded. The two receptors which exceed are located at the junction of High Street (A5183), London Road (A1081), Holywell Hill (A5183) and Chequer Street (A1081) just outside the boundary of St Albans AQMA No. 1.

The bus gating scenario was shown to marginally improve air quality in the study area in terms of a net impact. However, some areas were predicted to worsen and exceedences of the annual mean NO_2 AQS objective were still predicted to persist with the bus gating (based on 2013 model verification). The benefits of proceeding with the bus gating intervention may therefore be further considered as part of a package of measures as opposed to a single measure that will remove all exceedences.

6.3 Conclusion of Quantitative Appraisal of CAZ Implementation

Preliminary consideration of CAZ based interventions shows significant reductions in NO_x emissions and therefore NO_2 concentrations may be realised, but direct comparison to the BC and GC scenarios is problematic given the assumed base year of 2020 and the limited emissions data available (i.e. only available for the instantaneous method). It has therefore not been possible to quantify the NO_2 concentration impacts of the CAZ feasibility scenarios.

However, with respect to the available NO_x emissions data alone this would suggest that a CAZ with a focus comparable to the London ULEZ would bring forwards the most significant reductions in NO_x emissions relative to a 2020 base scenario with a 40% reduction, whilst a HDV only focus would translate to an 18% reduction. A Bus only CAZ focus would give rise to a 9% reduction in NO_x emissions; by way of comparison, introduction of the bus gating measure in 2020 will give rise to an estimated 6% NO_x emissions.

Further consideration to CAZ feasibility studies is therefore warranted as part of further work and is likely to bring forwards more significant air quality improvements when compared to the more vigorously tested bus gating scenario.

6.4 Conclusion of NO_x Source Apportionment

Source apportionment of NO_x shows the greater impact that HGV and bus emissions have to the overall road traffic NO_x contribution, relative to the proportion of these vehicles within the observed fleet.

Consideration should therefore be given to intervention strategies/measures that preferentially target reductions in HGV and bus (i.e. HDV) emissions sources, in order to provide the greatest cost-benefit to realising the overall objective of reducing NO_2 concentrations at receptor locations.

Appendices

Appendix 1 – Transport Technical Note

Appendix 2 – Instantaneous Emissions Modelling

Appendix 3 – 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 is the pollutant of greatest concern across the modelled area. This has been confirmed over recent years by the outcome of the Local Air Quality Management (LAQM) regime. The most recent statistics[11] regarding Air Quality Management Areas (AQMAs) show that, 601 AQMAs were declared in the UK, of which 562 include NO_2 and 99 include PM_{10} (a number of AQMAs have been declared for both pollutants). The majority (92%) 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 Nitrogen Oxides is provided below, 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 NO_x 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.

[11] Statistics from the UK AQMA website available at http://aqma.defra.gov.uk – Figures as of January 2013

Appendix 4 – Full list of Modelled Receptors

Table A1 - Modelled Receptors

ID	X(m)	Y(m)	Z(m)
1	514696.6	207110.9	1.5
2	514685.6	207078.6	1.5
3	514692.2	207096.4	1.5
4	514710.6	207106	1.5
5	514736.9	207097.1	1.5
6	514705.1	207092.5	1.5
7	514697.8	207072.5	1.5
8	514691.9	207055.1	1.5
9	514686.2	207039.1	1.5
10	514680.5	207022.6	1.5
11	514680.3	207063.3	1.5
12	514807.6	207331	1.5
13	514820.5	207316.9	1.5
14	514717.7	207168.2	1.5
15	514717.3	207127.8	1.5
16	514837.6	207070.8	1.5
17	514900.5	207044.5	1.5
18	514740.9	207207.5	1.5
19	514746.3	207188	1.5
20	514644	206949.1	1.5
21	514667.9	206981.4	1.5
22	514624.8	206894	1.5
23	515082.9	206907.5	1.5
24	515014.8	206967.1	1.5
25	514610.2	207134	1.5
26	514586.2	207154.7	1.5
27	514596.9	206769.5	1.5
28	514577.2	206714.2	1.5
29	514560.6	206709.1	1.5
30	514530.9	206574.1	1.5
31	514524.2	206554.3	1.5
32	514558.9	206505	1.5
33	514540.9	206488.2	1.5
34	514520.6	206536.4	1.5
35	514513.6	206519.9	1.5
36	514507.2	206495	1.5
37	514473.6	206436.5	1.5
38	514434	206377.5	1.5
39	514382.2	206399.6	1.5
40	514371.5	206378.9	1.5
41	514326.1	206340.3	1.5
42	514312	206226.7	1.5
43	514175.8	206174.9	1.5
44	514277.8	206239.5	1.5
45	514096.3	206133.6	1.5
46	514076.2	206096	1.5
47	514078.7	206069.3	1.5
48	514101.3	206026.4	1.5
49	514018.5	206076.9	1.5
50	514034.2	206012.2	1.5
51	513998.3	206024	1.5
52	514000	205942.3	1.5
53	513936.6	206136.6	1.5
54	513985.1	206146.4	1.5
55	514043	206124.1	1.5
56	514558.1	206636.1	1.5
57	514567.7	206679	1.5
58	514567.9	206735.8	1.5

Appendix 5 – Traffic Data

Table A2 - Traffic Data Base Case Scenario

Link ID	Link Name	AADT	Cars	LGVs	Mid-Range HGVs	BUS DD	BUS Sprinter	Speed (mph)
'0:296	Chequer Street NorthBound 1	4711	85.64	6.67	2.13	3.84	1.72	15
'296:113	Chequer Street NorthBound 2	4692	85.59	6.65	2.14	3.89	1.73	14
'113:27	Chequer Street NorthBound 3	4723	85.69	6.61	2.16	3.83	1.72	5
'27:14	Chequer Street NorthBound 4	4769	85.75	6.62	2.14	3.78	1.71	5
'296:0	Chequer Street SouthBound 1	6941	85.10	4.25	6.17	3.18	1.31	4
'113:296	Chequer Street SouthBound 2	6920	85.13	4.28	6.19	3.09	1.31	3
'27:113	Chequer Street SouthBound 3	6908	85.14	4.26	6.18	3.10	1.32	4
'14:27	Chequer Street SouthBound 4	6919	85.14	4.25	6.18	3.11	1.31	4
'251:62	George Street SEbound 1	0	0.00	0.00	0.00	0.00	0.00	0
'62:297	George Street SEbound 2	1133	95.46	2.83	1.71	0.00	0.00	13
'297:44	George Street SEbound 3	1162	95.36	2.98	1.66	0.00	0.00	4
'62:251	George Street NWbound 1	0	0.00	0.00	0.00	0.00	0.00	0
'297:62	George Street NWbound 2	1711	85.42	4.69	9.89	0.00	0.00	28
'44:297	George Street NWbound 3	1706	85.39	4.71	9.90	0.00	0.00	16
'44:132	High Street EastBound 1	7330	89.03	7.28	3.58	0.00	0.10	2
'132:1	High Street EastBound 2	7336	89.03	7.27	3.60	0.00	0.10	2
'1:0	High Street EastBound 3	8053	89.19	7.34	3.37	0.00	0.10	3
'132:44	High Street WestBound 1	6558	86.27	8.54	5.19	0.00	0.00	24
'1:132	High Street WestBound 2	6562	86.27	8.53	5.19	0.00	0.00	5
'0:1	High Street WestBound 3	6555	86.24	8.54	5.22	0.00	0.00	12
'117:335	Market Place (SWbound only) 1	732	91.30	8.07	0.63	0.00	0.00	8
'335:182	Market Place (SWbound only) 2	738	91.38	8.00	0.63	0.00	0.00	6
'182:334	Market Place (SWbound only) 3	743	91.13	7.95	0.92	0.00	0.00	3
'334:1	Market Place (SWbound only) 4	758	91.59	7.51	0.90	0.00	0.00	2
329v:44	Verulam Road Southbound 1	6533	88.05	7.78	4.05	0.00	0.11	3
61:329v	Verulam Road Southbound 2	6546	88.05	7.80	4.03	0.00	0.11	6
'301:61	Verulam Road Southbound 3	6393	87.58	8.22	4.09	0.00	0.11	14
'63:301	Verulam Road Southbound 4	7311	88.09	8.13	3.67	0.00	0.10	14
'224:63	Verulam Road Southbound 5	6156	86.58	9.01	4.30	0.00	0.11	27
44:329v	Verulam Road Northbound 1	5221	87.16	9.49	3.35	0.00	0.00	12
329v:61	Verulam Road Northbound 2	5235	87.20	9.46	3.34	0.00	0.00	22
'61:301	Verulam Road Northbound 3	5558	87.77	9.05	3.18	0.00	0.00	25
'301:63	Verulam Road Northbound 4	5439	87.51	9.23	3.26	0.00	0.00	25
'63:224	Verulam Road Northbound 5	5172	86.31	10.11	3.58	0.00	0.00	30
'135:0	Holywell Hill NorthBound 1	8168	90.47	5.70	1.26	2.20	0.37	2
'133:135	Holywell Hill NorthBound 2	8149	90.55	5.63	1.26	2.19	0.37	2
'43:133	Holywell Hill NorthBound 3	8202	90.63	5.54	1.27	2.18	0.38	2
'64:43	Holywell Hill NorthBound 4	9218	91.38	5.24	1.14	1.91	0.34	3
'345:64	Holywell Hill NorthBound 5	7483	91.38	4.63	1.24	2.36	0.39	3
'65:345	Holywell Hill NorthBound 6	7003	90.38	5.38	1.15	2.63	0.46	4
326z:65	Holywell Hill NorthBound 7	9491	92.00	4.86	0.85	1.94	0.35	4
66:326z	Holywell Hill NorthBound 8	9490	92.01	4.85	0.85	1.94	0.35	5
'99:66	Holywell Hill NorthBound 9	9532	92.19	4.73	0.83	1.90	0.35	3
'105:99	Holywell Hill NorthBound 10	9573	92.28	4.70	0.83	1.84	0.34	7
'373:105	Holywell Hill NorthBound 11	9698	92.34	4.69	0.82	1.82	0.34	10
'103:373	Holywell Hill NorthBound 12	9702	92.34	4.69	0.82	1.82	0.34	3
'101:103	Holywell Hill NorthBound 13	12704	92.82	5.02	0.49	1.39	0.27	5
'102:101	Holywell Hill NorthBound 14	12687	92.81	5.02	0.49	1.41	0.27	8
'100:102	Holywell Hill NorthBound 15	12770	92.83	5.05	0.48	1.36	0.27	6
'98:100	Holywell Hill NorthBound 16	12828	92.85	5.04	0.48	1.36	0.27	6
'0:135	Holywell Hill SouthBound 1	10291	92.10	4.30	1.52	1.57	0.52	22
'135:133	Holywell Hill SouthBound 2	10311	92.06	4.36	1.52	1.55	0.51	19
'133:43	Holywell Hill SouthBound 3	10313	92.07	4.36	1.52	1.55	0.51	19

Link ID	Link Name	AADT	Cars	LGVs	Mid-Range HGVs	BUS DD	BUS Sprinter	Speed (mph)
'43:64	Holywell Hill SouthBound 4	9349	92.03	4.40	1.37	1.73	0.48	18
'64:345	Holywell Hill SouthBound 5	11159	92.52	4.38	1.19	1.51	0.41	18
'345:65	Holywell Hill SouthBound 6	11400	92.81	4.54	0.74	1.51	0.41	22
65:326z	Holywell Hill SouthBound 7	12278	93.03	4.55	0.69	1.37	0.37	8
326z:66	Holywell Hill SouthBound 8	12312	93.01	4.57	0.68	1.36	0.37	27
'66:99	Holywell Hill SouthBound 9	12333	93.02	4.57	0.68	1.36	0.37	15
99:201z	Holywell Hill SouthBound 10	12340	93.02	4.56	0.68	1.36	0.37	20
201z:372	Holywell Hill SouthBound 11	12072	92.86	4.68	0.70	1.39	0.38	12
'372:68	Holywell Hill SouthBound 12	12068	92.85	4.68	0.70	1.39	0.38	25
'68:69	Holywell Hill SouthBound 13	12730	93.55	4.31	0.49	1.30	0.35	20
'69:70	Holywell Hill SouthBound 14	12652	93.48	4.39	0.48	1.30	0.35	19
70:71a	Holywell Hill SouthBound 15	12652	93.48	4.39	0.48	1.30	0.35	9
'0:2	London Road EastBound 1	8104	84.93	7.00	6.94	0.70	0.43	24
'2:295	London Road EastBound 2	7402	83.38	7.67	7.76	0.76	0.43	26
295:150z	London Road EastBound 3	7409	83.37	7.67	7.77	0.76	0.43	26
150z:293	London Road EastBound 4	7710	83.60	7.21	8.04	0.74	0.41	25
'293:3	London Road EastBound 5	7713	83.58	7.20	8.06	0.74	0.41	21
'3:294	London Road EastBound 6	4104	75.83	6.60	15.32	1.46	0.80	13
'294:283	London Road EastBound 7	4111	75.86	6.59	15.30	1.46	0.80	22
'283:163	London Road EastBound 8	4130	75.78	6.58	15.34	1.51	0.80	6
'163:4	London Road EastBound 9	6220	84.26	5.31	9.91	0.00	0.52	19
'4:284	London Road EastBound 10	5355	81.64	5.96	11.81	0.00	0.59	17
'284:191	London Road EastBound 11	5307	81.76	5.93	11.81	0.00	0.50	22
'191:6	London Road EastBound 12	5304	81.74	5.93	11.84	0.00	0.50	15
'2:0	London Road WestBound 1	6536	85.27	8.30	5.70	0.00	0.72	3
'295:2	London Road WestBound 2	7298	87.42	7.31	4.64	0.00	0.63	9
150z:295	London Road WestBound 3	7285	87.43	7.29	4.64	0.00	0.63	14
293:150z	London Road WestBound 4	7751	88.00	7.09	4.31	0.00	0.60	27
'3:293	London Road WestBound 5	7766	87.99	7.08	4.33	0.00	0.60	27
'294:3	London Road WestBound 6	12317	87.94	6.75	4.94	0.00	0.38	11
'283:294	London Road WestBound 7	12328	87.94	6.75	4.94	0.00	0.38	20
'163:283	London Road WestBound 8	12355	87.92	6.74	4.96	0.00	0.38	19
'4:163	London Road WestBound 9	13064	89.91	5.00	4.74	0.00	0.35	19
'284:4	London Road WestBound 10	11327	88.51	5.35	5.73	0.00	0.41	4
'191:284	London Road WestBound 11	11292	88.51	5.38	5.71	0.00	0.41	7
'6:191	London Road WestBound 12	11301	88.47	5.38	5.75	0.00	0.41	9
'14:15	St Peters Street 1 Northbound	5637	80.02	6.35	3.95	3.17	6.52	9
'15:28	St Peters Street 2 Northbound	5630	80.01	6.36	3.93	3.13	6.58	5
'28:29	St Peters Street 3 Northbound	5622	79.84	6.39	4.06	3.11	6.60	9
'29:16	St Peters Street 4 Northbound	5606	79.78	6.40	4.08	3.12	6.62	7
'16:17	St Peters Street 5 Northbound	5529	79.88	6.45	4.14	3.07	6.46	9
17:103zd	St Peters Street 6 Northbound	5527	79.59	6.40	4.20	2.56	7.25	6
'15:14	St Peters Street 1 Southbound	5652	78.56	4.43	7.10	3.89	6.02	4
'28:15	St Peters Street 2 Southbound	5616	78.48	4.43	7.15	3.92	6.03	5
'29:28	St Peters Street 3 Southbound	5573	78.97	4.43	7.20	3.32	6.07	9
'16:29	St Peters Street 4 Southbound	5569	78.84	4.40	7.20	3.49	6.07	4
'17:16	St Peters Street 5 Southbound	5563	78.84	4.41	7.25	3.65	5.85	13
103zd:17	St Peters Street 6 Southbound	5555	78.70	4.39	7.24	3.65	6.01	21
'154:14	Victoria Street Northbound 1	2696	81.01	3.31	5.00	0.00	10.69	4
'13:154	Victoria Street Northbound 2	2691	80.97	3.32	5.01	0.00	10.70	5
189z:13	Victoria Street Northbound 3	2699	80.75	3.49	5.11	0.00	10.65	8
12:189z	Victoria Street Northbound 4	2957	82.86	3.03	4.57	0.00	9.55	17
'11:12	Victoria Street Northbound 5	4247	82.90	6.91	3.50	0.00	6.69	19
'14:154	Victoria Street Southbound 1	542	42.91	0.67	0.17	1.01	55.24	11
'154:13	Victoria Street Southbound 2	542	42.91	0.67	0.17	1.01	55.24	13
13:189z	Victoria Street Southbound 3	541	42.84	0.68	0.17	1.01	55.30	14

Link ID	Link Name	AADT	Cars	LGVs	Mid-Range HGVs	BUS DD	BUS Sprinter	Speed (mph)
189z:12	Victoria Street Southbound 4	967	70.75	0.68	0.17	1.01	27.39	13
'12:11	Victoria Street Southbound 5	1716	81.50	1.99	2.13	0.42	13.96	5
'163:164	Watson’s Walk 1 SWbound	4191	97.07	1.42	0.05	1.46	0.00	17
'164:84	Watson’s Walk 2 SWbound	3894	96.05	2.40	0.04	1.51	0.00	19
'164:163	Watson's Walk 1 NEbound	5608	94.97	4.72	0.31	0.00	0.00	2
'84:164	Watson's Walk 2 NEbound	5237	95.91	3.82	0.28	0.00	0.00	2
43:319z	Albert street (SEbound only) 1	1998	94.92	3.33	1.36	0.00	0.38	16
319z:320y	Albert street (SEbound only) 2	2139	92.13	7.14	0.33	0.00	0.40	13
320y:83	Albert street (SEbound only) 3	2132	92.16	7.12	0.33	0.00	0.40	9
80:155z	Sopwell Lane (NWbound only) 1	3657	95.32	4.50	0.18	0.00	0.00	17
155z:317z	Sopwell Lane (NWbound only) 2	3562	92.32	7.10	0.58	0.00	0.00	10
317z:64	Sopwell Lane (NWbound only) 3	3558	92.26	7.20	0.53	0.00	0.00	3
65:318z	Bellmont Hill SEbound 1	3072	96.53	3.43	0.04	0.00	0.00	13
318z:79	Bellmont Hill SEbound 2	3084	96.47	3.49	0.04	0.00	0.00	17
79:318z	Bellmont Hill NWbound 1	1508	96.37	3.63	0.00	0.00	0.00	13
318z:65	Bellmont Hill NWbound 2	1497	96.34	3.66	0.00	0.00	0.00	3
'105:150	Abbey Lodge access road (entry to lodge) 1 - OR Westminster Lodge	962	100.00	0.00	0.00	0.00	0.00	24
'150:213	Abbey Lodge access road (entry to lodge) 2- OR Westminster Lodge	957	100.00	0.00	0.00	0.00	0.00	34
'213:260	Abbey Lodge access road (entry to lodge) 3- OR Westminster Lodge	955	100.00	0.00	0.00	0.00	0.00	31
'260:261	Abbey Lodge access road (entry to lodge) 4- OR Westminster Lodge	0	0.00	0.00	0.00	0.00	0.00	0
'150:105	Abbey Lodge access road (exit from Lodge) 1	585	100.00	0.00	0.00	0.00	0.00	10
'213:150	Abbey Lodge access road (exit from Lodge) 2	582	100.00	0.00	0.00	0.00	0.00	21
'260:213	Abbey Lodge access road (exit from Lodge) 3	580	100.00	0.00	0.00	0.00	0.00	23
'261:260	Abbey Lodge access road (exit from Lodge) 4	0	0.00	0.00	0.00	0.00	0.00	0
'68:349	Prospect Road (SEbound) 1	5807	94.09	5.11	0.80	0.00	0.00	21
349:327z	Prospect Road (SEbound) 2	6054	95.50	4.11	0.38	0.00	0.00	18
327z:78	Prospect Road (SEbound) 3	6061	95.51	4.11	0.38	0.00	0.00	15
'349:68	Prospect Road (NWbound) 1	3457	96.11	2.64	1.25	0.00	0.00	8
327z:349	Prospect Road (NWbound) 2	3892	96.71	2.04	1.25	0.00	0.00	20
78:327z	Prospect Road (NWbound) 3	3890	96.71	2.04	1.25	0.00	0.00	19
'69:202	Abbey Railway Stn access road (entry to stn) 1	162	100.00	0.00	0.00	0.00	0.00	14
'202:203	Abbey Railway Stn access road (entry to stn) 2	0	0.00	0.00	0.00	0.00	0.00	0
'202:69	Abbey Railway Stn access road (exit from stn) 1	110	50.00	0.00	0.00	0.00	0.00	5
'203:202	Abbey Railway Stn access road (exit from stn) 2	0	0.00	0.00	0.00	0.00	0.00	0
71b:73	Griffith's way (access to Sainsbury's) SEbound 1	6636	98.26	1.15	0.04	0.55	0.00	21
73:199z	Griffith's way (access to Sainsbury's) SEbound 2	6629	98.24	1.15	0.04	0.57	0.00	29
199z:200z	Griffith's way (access to Sainsbury's) SEbound 3	0	0.00	0.00	0.00	0.00	0.00	0
'123:122	Griffith's way (access to Sainsbury's) Nwbound 1	7359	97.73	0.84	0.07	1.36	0.00	13
199z:123	Griffith's way (access to Sainsbury's) Nwbound 2	7342	98.22	0.84	0.07	0.87	0.00	18
200z:199z	Griffith's way (access to	0	0.00	0.00	0.00	0.00	0.00	0

Link ID	Link Name	AADT	Cars	LGVs	Mid-Range HGVs	BUS DD	BUS Sprinter	Speed (mph)
	Sainsbury's) Nwbound 3							
'104:121	St Stephen's hill Southbound 1	11296	92.74	5.18	0.51	1.17	0.40	17
'121:72	St Stephen's hill Southbound 2	11281	92.72	5.16	0.51	1.21	0.40	18
'72:212	St Stephen's hill Southbound 3	11230	92.77	5.26	0.51	1.21	0.24	13
'212:219	St Stephen's hill Southbound 4	11234	92.77	5.28	0.51	1.21	0.23	5
'219:391	St Stephen's hill Southbound 5	0	0.00	0.00	0.00	0.00	0.00	0
121:71c	St Stephen's hill Northbound 1	10933	91.96	6.43	0.49	0.83	0.30	7
'72:121	St Stephen's hill Northbound 2	10969	92.08	6.47	0.49	0.82	0.14	10
'212:72	St Stephen's hill Northbound 3	11055	92.10	6.48	0.48	0.80	0.14	13
'219:212	St Stephen's hill Northbound 4	11386	92.13	6.51	0.52	0.85	0.00	16
'391:219	St Stephen's hill Northbound 5	0	0.00	0.00	0.00	0.00	0.00	0
390b:382	Watling street SEbound 1	6801	93.10	5.75	1.15	0.00	0.00	27
'391:382	Watling street SEbound 2	0	0.00	0.00	0.00	0.00	0.00	0
'382:375	Watling street SEbound 3	6809	93.12	5.73	1.15	0.00	0.00	30
'375:376	Watling street SEbound 4	0	0.00	0.00	0.00	0.00	0.00	0
382:390c	Watling street NWbound 1	0	0.00	0.00	0.00	0.00	0.00	0
'382:391	Watling street NWbound 2	0	0.00	0.00	0.00	0.00	0.00	0
'375:382	Watling street NWbound 3	6358	89.62	8.94	1.44	0.00	0.00	14
'376:375	Watling street NWbound 4	0	0.00	0.00	0.00	0.00	0.00	0
389c:381	King Harry Ln NWbound 1	4731	91.74	6.82	1.04	0.40	0.00	15
'381:383	King Harry Ln NWbound 2	10897	91.64	7.08	1.10	0.17	0.00	14
'383:384	King Harry Ln NWbound 3	10898	91.65	7.08	1.10	0.17	0.00	26
'384:385	King Harry Ln NWbound 4	10913	91.64	7.09	1.10	0.17	0.00	32
381:389c	King Harry Ln SEbound 1	6652	93.05	5.10	1.64	0.21	0.00	2
'383:381	King Harry Ln SEbound 2	6658	93.04	5.10	1.66	0.21	0.00	3
'384:383	King Harry Ln SEbound 3	6666	93.06	5.06	1.67	0.21	0.00	4
'385:384	King Harry Ln SEbound 4	6692	93.21	5.08	1.71	0.00	0.00	11
391:389b	Watford Road Southbound 1	0	0.00	0.00	0.00	0.00	0.00	0
389b:380	Watford Road Southbound 2	9215	91.62	6.14	0.92	1.32	0.00	21
'380:386	Watford Road Southbound 3	8897	91.55	6.15	0.94	1.36	0.00	18
'386:379	Watford Road Southbound 4	8905	91.57	6.13	0.94	1.36	0.00	30
'379:378	Watford Road Southbound 5	8898	91.64	6.14	0.94	1.28	0.00	30
'378:377	Watford Road Southbound 6	0	0.00	0.00	0.00	0.00	0.00	0
389b:391	Watford Road Northbound 1	0	0.00	0.00	0.00	0.00	0.00	0
380:389b	Watford Road Northbound 2	8070	92.58	6.25	0.13	1.04	0.00	4
'386:380	Watford Road Northbound 3	13907	92.34	6.55	0.51	0.59	0.00	10
'379:386	Watford Road Northbound 4	13938	92.34	6.56	0.51	0.59	0.00	16
'378:379	Watford Road Northbound 5	14028	92.32	6.57	0.53	0.59	0.00	20
'377:378	Watford Road Northbound 6	0	0.00	0.00	0.00	0.00	0.00	0

Table A3 - Traffic Data Gating Case Scenario

Link ID	Link Name	AADT	Cars	LGVs	Mid-Range HGVs	BUS DD	BUS Sprinter	Speed (mph)
'0:296	Chequer Street NorthBound 1	4826	85.94	7.03	1.68	3.63	1.72	14
'296:113	Chequer Street NorthBound 2	4809	85.85	7.10	1.69	3.64	1.72	11
'113:27	Chequer Street NorthBound 3	4800	85.96	7.05	1.66	3.65	1.69	4
'27:14	Chequer Street NorthBound 4	4806	85.98	7.03	1.65	3.64	1.69	4
'296:0	Chequer Street SouthBound 1	7118	86.35	4.17	5.50	2.86	1.12	3
'113:296	Chequer Street SouthBound 2	7124	86.25	4.21	5.54	2.81	1.18	3
'27:113	Chequer Street SouthBound 3	7095	86.16	4.17	5.66	2.82	1.19	4
'14:27	Chequer Street SouthBound 4	7090	85.99	4.19	5.77	2.82	1.23	4
'251:62	George Street SEbound 1	0	0.00	0.00	0.00	0.00	0.00	0
'62:297	George Street SEbound 2	1106	95.00	3.51	1.50	0.00	0.00	13
'297:44	George Street SEbound 3	1123	95.08	3.45	1.47	0.00	0.00	4

Link ID	Link Name	AADT	Cars	LGVs	Mid-Range HGVs	BUS DD	BUS Sprinter	Speed (mph)
'62:251	George Street NWbound 1	0	0.00	0.00	0.00	0.00	0.00	0
'297:62	George Street NWbound 2	1662	85.81	4.86	9.34	0.00	0.00	27
'44:297	George Street NWbound 3	1664	85.85	4.86	9.30	0.00	0.00	15
'44:132	High Street EastBound 1	6808	89.06	7.37	3.46	0.00	0.11	2
'132:1	High Street EastBound 2	6799	89.05	7.35	3.49	0.00	0.11	2
'1:0	High Street EastBound 3	7599	89.23	7.36	3.31	0.00	0.10	3
'132:44	High Street WestBound 1	6533	86.55	8.60	4.85	0.00	0.00	23
'1:132	High Street WestBound 2	6547	86.59	8.54	4.87	0.00	0.00	5
'0:1	High Street WestBound 3	6542	86.60	8.55	4.85	0.00	0.00	12
'117:335	Market Place (SWbound only) 1	898	91.71	7.69	0.60	0.00	0.00	6
'335:182	Market Place (SWbound only) 2	886	91.59	7.80	0.61	0.00	0.00	5
'182:334	Market Place (SWbound only) 3	843	91.61	7.76	0.64	0.00	0.00	4
'334:1	Market Place (SWbound only) 4	805	91.56	7.77	0.67	0.00	0.00	2
329v:44	Verulam Road Southbound 1	5993	87.90	7.90	4.07	0.00	0.13	3
61:329v	Verulam Road Southbound 2	5998	87.87	7.93	4.07	0.00	0.13	7
'301:61	Verulam Road Southbound 3	5850	87.62	8.12	4.13	0.00	0.13	14
'63:301	Verulam Road Southbound 4	6965	88.34	7.93	3.61	0.00	0.11	14
'224:63	Verulam Road Southbound 5	5858	86.65	8.98	4.25	0.00	0.12	25
44:329v	Verulam Road Northbound 1	5197	87.31	9.56	3.12	0.00	0.00	11
329v:61	Verulam Road Northbound 2	5170	87.26	9.61	3.14	0.00	0.00	20
'61:301	Verulam Road Northbound 3	5507	87.78	9.20	3.02	0.00	0.00	23
'301:63	Verulam Road Northbound 4	5409	87.56	9.36	3.08	0.00	0.00	23
'63:224	Verulam Road Northbound 5	5281	86.43	10.14	3.43	0.00	0.00	28
'135:0	Holywell Hill NorthBound 1	8140	90.47	5.89	1.08	2.14	0.42	2
'133:135	Holywell Hill NorthBound 2	8243	90.49	5.84	1.15	2.11	0.42	3
'43:133	Holywell Hill NorthBound 3	8285	90.67	5.77	1.08	2.12	0.36	4
'64:43	Holywell Hill NorthBound 4	8959	91.10	5.63	0.99	1.94	0.34	6
'345:64	Holywell Hill NorthBound 5	7210	91.40	4.77	1.01	2.39	0.42	8
'65:345	Holywell Hill NorthBound 6	6589	90.47	5.55	1.00	2.55	0.44	15
326z:65	Holywell Hill NorthBound 7	7953	91.76	4.94	0.80	2.13	0.38	13
66:326z	Holywell Hill NorthBound 8	7956	91.74	4.96	0.79	2.13	0.38	22
'99:66	Holywell Hill NorthBound 9	0	0.00	0.00	0.00	0.00	0.00	0
'105:99	Holywell Hill NorthBound 10	7795	94.11	5.07	0.81	0.00	0.00	2
'373:105	Holywell Hill NorthBound 11	7924	91.69	4.90	0.82	2.21	0.38	4
'103:373	Holywell Hill NorthBound 12	7926	91.70	4.90	0.82	2.21	0.38	2
'101:103	Holywell Hill NorthBound 13	11851	92.79	4.79	0.68	1.48	0.26	3
'102:101	Holywell Hill NorthBound 14	11838	92.78	4.80	0.68	1.48	0.26	4
'100:102	Holywell Hill NorthBound 15	11883	92.84	4.76	0.67	1.48	0.25	3
'98:100	Holywell Hill NorthBound 16	11889	92.83	4.76	0.68	1.47	0.25	3
'0:135	Holywell Hill SouthBound 1	10122	92.25	4.28	1.49	1.47	0.51	20
'135:133	Holywell Hill SouthBound 2	10111	92.21	4.33	1.47	1.48	0.51	25
'133:43	Holywell Hill SouthBound 3	10112	92.21	4.33	1.47	1.48	0.51	19
'43:64	Holywell Hill SouthBound 4	9128	92.14	4.40	1.35	1.64	0.47	17
'64:345	Holywell Hill SouthBound 5	11641	92.91	4.32	1.11	1.29	0.37	14
'345:65	Holywell Hill SouthBound 6	11778	93.08	4.47	0.76	1.31	0.38	24
65:326z	Holywell Hill SouthBound 7	12120	93.19	4.47	0.73	1.25	0.36	15
326z:66	Holywell Hill SouthBound 8	12082	93.17	4.49	0.73	1.25	0.36	26
'66:99	Holywell Hill SouthBound 9	0	0.00	0.00	0.00	0.00	0.00	0
99:201z	Holywell Hill SouthBound 10	12071	93.17	4.48	0.73	1.26	0.36	17
201z:372	Holywell Hill SouthBound 11	11727	92.94	4.63	0.75	1.30	0.37	11
'372:68	Holywell Hill SouthBound 12	11728	92.94	4.63	0.75	1.30	0.37	21
'68:69	Holywell Hill SouthBound 13	12957	93.69	4.14	0.68	1.15	0.33	17
'69:70	Holywell Hill SouthBound 14	12890	93.55	4.22	0.68	1.21	0.34	16
70:71a	Holywell Hill SouthBound 15	12885	93.53	4.24	0.68	1.21	0.34	8
'0:2	London Road EastBound 1	7485	84.66	7.34	6.95	0.69	0.37	22
'2:295	London Road EastBound 2	6655	82.71	7.98	8.12	0.78	0.41	23

Link ID	Link Name	AADT	Cars	LGVs	Mid-Range HGVs	BUS DD	BUS Sprinter	Speed (mph)
295:150z	London Road EastBound 3	6655	82.71	7.98	8.12	0.78	0.41	24
150z:293	London Road EastBound 4	6994	83.10	7.38	8.37	0.76	0.38	23
'293:3	London Road EastBound 5	6996	83.11	7.38	8.36	0.76	0.38	21
'3:294	London Road EastBound 6	3799	76.04	6.54	15.27	1.43	0.72	12
'294:283	London Road EastBound 7	3792	76.01	6.56	15.28	1.43	0.72	19
'283:163	London Road EastBound 8	3810	76.19	6.58	15.25	1.27	0.72	5
'163:4	London Road EastBound 9	5982	85.17	5.14	9.24	0.00	0.45	17
'4:284	London Road EastBound 10	5206	81.73	6.23	11.53	0.00	0.52	15
'284:191	London Road EastBound 11	5161	81.88	6.19	11.45	0.00	0.49	20
'191:6	London Road EastBound 12	5156	81.88	6.16	11.45	0.00	0.51	13
'2:0	London Road WestBound 1	6161	84.67	8.80	5.81	0.00	0.71	3
'295:2	London Road WestBound 2	6980	87.10	7.57	4.71	0.00	0.61	8
150z:295	London Road WestBound 3	6979	87.07	7.58	4.74	0.00	0.61	13
293:150z	London Road WestBound 4	7468	87.62	7.38	4.43	0.00	0.58	26
'3:293	London Road WestBound 5	7475	87.62	7.41	4.40	0.00	0.57	25
'294:3	London Road WestBound 6	11432	87.56	6.80	5.26	0.00	0.38	13
'283:294	London Road WestBound 7	11442	87.55	6.80	5.27	0.00	0.37	22
'163:283	London Road WestBound 8	11472	87.56	6.80	5.27	0.00	0.37	20
'4:163	London Road WestBound 9	12565	89.64	5.19	4.83	0.00	0.34	17
'284:4	London Road WestBound 10	10884	88.06	5.77	5.78	0.00	0.39	4
'191:284	London Road WestBound 11	10852	88.01	5.79	5.80	0.00	0.39	7
'6:191	London Road WestBound 12	10876	88.15	5.68	5.78	0.00	0.39	8
'14:15	St Peters Street 1 Northbound	5682	80.38	7.08	3.33	3.07	6.14	7
'15:28	St Peters Street 2 Northbound	5665	80.37	7.08	3.34	3.05	6.16	3
'28:29	St Peters Street 3 Northbound	5677	80.27	7.09	3.42	3.05	6.17	7
'29:16	St Peters Street 4 Northbound	5666	80.26	7.07	3.42	3.05	6.19	5
'16:17	St Peters Street 5 Northbound	5607	80.56	6.96	3.46	2.91	6.11	9
17:103zd	St Peters Street 6 Northbound	5603	80.41	7.07	3.44	2.35	6.73	7
'15:14	St Peters Street 1 Southbound	5853	80.12	4.67	6.25	3.51	5.46	3
'28:15	St Peters Street 2 Southbound	5884	80.21	4.59	6.28	3.49	5.43	3
'29:28	St Peters Street 3 Southbound	5840	80.70	4.62	6.29	2.92	5.47	6
'16:29	St Peters Street 4 Southbound	5814	80.56	4.59	6.26	3.10	5.49	3
'17:16	St Peters Street 5 Southbound	5791	80.65	4.58	6.36	3.28	5.13	10
103zd:17	St Peters Street 6 Southbound	5793	80.46	4.56	6.34	3.28	5.37	17
'154:14	Victoria Street Northbound 1	2924	81.80	4.22	4.39	0.00	9.59	4
'13:154	Victoria Street Northbound 2	2943	81.95	4.14	4.40	0.00	9.52	5
189z:13	Victoria Street Northbound 3	2996	82.21	4.17	4.32	0.00	9.30	6
12:189z	Victoria Street Northbound 4	3277	84.06	3.70	3.90	0.00	8.34	13
'11:12	Victoria Street Northbound 5	4388	83.85	6.59	3.40	0.00	6.15	17
'14:154	Victoria Street Southbound 1	732	52.96	3.18	0.00	0.71	43.15	6
'154:13	Victoria Street Southbound 2	728	53.46	3.23	0.00	0.71	42.60	10
13:189z	Victoria Street Southbound 3	725	53.33	3.26	0.00	0.71	42.70	8
189z:12	Victoria Street Southbound 4	1146	77.16	1.94	0.00	0.71	20.18	12
'12:11	Victoria Street Southbound 5	1717	82.57	2.16	2.03	0.42	12.81	4
'163:164	Watson's Walk 1 SWbound	4245	97.26	1.60	0.03	1.11	0.00	15
'164:84	Watson's Walk 2 SWbound	3970	96.10	2.74	0.03	1.13	0.00	17
'164:163	Watson's Walk 1 NEbound	5360	95.52	4.07	0.41	0.00	0.00	2
'84:164	Watson's Walk 2 NEbound	5036	96.43	3.24	0.33	0.00	0.00	2
43:319z	Albert street (SEbound only) 1	1661	94.04	3.89	1.62	0.00	0.46	15
319z:320y	Albert street (SEbound only) 2	1724	91.22	7.43	0.83	0.00	0.53	14
320y:83	Albert street (SEbound only) 3	1713	91.28	7.44	0.75	0.00	0.53	12
80:155z	Sopwell Lane (NWbound only) 1	4236	95.73	3.95	0.31	0.00	0.00	16
155z:317z	Sopwell Lane (NWbound only) 2	4286	93.58	5.92	0.50	0.00	0.00	13
317z:64	Sopwell Lane (NWbound only) 3	4263	93.55	5.95	0.51	0.00	0.00	7
65:318z	Bellmont Hill SEbound 1	1984	96.96	3.04	0.00	0.00	0.00	12
318z:79	Bellmont Hill SEbound 2	1986	96.97	3.03	0.00	0.00	0.00	16

Link ID	Link Name	AADT	Cars	LGVs	Mid-Range HGVs	BUS DD	BUS Sprinter	Speed (mph)
79:318z	Bellmont Hill NWbound 1	947	97.14	2.60	0.26	0.00	0.00	14
318z:65	Bellmont Hill NWbound 2	943	97.13	2.61	0.26	0.00	0.00	6
'105:150	Abbey Lodge access road (entry to lodge) 1 - OR Westminster Lodge	892	100.00	0.00	0.00	0.00	0.00	23
'150:213	Abbey Lodge access road (entry to lodge) 2- OR Westminster Lodge	893	100.00	0.00	0.00	0.00	0.00	31
'213:260	Abbey Lodge access road (entry to lodge) 3- OR Westminster Lodge	895	100.00	0.00	0.00	0.00	0.00	29
'260:261	Abbey Lodge access road (entry to lodge) 4- OR Westminster Lodge	0	0.00	0.00	0.00	0.00	0.00	0
'150:105	Abbey Lodge access road (exit from Lodge) 1	610	100.00	0.00	0.00	0.00	0.00	9
'213:150	Abbey Lodge access road (exit from Lodge) 2	618	100.00	0.00	0.00	0.00	0.00	23
'260:213	Abbey Lodge access road (exit from Lodge) 3	621	100.00	0.00	0.00	0.00	0.00	25
'261:260	Abbey Lodge access road (exit from Lodge) 4	0	0.00	0.00	0.00	0.00	0.00	0
'68:349	Prospect Road (SEbound) 1	5367	94.84	4.34	0.82	0.00	0.00	19
349:327z	Prospect Road (SEbound) 2	5821	96.34	3.43	0.23	0.00	0.00	18
327z:78	Prospect Road (SEbound) 3	5836	96.31	3.46	0.23	0.00	0.00	18
'349:68	Prospect Road (NWbound) 1	2660	97.20	1.75	1.05	0.00	0.00	19
327z:349	Prospect Road (NWbound) 2	3156	96.82	1.94	1.25	0.00	0.00	19
78:327z	Prospect Road (NWbound) 3	3162	96.82	1.93	1.24	0.00	0.00	19
'69:202	Abbey Railway Stn access road (entry to stn) 1	159	100.00	0.00	0.00	0.00	0.00	15
'202:203	Abbey Railway Stn access road (entry to stn) 2	0	0.00	0.00	0.00	0.00	0.00	0
'202:69	Abbey Railway Stn access road (exit from stn) 1	102	50.00	0.00	0.00	0.00	0.00	4
'203:202	Abbey Railway Stn access road (exit from stn) 2	0	0.00	0.00	0.00	0.00	0.00	0
71b:73	Griffith's way (access to Sainsbury's) SEbound 1	5922	98.41	0.96	0.05	0.58	0.00	19
73:199z	Griffith's way (access to Sainsbury's) SEbound 2	5911	98.41	0.96	0.05	0.59	0.00	28
199z:200z	Griffith's way (access to Sainsbury's) SEbound 3	0	0.00	0.00	0.00	0.00	0.00	0
'123:122	Griffith's way (access to Sainsbury's) Nwbound 1	7134	97.87	0.79	0.06	1.28	0.00	10
199z:123	Griffith's way (access to Sainsbury's) Nwbound 2	7130	98.31	0.79	0.06	0.84	0.00	15
200z:199z	Griffith's way (access to Sainsbury's) Nwbound 3	0	0.00	0.00	0.00	0.00	0.00	0
'104:121	St Stephen's hill Southbound 1	10986	92.67	5.23	0.56	1.13	0.40	13
'121:72	St Stephen's hill Southbound 2	10941	92.68	5.22	0.57	1.13	0.40	13
'72:212	St Stephen's hill Southbound 3	10699	92.73	5.31	0.58	1.13	0.25	11
'212:219	St Stephen's hill Southbound 4	10680	92.71	5.34	0.58	1.13	0.23	4
'219:391	St Stephen's hill Southbound 5	0	0.00	0.00	0.00	0.00	0.00	0
121:71c	St Stephen's hill Northbound 1	8869	91.01	6.95	0.60	1.12	0.32	2
'72:121	St Stephen's hill Northbound 2	8864	91.26	6.85	0.59	1.14	0.17	3
'212:72	St Stephen's hill Northbound 3	8866	91.24	6.90	0.59	1.10	0.17	3
'219:212	St Stephen's hill Northbound 4	8896	91.52	6.89	0.61	0.99	0.00	3
'391:219	St Stephen's hill Northbound 5	0	0.00	0.00	0.00	0.00	0.00	0
390b:382	Watling street SEbound 1	5362	93.01	5.77	1.22	0.00	0.00	25
'391:382	Watling street SEbound 2	0	0.00	0.00	0.00	0.00	0.00	0
'382:375	Watling street SEbound 3	5369	93.07	5.77	1.16	0.00	0.00	28

Link ID	Link Name	AADT	Cars	LGVs	Mid-Range HGVs	BUS DD	BUS Sprinter	Speed (mph)
'375:376	Watling street SEbound 4	0	0.00	0.00	0.00	0.00	0.00	0
382:390c	Watling street NWbound 1	0	0.00	0.00	0.00	0.00	0.00	0
'382:391	Watling street NWbound 2	0	0.00	0.00	0.00	0.00	0.00	0
'375:382	Watling street NWbound 3	5294	89.17	9.42	1.41	0.00	0.00	2
'376:375	Watling street NWbound 4	0	0.00	0.00	0.00	0.00	0.00	0
389c:381	King Harry Ln NWbound 1	4476	92.10	6.61	0.91	0.39	0.00	14
'381:383	King Harry Ln NWbound 2	9293	91.72	7.03	1.06	0.19	0.00	13
'383:384	King Harry Ln NWbound 3	9290	91.72	7.03	1.06	0.19	0.00	24
'384:385	King Harry Ln NWbound 4	9303	91.76	6.99	1.06	0.19	0.00	30
381:389c	King Harry Ln SEbound 1	3657	93.24	5.18	1.35	0.23	0.00	1
'383:381	King Harry Ln SEbound 2	3668	93.19	5.24	1.35	0.23	0.00	1
'384:383	King Harry Ln SEbound 3	3671	93.19	5.23	1.35	0.23	0.00	1
'385:384	King Harry Ln SEbound 4	3693	93.41	5.17	1.42	0.00	0.00	1
391:389b	Watford Road Southbound 1	0	0.00	0.00	0.00	0.00	0.00	0
389b:380	Watford Road Southbound 2	7202	91.42	6.43	0.73	1.42	0.00	20
'380:386	Watford Road Southbound 3	7197	91.43	6.45	0.71	1.42	0.00	17
'386:379	Watford Road Southbound 4	7208	91.42	6.46	0.70	1.42	0.00	28
'379:378	Watford Road Southbound 5	7210	91.42	6.45	0.70	1.42	0.00	28
'378:377	Watford Road Southbound 6	0	0.00	0.00	0.00	0.00	0.00	0
389b:391	Watford Road Northbound 1	0	0.00	0.00	0.00	0.00	0.00	0
380:389b	Watford Road Northbound 2	6515	92.27	6.27	0.27	1.19	0.00	2
'386:380	Watford Road Northbound 3	11339	92.16	6.56	0.59	0.69	0.00	3
'379:386	Watford Road Northbound 4	11377	92.16	6.55	0.60	0.68	0.00	4
'378:379	Watford Road Northbound 5	11531	92.16	6.58	0.58	0.68	0.00	4
'377:378	Watford Road Northbound 6	0	0.00	0.00	0.00	0.00	0.00	0
105:395z	Bus Gate 1	205	0.00	0.00	0.00	85.99	14.01	0
395z:395	Bus Gate 2	205	0.00	0.00	0.00	85.99	14.01	0
'105:99	Hollywell Hill Northbound 10P1	7795	94.11	5.07	0.81	0.00	0.00	2
'99:395	Hollywell Hill Northbound 10P2	7778	94.10	5.09	0.81	0.00	0.00	19
'395:66	Hollywell Hill Northbound 9P	7959	91.67	4.95	0.79	2.20	0.38	25
'66:395	Hollywell Hill Southbound 9P	12069	93	4	1	1	0	16
'395:99	Hollywell Hill Southbound 10P2	12069	93	4	1	1	0	11

Appendix 6 – Air Quality Model Results

Table A4 - Air Quality Modelling Results – Approach V1

ID	V1 BC	V1 GC	% Change relative to AQS	% DC OF AQS	EPUK/IAQM Guidance Descriptor
1	62.2	61.2	-2.6%	152.9%	Substantial Beneficial
2	52.4	51.9	-1.5%	129.6%	Moderate Beneficial
3	65.5	64.5	-2.3%	161.3%	Substantial Beneficial
4	49.0	48.2	-2.0%	120.5%	Substantial Beneficial
5	45.5	44.7	-2.1%	111.7%	Substantial Beneficial
6	47.9	47.2	-1.7%	118.0%	Substantial Beneficial
7	50.7	50.1	-1.4%	125.2%	Moderate Beneficial
8	50.1	49.5	-1.4%	123.8%	Moderate Beneficial
9	52.0	51.3	-1.7%	128.3%	Substantial Beneficial
10	46.5	45.2	-3.3%	113.0%	Substantial Beneficial
11	51.5	50.9	-1.4%	127.3%	Moderate Beneficial
12	50.9	52.4	3.8%	131.0%	Substantial Adverse
13	40.9	41.3	1.2%	103.4%	Moderate Adverse
14	34.8	34.5	-0.5%	86.4%	Negligible
15	48.5	47.9	-1.6%	119.7%	Substantial Beneficial
16	30.9	30.7	-0.4%	76.7%	Negligible
17	31.8	31.5	-0.7%	78.7%	Negligible
18	36.7	36.3	-1.0%	90.8%	Negligible
19	49.7	49.0	-1.7%	122.5%	Substantial Beneficial
20	35.2	34.5	-1.6%	86.3%	Slight Beneficial
21	44.3	42.9	-3.4%	107.3%	Substantial Beneficial
22	48.4	48.5	0.3%	121.2%	Negligible
23	45.4	44.1	-3.2%	110.2%	Substantial Beneficial
24	39.4	38.3	-2.9%	95.7%	Moderate Beneficial
25	30.8	30.3	-1.4%	75.7%	Negligible
26	31.0	30.4	-1.5%	75.9%	Negligible
27	34.8	30.6	-10.4%	76.5%	Moderate Beneficial
28	34.8	30.3	-11.4%	75.7%	Moderate Beneficial
29	40.6	34.7	-14.9%	86.7%	Substantial Beneficial
30	28.7	27.3	-3.5%	68.1%	Negligible
31	27.6	26.9	-1.7%	67.4%	Negligible
32	23.2	22.4	-2.2%	55.9%	Negligible
33	23.0	22.3	-1.7%	55.9%	Negligible
34	26.7	26.1	-1.3%	65.3%	Negligible
35	28.0	27.3	-1.8%	68.3%	Negligible
36	25.8	25.5	-0.8%	63.8%	Negligible
37	24.3	24.4	0.4%	61.0%	Negligible
38	25.2	25.4	0.5%	63.6%	Negligible
39	23.5	23.4	0.0%	58.6%	Negligible
40	23.9	23.9	0.0%	59.7%	Negligible
41	22.4	22.5	0.4%	56.3%	Negligible
42	22.8	22.9	0.4%	57.3%	Negligible
43	28.8	29.2	0.9%	72.9%	Negligible
44	32.4	32.9	1.4%	82.3%	Negligible
45	26.9	26.9	-0.2%	67.2%	Negligible
46	23.2	22.5	-1.7%	56.2%	Negligible
47	23.0	22.4	-1.6%	55.9%	Negligible
48	22.7	22.1	-1.5%	55.3%	Negligible
49	22.1	21.5	-1.5%	53.7%	Negligible
50	23.7	23.6	-0.1%	59.0%	Negligible
51	21.2	21.2	0.0%	53.0%	Negligible
52	23.4	23.7	0.8%	59.2%	Negligible
53	20.1	19.4	-1.9%	48.4%	Negligible
54	22.4	21.2	-3.1%	53.0%	Negligible
55	22.8	21.8	-2.5%	54.5%	Negligible
56	27.7	24.5	-8.0%	61.3%	Slight Beneficial
57	31.2	27.5	-9.2%	68.7%	Moderate Beneficial
58	33.7	29.5	-10.5%	73.8%	Moderate Beneficial

Table A5 - Air Quality Modelling Results – Approach V2

ID	V2 BC	V2 GC	% Change relative to AQS	% DC OF AQS	EPUK/IAQM Guidance Descriptor
1	61.0	60.0	-2.5%	150.0%	Substantial Beneficial
2	51.3	50.7	-1.4%	126.9%	Moderate Beneficial
3	64.2	63.3	-2.3%	158.2%	Substantial Beneficial
4	47.8	47.0	-1.9%	117.6%	Substantial Beneficial
5	44.6	43.8	-2.0%	109.5%	Substantial Beneficial
6	46.8	46.2	-1.7%	115.4%	Substantial Beneficial
7	50.0	49.5	-1.4%	123.7%	Moderate Beneficial
8	49.4	48.9	-1.4%	122.2%	Moderate Beneficial
9	51.2	50.5	-1.7%	126.3%	Substantial Beneficial
10	45.8	44.5	-3.2%	111.3%	Substantial Beneficial
11	50.3	49.8	-1.4%	124.5%	Moderate Beneficial
12	49.8	51.3	3.7%	128.3%	Substantial Adverse
13	40.0	40.5	1.2%	101.2%	Slight Adverse
14	34.3	34.2	-0.5%	85.4%	Negligible
15	47.9	47.3	-1.5%	118.2%	Moderate Beneficial
16	30.3	30.1	-0.4%	75.3%	Negligible
17	31.2	30.9	-0.7%	77.3%	Negligible
18	36.3	35.9	-0.9%	89.7%	Negligible
19	49.1	48.5	-1.7%	121.1%	Substantial Beneficial
20	34.6	34.0	-1.6%	84.9%	Slight Beneficial
21	43.6	42.3	-3.3%	105.6%	Moderate Beneficial
22	47.3	47.4	0.3%	118.5%	Negligible
23	44.6	43.4	-3.1%	108.4%	Substantial Beneficial
24	38.8	37.7	-2.8%	94.2%	Moderate Beneficial
25	30.5	29.9	-1.4%	74.9%	Negligible
26	30.8	30.2	-1.4%	75.6%	Negligible
27	33.9	29.9	-9.9%	74.8%	Moderate Beneficial
28	33.9	29.6	-10.9%	74.0%	Moderate Beneficial
29	39.7	34.0	-14.4%	84.9%	Substantial Beneficial
30	28.1	26.7	-3.3%	66.8%	Negligible
31	27.1	26.4	-1.6%	66.1%	Negligible
32	22.9	22.1	-2.1%	55.3%	Negligible
33	22.8	22.1	-1.7%	55.3%	Negligible
34	26.2	25.7	-1.3%	64.1%	Negligible
35	27.5	26.8	-1.7%	67.1%	Negligible
36	25.4	25.1	-0.7%	62.8%	Negligible
37	23.9	24.0	0.4%	60.1%	Negligible
38	24.8	25.0	0.5%	62.5%	Negligible
39	23.3	23.3	0.0%	58.2%	Negligible
40	23.7	23.6	0.0%	59.1%	Negligible
41	22.2	22.4	0.4%	55.9%	Negligible
42	22.5	22.7	0.4%	56.6%	Negligible
43	28.5	28.8	0.9%	72.0%	Negligible
44	32.0	32.5	1.4%	81.2%	Negligible
45	26.8	26.8	-0.1%	66.9%	Negligible
46	22.9	22.3	-1.6%	55.7%	Negligible
47	22.8	22.2	-1.6%	55.5%	Negligible
48	22.5	21.9	-1.5%	54.8%	Negligible
49	22.0	21.4	-1.5%	53.4%	Negligible
50	23.4	23.3	-0.1%	58.3%	Negligible
51	21.1	21.1	-0.1%	52.8%	Negligible
52	23.1	23.4	0.7%	58.5%	Negligible
53	20.1	19.3	-1.8%	48.3%	Negligible
54	22.2	21.0	-3.0%	52.5%	Negligible
55	22.6	21.6	-2.4%	54.0%	Negligible
56	27.2	24.1	-7.7%	60.3%	Slight Beneficial
57	30.5	26.9	-8.8%	67.4%	Moderate Beneficial
58	33.2	29.1	-10.3%	72.7%	Moderate Beneficial

Table A6 - Air Quality Modelling Results – Approach V3

ID	V3 BC	V3 GC	% Change relative to AQS	% DC OF AQS	EPUK/IAQM Guidance Descriptor
1	72.1	70.4	-4.3%	176.1%	Substantial Beneficial
2	57.3	54.0	-8.2%	135.1%	Substantial Beneficial
3	75.7	72.3	-8.5%	180.8%	Substantial Beneficial
4	54.0	52.7	-3.0%	131.9%	Substantial Beneficial
5	49.9	49.0	-2.2%	122.5%	Substantial Beneficial
6	52.8	50.9	-4.8%	127.2%	Substantial Beneficial
7	55.6	52.4	-7.9%	131.0%	Substantial Beneficial
8	54.6	51.2	-8.4%	128.0%	Substantial Beneficial
9	56.0	52.1	-9.8%	130.2%	Substantial Beneficial
10	45.7	40.1	-14.0%	100.3%	Substantial Beneficial
11	55.9	52.4	-8.6%	131.1%	Substantial Beneficial
12	46.7	45.7	-2.5%	114.2%	Substantial Beneficial
13	38.4	38.1	-0.8%	95.2%	Slight Beneficial
14	34.2	34.4	0.5%	85.9%	Negligible
15	52.7	51.9	-2.0%	129.7%	Substantial Beneficial
16	26.4	26.1	-0.9%	65.2%	Negligible
17	25.4	25.1	-0.9%	62.7%	Negligible
18	34.8	34.8	-0.2%	86.9%	Negligible
19	45.8	46.0	0.4%	114.9%	Negligible
20	33.8	29.7	-10.3%	74.2%	Moderate Beneficial
21	42.8	36.9	-14.6%	92.3%	Substantial Beneficial
22	44.4	39.9	-11.3%	99.7%	Substantial Beneficial
23	47.3	46.8	-1.0%	117.1%	Moderate Beneficial
24	32.7	32.5	-0.5%	81.2%	Negligible
25	35.3	34.6	-2.0%	86.4%	Slight Beneficial
26	32.0	31.7	-0.8%	79.2%	Negligible
27	30.5	23.8	-16.9%	59.5%	Moderate Beneficial
28	30.4	24.1	-15.8%	60.2%	Moderate Beneficial
29	35.1	26.5	-21.4%	66.3%	Moderate Beneficial
30	24.4	24.0	-1.2%	59.9%	Negligible
31	24.6	25.6	2.3%	63.9%	Negligible
32	21.4	21.0	-1.1%	52.4%	Negligible
33	21.4	21.1	-0.7%	52.8%	Negligible
34	24.5	24.8	0.6%	61.9%	Negligible
35	26.3	26.1	-0.4%	65.4%	Negligible
36	24.3	24.8	1.1%	61.9%	Negligible
37	21.6	22.1	1.4%	55.3%	Negligible
38	23.2	22.0	-3.1%	55.0%	Negligible
39	22.3	22.0	-0.9%	54.9%	Negligible
40	22.5	23.0	1.3%	57.6%	Negligible
41	20.5	21.5	2.5%	53.7%	Negligible
42	19.9	20.9	2.4%	52.1%	Negligible
43	22.5	24.7	5.4%	61.7%	Negligible
44	23.9	26.9	7.5%	67.2%	Slight Adverse
45	24.1	24.4	0.7%	61.0%	Negligible
46	23.7	23.9	0.6%	59.8%	Negligible
47	24.0	24.1	0.4%	60.3%	Negligible
48	24.2	24.0	-0.4%	60.1%	Negligible
49	22.4	22.9	1.2%	57.2%	Negligible
50	21.7	22.6	2.3%	56.5%	Negligible
51	19.7	20.4	1.8%	51.1%	Negligible
52	20.5	21.5	2.5%	53.7%	Negligible
53	18.6	19.4	2.0%	48.5%	Negligible
54	20.0	21.3	3.2%	53.2%	Negligible
55	23.5	24.0	1.1%	59.9%	Negligible
56	23.0	19.7	-8.3%	49.2%	Slight Beneficial
57	27.2	22.4	-12.2%	55.9%	Moderate Beneficial
58	29.9	23.8	-15.0%	59.6%	Moderate Beneficial

Appendix 7 – Concentration Isopleths

Figure A1 - Annual Mean NO_2 concentration isopleths for the V1 BC scenario ($\mu g/m^3$)

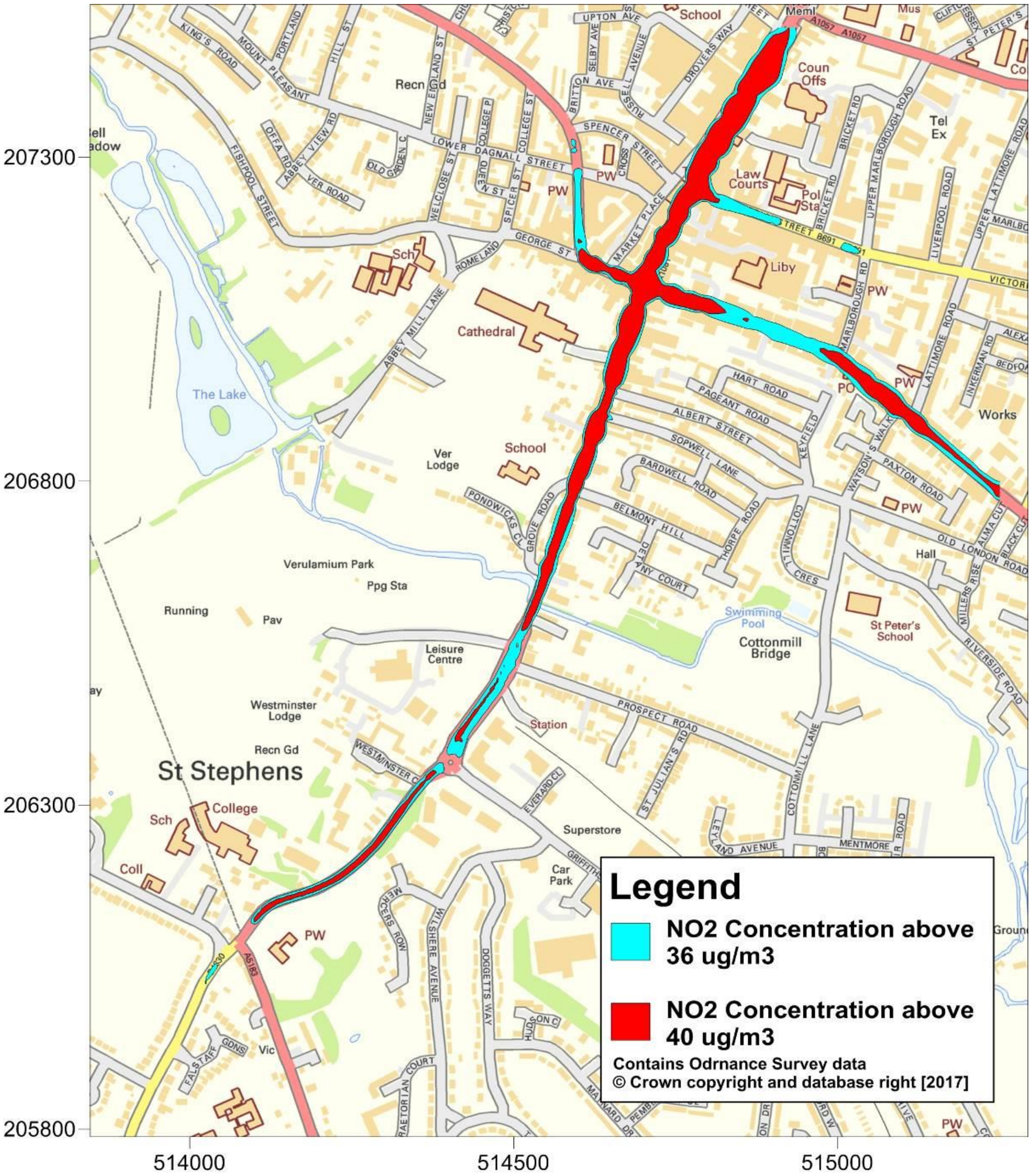


Figure A2 - Annual Mean NO_2 concentration isopleths for the V1 GC scenario (µg/m^3)

Figure A3 - Annual Mean NO_2 concentration isopleths showing the difference between the V1 BC and V1 GC scenarios (µg/m^3)

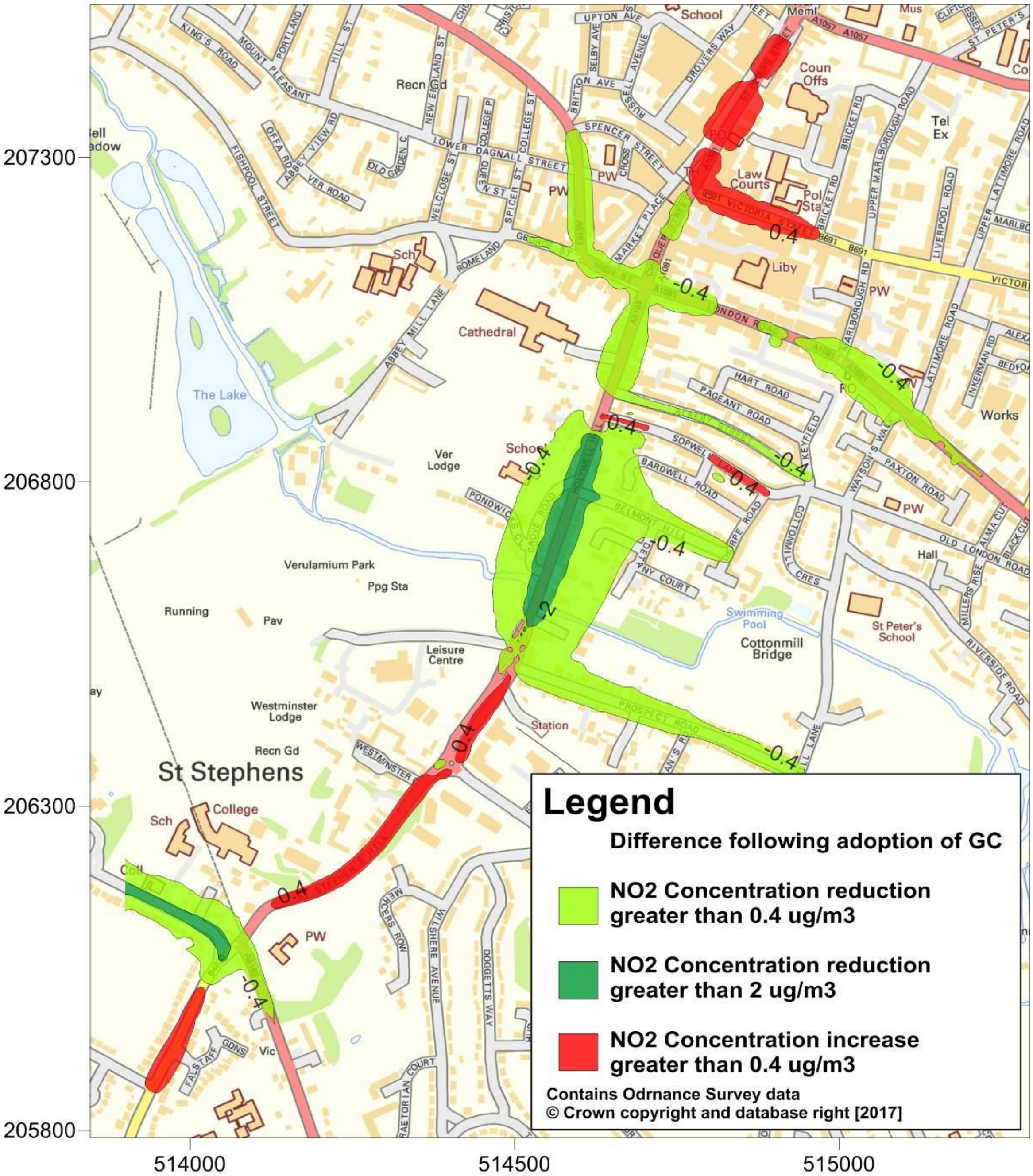


Figure A4 - Annual Mean NO_2 concentration isopleths for the V2 BC scenario ($\mu g/m^3$)

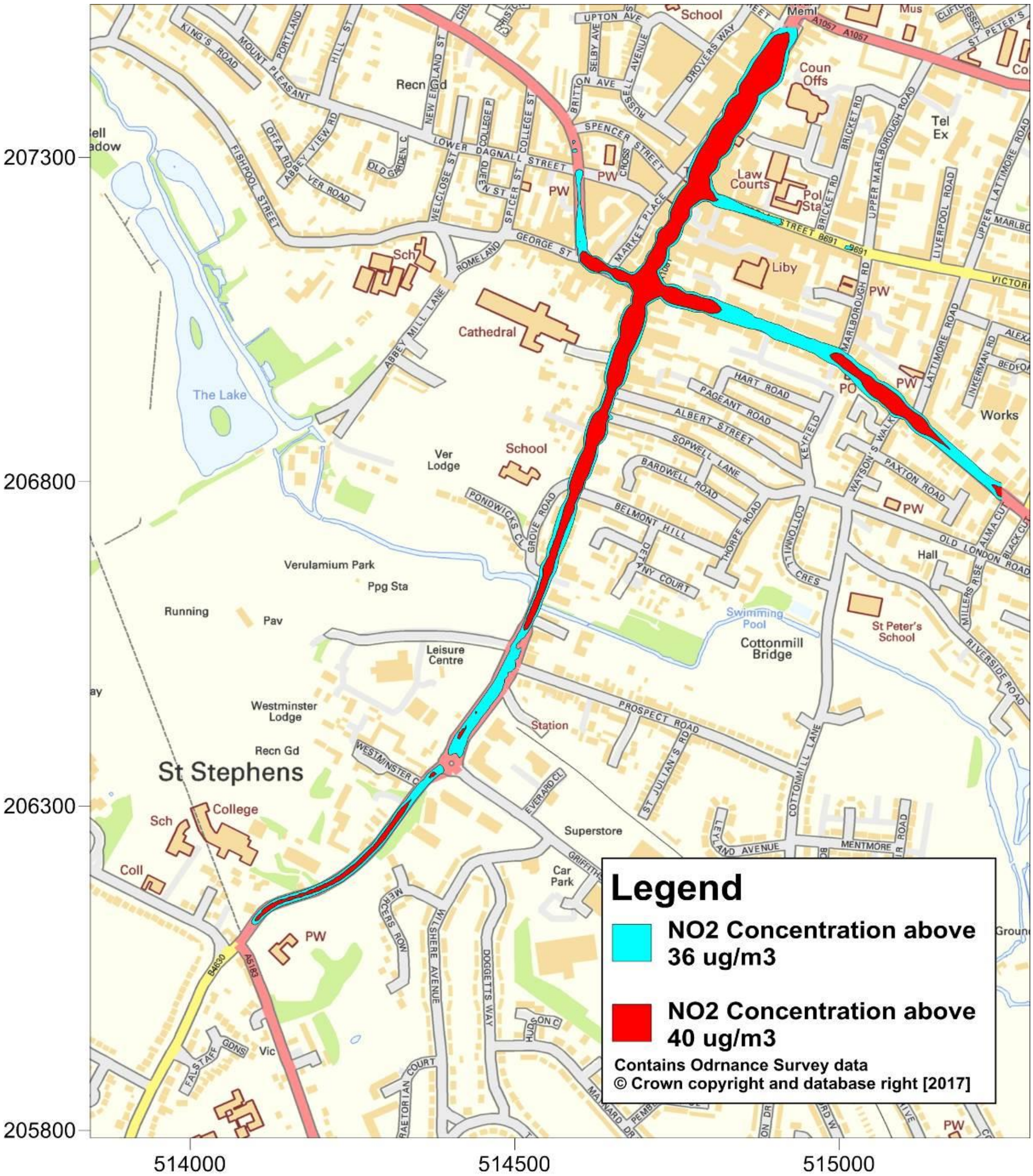


Figure A5 - Annual Mean NO_2 concentration isopleths for the V2 GC scenario (µg/m^3)

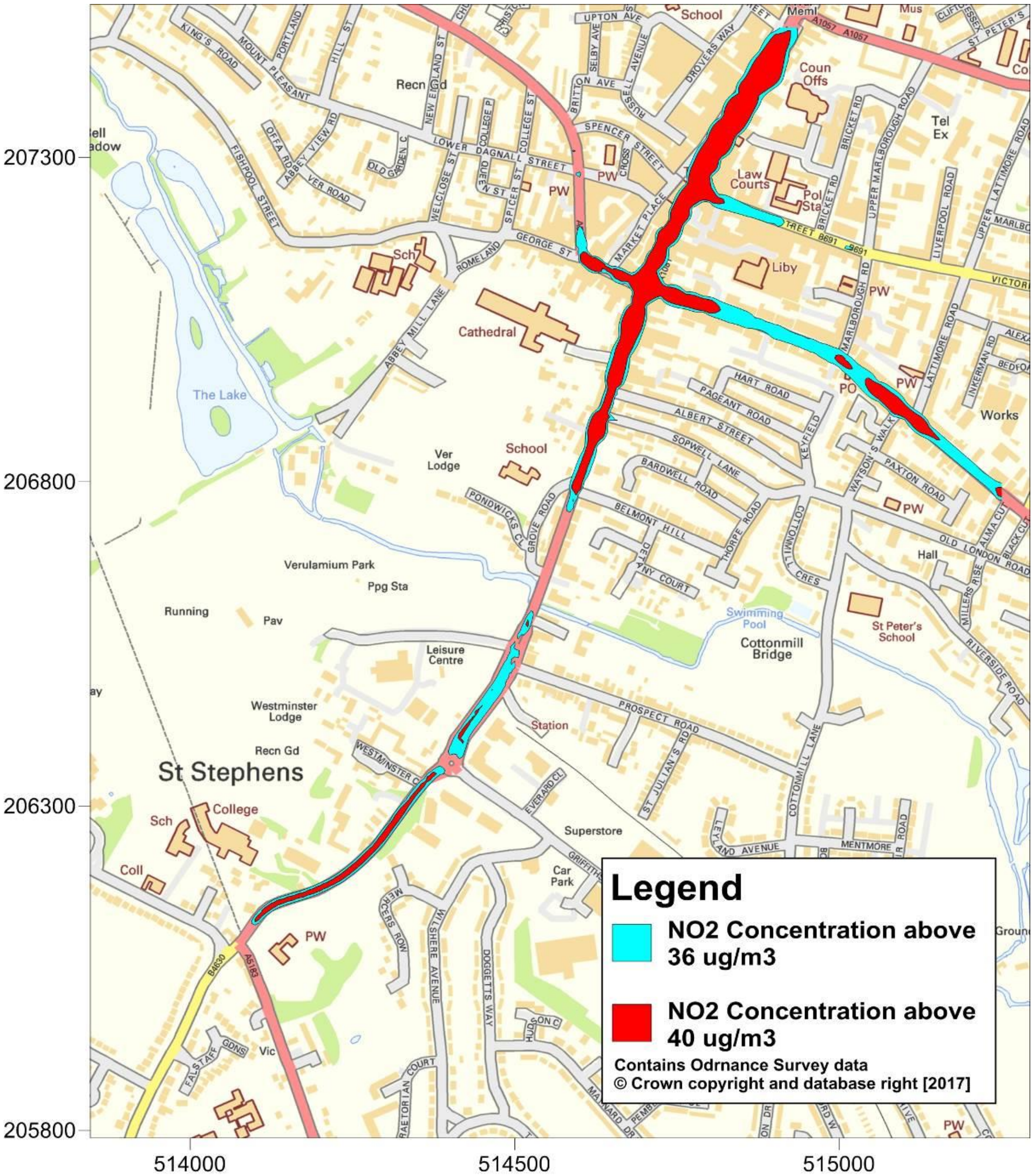


Figure A6 - Annual Mean NO_2 concentration isopleths showing the difference between the V2 BC and V2 GC scenarios (µg/m^3)

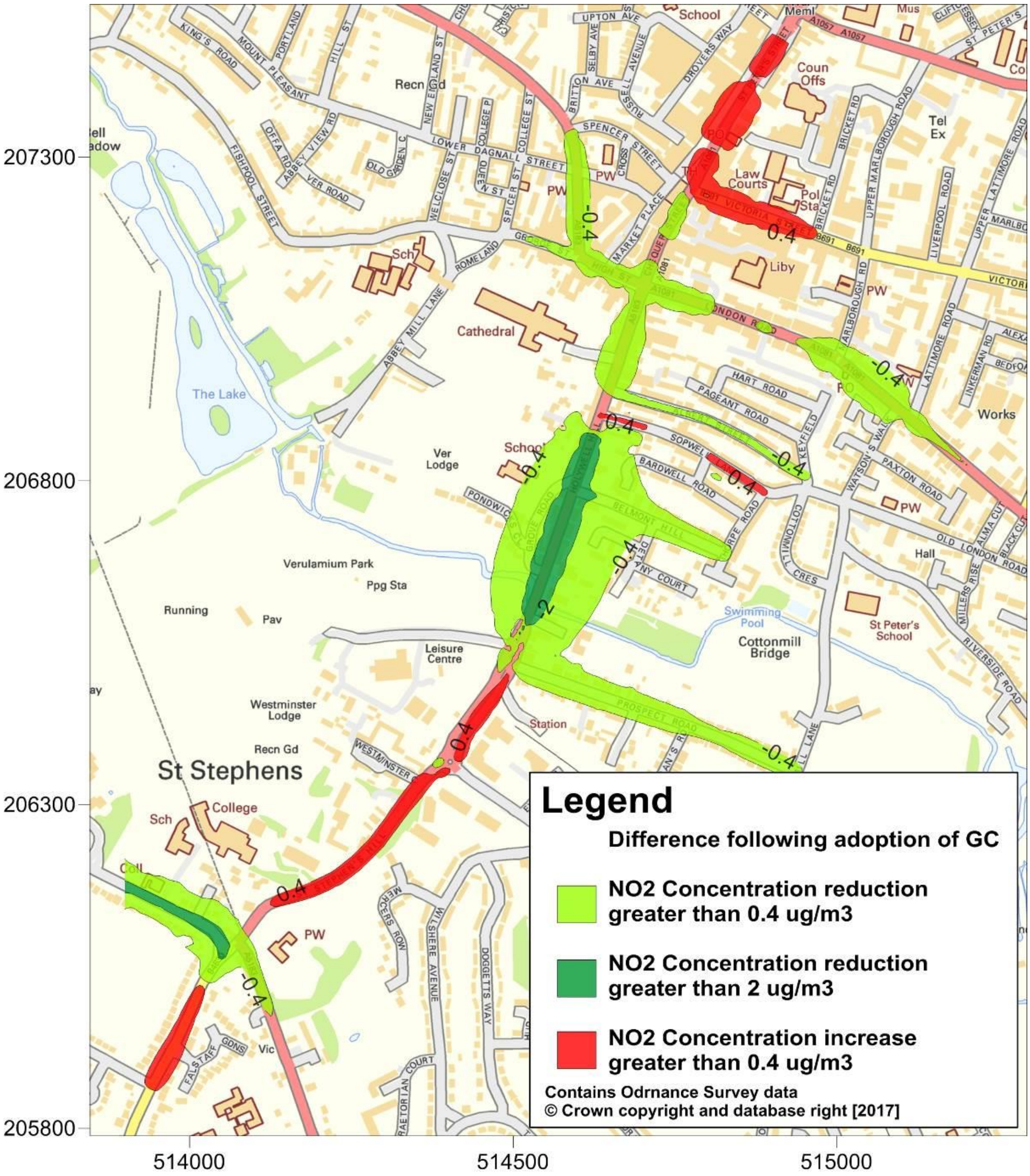


Figure A7 - Annual Mean NO_2 concentration isopleths for the V3 BC scenario ($\mu g/m^3$)

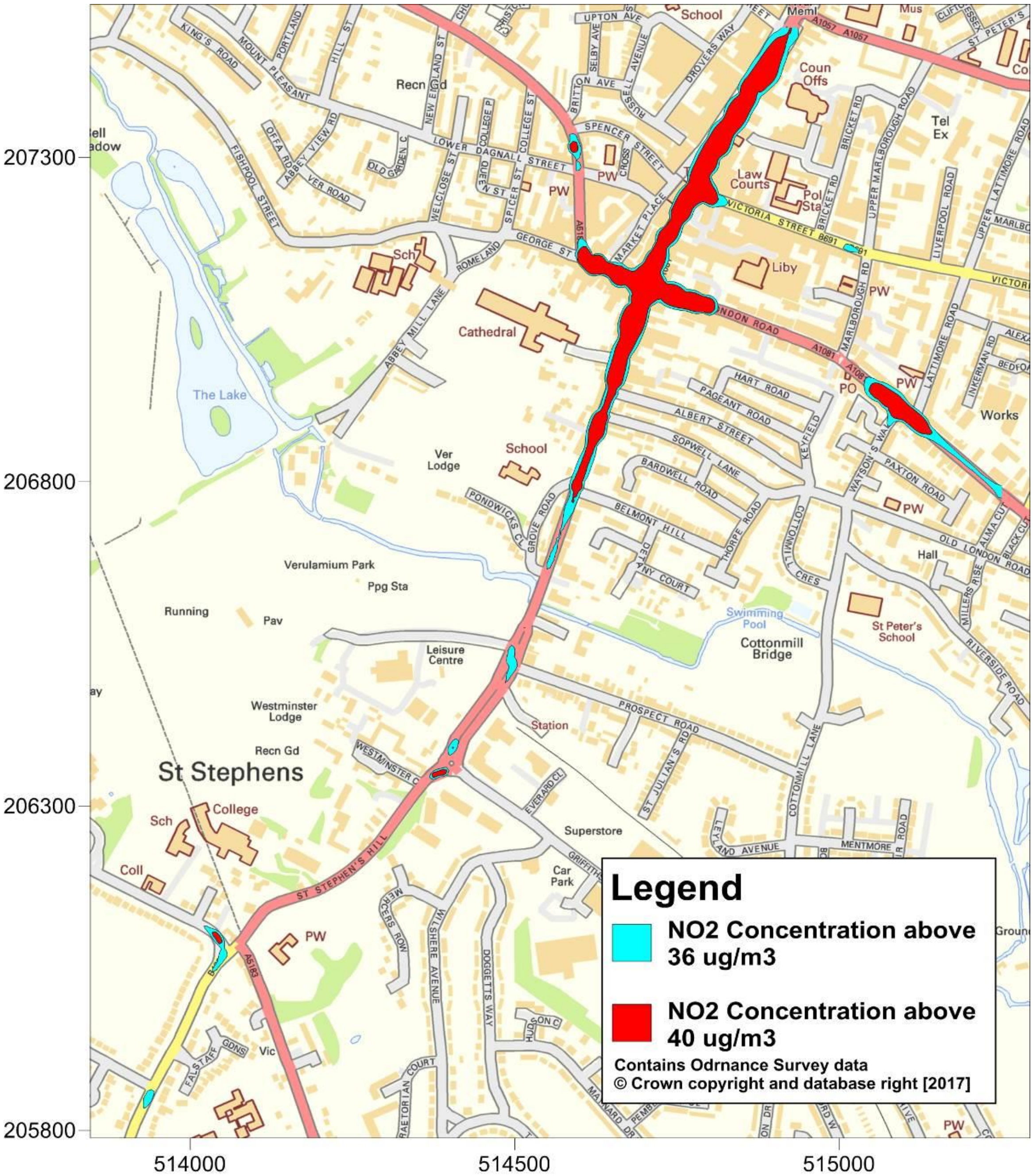


Figure A8 - Annual Mean NO_2 concentration isopleths for the V3 GC scenario ($\mu g/m^3$)

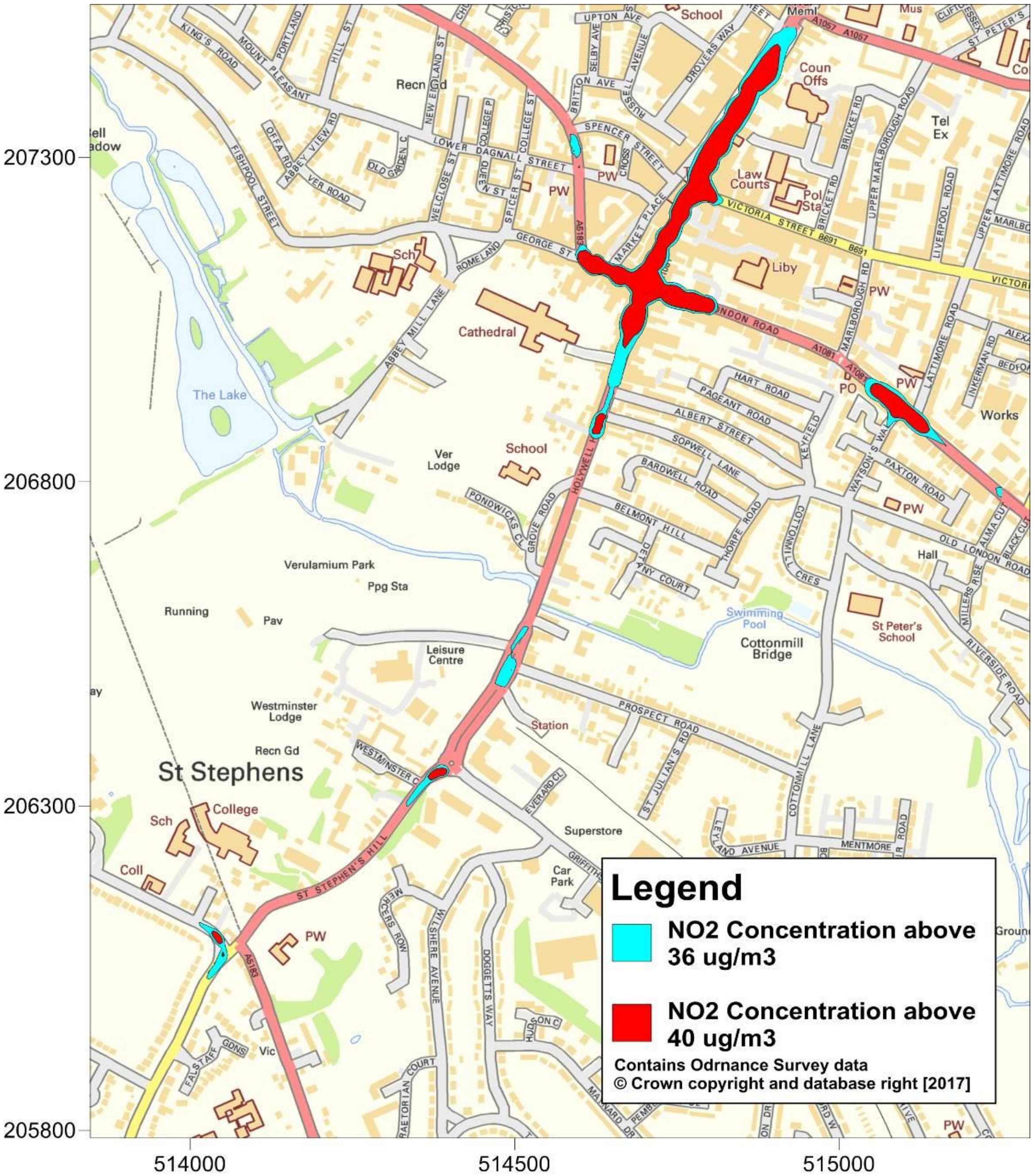


Figure A9 - Annual Mean NO_2 concentration isopleths showing the difference between the V3 BC and V3 GC scenarios ($\mu g/m^3$)