AIR POLLUTION
SERVICES
Chapel House, Barton Manor, Bristol, BS2 0RL
Tel: 01179 112434. Email: contact@airpollutionservices.co.uk

Guildford Borough Council: Air Quality Detailed Assessment

Date: 8 October 2021

Quality Assurance

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Contact Details

Contact Name:	Dr Austin Cogan and George Bratchel
Tel:	01179 112434
Email:	contact@airpollutionservices.co.uk

Experts in Air Quality, Odour and Climate Change








Executive Summary

Following measured exceedances of the annual mean nitrogen dioxide air quality objective in Guildford, a Detailed Assessment has been carried out as part of the District Council's Local Air Quality Management duties.

Annual mean nitrogen dioxide concentrations have been predicted across an area covering the town of Guildford. The predictions demonstrate that there are several locations with relevant exposure where exceedances of the annual mean objective and the 1-hour mean objective may occur and therefore, there is a requirement to declare an AQMA.

Contents

1 Introduction

1.1 This report presents a Detailed Assessment of nitrogen dioxide (NO_2) concentrations in the town of Guildford. It has been produced on behalf of Guildford Borough Council (GBC), as part of its Local Air Quality Management (LAQM) duties which includes a requirement to periodically review and assess air quality within the Borough.

1.2 GBC accepts the conclusions of this report and intends to implement all recommendations.

Background

1.3 GBC's 2019 Air Quality Progress Report (GBC, 2019) identified the risk of exceedance of the annual mean Air Quality Objective (AQO) for NO_2 along the A3100 in Guildford and a risk of further exceedances were identified in GBC's 2020 Air Quality Progress Report (GBC, 2020) along the A281 in Guildford.

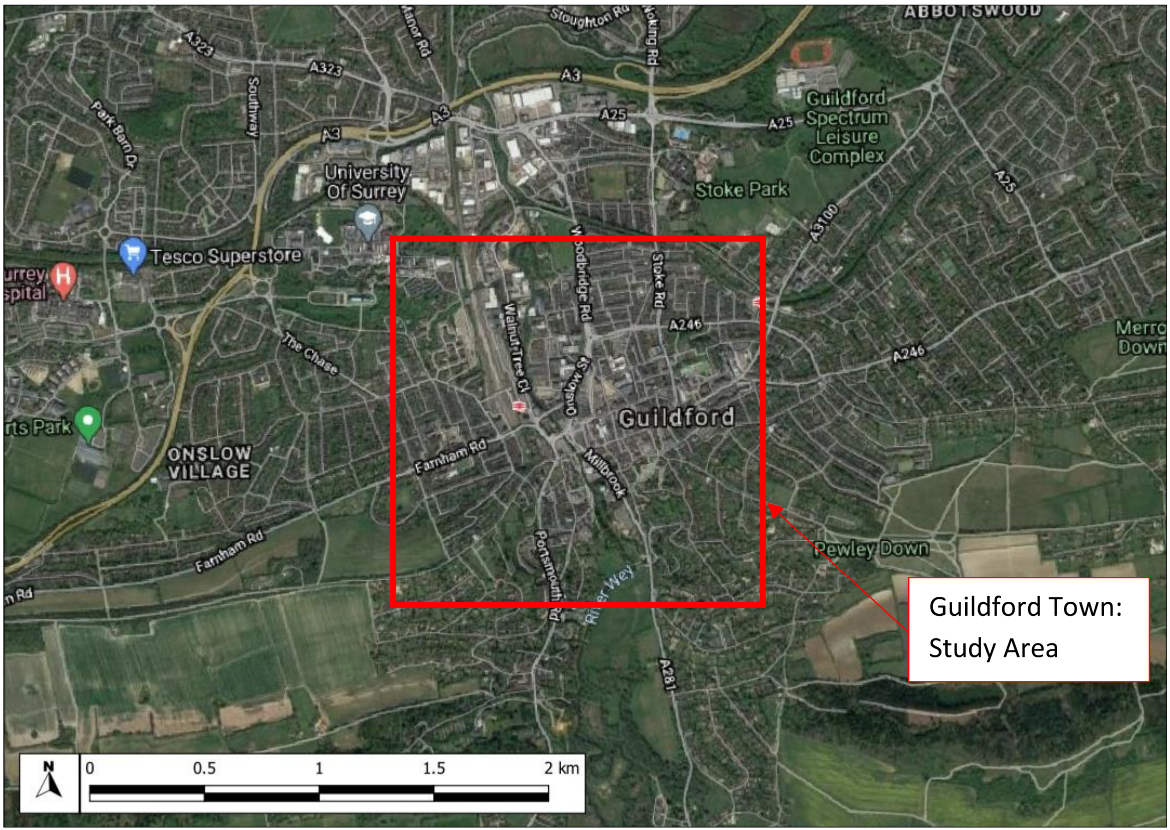
1.4 Since there is a risk of NO_2 being exceeded at a number of locations of sensitive exposure, GBC is considering declaring an air quality management area (AQMA) in Guildford due to the persistent NO_2 exceedances recorded in the town.

1.5 This Detailed Assessment has been undertaken in accordance with current Government guidance to assess and determine the need for, and geographical extent of, an AQMA in Guildford.

1.6 The study area considered in the Detailed Assessment is shown in Figure 1 and covers the town of Guildford and all locations currently monitored by the Council within or close to Guildford town centre.

1.7 This report does not consider the impacts of air quality on the health implications associated with Covid-19, as there remains too much uncertainty at this stage to consider this explicitly.

Figure 1: Study Area Location



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2 Legislation and Guidance

Air Quality Standards and Air Quality Objectives

2.1 The Environment Act 1995 (HMSO, 1995) sets out the requirements of the Local Air Quality Management (LAQM) regime and the requirement for the Government to produce an Air Quality Strategy including standards and objectives.

2.2 The latest Air Quality Strategy (The Strategy) was published in 2007 (Defra, 2007) and sets out the Air Quality Standards (AQS), which consider the effects on human health and ecosystems, and the National AQOs, which are policy targets for ambient air pollution. The AQOs, for use by local authorities when considering human health, were incorporated into UK legislation within the Air Quality (England) Regulations, 2000, Statutory Instrument 928 (2000) and the Air Quality (England) (Amendment) Regulations 2002, Statutory Instrument 3043 (2002).

2.3 The Strategy explains that the AQSs for the protection of human health are defined as concentrations below which effects are unlikely even in sensitive population groups, or below which risks to public health would be exceedingly small. They are based purely upon the scientific and medical evidence of the effects of an individual pollutant. The AQS are set for individual pollutants and are made up of a concentration value and an averaging time over which it is to be measured.

2.4 The AQO's set out the extent to which the Government expects the AQS to be achieved by a certain date. They take account of economic efficiency, practicability, technical feasibility, and possible timescales. AQOs are policy targets often expressed as a maximum ambient concentration not to be exceeded, either without exception or with a permitted number of exceedances, within a specified timescale. An exceedance is a breach of the threshold for the concentration for the specific averaging period.

2.5 The Strategy also describes the LAQM regime that has been established by Part IV of the Environment Act 1995, whereby every authority has to carry out regular reviews and assessments of air quality in its area to identify whether the AQOs have been, or will be, achieved at relevant locations, by the applicable date and going forwards. If this is not the case, the authority must declare an AQMA and prepare an action plan which identifies appropriate measures that will be introduced in pursuit of the objectives. The Strategy also provides the policy framework for air quality management and assessment in the UK.

Limit Values

2.6 In addition to the AQOs set within The Strategy and relevant regulations, the European Union (EU) has also set limit values and target values for the protection of human health and critical levels for the protection of ecosystems. These were transposed into the Air Quality Standards Regulations (HMSO, 2010), which sets out the UK limit values, target values and critical levels for specific pollutants. Like the AQO, the limit values are set for individual pollutants and are made up of a concentration value, an averaging time over which it is to be measured, the number of exceedances allowed per year (if any) and a date by which it must be achieved. Some pollutants have more than one value covering different dates or averaging times. While the AQO are policy targets, the government has the duty to ensure compliance with the legally binding limit values which is a national obligation rather than a local one. These remain in UK legislation at present, although it is understood the proposed Environment Bill is likely to result in the Air Quality Standards Regulations being removed.

WHO Guidelines

2.7 WHO Member States (which includes the UK) recently adopted a resolution (WHO, 2015) and a road map (WHO, 2018) for an enhanced global response to the adverse health effects of air pollution. WHO develops and produces air quality guidelines recommending exposure limits to key air pollutants.

2.8 In addition, the recent coroners court case investigating a young girl's death in 2013 concluded that air pollution was a significant contributing factor to both the induction of her asthma and the exacerbation of her symptoms, due to exposure in exceedance of WHO guideline values for pollutants. This set a precedence to consider WHO guideline values when determining the significance of air quality and has thus been considered when undertaking this assessment.

2.9 The WHO guidelines were updated in September 2021 based on the latest health evidence and demonstrate that health effects can occur at much lower levels than those legislated within the AQOs and limit values (WHO, 2021).

The Air Pollutant of Concern

2.10 The AQOs, limit values and WHO guidelines for NO_2 (the pollutant focused on in this report) are set out in Table 1.

Table 1: AQOs, Limit Values and WHO Guidelines

Pollutant	Time Period	AQO / Limit Value	Concentration, and the number of exceedances allowed per year (if any)	Date Value to be Achieved From and Maintained After
Nitrogen Dioxide (NO_2)	1-hour Mean	AQO	200 µg/m^3 not to be exceeded more than 18 times a year	31st December 2005
		Limit Value	200 µg/m^3 not to be exceeded more than 18 times a year	1st January 2010
		WHO Guideline	200 µg/m^3	-
	24-hour Mean	WHO Guideline	25 µg/m^3	-
	Annual Mean	AQO	40 µg/m^3	31st December 2005
		Limit Value	40 µg/m^3	1st January 2010
		WHO Guideline	10 µg/m^3 [a]	-

[a] The value presented is the air quality guideline (AQG) level. The WHO also set out interim targets to assist countries in working towards achieving the AQG level. The annual mean interim targets are 40 µg/m^3, 30 µg/m^3 and then 20 µg/m^3. The annual mean AQO and limit value are both equivalent to the first interim target.

Relevant exposure

2.11 It is important to understand where the AQOs, limit values, and WHO Guidelines are applicable when considering what locations are at risk of exceedances.

AQO Receptors

2.12 The annual mean AQOs apply at locations where members of the public might be regularly exposed, such as building façades of residential properties, schools, hospitals, and care homes.

2.13 The 1-hour mean AQO applies at the annual mean locations of exposure and at hotels, residential gardens, and any outdoor location where members of the public might reasonably be expected to spend one hour or longer, such as busy pavements, outdoor bus stations and locations with outdoor seating.

2.14 Places of work like factories or offices are not considered places where members of the public might be regularly exposed and therefore the AQO's do not apply at these locations.

Limit Value Receptors

2.15 In accordance with Article 2(1), Annex III, Part A, paragraph 2 of Directive 2008/50/EC details locations where compliance with the limit values does not need to be assessed:

"Compliance with the limit values directed at the protection of human health shall not be assessed at the following locations:

a) Any locations situated within areas where members of the public do not have access and there is no fixed habitation;

b) In accordance with Article 2(1), on factory premises or at industrial installations to which all relevant provisions concerning health and safety at work apply; and

c) On the carriageway of roads; and on the central reservation of roads except where there is normally pedestrian access to the central reservation."

2.16 The Government models compliance with the Directive at locations 4 m from the kerbside, 2 m high, more than 25 m from major road junctions and adjacent to at least 100 m of road length where the limit value applies.

WHO Guideline Receptors

2.17 The WHO criteria apply wherever there is relevant exposure in relation to each time period for each pollutant. These are considered to be the same as those set out above for AQO receptors.

Health Effects

2.18 Air pollution has a significant effect on public health. Long-term exposure (over years) reduces life expectancy, mainly due to cardiovascular and respiratory diseases and lung cancer. Recent evidence suggests that it can also adversely affect cognitive ability, and is associated with dementia, diabetes, obesity, and low birth weight (Royal College of Physicians, 2016).

2.19 Short-term exposure (over hours or days) to elevated levels of air pollution can also cause a range of health effects, including on lung function and exacerbation of asthma, resulting in respiratory and cardiovascular hospital admissions and mortality.

2.20 It has been estimated that exposure to man-made air pollution in the UK gives rise to 28,000 to 36,000 deaths a year (Public Health England, 2018). Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NO_2. Reduced lung function growth is also linked to NO_2 at concentrations currently measured in urban areas of the UK. PHE believe that reductions of NO_2 concentrations below the current standards is likely to bring health benefits.

Guidance Documents

LAQM Technical Guidance

2.21 Defra and the devolved administrations have published a guidance document on Local Air Quality Management (LAQM) - *Local Air Quality Management Technical Guidance (TG16) April 2021* (Defra, 2021a). This document is designed to support local authorities in carrying out their duties under the Environment Act 1995, the Environment (England) Order 2002, and subsequent regulations. LAQM is the statutory process by which local authorities monitor, assess, and take action to improve local air quality. The Technical Guidance provides tools, approaches and technical information related to air quality.

LAQM Policy Guidance

2.22 LAQM PG16 was published in 2016 to provide information on the LAQM process and principles, including those for the setting of AQMA boundaries (Defra, 2016). It notes that the setting of the boundaries involves an element of judgement considering the extent of the exceedance areas, locations of relevant receptors, the nature and location of relevant sources, and other local factors.

3 Local Air Quality Management

Introduction to Review and Assessment

3.1 The LAQM process places an obligation on local authorities to regularly review and assess air quality in their areas, and to determine whether or not an AQO is likely to be achieved.

3.2 Review and Assessment in England is undertaken in a series of rounds as set out in Local Air Quality Management Technical Guidance (LAQM.TG(16)) (Defra, 2021a). This prescribes an initial Annual Status Report (ASR), which all authorities in England must undertake. It is based on a checklist to identify any matters that have changed since the previous report, including new monitoring information. If the ASR identifies any areas where there is a risk that an AQO may be exceeded, which was not identified in the previous report, then the Local Authority should proceed to declare an AQMA or collate additional technical information before deciding whether an AQMA is required or not. This may, for example, include a detailed assessment to determine both its magnitude and geographical extent.

3.3 After the declaration of an AQMA, the Local Authority is required under Part IV of the Environment Act 1995 to provide an Air Quality Action Plan (AQAP) as a means to address the areas of poor air quality that have been identified within the AQMA.

Existing AQMAs

3.4 GBC has investigated air quality within its area as part of its responsibilities under the LAQM regime. The Council have declared two AQMAs for exceedances of the annual mean NO_2 AQO. In 2018, an AQMA was declared to the south of the town of Guildford covering a section of the A281 (A281, The Street, Shalford). The second AQMA was declared in 2019 to the southwest of the town, covering a section of the B3000 (The Street, Compton). Both AQMAs are shown in Figure 2.

Figure 2: Existing AQMA locations

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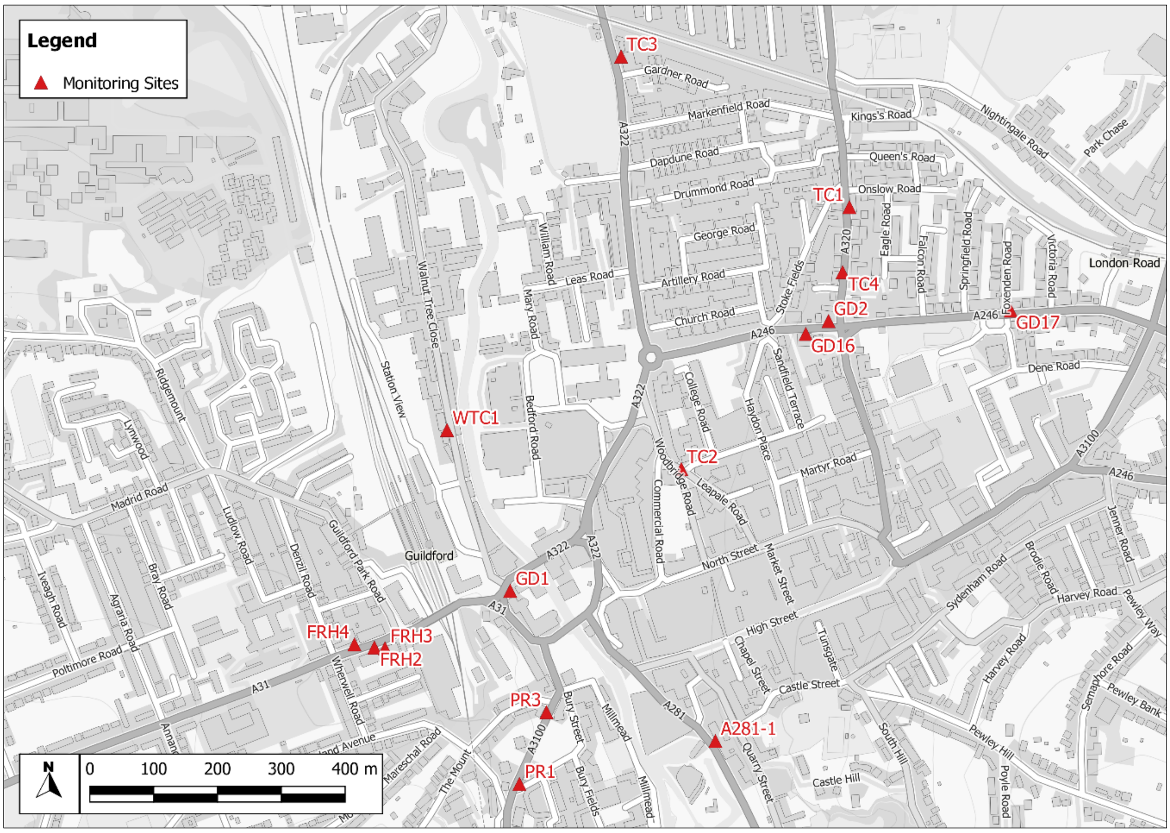
Local Air Quality Monitoring

3.5 GBC measures NO_2 concentrations using 33 passive monitors (diffusion tubes). GBC does not operate any automatic monitoring stations. The locations of the monitoring sites within Guildford town are shown in Figure 3. It is worth noting that the monitoring network has expanded significantly in since 2018.

Figure 3: Monitoring sites in the study area



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3.6 The measured annual mean NO_2 concentrations for the years 2015 to 2019 are presented in Table 2. Measured concentrations were below the annual mean AQO at most of the monitoring sites in Guildford between 2015 and 2019, but exceed the AQO at two monitoring sites; PR1 in 2018 and A281-1 in 2019. Both of these sites are located at roadside/kerbside locations along key arterial roads, feeding into Guildford from the south, and where emissions associated with road traffic are likely to have contributed to the elevated measured concentrations. There are residential properties close to both these monitoring sites which are considered sensitive exposure to air pollution. PR1 represents a location where emissions may be elevated due to a gradient and some streetscape effects, whereby the dispersion of pollution away from the road is restricted by the buildings along the road entrapping pollution within the street zone. A281-1 represents a location where the road is fairly flat but there are some streetscape effects. The other monitoring sites are generally located along flat roads with limited streetscape effects. There is therefore a risk that other locations which do not have a monitoring site located in them may be prone to exceedances of the AQO where the road is steeper and/or there are significant streetscape effects.

3.7 Previous research carried out on behalf of Defra identified that exceedances of the 1-hour mean NO_2 AQO are unlikely to occur where the annual mean is below 60 µg/m^3 (Defra, 2021a). Although no monitoring of 1-hour concentrations has been carried out by GBC, the measured annual mean concentrations indicate that there was unlikely to be any exceedances of the 1-hour mean AQO at the monitoring sites. As mentioned above though, there are other locations not monitored which have steeper gradients and/or significant streetscape effects and may therefore experience a higher risk of potentially exceeding the 1-hour mean AQO.

Table 2: Relevant Measured NO_2 Annual Mean Concentrations (µg/m^3) [a]

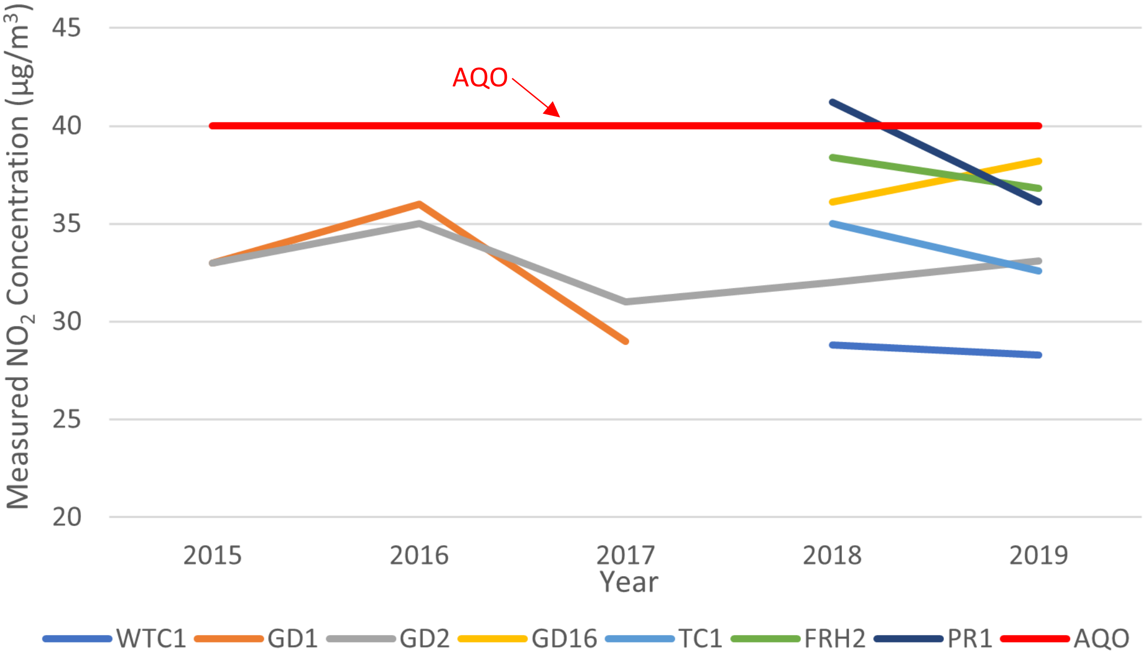
Site Name (ID – Type)	2015	2016	2017	2018	2019
Walnut Tree Close (WTC1 – Roadside)	n/a	n/a	n/a	28.8	28.3
Bridge Street/Walnut Tree Cl (GD1 – Roadside)	33.0	36.0.	29.0	n/a	n/a
York Road (GD2 – Roadside)	33.0	35.0	31.0	32.0	33.1
Sandfields 2 (GD16 – Roadside)	n/a	n/a	n/a	36.1	38.2
York Road (GD17 – Kerbside)	n/a	n/a	n/a	30.0	n/a
Stoke Road (TC1 – Kerbside)	n/a	n/a	n/a	35.0	32.6
Woodbridge Chambers, Woodbridge Road (TC2 – Kerbside)	n/a	n/a	n/a	34.0	n/a
Woodbridge Road (TC3 – Near Road)	n/a	n/a	n/a	n/a	30.5
Stoke Road (Stoke Mews) (TC4 – Roadside)	n/a	n/a	n/a	n/a	31.8
38 Farnham Road (FRH2 – Roadside)	n/a	n/a	n/a	38.4	36.8
Dental Surgery, Farnham Road (FRH3 – Roadside)	n/a	n/a	n/a	n/a	33.1
Katherine Nursing Home, Farnham Road (FRH4 – Roadside)	n/a	n/a	n/a	n/a	26.5
Wycliffe Buildings (PR1 – Roadside)	n/a	n/a	n/a	**41.2**	36.1
Oppo The Cannon (PR3 – Roadside)	n/a	n/a	n/a	n/a	28.1
A281 Nr Legion (A281-1 – Kerbside)	n/a	n/a	n/a	n/a	**43.4**

[a] Exceedances of the AQO level are shown in bold.

3.8 It is worth noting that the annual mean AQO was exceeded at monitoring site PR1 in 2018, but not in 2019. The reason for the disparity between the measured concentrations is not known. It is thus unclear which of the two values is most representative of the area and therefore there may be an exceedance or concentrations close to the AQO at the Wycliffe Buildings on Portsmouth Road.

3.9 The trends in local measured concentrations have been reviewed. Only one monitoring site in Guildford (GD2) has measured concentrations throughout the period of 2015 to 2019 and a small number of other monitoring sites have measured for several years. Meaningful trend analysis requires at least five years of data for each considered site and therefore it is not possible to determine reliably the trend in long term changes in concentration within Guildford town based on this data. The annual mean measured NO_2 concentrations are shown in Figure 4, along with the AQO (40 µg/m^3). Based on GD2, there is no clear trend.

Figure 4: Trends in Historical Annual Mean NO_2 Concentrations ($\mu g/m^3$) in Guildford



Monitoring in 2020

3.10 GBC continued to operate many of the diffusion tube monitoring sites in 2020, whilst the Covid-19 Pandemic occurred. Due to the Pandemic, monitoring carried out in 2020 is not representative of typical air quality within the borough. The Pandemic is likely to have caused significant changes in 2020, such as reductions in road traffic resulting much lower vehicle emissions within the borough.

3.11 While this section discusses the pandemic influences, it is useful to start by noting that analysis has shown that atypical meteorological conditions during 2020 have had a significant influence on pollutant concentrations, this confounds the issues as it is hard to disaggregate the influences of behaviour due to the pandemic and the meteorological conditions.

3.12 The Position Statement published by the IAQM (2020) explains the likely effects of the Pandemic on air quality monitoring, in particular that monitoring may show misleading improvements in air quality and that monitoring surveys may have been disrupted. Specifically, for passive monitoring, the Position Statement states:

> *"It is unlikely that site visits can occur and laboratories providing tubes are beginning to close, meaning exposed tubes cannot be analysed and new tubes are not available. It is unlikely that tube changeover will occur on the designated days and monitoring periods may be longer than the ~4 week period recommended. Tubes have a shelf life (preparation to analysis) of between 6 weeks and 4 months (depending on pollutant). Diffusion tubes can become saturated or degraded if left out for longer. Nevertheless, it may be useful if the tubes are left out for the duration of the restricted travel period. Where tubes are collected and cannot be immediately analysed it is recommended that they be stored in line with the laboratory guidelines and analysed when possible. The data may be usable but with reduced confidence, depending on the length of the pandemic restrictions. Data collected from monitoring surveys which span the restricted travel period may not be representative of the typical longer term concentrations".*

3.13 GBC continued to operate passive monitoring in 2020 and managed to complete all change overs in accordance with the correct designated days. No tubes were left out longer and none became saturated or degraded. It is therefore considered that the 2020 monitoring can be used with confidence, but the results will not be representative or comparative to those measured in retrospective years.

3.14 The measured annual mean NO_2 concentrations for 2020 are given in Table 3. This presents the raw annual mean concentrations as well as preliminary bias adjusted concentrations. National and Surrey wide bias adjustment factors for 2020 are not yet available. In the absence of 2020 a factor, concentrations have been estimated using the Surrey wide bias adjustment factor for 2019. Although the results are uncertain, they provide an early indication of potential concentrations measured in 2020.

3.15 Table 3 demonstrates that there was a reduction of approximately 33% in measured annual mean NO_2 concentrations within the town of Guildford in 2020, compared to 2019. Despite these reductions, an exceedance was potentially measured at Park Street (TC6). Given that concentrations in 2020 are abnormally lower than typical years in Guildford, there is a high risk of exceedances at Park Street. There are several locations of sensitive exposure along Park Street, including residential houses and residential flats, some of which are located within a ‘street canyon’ setting where the dispersion of emissions will be restricted, and several are located adjacent to sections of road where congestion likely occurs leading to an accumulation of emissions in close proximity to the locations of sensitive exposure.

Table 3: Measured NO_2 Annual Mean Concentrations in 2020 (µg/m^3)

Site Name (ID – Type)	Annual Mean Concentration		Change Since 2019 (%)
	Raw	Bias Adjusted	
Walnut Tree Close (WTC1 – Roadside)	19.2	17.7	-37%
York Road (GD2 – Roadside)	22.8	20.9	-37%
YMCA (GD13 – Kerbside)	25.0	23.0	n/a
Sandfields 2 (GD16 – Roadside)	26.7	24.5	-36%
Haydon Place (GD19 – Kerbside)	19.2	17.7	n/a
Stoke Road (TC1 – Kerbside)	23.5	21.6	-34%
Woodbridge Road (TC3 – Near Road)	22.9	21.1	-31%
Stoke Road (Stoke Mews) (TC4 – Roadside)	22.2	20.4	-36%
Mangles Court (TC5 – Near Road)	17.7	16.3	n/a
Park Street, Guildford (TC6 – Kerbside)	44.8	41.3	n/a
38 Farnham Road (FRH2 – Roadside)	26.8	24.7	-33%
Dental Surgery, Farnham Road (FRH3 – Roadside)	22.5	20.7 [a]	-37%
Wycliffe Buildings (PR1 – Roadside)	24.9	22.9	-37%
Oppo The Cannon (PR3 – Roadside)	21.8	20.1	-29%
A281 Nr Legion (A281-1 – Kerbside)	39.0	35.8	-17%
22 Farnham Road (FRH6 – Roadside)	28.8	26.5 [a]	n/a

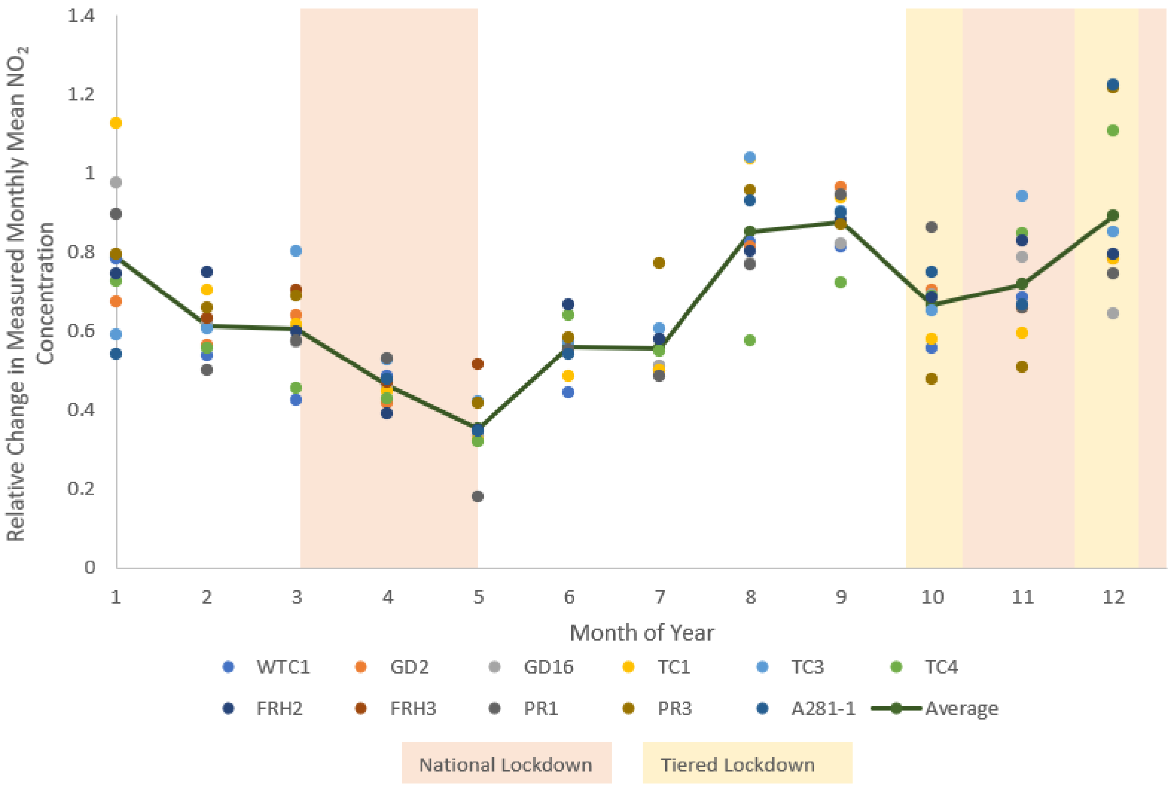
[a] Based on five months of data. Data has not been annualised.

3.16 While the concentrations are likely to be broadly reliable, the changes (reductions) in concentrations cannot be purely attributed to pandemic influences. Year on year variation is standard, as demonstrated in Table 2, where annual mean NO_2 concentration fluctuate each year despite a likely slight downward trend between 2015 and 2019. These variations can be due to a number of factors but the greatest influence is meteorological conditions during each year.

3.17 To get a further understanding of how the Covid-19 Pandemic may have affected air quality within the town of Guildford, the raw annual mean measured NO_2 concentrations in 2020 have been compared to those in 2019. These relative changes (2020 monthly data / 2019 monthly data) are presented along with the average across all the monitoring sites in Figure 5, which also highlights the key lockdown periods introduced by the UK Government during 2020. The information presented is only indicative.

3.18 This demonstrates that the raw measured concentrations were lower than normal in January and February and then decreased significantly during the first national lockdown. Once the first lockdown was eased, concentrations increased and reached similar levels to that of 2019 in late summer. A decreased was measured in September and then concentrations increased back to similar levels as 2019 again by December. There is thus no clear trend to show any long-term improvement in air quality as a result of potential behavioural changes due to the Pandemic. This pattern generally follows the expected trend for 2020 based upon the travel restrictions implemented by the Government. It is important, however, to acknowledge that there is typically monthly variation in measured concentrations and the comparison is based upon raw values, which have not been bias adjusted; the implications should thus be treated with caution. More importantly the effects of meteorological conditions have not been accounted for in this simple analysis. Quantifying the air quality benefit of lockdown is more complex, and weather is a key confounding factor, as is the spatial variation of pollutant concentrations within any given area. Although it is considered fair to state that any short-term reductions in pollutants concentrations due to the lockdowns have not been sustained after the lockdowns.

Figure 5: Relative Seasonal Change in Raw Monthly Measured NO_2 Concentrations at Monitoring Sites in 2020 Compared to 2019



2020 Air Quality Research

3.19 Various research has been carried out reviewing the impacts of the pandemic, however, this research can only focus on what has happened and how things change in the future is very uncertain.

3.20 The Government formed Air Quality Expert Group (AQEG) in conjunction with Defra issued a call for evidence on 7th April 2020, identifying seven areas of current scientific uncertainty related to the potential interactions between the Covid-19 Pandemic and UK air pollution. Initial conclusions of the research (Air Quality Expert Group, 2020) are:

1. *“There have been significant changes in the emissions of air pollutants from several sectors, but, with the exception of the transport sector which showed a marked decrease, availability of activity and emissions data for the lockdown period is still limited.”*

2. *“UK air quality has been negatively influenced by a significant change in meteorology between the weeks preceding and following the lockdown in addition to changes (both positive and negative) arising from actions in response to Covid-19.”*

3. *“The most pronounced changes in UK air quality during lockdown have been in the urban environment, notably for nitrogen oxides (NOx). Once weather effects are accounted for, mean reductions in urban NOx averaged over the lockdown period considered have been typically 30-40%, with mean NO_2 reductions of 20-30%. In general, NOx and NO_2 reductions have been greater at roadside than at urban background sites. These reductions would typically correspond to decreases in concentrations of 10-20 $\mu g/m^3$ if expressed relative to annual averages.”*

4. *“Meteorological conditions have led to higher $PM_{2.5}$ during lockdown than the average experienced in equivalent calendar periods from previous years. Analysis combining observations and models indicates however that $PM_{2.5}$ concentrations were of the order 2 - 5 $\mu g/m^3$ lower in Southern England than would have been expected under a business-as-usual emissions scenario. The changes to UK $PM_{2.5}$ in terms of contributing sources and transboundary influences have yet to be determined.”*

5. *“Changes to population exposure to air pollution are variable and more uncertain than estimates of changes in ambient concentrations. Some urban locations have seen significant falls in NO_2, and wider working from home has reduced travel exposure more generally in cities. In London, initial estimates of reduction in $PM_{2.5}$ exposure compared to business-as-usual are in the range 5-24% depending on factors such as commuting mode.”*

6. *“Increased ozone has been observed at some urban monitoring stations, a result of lower local NO. Models suggest the responses in UK ozone for this [2020] summer compared to business-as-usual are variable, with no single direction of change, although there may be some modest increases in urban areas and in central and south-eastern parts of the UK.“*

3.21 The AQEG analysis was completed in 2020 and supports the conclusions that there were some reductions in concentration due to the pandemic. Although there were other confounding influences, notably unusual meteorological conditions, and the long-term impacts were not considered.

Predicted Background Concentrations

3.22 Ambient background concentrations of NO_2 have been defined using the national pollution maps published by Defra (2021b). These cover the whole of the country on a 1x1 km grid for each year from 2018 until 2030. Concentrations for 2018 to 2030 have been extracted for the grid cells that cover the Guildford. The values are presented in Table 4 and shown in Figure 6. All predicted background concentrations are well below the AQOs in all years.

Table 4: Mapped Background Concentrations ($\mu g/m^3$)

Year	NO_2
2018	11.0 – 21.6
2019	10.6 – 20.9
2020	10.1 – 20.1
2021	9.8 – 19.3
2022	9.4 – 18.6

2023	9.2 – 18.0
2024	8.8 – 17.3
2025	8.4 – 16.7
2026	8.3 – 16.2
2027	8.1 – 15.8
2028	7.9 – 15.5
2029	7.8 – 15.1
2030	7.5 – 14.9

Predicted Roadside Concentrations

3.23 Defra has predicted roadside concentrations of NO_2 for the main roads in Guildford (Defra, 2021c) for the years 2017 to 2030 as part of Defra's commitment to report exceedances of the NO_2 limit value. For 2017, the year associated with the highest predictions, no exceedances of the limit values are predicted in the study area, see Figure 6, and this is predicted to continue until 2030.

3.24 More widely within the borough, the A331, Blackwater Valley Relief Road located approximately 9 km from the town of Guildford, has been identified within the UK Plan for tackling roadside nitrogen dioxide concentrations (Defra, 2017) as exceeding the statutory annual mean limit value for NO_2. The Blackwater Valley Group of local authorities (Guildford, Rushmoor, and Surrey Heath Borough Councils), are working collaboratively on a Local Plan (Blackwater Valley Group, 2018), along with the respective highway authorities of Hampshire and Surrey County Councils and National Highways, to identify measures that can be implemented to reduce roadside annual mean NO_2 concentrations within the shortest possible time.

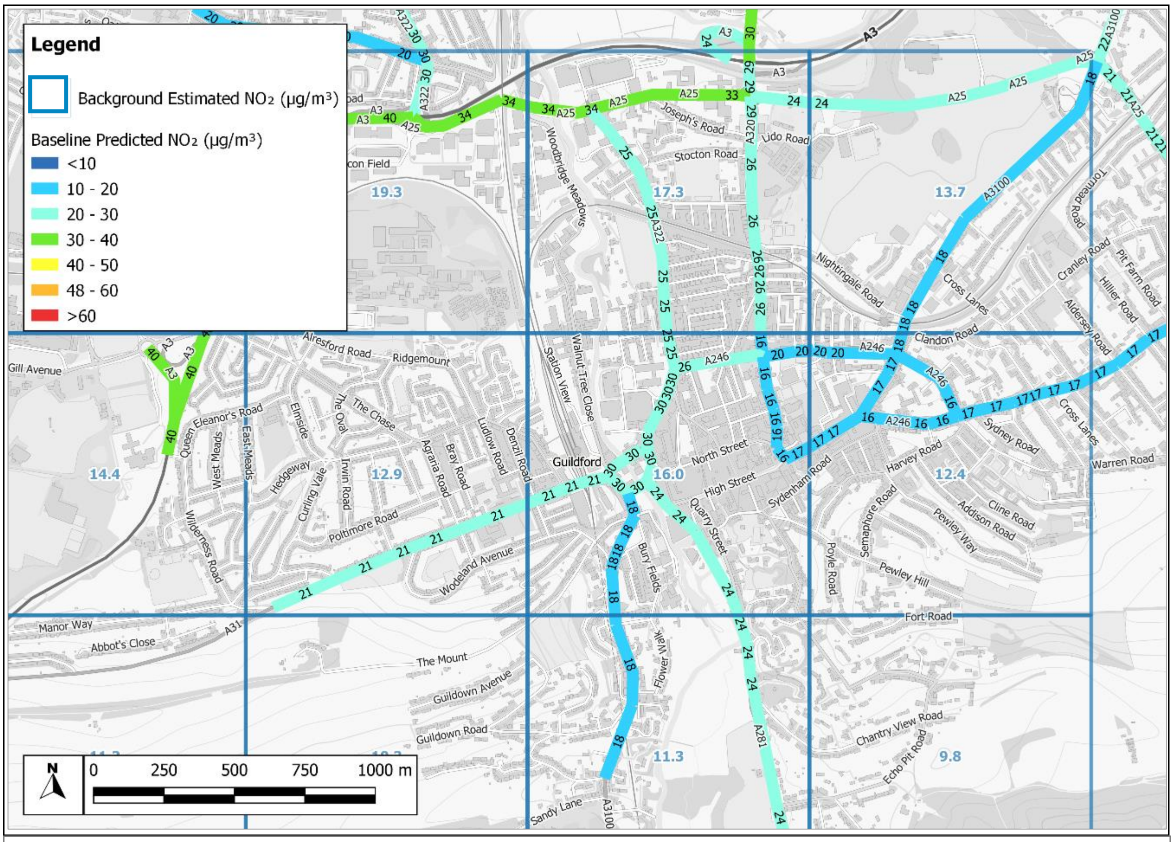
3.25 It should also be noted that it is widely accepted that in many locations in the UK Defra's modelling has underpredicted roadside concentrations when compared with local monitoring and these Defra roadside estimates should be treated with caution. The predicted roadside concentrations of NO_2 for roads in the study area are given in Table 5 for 2021. All values are well below the limit values but are also well below the local monitoring measurements, indicating Defra's predictions are significantly underestimating concentrations at roadside locations in the town of Guildford.

Table 5: Defra Predicted Roadside Concentrations for 2021

Road	PCM Link Census ID	Predicted NO_2 Concentration in 2021 ($\mu g/m^3$)
A322	17775	25.1
A246 West	38102	25.9
A320 North	56928	25.5
A246 East	8021	19.8
A320 South	8019	16.3
A3100 East	47652	16.9
A322	48087	29.5
A31	78188	20.6
A281	57793	23.8

A3100 West	78187	18.3

Figure 6: Defra estimated background concentrations and PCM baseline roadside predicted NO_2 concentrations for 2021



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Key Findings of Local Monitoring

3.26 Annual mean concentrations of NO_2 have been measured using passive monitors at a number of locations within and close to Guildford town centre, mostly between 2018 to 2019. The existing monitoring network includes locations in some areas where elevated concentrations are likely to occur. This includes measured exceedances of the annual mean NO_2 AQO along the two southern arterial roads (A3100 and A281).

3.27 Previous research carried out on behalf of Defra identified that exceedances of the 1-hour mean NO_2 AQO are unlikely to occur where the annual mean is below 60 µg/m^3 (Defra, 2021a). Since measured annual mean concentrations have been below 60 µg/m^3 at all monitoring sites, there is unlikely to have been any exceedances of the 1-hour mean AQO throughout Guildford town centre.

3.28 Since exceedances of the annual mean AQO have been identified, a Detailed Assessment has been carried out. The following sections set out the methodology and findings of the detailed assessment.

4 Methodology

Modelling approach

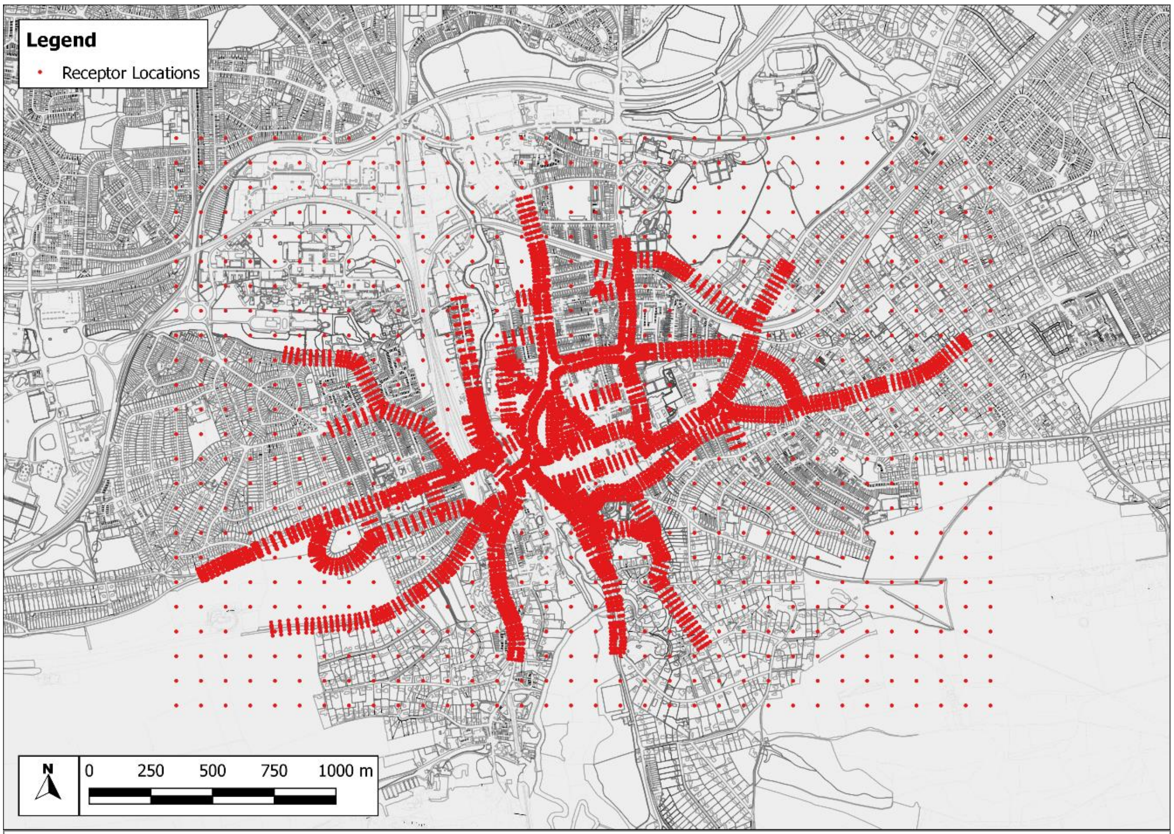
4.1 Concentrations of annual mean NO_2 have been predicted for 2019 within the study area. This year was chosen for three reasons: 1) the 2020 traffic data is likely to have been impacted by the Covid-19 restrictions, 2) Defra's diffusion tube basis adjustment factors for 2020 were not available at the time of preparing this detailed assessment, and 3) it is the most recent applicable monitoring data.

4.2 Annual mean concentrations have been predicted using the ADMS-Roads atmospheric dispersion model (v5) with the latest vehicle emission factors available from Defra's Emission Factor Toolkit (EFT) (v10.1). ADMS-Roads was developed and validated by Cambridge Environmental Research Consultants (CERC) and is used extensively throughout the UK for dispersion modelling and is accepted as an appropriate tool by local authorities. The model requires a range of input parameters which are discussed below.

Modelled Receptors

4.3 NO_2 concentrations have been predicted for a hybrid grid of receptors covering the study area, comprising a 100 x 100 m cartesian grid and transects every 4 m along the roads with receptors located at distances of 0, 2, 4, 7, 12, and 25 m from the kerb.

Figure 7: Gridded Receptor Locations within the Study Area



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4.4 In addition, concentrations have been predicted at 15 monitoring sites located in the local area, to improve and verify the model (see paragraph A2.25).

Modelled Roads

4.5 The road link lengths, widths, and heights, and the street canyons included in the dispersion model have been aligned with data from Ordinance Survey maps, google maps and considering distances based on a range of mapping sources ensuring relative distances from the roadsides to receptors and monitoring sites are carefully set. The modelled road links, speeds and street canyons are shown in Figure 8 and Figure 9.

Figure 8: Modelled Roads Links, Speeds (24-hour flow weighted average)

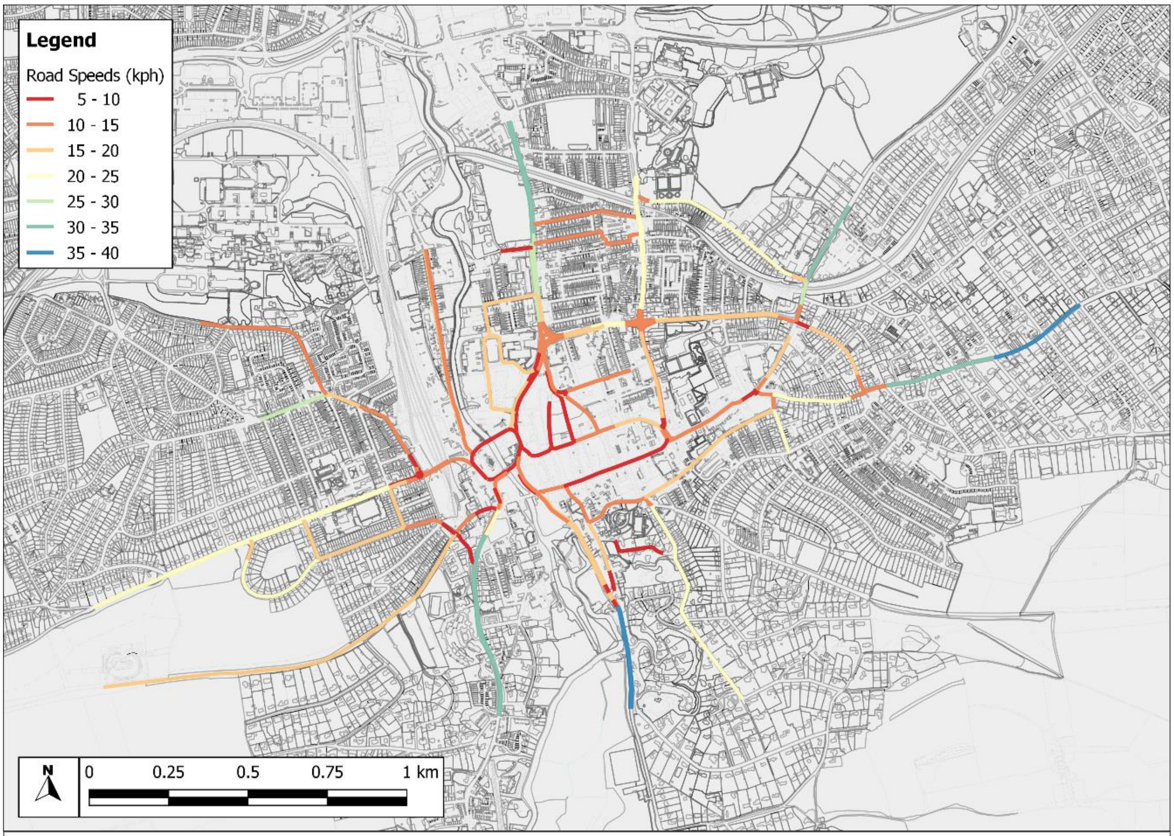

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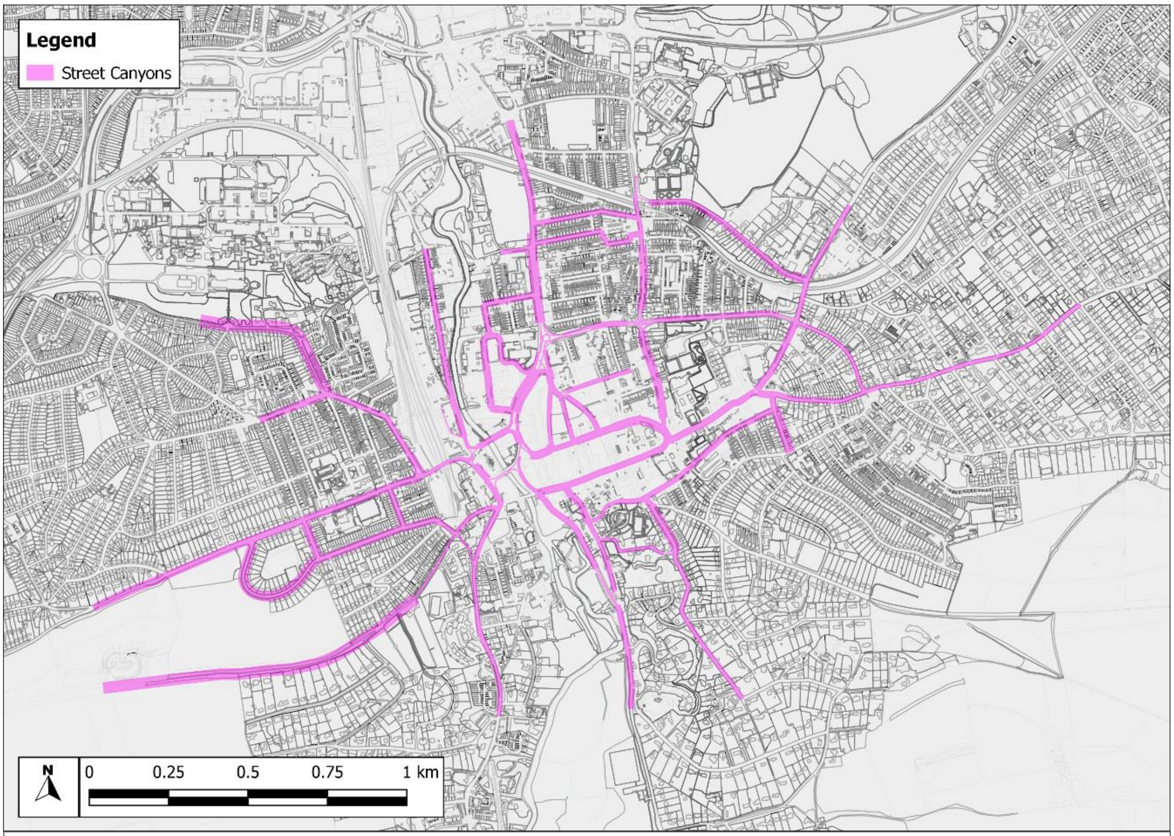
Figure 9: Modelled Street Canyons



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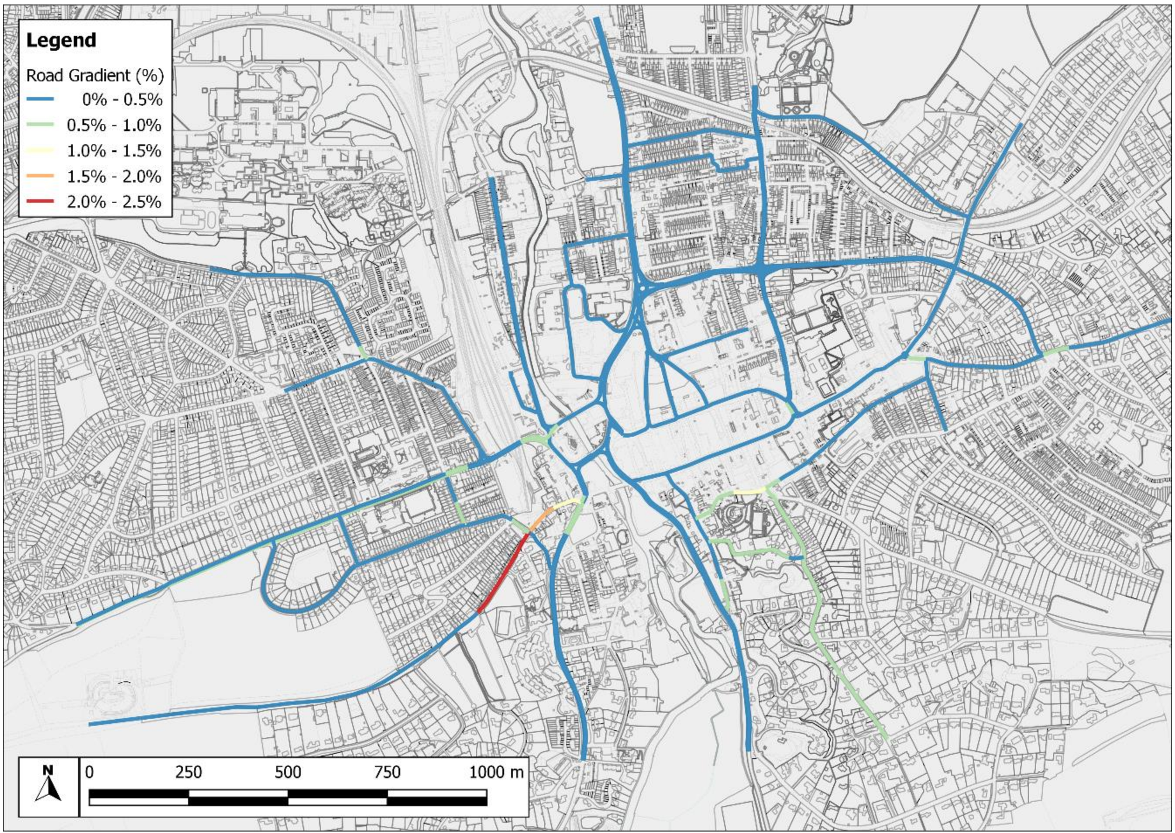
Modelled Gradients

4.6 The local area is slightly hilly; gradients have therefore been taken account of within the modelling. The gradients of the roads have been calculated using the Environment Agency's LIDAR measurements of elevations and are shown in Figure 10 and have been included within the calculation of vehicle emissions.

4.7 The EFT does not currently include the additional emissions from light goods vehicles (LGVs) on hilly roads and therefore the model may underpredict the contribution from LGVs using the steep sections of the roads.

Figure 10: Modelled Road Gradients



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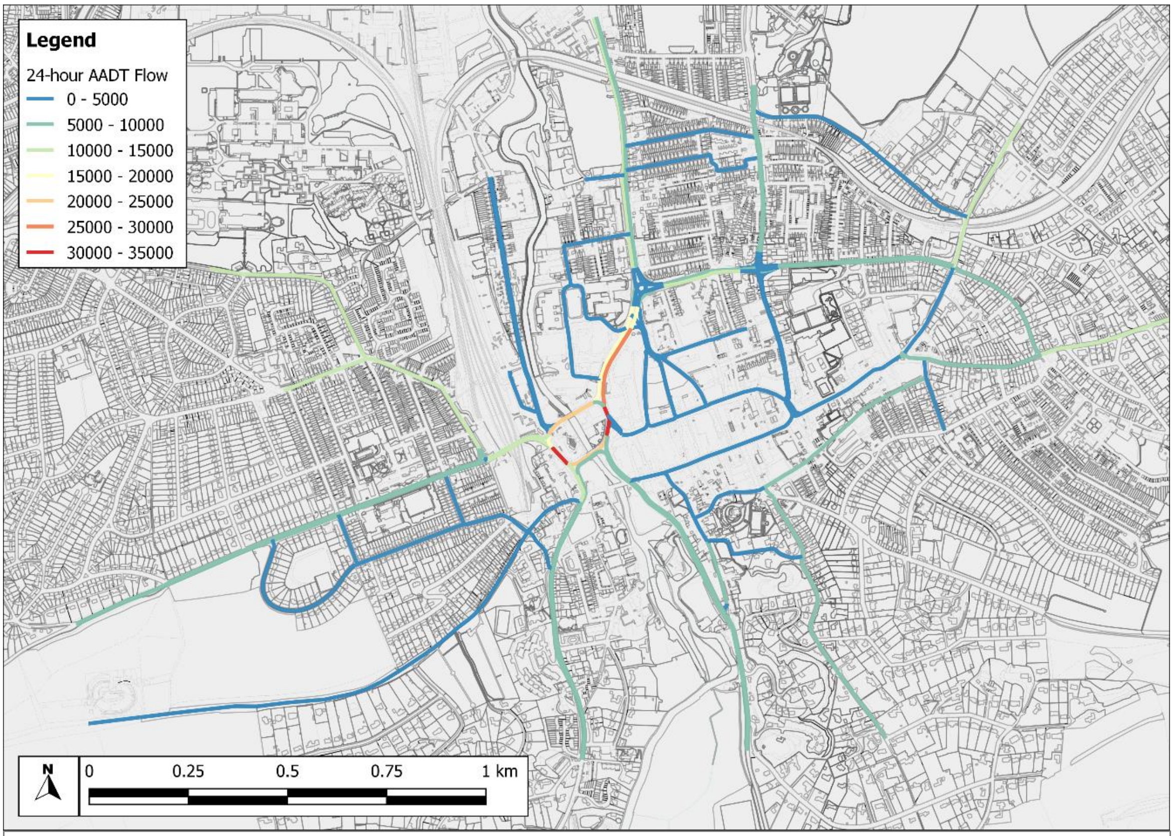
Traffic Data

4.8 Traffic data was provided by Surrey County Council (SCC) for most of the roads within Guildford town centre. Data from a range of surveys were provided, including:

- Automatic Traffic Counts (ATC) of vehicle flows and speeds for a range of vehicle compositions for all hours of a week;
- Manual Classified Traffic Counts (MCTC) of vehicle flows and a breakdown of vehicle compositions for hours between 7am and 7pm for single days;
- CSC junction surveys of vehicle flows and a breakdown of vehicle compositions for hours in the peak hours (7am – 10am and 4pm – 7pm) for single days; and
- ATC data obtained from the Department for Transport (DfT) of vehicle flows and a breakdown of vehicle compositions over entire year periods.

4.9 The data covers a range of years, from 2010 to 2019. All data has been factored forwards to the year of 2019 using traffic growth factors obtained from DfT's Trip End Model Presentation Program (TEMPro) which extracts information from the National Trip End Model (DfT, 2017). Traffic flows for the Park St / Bridge St / Onslow St gyratory have been calculated based on the proportion of flows entering and exiting each arm of the gyratory. The composition of vehicles used in the model includes cars, Light Goods Vehicles (LGVs), Heavy Goods Vehicles (HGVs), buses and coaches, and motorbikes. Diurnal flow profiles for each vehicle type have been determined from the ATC data and the average profiles used to estimate vehicle flows for the hours not measured by MCTC and CSC surveys, in order to derive flows for all hours of the day for all surveyed roads. Further details are given in Appendix A2.

Figure 11: Traffic Flows (AADT)



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4.10 Further data on traffic speeds were provided by Surrey County Council (SCC) for all roads in Guildford town centre, sourced from speed information obtained by Highways and Basemap Ltd. Speed information has been provided for AM and PM peak hour periods, inter-peak period, and off-peak period for each section of road, as well as the 24-hour average speeds. Traffic speeds have been assigned to each hour of the day following the National Highways definition of peak periods, as set out in LA 105 Air Quality (Highways England, 2019). These are 7am – 10am for the AM peak, 10am – 4pm for the inter-peak, 4pm – 7pm for the PM peak, and 7pm – 7am for the off-peak. Where appropriate, the vehicle speeds have been reduced to take account of slower speeds at junctions and queuing.

Predicted Background Concentration

4.11 Ambient background concentrations of annual mean NO_2 have been taken from the national pollution maps published by Defra (Defra, 2021b). These cover the whole of the country on a 1x1 km grid for each year from 2018 until 2030. Concentrations for 2019 were extracted for the study area. The values range between 10.0 $\mu g/m^3$ and 21.5 $\mu g/m^3$ within the study area. These concentrations have been bilinearly interpolated to give specific background concentrations at each receptor location. All predicted background concentrations are well below the AQOs.

Additional Model Setup Parameters and Post-processing

4.12 Further details on additional model setup parameters and post-processing approaches are set out in Appendix A3. These include the vehicles emission factors, meteorology, model verification and other key modelling considerations.

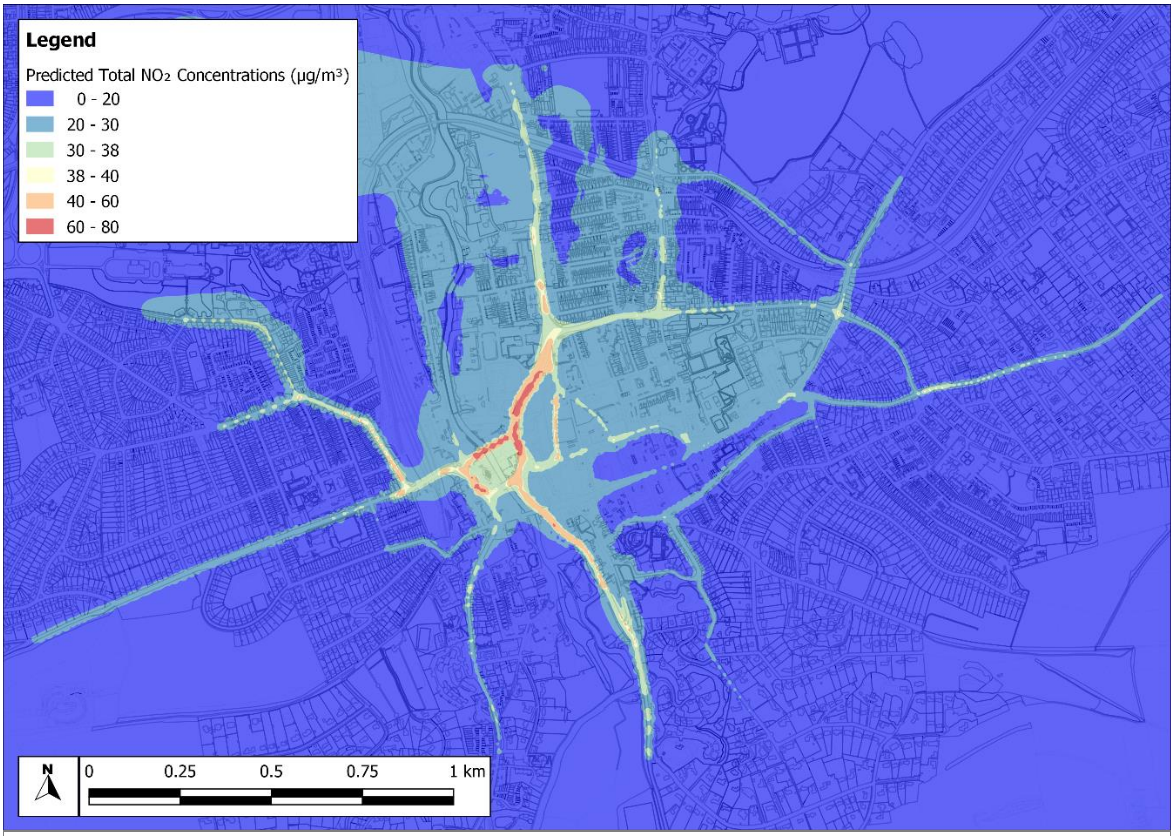
Uncertainty and limitations

4.13 The assessment involves a range of uncertainties, including the model inputs, assumptions, the model, model verification and post-processing of model results. Further details are discussed in Appendix A2.

5 Predicted Concentrations

5.1 Figure 12 presents the 20, 30, 38, 40 and 60 µg/m^3 NO_2 contours derived from the hybrid grid of receptors. The key areas where exceedances potentially exist are shown in greater detail in the enlarged images in Figure 13 to Figure 18.

Figure 12: Contour Plot of Predicted NO_2 Concentrations



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Discussion of Findings

5.2 The results suggest that there are potential exceedances of the AQO at five roads:

- Millbrook;
- Commercial Road;
- Onslow Street;
- Gyratory – Bridge Street / Onslow Street; and
- Gyratory – Park Street.

5.3 Each of these roads have been considered carefully, taking account of the predicted concentrations, the AQOs, and whether there is relevant exposure. Discussions of each of these roads is set out below.

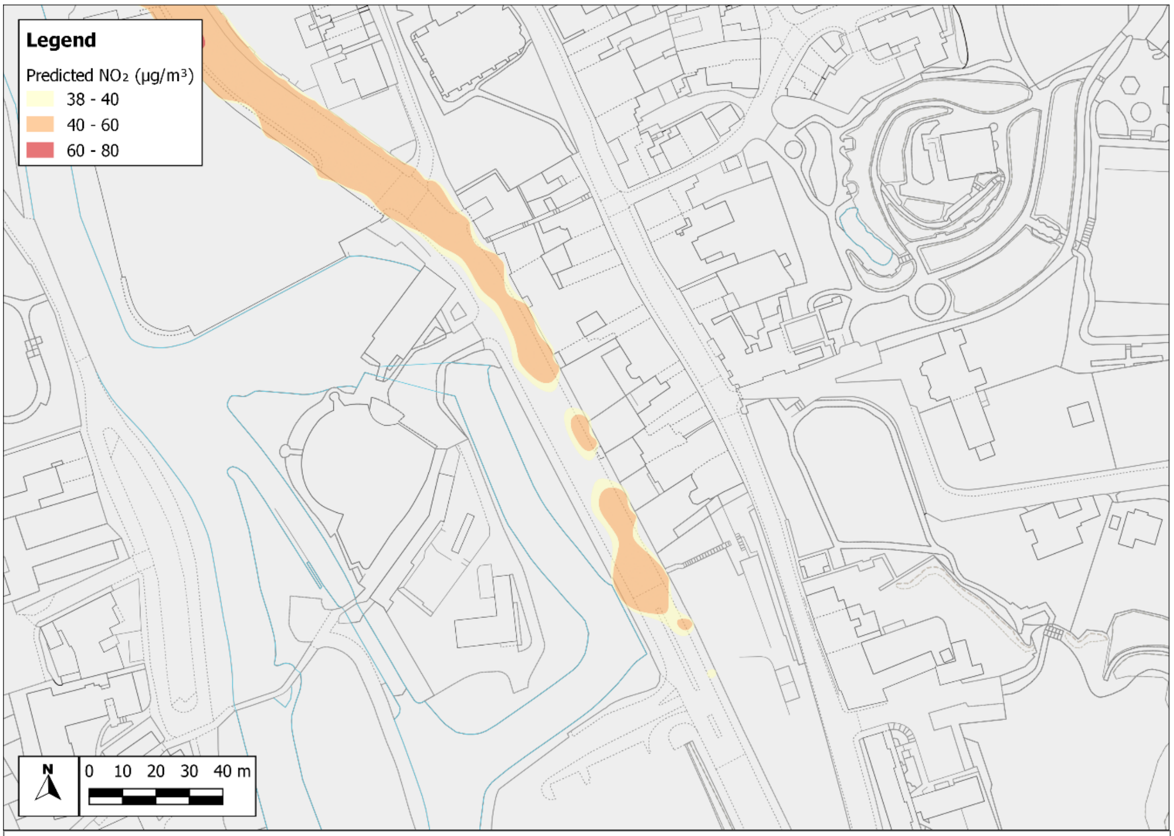
5.4 A precautionary approach has been undertaken to consider exceedances of 38 µg/m^3, to take account of model uncertainties. It is also important to take knowledge the latest evidence from the WHO, that health effects can occur at lower levels.

Millbrook

5.5 Exceedances of the annual mean NO_2 AQO have been predicted at several properties along this road, as demonstrated in Figure 13.

5.6 An AQMA would be needed for these properties along Millbrook.

Figure 13: Risk of Exceedance Contour Plot for Millbrook



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Commercial Road

5.7 Predicted concentrations are above the annual mean NO_2 AQO along Commercial Road. This road is known to experience traffic congestion. Currently there is no relevant exposure adjacent to this road. However, Commercial Road is part of a wider site allocated as part of the GBC's Local Plan and a development including residential use is currently seeking planning permission for this site, retaining Commercial Roads and the bus station at its current position. The area may thus soon include relevant exposure which would likely experience exceedances of the annual mean NO_2 AQO.

Figure 14: Risk of Exceedance Contour Plot at Commercial Road

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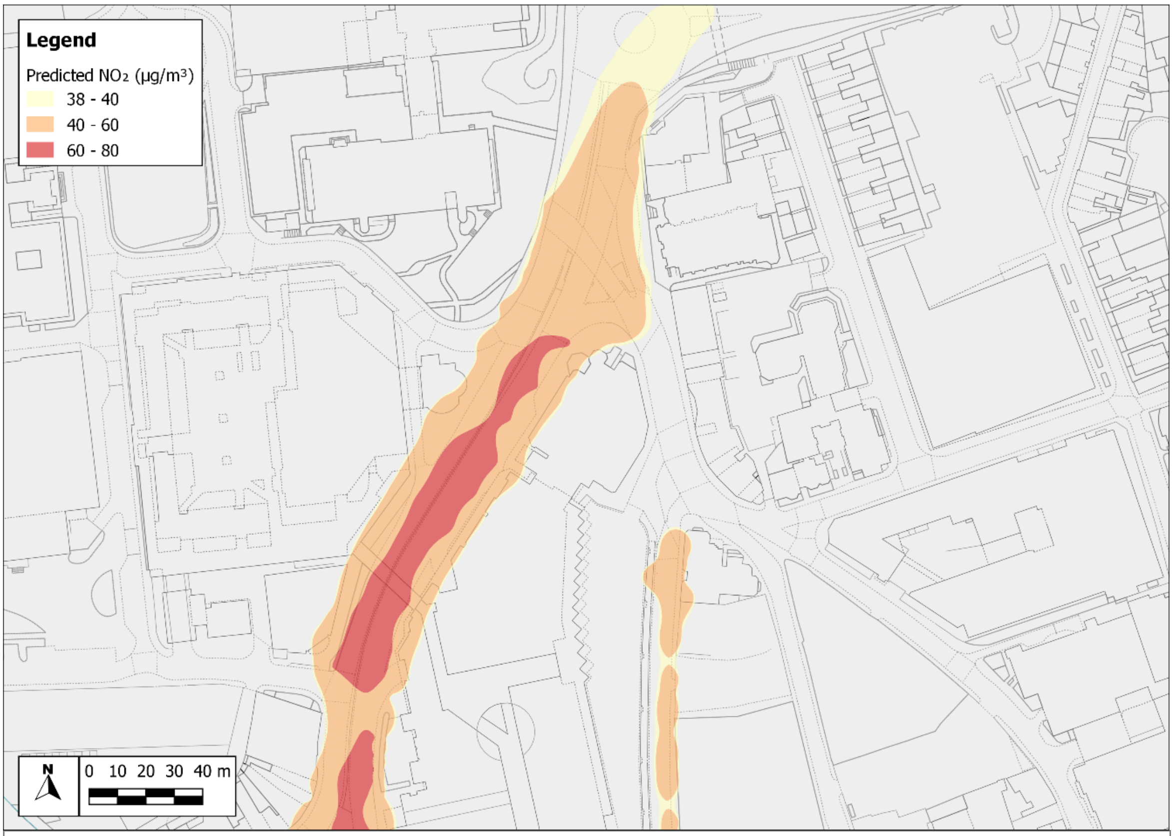
Onslow Street

5.8 Predicted concentrations are above the annual mean NO_2 AQO but there is no relevant exposure.

5.9 Potential exceedances of the 1-hour mean NO_2 AQO are predicted along the pavement, however it is considered unlikely that members of the public will reside along these pavement areas for more than 1-hour.

5.10 It is therefore considered that no AQMA is needed for Onslow Street although future development along this road should be considered for suitability in case relevant exposure is introduced. Consideration should be given to including Onslow Street within an AQMA when taking a precautionary approach.

Figure 15: Risk of Exceedance Contour Plot at Onslow Street



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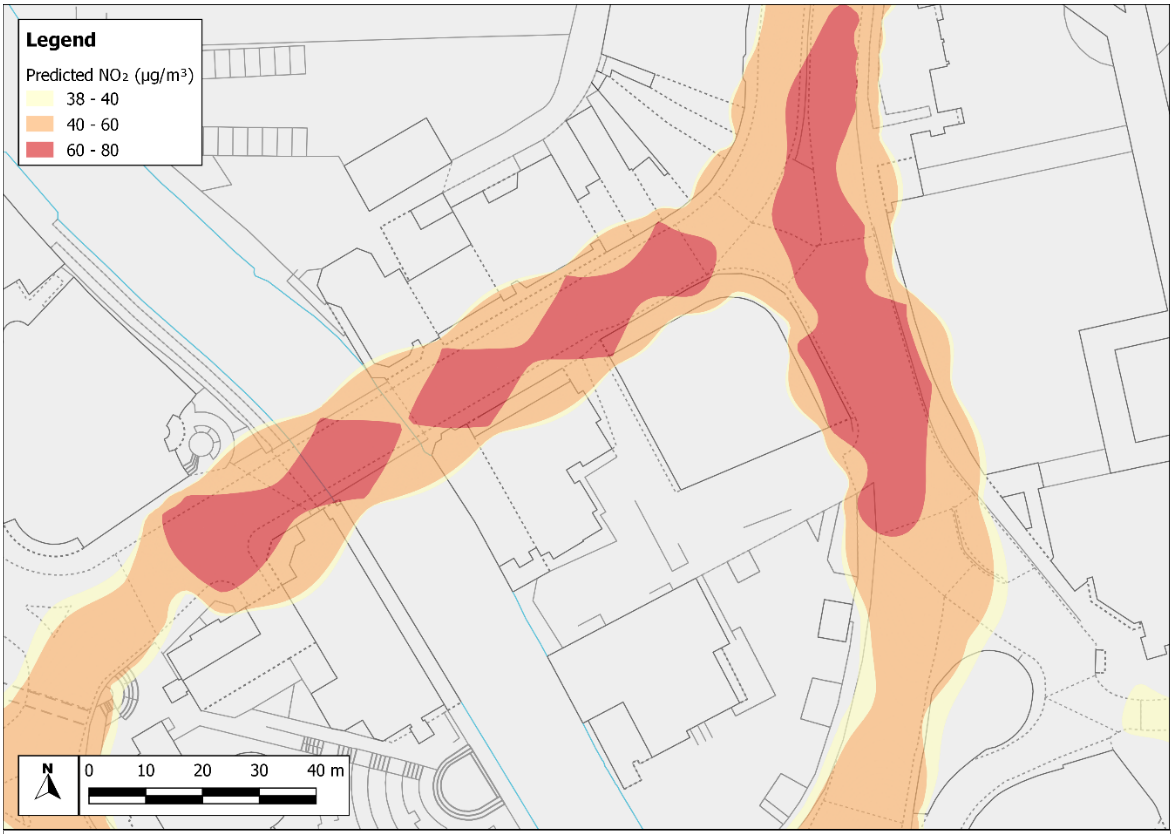
Gyratory – Bridge Street / Onslow Street

5.11 Potential exceedances of the 1-hour mean NO_2 AQO have been predicted along the pavement, particularly close to the public house to the west (Wetherspoons). An AQMA would therefore be needed in relation to the 1-hour mean AQO along the pavement of the Bridge Street / Onslow Street section of the gyratory.

Figure 16: Risk of Exceedance Contour Plot at Gyratory – Bridge Street / Onslow Street



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5.12 Concentrations have been predicted which are above the annual mean NO_2 AQO. In considering whether there is any relevant exposure:

- There is no relevant exposure to the east.
- There is relevant exposure to the west at the YMCA/The Bridge building at first and second floor levels.

5.13 Concentrations of NO_2 have been predicted at a number of worst-case locations representing the upper floors of the YMCA/The Bridge building to understand whether there are any exceedances of the annual mean AQO at the upper floors. These locations and concentrations are presented in Figure 17.

5.14 There are no exceedances of the annual mean AQO predicted at the upper floors of the YMCA/The Bridge building (see locations 1 – 9 within Figure 17). There are several locations where concentrations are above the AQO level at the adjacent building (Stevens & Bolton) but there is no relevant exposure within the building (locations 10 – 25 within Figure 17).

5.15 An AQMA for the annual mean AQO would therefore not be needed for the Bridge Street / Onslow Street section of the Gyratory.

Figure 17: Risk of Exceedance at Upper Floor Levels

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Gyratory – Park Street

5.16 Concentrations have been predicted above the annual mean NO_2 AQO. In considering whether there is any relevant exposure:

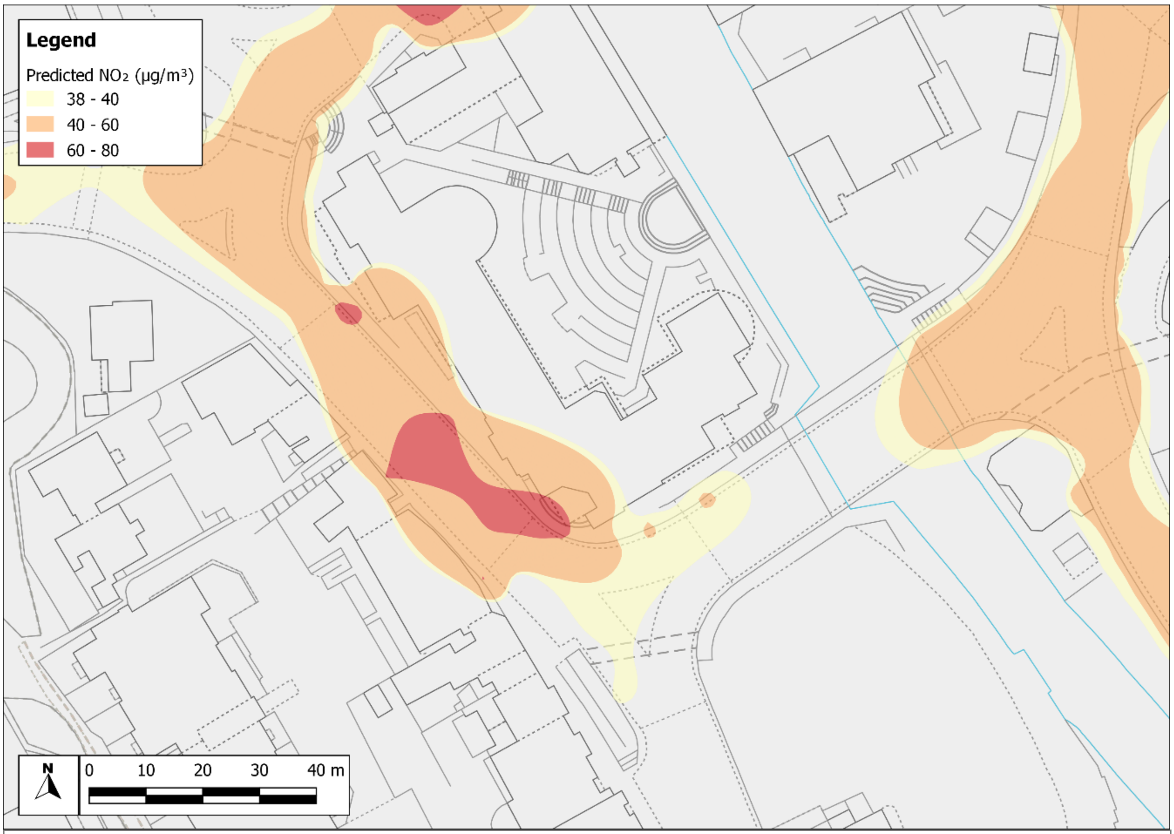
- There is no relevant exposure to the east side of Park Street (Stevens & Bolton building).
- There is relevant exposure to the west side of Park Street.

5.17 It is therefore considered that an AQMA is needed for the properties on the west side of Park Street.

5.18 Furthermore, concentrations have been predicted at the upper floors of the building of relevant exposure on the west side of Park Street to understand the extent of the exceedances. These locations and concentrations are presented in Figure 17 (see locations 26, 27 and 28 within Figure 17). Exceedances are predicted at all floors of the building.

5.19 Potential exceedances of the 1-hour mean NO_2 AQO have been predicted along the pavement. It is, however, considered unlikely that members of the public will reside there for more than 1-hour. It is therefore considered that no AQMA is needed for the Park Street section of the gyratory in relation to the 1-hour mean AQO.

Figure 18: Risk of Exceedance Contour Plot at Gyratory – Park Street



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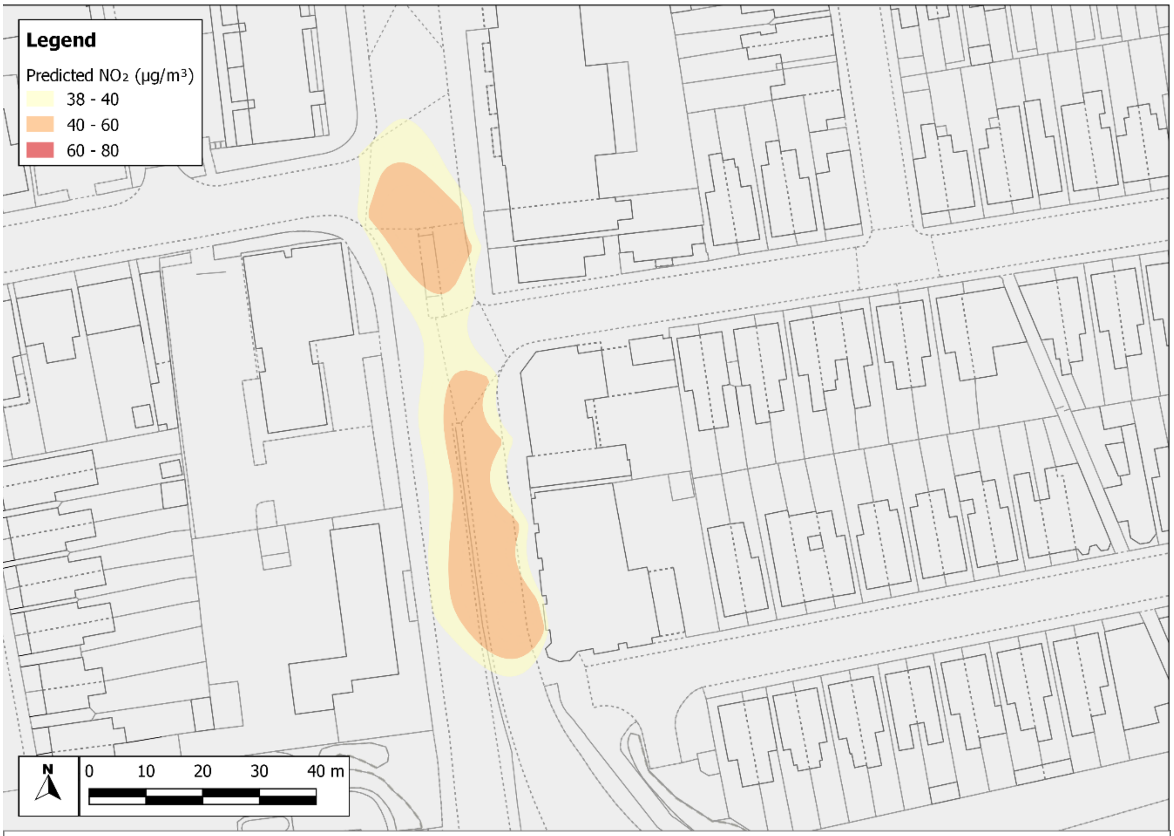
Further Consideration of a Precautionary Approach

5.20 In addition to the areas set out above, there are two further locations of concern where there is a potential risk of concentrations being higher than 38 µg/m^3. These locations are described below.

Woodbridge Road

5.21 The predicted annual mean concentrations are greater than 38 µg/m^3 at single property along Woodbridge Road, located close to the junction with Onslow Street and York Road. This property is commercial at ground floor, where the AQOs and limit values do not apply. There is relevant exposure at the first and second floor levels, however since the concentrations only just exceed 38 µg/m^3 at the facade of the building at ground floor, it is unlikely that concentrations will be exceeded at the uppers floors which are located further away from the main source of pollutant emissions (road traffic). Nevertheless, taking a precautionary approach, consideration should be given to including Woodbridge Road within an AQMA.

Figure 19: Risk of Exceedance Contour Plot at Gyratory –Woodbridge Road



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Farnham Road / Guildford Park Road

5.22 There are four residential properties along Guildford Park Road where annual mean concentrations are predicted to be greater than 38 µg/m^3 and several others where the contours come very close to the facades of dwellings. Although there are no exceedances predicted along Farnham Road, the contours come close to the property at the corner of Farnham Road and Guildford Park Road. Furthermore, monitoring site FRH2, which is located along Farnham Road, measured 38.4 µg/m^3 in 2018.

5.23 Taking a precautionary approach, consideration should be given to including Guildford Park Road and the junction with Farnham Road within an AQMA.

Figure 20: Risk of Exceedance Contour Plot at Gyratory –Farnham Road / Guildford Park Road

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Summary of Predicted Concentrations

5.24 In summary, the modelling suggests that there will be exceedances of the annual mean AQO at relevant locations of exposure along Millbrook and Park Street, and exceedances of the 1-hour mean AQO along Bridge Street / Onslow Street. In addition, there is a risk of potential exceedances of the annual mean AQO along Commercial Road. Furthermore, caution should be taken regarding future development which could introduce new exposure in locations where there is currently none. There are also other areas where concentrations are above 38 µg/m^3; these include Woodbridge Road, Farnham Road and Guildford Park Road.

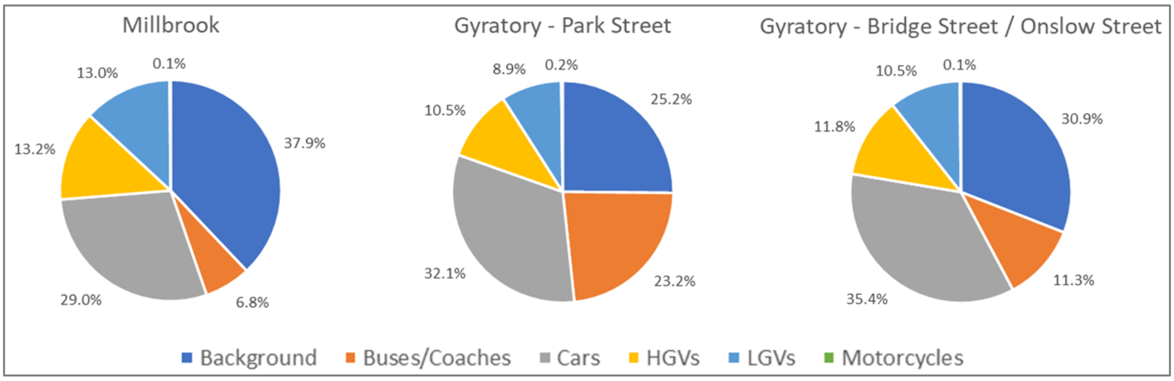
6 Source Apportionment

6.1 Table 6 and Figure 21 provide the NO_2 source apportionment for the three areas of most concern where potential exceedances of the NO_2 AQOs have been identified.

Table 6 Approximate Percentage Contributions to NO_2 from Relevant Sources

Location	Background	Buses / Coaches	Cars	HGVs	LGVs	Motorcycles
Millbrook	37.9%	6.8%	29.0%	13.2%	13.0%	0.1%
Gyratory - Park Street	25.2%	23.2%	32.1%	10.5%	8.9%	0.2%
Gyratory - Bridge Street / Onslow Street	30.9%	11.3%	35.4%	11.8%	10.5%	0.1%

Figure 21: Approximate NO_2 Source Apportionment



6.2 The main sources are cars and background levels, which together contribute over half the NO_2 in the areas of potential exceedance. Therefore, any plan to improve air quality should focus on these vehicles.

6.3 Heavy goods vehicles (HGVs), light goods vehicles (LGVs) and buses/coaches also contribute around 10% each in general, with Park Street having a higher contribution from buses/coaches (23%). Very little is contributed from motorcycles. Measures focusing on HGVs, LGVs and buses/coaches would also help to improve air quality. In particular, buses/coaches are clearly important on Park Street.

7 Recommendations

7.1 This Detailed Assessment suggests that there may be exceedances of the annual mean and 1-hour NO_2 AQO in the centre of Guildford, along several roads.

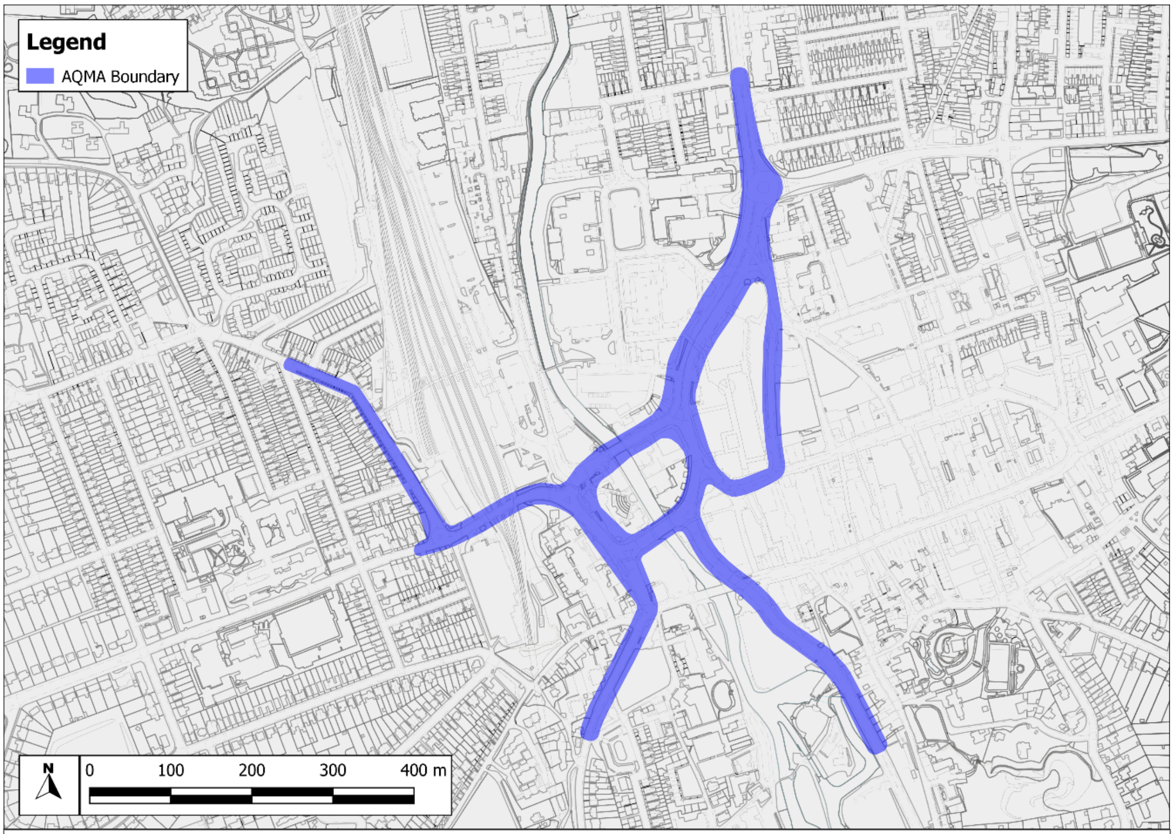
7.2 Declaration of an AQMA is therefore recommended which should consider the area where potential current exposure is located or may be in the very near future, i.e. Millbrook, Commercial Road, and the Park Street, Bridge Street/Onslow Road sections of the Gyratory.

7.3 Consideration has also been given to the uncertainty of the modelling, which has been verified against monitoring in 2019. GBC expanded their monitoring program in 2018 to include many more measurement locations. Before 2018 there were only a couple of monitors. It is therefore not possible to fully understand the yearly variability or trends of air quality at most of the monitoring sites. In 2018 an exceedance of the annual mean AQO was measured at monitoring site PR1 located at the Wycliffe Buildings along Portsmouth Road. The measured concentration dropped from 41.2 µg/m^3 in 2018 to 36.1 µg/m^3 in 2019, for which the reason is unknown. Given that there has recently been a measured exceedance, it is recommended that a conservative approach is taken to include Portsmouth Road within the AQMA.

7.4 Taking account of potential uncertainties, it is considered that a precautionary approach is taken to include several other roads with predicted concentrations above 38 µg/m^3 linked to those roads with predicted exceedances. This includes Guildford Park Road, Farnham Road, Onslow Street, North Street (between the Gyratory and Commercial Road) and Woodbridge Road. Although there is not any relevant long-term exposure along these roads currently, there is a risk of exceedances should any new exposure be introduced into these areas. Furthermore, there is relevant exposure of the 1-hour mean AQO along North Street. Including these roads will help focus the air quality action plan to promote measures that help reduce pollution both in the areas with exceedances and those with a risk of future exceedances.

7.5 Figure 22 shows the proposed extent of the AQMA, which is proposed to be declared for both the annual mean NO_2 AQO and the 1-hour mean NO_2 AQO.

Figure 22: Proposed AQMA



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8 Glossary, References and Appendices

Glossary

AADT	Annual Average Daily Traffic
Air Quality Standards	Concentrations recorded over a given time period, which are considered to be acceptable in terms of what is scientifically known about the effects of each pollutant on health and on the environment.
An exceedance	A period of time (defined for each standard) where the concentration is higher than that set out in the Standard.
An objective	The target date on which exceedances of a Standard must not exceed a specified number.
APS	Air Pollution Services
AQO	Air Quality Objective
AQMA	Air Quality Management Area
Limit Values	Legally binding UK parameters that must not be exceeded. Limit values are set for individual pollutants and are made up of a concentration value, an averaging time over which it is to be measured, the number of exceedances allowed per year, if any, and a date by which it must be achieved. Some pollutants have more than one limit value covering different endpoints or averaging times.
IAQM	Institute of Air Quality Management
LAQM	Local Air Quality Management
NO	Nitrogen Oxide
NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxides
O_2	Oxygen
O_3	Ozone
$\mu g/m^3$	Microgrammes per cubic metre
Streetscape effects	Where street massing restricts dispersion and entraps it within the street zone.
WHO	World Health Organization

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A1 Professional Experience

Dr Austin Cogan, MPhys (Hons) PhD CEnv MIEnvSc MIAQM

Dr Cogan is a Director and founder of APS, is a Chartered Environmentalist and has over thirteen years' experience in environmental sciences. Austin has extensive experience of air quality, dust, and odour assessments for a range of industries as well as services for local authorities. He is also an international expert in the field of climate change, having monitored greenhouses gases globally, published numerous scientific papers and presented at conferences internationally.

Dr Austin Cogan has carried out city and borough scale modelling for many parts of the UK. This has included Clean Air Zone studies for Bristol, Bath and North East Somerset, Newcastle, Gateshead, and Tyneside, which involved predicting baseline pollutant concentrations and modelling various future schemes. It also included the development of ranked lists of measures to improve local air quality and carrying out streamlined calculations to calculate the likely improvements achieved by each measure to produce short lists of options for detailed scenario testing.

Austin also has substantial experience in modelling Air Quality Action Plan (AQAP) options, having completed AQAP feasibility studies for Reigate and Banstead, South Gloucestershire, Thurrock, Warwick, Leamington Spa, and most recently Harborough. He has also carried out borough wide modelling on behalf of local authorities to provide evidence bases for Borough Plans, most recently for Nuneaton and Bedworth Borough Council. These included the use of micro-simulation traffic modelling and a range of vehicle emission databases, such as average-speed emissions from the EFT and instantaneous emissions from AIRE and TNO.

In addition, he has undertaken analysis and interpretation of air quality data and the preparation of annual status reports on behalf of local authorities.

Kieran Laxen, MEng (Hons) MIEnvSc MIAQM

Mr Laxen is a Director of APS and has over thirteen years' experience in the field of air quality. Kieran is an active member of the IAQM committee. He has extensive experience of air quality monitoring and is a leading UK expert in the assessment of power generating facilities for both permitting and planning applications. He has been a stakeholder in Defra's and the Environment Agency's consultations into implementing the MCPD and Specified Generator Controls.

George Bratchel, BSc (Hons) AMIAQM

Mr Bratchel is a graduate air quality consultant of APS. He completed his BSc Environmental Science at Plymouth University and previously worked as a graduate consultant at Create Consulting Engineers. He has experience working on residential planning applications of various sizes. He is currently gaining further experience of undertaking air quality assessments for planning and permit applications while supporting on a wide range of projects.

A2 Modelling

The model

A2.1 Parameters and data relating to the detailed dispersion modelling approach are set out below.

Vehicle Emissions

A2.2 Emissions of road-NOx (i.e., the contribution from vehicles using roads), have been derived from the latest version of Defra's Emission Factor Toolkit (EFT) (v10.1) using the traffic data discussed in paragraphs 4.8 to 4.10. The EFT is based on the COPERT 5 (Computer Programme to calculate Emissions from Road Transport) vehicle emission model and provides speed-average based emission rates.

Fraction of Primary NO_2

A2.3 In addition to emission rates, the fraction of primary NO_2 (f-NO_2) has be obtained from the EFT. This represents the amount of NO_2 released from vehicle exhausts, before any further chemical reactions in the atmosphere, which becomes an important variable when post-processing the model predictions. In order to obtain the f-NO_2 value at each receptor location, the NOx emission rates have been multiplied by f-NO_2 values to derive NO_2 emission rates. These NO_2 emissions have been included in the model and primary NO_2 concentrations have been predicted at the receptors. The predicted NOx concentrations have been divided by the predicted primary NO_2 concentrations to calculate the f-NO_2 values at the receptor locations. The f-NO_2 values have then been used in the model post-processing (see paragraph A2.32).

Time-Based Profiles

A2.4 Vehicle emissions vary over time depending on the volume of traffic, this includes hourly, daily, and seasonal variations. Urban seasonal (monthly) traffic flow profiles have been taken from DfT national statistics (DfT, 2020). The daily and hourly profiles have been taken from the ATC survey data provided by SCC. These profiles have been used in the model to adjust the emissions for each hour of the year modelled. These profiles are shown in Figure A1 and Figure A2.

Figure A1: Diurnal profile for each day of the week used in the model

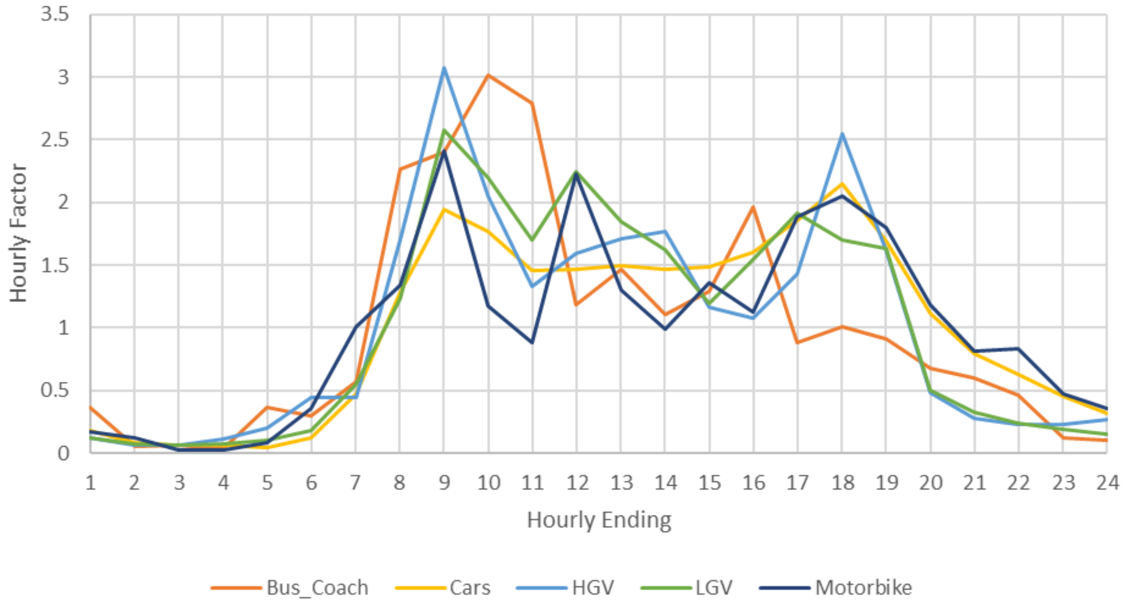
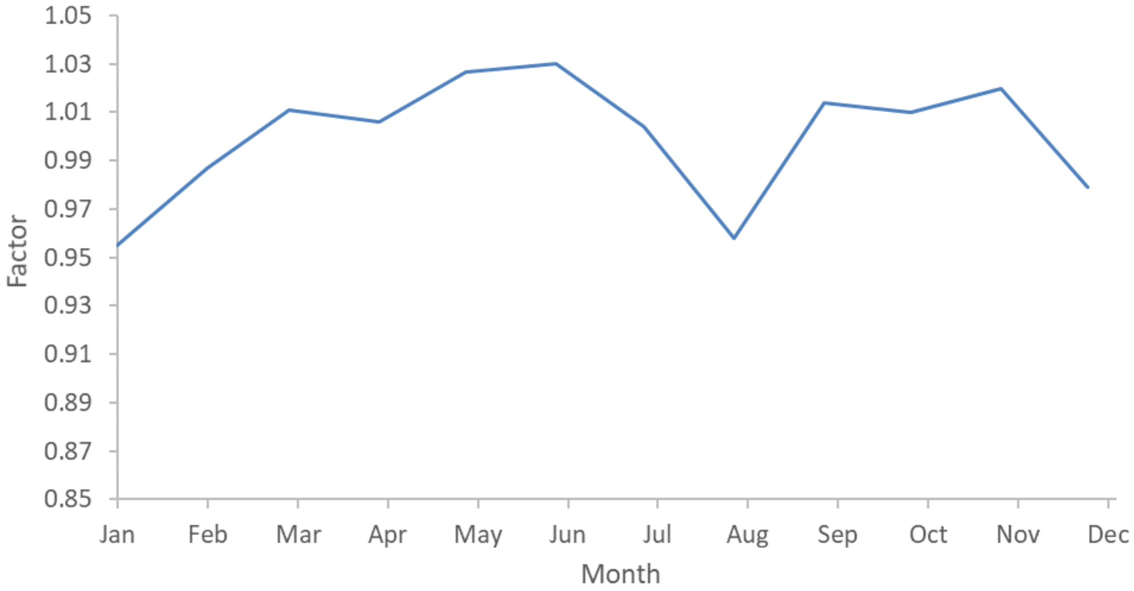


Figure A2: Seasonal profile for each month of the year used in the model



Wake effects

A2.5 As vehicles travel along a road a wake is left behind the vehicles as air in the path of travel is forced around the vehicle. The wake can be considered the turbulence induced by the movement of the vehicle, which affects the dispersion of pollution away from roads. The AADT traffic flows have been entered into the ADMS-roads dispersion model in order to account for vehicle wake effects which will vary on each link depending on the proportion of large vehicles to small vehicles.

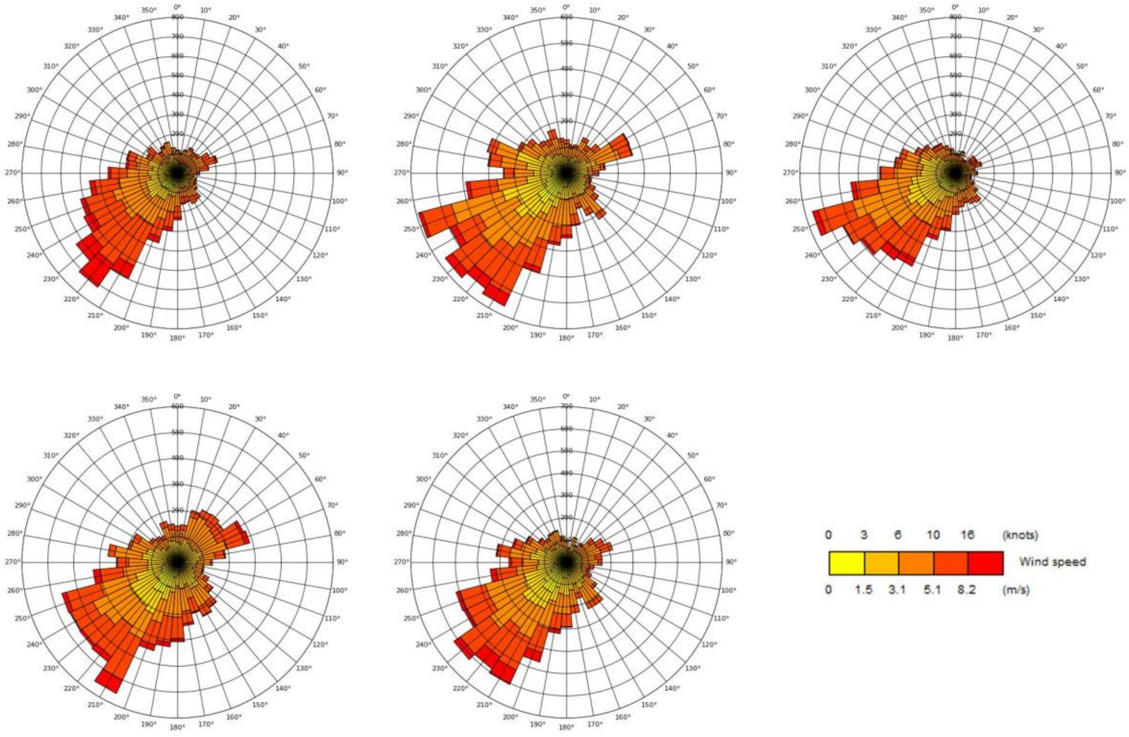
Street Canyons

A2.6 Roads in the local area are enclosed by massing along either sides of the roads (i.e. buildings and vegetation) which likely obstruct or restrict dispersion or result in recirculation of pollution within the streetscape. This typically leads to lower pollutant concentrations away from roads and higher concentrations close to and within the street zone. This is known as the 'street canyon' effect. The roads have therefore been modelled as asymmetric street canyons using the Advanced Street Canyon Module in network mode, within the ADMS-Roads model.

Meteorology

A2.7 Meteorological data has been taken from the Farnborough Meteorological Station for the year of 2019. This station is located approximately 14 km northwest of Guildford town centre and is considered representative of meteorological conditions in Guildford. Meteorological data for the year of 2019 is considered to provide typical conditions. Illustrations of wind speed and direction for 2019 and other recent years are presented in Figure A3.

Figure A3: Windrose of wind speed and direction for each year from 2015 (top left) to 2019 (bottom right) at the Meteorological Station



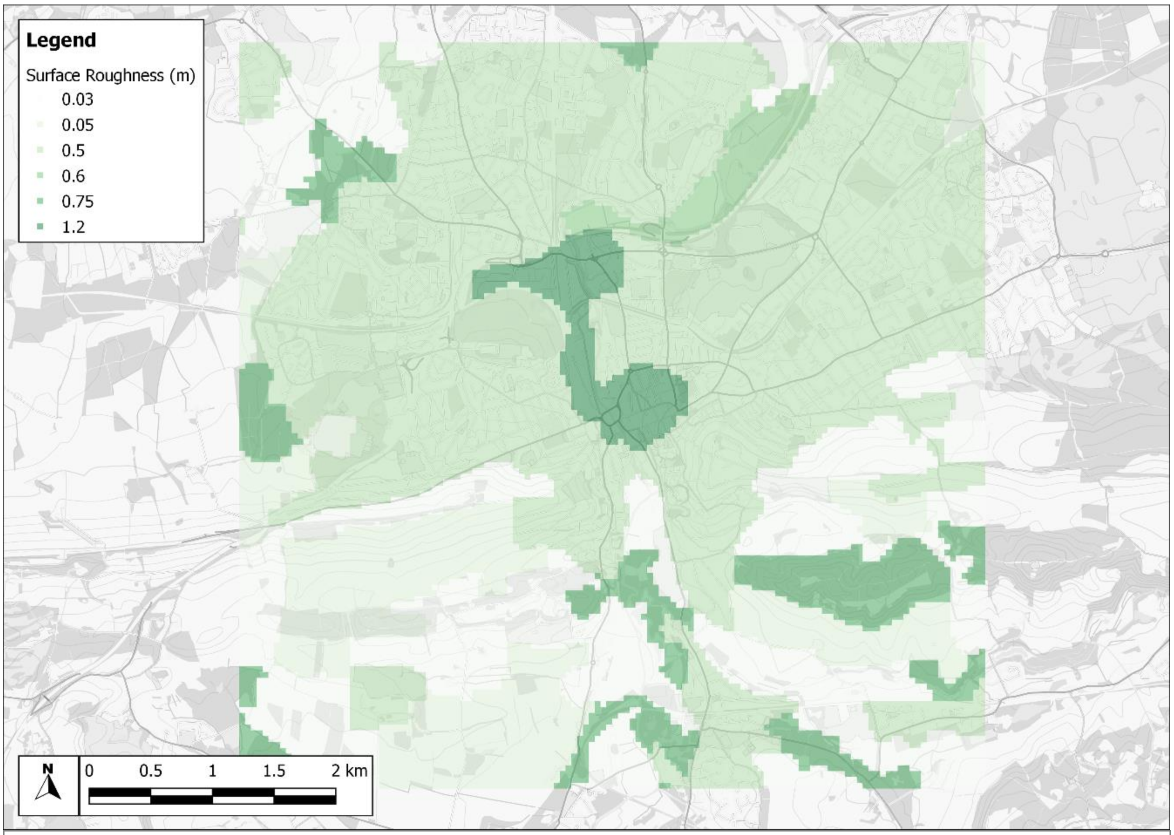
Meteorological Parameters

A2.8 In addition to the meteorological data, the model requires values to be set for a number of meteorological related parameters, for the study area. Details of the parameter values used in the modelling are provided in Table A1 below.

A2.9 Land-use and surface characteristics have an important influence in determining turbulent fluxes and, hence, the stability of the boundary layer and atmospheric dispersion.

A2.10 Surface roughness length used within the model represents the aerodynamic effects of surface friction and is defined as the height at which the extrapolated surface layer wind profile tends to zero. This value is an important parameter used by the built-in meteorological pre-processor of ADMS to interpret the vertical profile of wind speed and estimate friction velocities which are, in turn, used to define heat and momentum fluxes and, consequently, the degree of turbulent mixing. Surface roughness values for different land-use classifications are provided in the 2018 Corine Land Use dataset (Copernicus, 2018). A surface roughness file has been used within the model based on the spatially variable land-uses and the equivalent roughness values from the dataset.

Figure A4: Surface Roughness for the Study Area



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A2.11 The surface albedo is the ratio of reflected to incident shortwave solar radiation at the surface of the earth. This varies depending on the land use, and thus area-weighted average albedos have been derived for the meteorological and dispersion sites and used in the models. Albedo values have been taken from US Environmental Protection Agency (EPA) guidance (2018) and associated with the different land uses in the 2018 Corine Land Use dataset (Copernicus, 2018).

A2.12 The Priestley-Taylor parameter is a parameter representing the surface moisture available for evaporation. A Priestley-Taylor parameter of 1 has been set in the model.

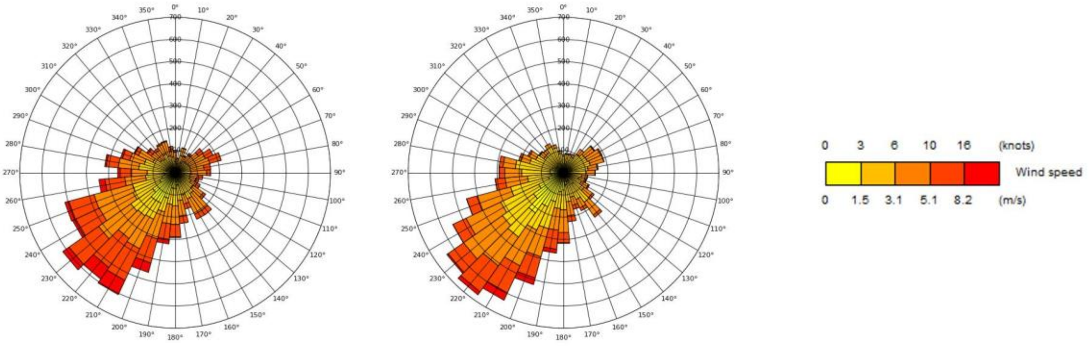
A2.13 The CERC user guide explains that "*the Monin-Obukhov length provides a measure of the stability of the atmosphere. In very stable conditions in a rural area its value would typically be 2 to 20 m. In urban areas, there is a significant amount of heat generated from buildings and traffic, which warms the air above the town/city*". For large urban areas this is known as the urban heat island. It has the effect of preventing the atmosphere from ever becoming very stable. The model has the ability to define the minimum Monin-Obukhov length to account for the urban heat island effect which is not represented by the meteorological data. This varies depending on the land use, and thus area-weighted average minimum Monin-Obukhov lengths have been derived for the meteorological and dispersion sites and used in the models.

Table A1: Meteorological Parameter Values used in the Model

Parameter	Meteorological Site Value	Dispersion Site Value
Surface roughness (m)	0.053	n/a
Surface albedo	0.179	0.173
Minimum Monin-Obukhov length (m)	29.542	27.000
Priestley-Taylor parameter	1	1

A2.14 The meteorological parameters alter the meteorological data inputted into the model to reflect conditions at the dispersion site. For example, if the dispersion site has a higher surface roughness value than the meteorological site, then the model will reduce the wind speed at the dispersion site to reflect this. Figure A5 shows the frequency of wind speeds and directions measured at the meteorological station in 2019 (left), which has been inputted into the model, as well as the frequency of wind speeds and directions processed by the ADMS-roads model for the dispersion site (right). These illustrate that wind predominantly comes from the southwest and that the model has slightly lower wind speed at the dispersion site.

Figure A5: Wind Rose showing the frequency of wind speed and wind direction for the meteorological station (Left) and the modelled dispersion site (Right) for the year of 2019



Background Calibration

A2.15 Defra's national background maps have been calibrated against locally measured concentrations at several background monitoring sites, to ensure the maps are locally robust. GBC measured concentrations of NO_2 in 2019 at two background monitoring sites near to Guildford town centre (monitors GD3 and GD6). These measurements have been compared to those estimated by Defra to derive calibration factors and the average of these has been used to adjust all background mapped concentrations. All mapped concentrations have thus been uplifted by approximately 3% to match local background measurements. Details are provided in Table A2 below.

Table A2: Details of background calibration

Monitor	Location (BNG coordinates)	Measured NO_2 (µg/m³)	Defra Mapped NO_2 (µg/m³)	Factor
GD3	499659,159739	17.8	17.5	0.99
GD6	500385,148342	10.1	10.8	1.07
Average Calibration Factor				1.03

Model Performance

A2.16 The modelling will inherently have some uncertainties and may not reflect real conditions in the local area. An important part of modelling is reviewing the model results carefully and checking the model setup parameters and input data to minimise uncertainties.

A2.17 LAQM.TG(16) (Defra, 2021a), provides local authorities with advice on good practice for modelling air quality. This advice is widely applied for air quality assessments of proposed developments, although it is specifically aimed at local authority's duties to review and assess air quality. LAQM.TG(16) states that model verification, defined as a comparison of modelled results with monitoring results at relevant locations, is necessary (paragraph 7.520).

A2.18 There are many reasons why there may be a difference between modelled and monitored concentrations and LAQM.TG(16) states *"Model verification is the process by which these and other uncertainties are investigated and where possible minimised."* (paragraph 7.512). It provides a list of the factors that may explain the differences including meteorological data, source activity data (e.g., traffic flow and speed), emission factors, model input parameters such as roughness length, and monitoring data.

A2.19 The advice in LAQM.TG(16) is generic for all dispersion models. ADMS has been shown to predict concentrations well given sufficiently accurate data inputs.

A2.20 It is important to review the results of the modelling carefully and check the model setup parameters and input data. Once reasonable efforts have been made to reduce the uncertainties of input data for a model, further comparison of modelled and monitored results should be undertaken. Where discrepancies remain, consideration may be given to adjusting the model.

A2.21 Using good modelling techniques provides confidence that the model is performing as well as possible everywhere in the modelling area in the base year, not just at the monitoring locations. Modelling is often an iterative process of improving the model setup and evaluating the impact on model performance. The same principles need to be applied to the entire modelling study area to ensure the model performs well throughout the study area.

A2.22 All reasonable efforts have been made to improve the model inputs. The model has gone through several modelling iterations to consider whether the performance of the modelled inputs can be improved. Improvements are based on comparison with the measured concentrations at specific monitoring locations and where improvements have been made, they have been applied as a wholistic approach with systematic updates to the entire model study area to ensure that the model is not performing well exclusively at the monitoring locations.

A2.23 A final model verification exercise has been undertaken to determine whether there are any remaining discrepancies and to derive a factor with which to adjust the predicted concentrations from the model so that they match local conditions as closely as possible.

Final Model Verification

A2.24 A final model verification exercise has been undertaken, following the guidance set out by Defra in Box 7.14 and Box 7.15 of LAQM.TG(16) (Defra, 2021a).

A2.25 Concentrations of road-NOx, and primary NO_2 have been predicted for the year of 2019 using the ADMS-roads dispersion model for the diffusion tubes within and close to Guildford town centre. Predictions have been made at the heights of the monitor inlets.

A2.26 Initially, the measured NO_2 concentrations at the monitoring sites have been inputted into Defra's NOx to NO_2 Calculator, along with the background NO_2 concentrations and f-NO_2 values, in order to obtain 'measured' road-NOx concentrations at the monitoring sites. The primary NO_2 emission factor (f-NO_2) at each monitoring site was calculated by taking the ratio of predicted primary NO_2 concentration to predicted road-NOx concentration.

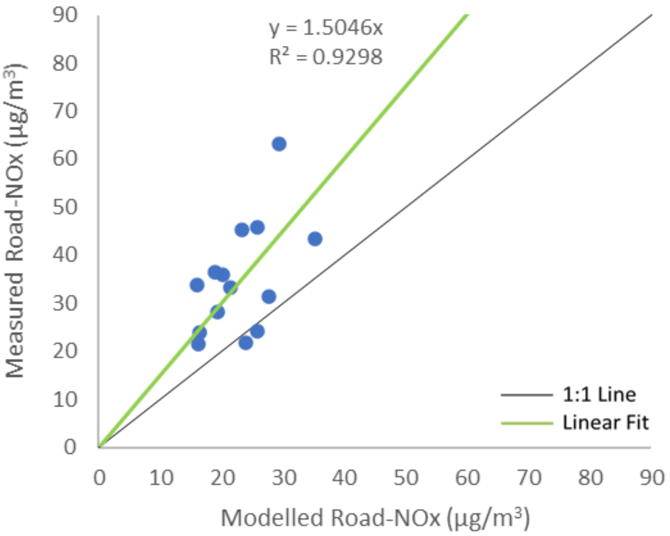
A2.27 The predicted road-NOx concentrations have then been compared to the 'measured' road-NOx concentrations and NOx factor calculated for each monitor, see Table A3.

Table A3: Measured and Modelled NOx Comparison

Monitor	Measured NO_2	Background NO_2	Predicted f-NO_2	Measured Road-NOx	Modelled Road-NOx	NOx Factor
FRH2	36.80	16.00	0.24	45.72	25.86	1.768
PR1	36.10	15.88	0.25	43.45	35.18	1.235
WTC1	28.30	17.61	0.27	21.64	16.24	1.333
TC2	34.00	17.86	0.22	35.81	20.22	1.771
GD16	38.20	17.34	0.26	45.16	23.36	1.933
GD2	33.10	17.24	0.24	33.90	16.05	2.112
GD17	30.00	16.12	0.27	28.25	19.44	1.453
TC1	32.60	17.38	0.23	33.18	21.35	1.554
TC4	31.80	17.27	0.23	31.44	27.64	1.138
PR3	28.10	16.41	0.24	24.31	25.83	0.941
A281	43.40	16.09	0.24	63.20	29.33	2.155
TC3	30.50	19.13	0.24	23.90	16.33	1.463
FRH4	26.50	15.99	0.24	21.71	23.94	0.907
FRH3	33.10	16.15	0.24	36.48	18.96	1.924

A2.28 This demonstrates that the model is generally performing reasonably well at all the monitoring sites with factors ranging between 0.907 to 2.155, which is considered fairly typical for air quality modelling. An adjustment factor of 1.505 has been derived from the equation of the linear trend line of the comparison (that has been fitted through zero), as shown in Figure A6. If this adjustment factor was applied to all modelled predictions, then it would lead to some locations being underpredicted and some overpredicted. Although this is not uncommon, it would result in concentrations being underpredicted at monitoring site A281, where exceedances of the AQO have been measured. Thus, to ensure that the model robustly represents this location and other locations where potential exceedances might exist, a zonal verification has been utilised instead.

Figure A6: Comparison of predicted road-NOx to 'measured' road-NOx



A2.29 The individual adjustment factors derived in Table A3 have been associated with the roads upon which the monitoring sites are located adjacent to. For roads without monitoring sites, relevant monitoring sites have been associated where appropriate and the overall adjustment factor of 1.505 has been used elsewhere. For each receptor, these 'zonal' factors have been applied to the predicted road-NOx contributions from each road and these uplifted contributions have then been summed to obtain the total predicted road-NOx.

A2.30 When undertaking the zonal verification consideration has been given to roads where multiple monitoring sites are located adjacent. Both TC1 and TC4 are located adjacent to Stoke Road; Table A3 demonstrates that TC1 has a higher adjustment factor and has therefore been used to provide a conservative assessment (TC4 has therefore not been used). Both FRH2 and FRH4 are located adjacent to Farnham Road; Table A3 demonstrates that FRH2 has a higher adjustment factor and has therefore been used to provide a conservative assessment (FRH4 has therefore not been used).

A2.31 The road-NOx contributions have then been inputted into Defra's NOx to NO_2 Calculator, along with the background NO_2 concentrations and f-NO_2 values, in order to obtain 'road- NO_2 concentrations at the monitoring sites. These have then been added to the background NO_2 concentrations to derive total NO_2 concentrations, which are directly comparable with the measured NO_2 concentrations at each monitoring site. Figure A6 shows that the modelled NO_2 concentrations are within 10% of the measured concentrations. The model statistics are shown in Table A4, which demonstrates that the predicted NO_2 concentrations have an insignificant fractional bias (~0) and an acceptable root mean square error (RMSE <10).

Figure A7: Comparison of predicted NO_2 to measured NO_2

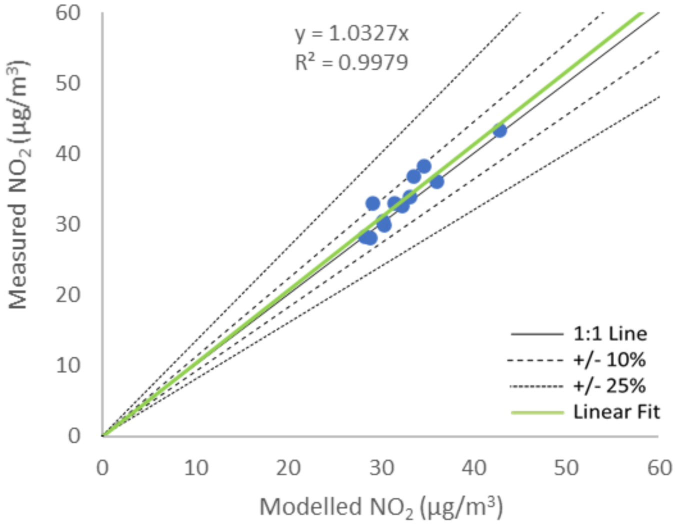


Table A4: Model Verification Statistics

Statistic	NO_2
Correlation Coefficient (r) [a]	0.932
Real Mean Squared Error (RSME) [b]	1.876
Fractional Bias (FB) [c]	0.032

a. This is used to measure the linear relationship between predicted and measured concentrations. A value of zero means no relationship and a value of 1 means absolute relationship (ideal value).

b. RMSE is used to define the average error or uncertainty in the model. The ideal value for NO_2 is zero, and a value within 10% of the AQO (i.e., 4 µg/m^3) is general acceptable although models should always be improved where possible even where the value is less than 10% of the AQO. If the value is greater than 25% of the AQO (i.e., 10 µg/m^3) then it is recommended that the model be revisited (this only applies to NO_2).

c. This is used to identify if the model shows a systematic tendency to over or under predict. FB values range between -2 and +2 and has an ideal value of zero. Negative values indicate a model over-prediction and positive values indicate a model under-prediction.

Post Processing

A2.32 Concentrations of road-NOx and primary NO_2 have been predicted at each receptor using the ADMS-Roads model. The primary NO_2 emission factor (f-NO_2) at each receptor has been calculated by taking the ratio of predicted primary NO_2 concentration to road-NOx concentration.

A2.33 The f-NO_2 values along with the adjusted modelled road-NOx concentrations and background NO_2 concentrations have been inputted into Defra's NOx to NO_2 calculator (v8.1) in order to obtain predicted road-NO_2 concentrations at each receptor. This tool has been run assuming the traffic is described as 'All other urban UK traffic', which is considered appropriate for the traffic associated with Guildford. It should be noted, however, that receptor specific f-NO_2 values have been used in the NOx to NO_2 calculator, which supersede the traffic selection.

A2.34 The road-NO_2 concentrations have then been added to the background NO_2 concentrations to obtain total NO_2 concentrations at the receptors.

Uncertainty and limitations

A2.35 The assessment involves a range of uncertainties, including the model inputs, assumptions, the model, model verification and post-processing of model results. A brief overview of the key uncertainties is discussed below.

A2.36 There are inherent uncertainties associated with the traffic data, which provides estimated vehicle trips in an average way, but the specific routing, timing, driving conditions and driving behaviour of vehicles will vary and potentially lead to different emission levels.

A2.37 The emission factors also involve a considerable amount of uncertainty. Emissions from the emission factor toolkit (EFT) are link averages and do not explicitly take account of acceleration or deceleration. Modelled speeds have been adjusted to account for this where possible.

A2.38 Analyses of recent NOx measurements now provide evidence that Defra's EFT (v10.1) can be relied upon to give the most likely emissions. The approach of this assessment has been to utilise the EFT as recommended by Defra in the LAQM.TG(16) guidance (Defra, 2021a).

A2.39 The model itself is based on assumptions of a range of parameters, including road geometries, road widths, street canyons and meteorological related parameters. There is uncertainty in all these parameters, but the modelling has been setup in a robust way based on professional experience to best represent the conditions.

A2.40 The ambient background concentrations are also uncertain. While these are provided by Defra, the 1x1 km resolution is coarse, and the maps do not include all sources of pollution. Given the nature of the study area, it is considered likely that the background maps for this area are reasonable. There is, however, no background measured data in Downpatrick to confirm this. To minimise uncertainty in the spatial resolution of the maps, the background concentrations have been interpolated to each receptor; essentially smoothing out the coarseness of the maps.

A2.41 Emerging evidence (Grange, S, et al., 2017) suggests that the f-NO_2 has been decreasing in recent years, which is not taken into account within Defra's EFT or NOx to NO_2 Calculator. If lower f-NO_2 values were assumed, then the predicted concentrations would likely be slightly lower throughout the study area. Until more detailed scientific analysis is undertaken to understand the full extent of why f-NO_2 is decreasing it remains an uncertainty.

A2.42 A model improvement and verification exercise has been undertaken to check the model and adjust the predicted concentrations from the model so that they match local conditions as best as possible. This has adjusted concentrations to match average conditions; some locations will remain underpredicted and some overpredicted.

A2.43 Although there is uncertainty associated with air quality modelling, the predictions made by this assessment have been carried out in a robust manner to minimise uncertainties where possible.

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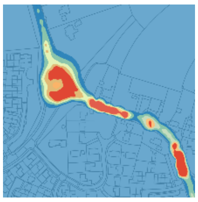

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