Clean Air Zone (CAZ) Feasibility Study – Swale Borough

Final Report for Swale Borough Council

ED 13676 | 17th November 2020

Customer:

Swale Borough Council

Customer reference:

Swale CAZ Feasibility Study

Confidentiality, copyright & reproduction:

Contact:

Guy Hitchcock

Ricardo Energy & Environment

Gemini Building, Harwell, Didcot, OX11 0QR, United Kingdom

t: +44 (0) 1235 75 3019
e: thomas.buckland@ricardo.com

Ricardo-AEA Ltd is certificated to ISO9001 and ISO14001

Authors:

Mark Attree, Chris Williams, Sam Stephenson, Jamie Bost, Ancelin Coulon, Guy Hitchcock

Approved By:

Guy Hitchcock

Date:

17 November 2020

Ricardo Energy & Environment reference:

Ref: ED13676

Executive Summary

The A2 corridor through Swale Borough suffers from heavy traffic and congestion which has led to the declaration of 4 Air Quality Management Areas (AQMAs) along the A2 itself and one related AQMA in the St Paul's Street area of Sittingbourne. All the AQMAs have been declared on basis of exceedance of the Nitrogen Dioxide (NO_2) limit value of 40µgm^{-3} annual average. The annual average value relates to the average concentration over the year and there will times when the actual concentrations could be higher than this. There are also concerns in relation to particulate matter (PM) in the St Paul's Street AQMA. Since the commissioning of this work Keycol Hill has also been declared an AQMA but is not shown explicitly on the maps as an AQMA.

An interim Air Quality Action Plan (AQAP) was developed in 2017 to reduce pollution across all 5 AQMAs. Further work was then done in 2018 to provide a wider evidence base for the AQAP covering a modelling and source apportionment study and an assessment of initial options. This provided the basis for the full AQAP in 2019 which was approved by DEFRA. The revised AQAP took a more holistic AQAP combining AQMA specific actions and measures, plus provide a wider strategic approach to improving air quality across the Borough. A key plank of the proposed actions in the AQAP was the assessment and development of a Clean Air Zone, both a formal charging zone and non-charging additional measures targeting the AQMAs along the A2.

The report sets out an assessment of a range of potential measures to address air quality both locally and more strategically across the Borough including a specific assessment and feasibility of a Charging Clean Air Zone (CCAZ). The approach taken to the study builds on the guidance provided by the Government's Joint Air Quality Unit (JAQU) for Clean Air Zone feasibility studies to provide a robust assessment approach for Swale and the A2 corridor. The key steps of the assessment process undertaken were:

- *Baseline air quality modelling* – covering the whole A2, related roads and the AQMAs and focused on NO_2 concentrations. This was carried out for the base year in 2019 and a future year in 2022. This builds on the existing source apportionment work and related data sources to confirm the compliance gap to be addressed.
- *Development of potential mitigation options* - this task reviewed existing plans and policies, and worked with local stakeholders, to develop a long list of potential CAZ options. This was then reduced to through a stakeholder engagement workshop and simplified multi criteria assessment (MCA).
- *Appraisal of the mitigation options* – using the baseline model each of the options was assessed in the future year to estimate its air quality impact. This was complemented by an indicative cost benefit analysis (CBA) allowing comparison of the measures on both an air quality and cost effectiveness basis.

Current and forecast air quality along the A2

Air quality along the A2 was modelled using traffic data from the existing regional traffic model, fleet composition data collected from the previous source apportionment study, that latest emissions factors from DEFRA's Emission Factor Toolkit and our in-house dispersion model RapidAir®. The model was then verified and adjusted against 2019 monitoring data.

The modelling provides detailed results expressed in 2 ways to provide an assessment of air quality along the A2 and related AQMAs:

- Compliance data in relation to the air quality limit values for all roads in the modelled area – this extracts results at 4m from the roadside and presents the highest concentration along each road link.
- Monitoring point location results – which have been extracted both with the overall model adjustment factor (global) and adjusted to match the actual monitored value (site-specific) in

2019. These latter site-specific adjusted results are intended to reflect any specific conditions around the diffusion tube location that could be influencing the results.

The baseline compliance air quality results in 2019 indicated a number of areas where the NO_2 limit value is being exceeded principally in Sittingbourne at Keycol Hill, and in the St Paul's Street and East Street AQMAs. There is also a slight exceedance in Ospringe. In relation to the monitoring locations, 9 of the locations are showing exceedances of the 40 ugm^{-3} limit value.

Moving forward to 2022 the results show a significant improvement based on business as usual conditions, generated primarily by improvement to the vehicle fleet as vehicles renew and become cleaner. Road link based compliance results showed that no roads were expected to exceed the limit value although there are roads in Sittingbourne, again within the St Paul's Street and East Street AQMAs that are at risk of exceedance being above 35 ugm^{-3} which is within model error estimated from the model verification. The monitoring location results with the global adjustment reflect the same picture showing no monitoring sites expected to exceed in 2022. However, when using the local adjustment factor one monitoring site in St Paul's Street AQMA (SW82) is showing an exceedance and one location at Keycol Hill (SW124) is very close.

For the 2022 year a sensitivity test was also carried out to assess the impact of a slower fleet turnover potentially from an economic slow-down related to COVID 19. This sensitivity suggested that there could potentially be exceedances remaining in Sittingbourne in the St Paul's Street and East Street AQMAs.

This analysis suggested that although a standard business as usual assessment in 2022 indicated that there would be no exceedances, sensitivity assessment using site-specific adjustment at monitoring locations and slower fleet turnover could well result in exceedances in Sittingbourne. The highest level of NO_2 under these tests was 44 ugm^{-3} estimated at monitoring location SW82 in the St Paul's Street AQMA. So, the aim of any mitigation measures should to reduce the risk of these potential exceedances occurring, especially in St Paul's Street AQMA.

Developing the mitigation options

The starting point for the long list of options was a review of existing plans from Swale Borough Council (SBC), Kent County Council (KCC) and Transport for the South East (TfSE) as the key bodies responsible for transport in the area. The documents were evaluated looking at: air quality action plans, development plans, transportation strategy (incl. rail, active travel, taxi, parking) and sustainable growth, including any progress reports in these areas.

From these documents an initial long list of measures was generated by collating similar and overlapping measures into key themes. These themes were then reviewed to identify any potential gaps building on experience from measures being implemented in other CAZ cities or through the concept of Low Emission Strategies such as those developed in Southampton, Leicester and York. This initial long list defined 25 key groups in 4 themes:

1. A formal charging CAZ and options on this;
2. Low emission vehicle measures to promote and support the uptake of low emission vehicles;
3. Traffic and travel management to promote mode shift and the efficient flow of vehicles;
4. Longer term development policy.

The long list of measures was refined into a shortlist of measures through two stakeholder engagement workshops. The key stakeholders included in the workshops were:

- Relevant KCC departments i.e. KCC Highways; Transport Innovations; Public Transport; Transport and Development Planners
- Medway Council - Departments – Planning and Environmental protection
- All parish councils

- Swale Officers - Planning and Policy, Economy and Community Services, Environmental Protection, Environmental Services, Parking Services
- Relevant Swale Management Officers and Councillors
- All public transport sector operators (buses and trains)

The outcome of the shortlisting process was the generation of 6 key options to assess plus two packages of options as summaries below in Table ES1.

Table ES1 - Summary of short listed mitigation options

Option	Description
Charging CAZ B	CAZ B (covering HGV's, Buses and Taxis) charging vehicles that do not meet a Euro 6/VI standard for diesel vehicles operating along the A2 from A249 to A299, including St Paul's AQMA. Proposed exemption for 3 years for buses and taxis while supporting then upgrade to compliant vehicles
Charging CAZ D	CAZ D (covering HGV's, Buses, Taxis, LGVs and cars) charging vehicles that do not meet a Euro 6/VI standard for diesel or Euro 4 standard for petrol vehicles operating along the A2 from A249 to A299, including St Paul's AQMA. Proposed exemption for 3 years for buses and taxis while supporting then upgrade to compliant vehicles
Mode shift package	Mode shift package targeting Swale in general but focusing along the A2 including: - Travel plans – schools and businesses - Work with KCC in investment in walking and cycling infrastructure - Invest in secure cycle parking - Pilots/loans/trials with e-bikes/scooters - Car club in Sittingbourne and Faversham
Freight package	Package focused on freight, again covering the main Swale towns but with focus along A2, including: - Delivery and servicing plans, link to travel plans - Consolidation centre servicing Sittingbourne and Faversham
Electric vehicle support package	Package to promote electric cars and vans across Swale including: - Parking charge incentives - Charging infrastructure in Council car parks also working with businesses - Promotion – link to travel plans - E-car clubs linked to car clubs (could just shift car clubs here)
Pinch point parking removal	Remove pinch point parking on A2
Non charging Package	Bundle of mode shift, freight, electric vehicles and pinch point removal
CAZ B plus non charging package	This was a simple addition of the benefits of the CAZ B and the non-charging package. This was only carried out for the monitoring site results.

Appraisal of the mitigation options

The 6 shorted listed options and the two packages were appraised for their potential impact on air quality and with an indicative costs benefit analysis (CBA). A summary of the key air quality and cost benefit results associated with the modelled options is set out in the table below and discussed in the following sections.

Table ES2 - Summary results for the mitigation options

Category	Reference Case	CAZ B	CAZ D	EV	Freight	Mode Shift	Pinch Point	All non-charging	CAZ B + non-charging
Average reduction concentration reduction across all monitoring sites									
Reduction	0%	1.7%	18.4%	1.2%	0.6%	2.1%	0.3%	3.0%	4.7%
Number of monitoring sites exceeding or at risk (global adjustment)									
Exceeding	0	0	0	0	0	0	0	0	0
At risk	2	2	0	2	2	2	2	2	2
Number of monitoring sites exceeding or at risk (site-specific adjustment)									
Exceeding	1	1	0	1	1	1	1	0	0
At risk	1	1	0	1	1	1	1	2	2
Summary cost benefit analysis results (Million £)									
Total NPV	N/A	-15.0	-118.1	-1.9	0.3	-13.3	0.4	-15.6	-30.6
Implementation only	N/A	2.26	2.26	0.14	0.29	15.17	<0.01	15.61	17.86

Charging Clean Air Zones

Two formal CAZ options were assessed in terms of a full CAZ D covering all vehicle types and a CAZ B targeted at HGV's. These would both be enforced in the same way with a set of fixed ANPR cameras along the A2 and hence would have similar direct implementation costs to the Council estimated at about £2.2 million.

Clearly the CAZ D would generate the greatest air quality benefit as more vehicles are being targeted. On average it would reduce concentrations by some 18% resulting in no areas with exceedances of the annual NO_2 limit value or even being at risk of exceeding. The CAZ B has a much smaller impact as it is only targeting HGVs, many of which already meet the CAZ standard, and reduced concentrations on average by about 2%. However, this will still remove all exceedances with the possible exception of monitoring location SW82 in the St Paul's Street AQMA.

On the face of it this might indicate that the CAZ D would provide the greatest benefit for a similar cost. However, just implementation costs ignore the wider costs to vehicle owners for upgrading their vehicles. Taking these costs into account the CAZ D would cost local businesses and residents some £142 million in compliance costs to upgrade vehicles and have an overall negative net present value (NPV) from the CBA of £118 million over 10 years. This compares to the CAZ B which would have some £17 million in compliance costs borne by freight companies and an overall negative NPV of £15 million.

So both are costly measures to society as a whole but the CAZ B has a significantly lower cost while still largely mitigating any air quality limit value exceedance risk.

Non-charging measures

Four non-charging measures were assessed: a mode shift package, a freight package, support for electric vehicles and removal of pinch point parking. Of these the mode shift package was estimated to have the largest impact on air quality reducing concentrations by an average of 2.1% which is in fact a greater impact than the CAZ B. The EV measures had the next largest impact at a 1.2% average reduction in concentrations, followed by the freight measures at only a 0.6% average reduction. The smallest average impact was from the removal of pinch point parking, as might be expected, as the benefits of this measure are greatest at these specific points.

The costing of these measures was carried out in a fairly generic way as the specific details of what would be included was not developed and so the CBA can only be considered indicative. The mode shift package was the costliest as it assumed a significant investment in walking and cycling infrastructure of some £15 million. However, this provides a better, though still negative, overall NPV than a CAZ B of £13 million. This suggests it would be a better option for society in general than the CAZ B though it has higher direct costs to the public sector (in this case the County Council). It should also be noted that the mode shift CBA does not include the assessment of any wider health or congestion benefits.

The EV measure is the next most costly with a negative NPV of some £1 million overall, but with a potential implementation cost to the Borough and County Councils in terms of supporting charging infrastructure of some £137,000. The freight measures could potentially cost the councils some £300,000 but this would be outweighed by the air quality benefit to give a positive NPV for the measure. The pinch point parking removal is likely to fairly low cost, if no additional provision is made for parking elsewhere, and has air quality benefits that again outweigh the costs to give a positive NPV.

All the non-charging measures have a better overall NPV than either of the CAZ measures with two being positive. The mode shift measure also has a greater air quality impact than the CAZ B though not the CAZ D. The other measures all have lower, but still positive impacts on air quality.

A package approach

Two packages of measures were also considered: a combination of all the non-charging measures, and the CAZ B combined with the all of the non-charging measures. The impact of the latter package was not formally modelled but estimated by simply adding the impacts (and costs and benefits) of the CAZ B and package of non-charging measures.

The package of non-charging measures generated an average reduction in NO_2 concentrations of some 3%, about twice that of the CAZ B on its own. It also removes all exceedances of the limit value even the site-specific adjusted monitoring locations in St Paul's Street AQMA (though only just). The CBA indicates that it has a negative NPV of around £15 million which is the same as the CAZ B but with about twice the benefit to air quality.

Combining CAZ B with the package of non-charging measures gives an estimated reduction in concentrations of some 4.7% which is clearly better than either on their own, but less than the CAZ D. This combined package also removes all exceedances even for the site-specific adjusted monitoring location in St Pauls Street AQMA at monitoring location SW82. It has a negative NPV of some £30 million (basically twice that of the CAZ B and Non-charging package individually), but this is an order of magnitude less than the cost of the CAZ D.

Recommendations

Air quality along the A2 is expected to improve significantly over the next 3 years out to 2022 as the vehicle fleet renews and the proportion of vehicles of the latest Euro emission standard increases significantly. As such by 2022 a standard reference forecast suggests the annual average NO_2 limit values will be achieved. However, there is clearly uncertainly in the modelling and exploring this through site-specific adjustment at monitoring locations and a sensitivity test with a slower fleet turn over indicates that there is a risk of remaining exceedances especially in the St Pauls Street AQMA. As such there is still a need to take further action to reduce transport related emissions and concentrations along the A2.

The implementation of a Charging Clean Air Zone would reduce concentrations and manage the risk of further exceedances. However, the overall economic cost of these measures would be high (£30 million for a CAZ B and £118 million for a CAZ D) and likely to be politically challenging to implement. As such given the scale of the air quality challenge, largely around managing risk rather than tackling significant exceedances, these would appear to be a disproportionate response.

This suggests that a more appropriate approach is to implement a package of non-charging measures which have been shown to have about twice the benefit of the CAZ B, in terms of air quality, but at a similar economic cost. It is also clear that there would be further benefits for example in terms of health from active travel that have not been accounted for here.

Moving forward we would recommend that the Swale Borough Council work with the Kent County Council, who are the highways authority and so largely responsible for implementing transport measures, to develop in more detail a package of measures to reduce traffic, improve flow and improve the vehicle fleet operating along the A2 comprising:

- The removal of key pinch point parking areas – which is likely to be low cost (dependant on whether alternative parking locations are required), have both air quality and traffic flow benefits and is already being explored by the County Council.

- Assessment of the feasibility of a freight consolidation centre serving Sittingbourne (and potentially other areas) along with developing Delivery and Servicing Plans (DSPs) with local business to reduce freight movements in the area.

- Further work on the development of EV charging infrastructure and other incentives to accelerate the uptake of EVs in the area.

- Significant investment in walking and cycling schemes, travel plans and other information campaigns, as well as exploring micro-mobility options to manage traffic growth and congestion. This could also be an important element of economic recovery following the COVID 19 pandemic and would support wider public health in the area.

Table of contents

Appendices

Glossary

Abbreviation	Description
ANPR	Automatic Number Plate Recognition
AQAP	Air Quality Action Plan
AQD	Air Quality Directive
AQMA	Air Quality Management Area
BEIS	Department for Business, Energy, and Industrial Strategy
CAZ	Clean Air Zone
CBA	Cost Benefit Analysis
CNG	Compressed Natural Gas
CAPEX	Capital expenditure
CO2	Carbon dioxide
Defra	Department for Environment, Food, and Rural Affairs
DfT	Department for Transport
EFT	Emissions Factor Toolkit
EV	Electric vehicle
FPN	Fixed Penalty Notice
GHG	Greenhouse gas
HGV	Heavy goods vehicle
JAQU	Joint Air Quality Unit of the UK government
KCC	Kent County Council
LAEI	London Atmospheric Emissions Inventory
LAQM	Local Air Quality Management
LGV	Light goods vehicle
MCA	Multi-criteria assessment to determine short list of CAZ options
NO2	Nitrogen dioxide
NOX	Oxides of nitrogen
NPV	Net present value
OPEX	Operating expenditure
PM	Particulate matter
RMSE	Root mean square error
SBC	Swale Borough Council
SCRT	Selective Catalytic Reduction and particle Trap
SHM	Swale Highway Model, a traffic model developed by Sweco
TfL	Transport for London
TfSE	Transport for South East
TRO	Traffic Regulation Orders
ULEV	Ultra low emission vehicle
ULEZ	Ultra low emission zone
USEPA	US Environmental Protection Agency

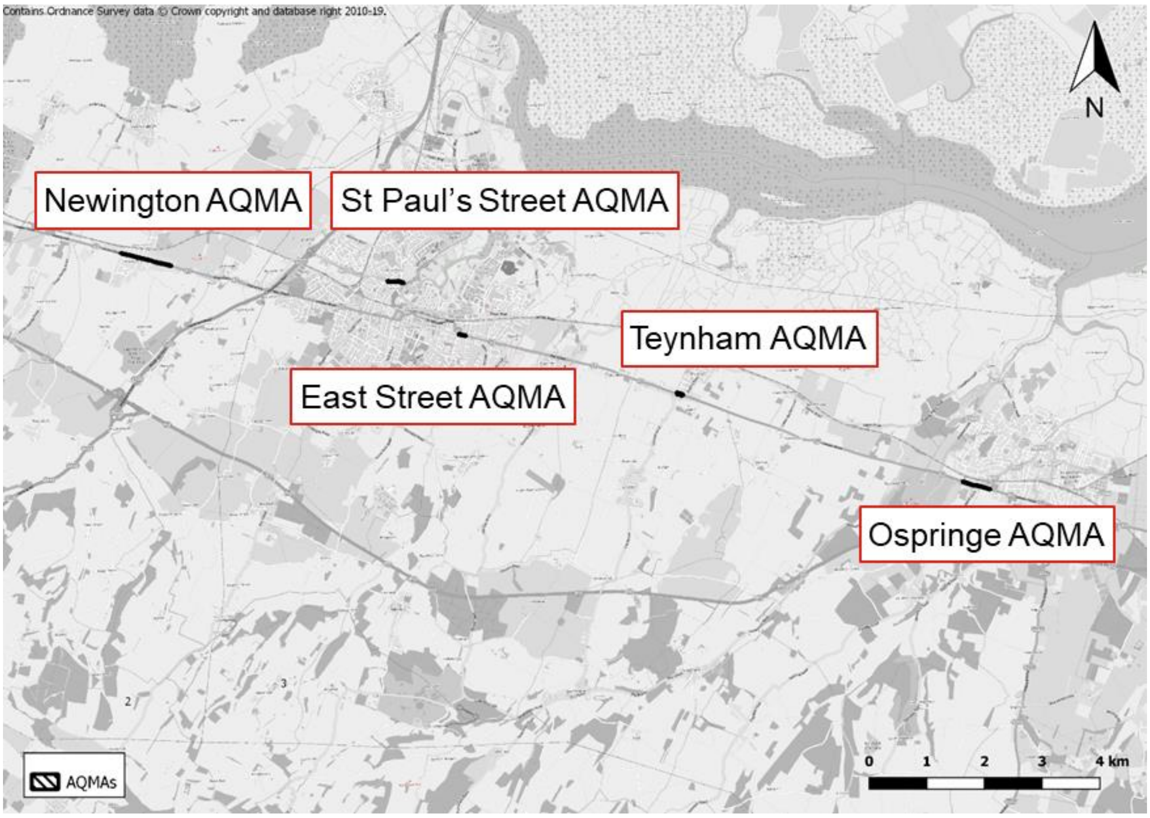
1 Introduction and scope of feasibility study

Swale Borough Council (SBC) has commission Ricardo to assess the impact and feasibility of a range of measures to address air quality issues, specifically Nitrogen Dioxide (NO_2) concentrations, along the A2 route through the Borough. The study has reviewed potential measures to address air quality both locally and more strategically across the Borough including a specific assessment and feasibility of a Charging Clean Air Zone (CCAZ). The study has carried out an air quality impact assessment of the measures along with a simple cost benefit analysis and sets out recommendations for progressing measures to improve air quality along the A2 corridor.

1.1 Background

The A2 corridor through the Borough suffers from heavy traffic and congestion which has led to the declaration of 4 Air Quality Management Areas (AQMAs) along the A2 itself and one related AQMA in the St Paul's Street area of Sittingbourne, as illustrated in Figure 1-1 below. All the AQMAs have been declared on basis of exceedance of the Nitrogen Dioxide (NO_2) limit value, but there are also concerns in relation to particulate matter (PM) in the St Paul's Street AQMA. Since the commissioning of this work Keycol Hill has also been declared an AQMA but is not shown explicitly on the maps as an AQMA.

Figure 1-1 Air Quality Management Areas in Swale Borough



Note: Keycoll Hill was declared an AQMA on 23/10/2020 towards the end of this study and as such is not shown on the maps.

An interim Air Quality Action Plan (AQAP) was developed in 2017 to reduce pollution across all 5 AQMAs. Further work was then done in 2018 to provide a wider evidence base for the AQAP covering a modelling and source apportionment study and an assessment if initial options[1][2]. This provided the basis for the full AQAP in 2019 which was approved by DEFRA[3]. The revised AQAP took a more holistic AQAP combining AQMA specific actions and measures, plus provide a wider strategic approach to improving air quality across the borough. A key plank of the proposed actions in the AQAP was the assessment and development of a Clean Air Zone, both a formal charging zone and non-charging additional measures targeting the AQMAs along the A2.

Ricardo was commissioned to carry out the feasibility study for the CAZ, building on their work with a number of UK CAZ projects, and this report summaries the outcome of that study.

1.2 Overview of assessment approach

The approach taken to the feasibility study builds on the approach taken for other CAZ studies across the UK and guidance provided by the Government's Joint Air Quality Unit (JAQU) to support these studies to provide a robust assessment approach for Swale and the A2 corridor. The key steps of the assessment process undertaken were:

- Baseline air quality modelling – covering the whole A2, related roads and the AQMAs and focused on NO_2 concentrations. This was carried out for the base year in 2019 and a future year in 2022. This builds on the existing source apportionment work and related data sources to confirm the compliance gap to be addressed.

- Long list of options–this task reviewed existing plans and policies, and worked with local stakeholders, to develop a long list of potential CAZ options.

- Short list of options – a qualitative assessment of the options through a stakeholder workshop and simplified multi criteria assessment (MCA) was carried out to reduce the long list of a short list for detailed assessment. As part of this short-listing process the project team also worked with the borough and county council to define the assumptions to be used for the assessment.

- Air quality modelling of the options – using the baseline model each of the options was assessed in the future year, using the assumptions agreed above.

- Cost benefit analysis – a basic assessment of costs and benefits of the options was carried out allowing comparison of the measures on both the impact on air quality and cost effectiveness.

The details of each of these steps and the resulting outcomes in terms of the short list of measures, their impacts on air quality and the cost benefit analysis are set out in the following sections. The final section pulls together all of these results to provide a set of recommendations for tackling air quality along the A2.

[1] Swale Strategic AQAP 2018 – 2022, Report 1: Source Apportionment and Options Assessment. October 2018, Phlorum

[2] Swale Strategic AQAP 2018 – 2022, Report 2: AQMA options assessment, October 2018, Plorum

[3] Swale Borough Council, Air Quality Action Plan (2018 – 2022), 2019

2 Baseline air quality modelling

2.1 Study methodology

Baseline conditions in 2019 and the impact of future 2022 scenarios have been assessed using atmospheric dispersion modelling to predict the concentrations of NO_2. The general approach taken was:

- Collect and analyse recent traffic, pollutant monitoring, meteorological and background pollutant concentration data for use in a dispersion modelling study.
- Model Baseline road traffic emissions in 2019 using the RapidAir atmospheric dispersion model and refine/verify the model to gain good agreement with nearby NO_2 monitoring data.
- Use the verified dispersion model to predict annual mean pollutant concentrations at NO_2 monitoring locations within the study area for the following three scenarios:
- Current/most recent year where pollutant measurements are available (2019) Baseline. This represents 2019 traffic conditions within Swale and provides an indication of current air quality conditions.
- Future year Baseline (2022) without intervention.
- Future year (2022) with a shortlist of individual interventions.
- Describe the predicted impacts of the shortlisted options on air quality within the AQMAs in Swale, referring to modelled concentrations at NO_2 monitoring sites and contour maps of NO_2 concentrations across the study area.

The modelling methods outlined in the Defra Technical Guidance LAQM.TG(16) were used throughout the study.

2.2 Study area

2.2.1 Model domain

To assess the transport and air quality impacts of the scheme, a model domain is required that covers the potential scheme options and relevant AQMAs. The model domain used is shown in Figure 2-1 and Figure 2-2 and has been chosen to cover the following:

- The full extent of the A2 through Swale and adjoining roads which is the main air quality concern in the borough;
- All of the AQMAs in Swale;
- Areas of concern identified from measurement data.

Concentrations were calculated across a grid covering this area at 3m resolution.

2.2.2 Baseline air quality

Swale Borough Council operates a wide network of monitoring locations comprising both automatic monitoring stations and passive diffusion tube samplers. All available locations where NO_2 monitoring data were measured during 2019 were specified as receptors in the model; and where appropriate, used for model verification and calculating model performance statistics including the Root Mean Square Error (RMSE). A map of the monitoring locations is presented in Figure 2-1 and Figure 2-2.

Figure 2-1: Monitoring sites operated in 2019 (west)

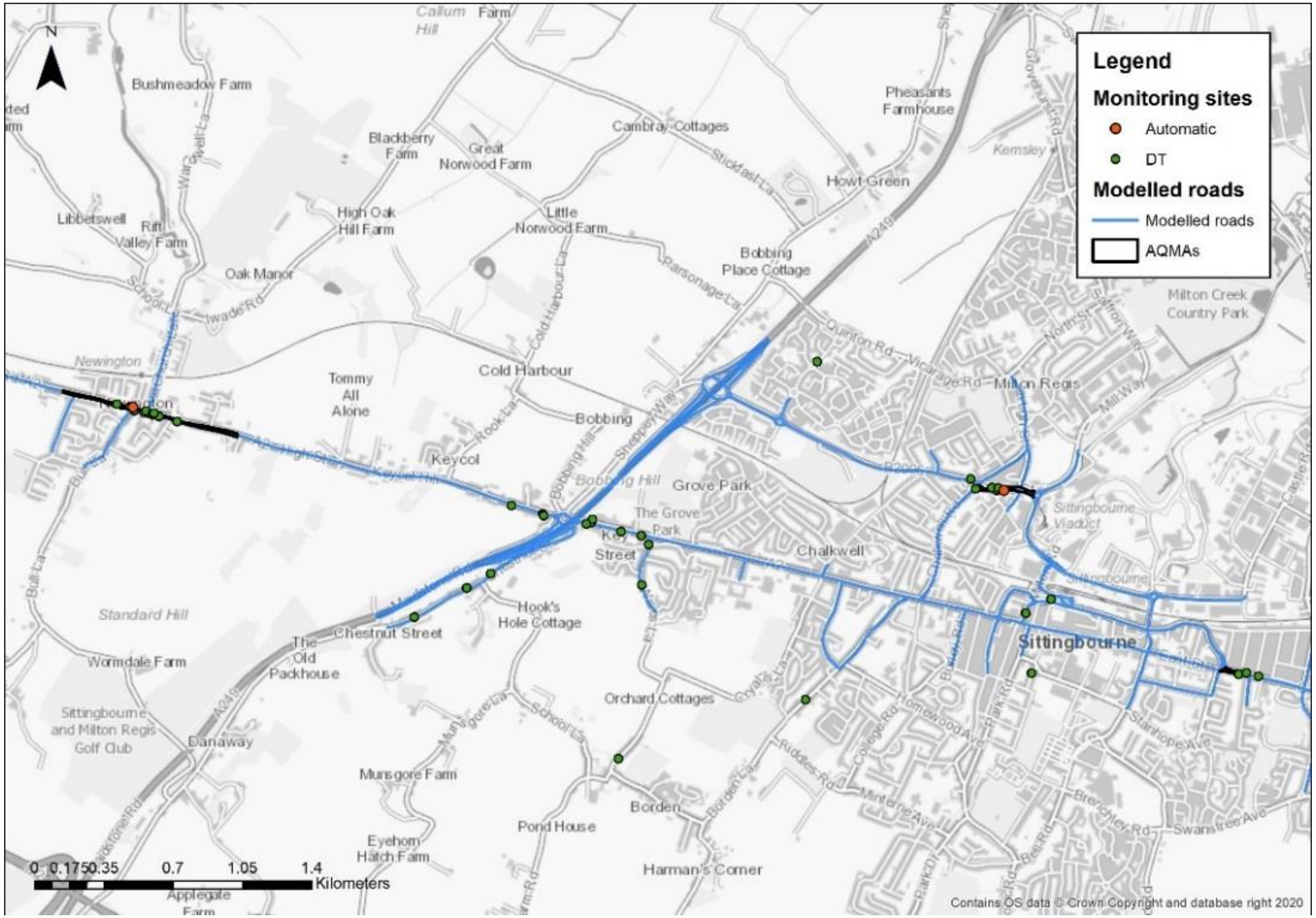
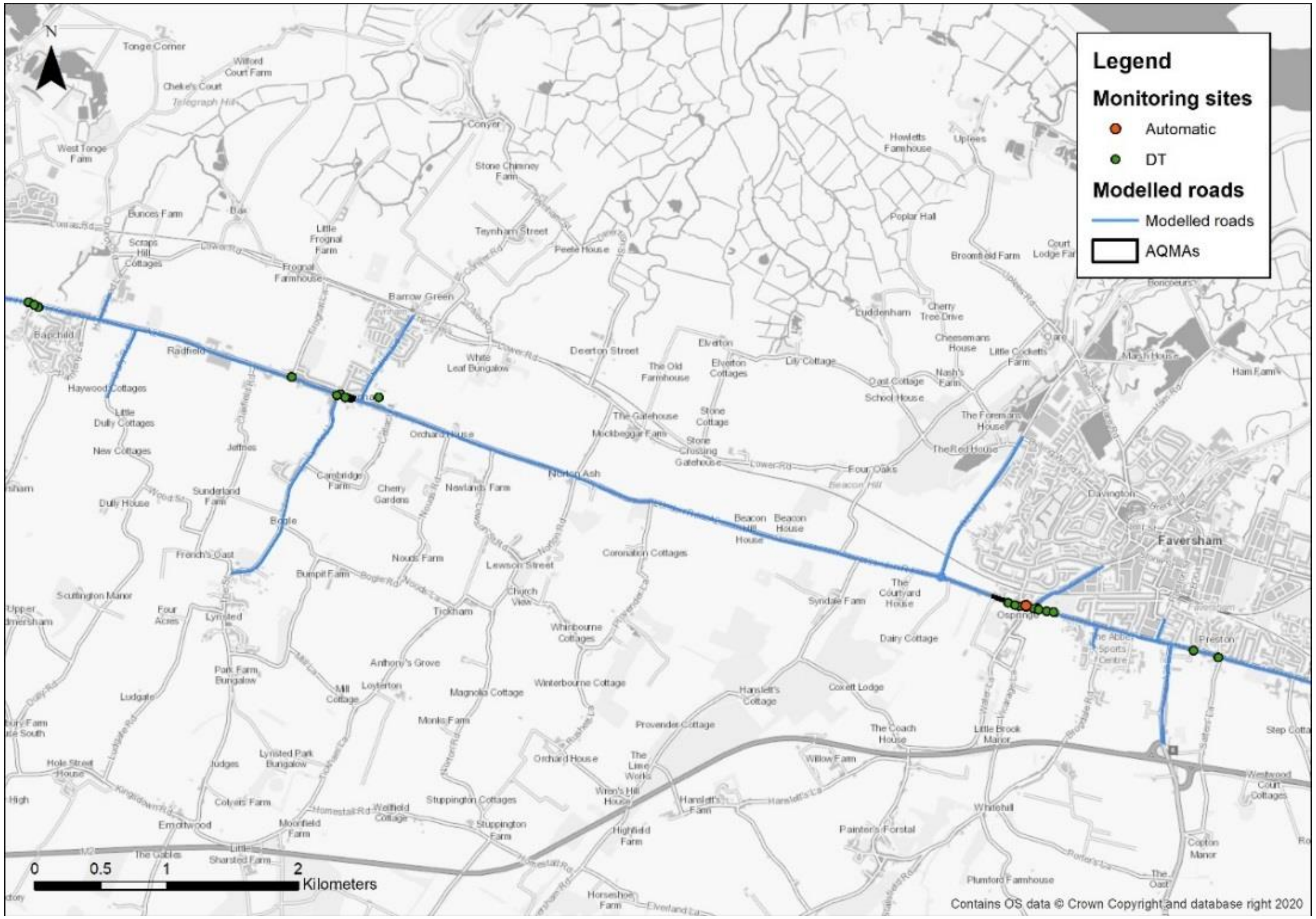


Figure 2-2: Monitoring sites operated in 2019 (east)



2.3 Model description and setup

2.3.1 Model description

The RapidAir© dispersion modelling system was used for the study. This is Ricardo Energy & Environment's proprietary modelling system developed for urban air pollution assessment.

The model calculates pollutant concentrations through convolution of an emissions grid with dispersion kernels derived from the USEPA AERMOD[4] model. The physical parameterisation (release height, initial plume depth and area source configuration) closely follows guidance provided by the USEPA in their statutory road transport dispersion modelling guidance[5]. AERMOD provides the algorithms which govern the dispersion of the emissions and is an accepted international model for road traffic studies (it is one of only two mandated models in the US and is widely used overseas for this application). The combination of an internationally recognised model code and careful parameterisation matching international best practice makes RapidAir demonstrably fit for purpose for this study.

The model produces high resolution concentration fields at the city scale (1 to 3m scale) so is ideal for spatially detailed compliance modelling. A validation study has been conducted in London using the same datasets as the 2011 Defra inter-comparison study[6]. Using the LAEI 2008 data and the measurements for the same time period the model performance is consistent (and across some metrics performs better) than other modelling solutions currently in use in the UK. A RapidAIR model validation paper has also recently been published with our partners at Strathclyde University in the well-known Environmental Modelling and Software journal[7].

2.3.2 Chemistry, meteorology and topology

NOx to NO_2 chemistry was modelled using the Defra NOx/NO_2 calculator (v7.1). Modelled annual mean road NOx concentrations were combined with background NOx and a receptor-specific f-NO_2 fraction to calculate NO_2 annual mean concentrations. The receptor-specific f-NO_2 fraction was calculated by dividing the modelled road primary NO_2 contribution by the modelled road NOx contribution at each receptor.

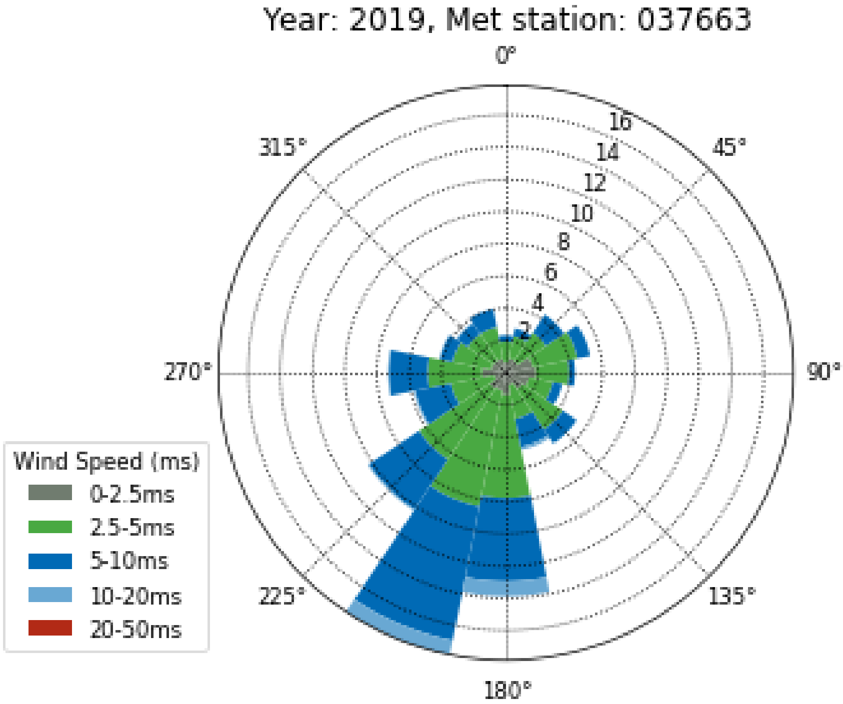
2.3.3 Meteorology

Modelling was conducted using the 2019 annual surface meteorological dataset measured at Biggin Hill weather station (see the 2019 wind rose in Figure 2-3). The dataset was processed in house using our own meteorological data gathering and processing system. We used freely available overseas meteorological databases which hold the same observations as supplied by UK meteorological data vendors. Our RapidAir model also takes account of upper air data which is used to determine the strength of turbulent mixing in the lower atmosphere; this was obtained from the closest radiosonde site and processed with the surface data in the USEPA AERMET model. We have utilised data filling where necessary following USEPA guidance which sets out the preferred hierarchy of routines to account for gaps (persistence, interpolation, substitution). AERMET processing was conducted following the USEPA guidance. To account for differences between the meteorological site and the dispersion site, surface parameters at the meteorological site were included as recommended in the guidance and the urban option specified for the dispersion site.

---

[4] https://www3.epa.gov/ttn/scram/dispersion_prefrec.htm#aermod
[5] https://www.epa.gov/state-and-local-transportation/project-level-conformity-and-hot-spot-analyses
[6] https://uk-air.defra.gov.uk/research/air-quality-modelling?view=intercomparison
[7] Masey, Hamilton, Beverland (2018) Development and evaluation of the RapidAir® dispersion model, including the use of geospatial surrogates to represent street canyon effects

Figure 2-3 Biggin Hill wind rose in 2019



2.3.4 Non-road transport modelling and background concentrations

Emissions from non-road sources were considered in the study by using spatially varying background maps. This study uses the 2017 base year LAQM background maps published by Defra. The contributions from local road transport source sectors that were modelled explicitly were subtracted from the background maps. Defra's 2022 background map was also downloaded and processed as described to use for the future year reference case.

2.3.5 Roadside receptors and grid

RapidAir was used to model concentrations at 3m grid resolution. As RapidAir produces concentration grids (in raster format), modelled NO_2 concentrations can be extracted at receptor locations anywhere on the 3m resolution model output grid. For assessment of compliance with the Air Quality Directive, annual mean concentrations at a distance of 4m from the kerb and at 2m height were extracted from the RapidAir model outputs at 10m intervals along each road. This provides an assessment of compliance at relevant roadside locations where there may be public access as specified in the Air Quality Directive (AQD) requirements Annex III A, B, and C3.

Annex III of the AQD specifies that microscale sampling should be at least 25m from the edge of major junctions. Therefore, when reporting model results relevant to compliance with the AQD, locations up to 25m from the edge of major junctions in the model domain were excluded.

2.3.6 Road geometry

Road geometry information was derived from the Ordnance Survey OpenMap Local dataset. Road widths were estimated using aerial imagery in Google Maps.

2.3.7 Canyon modelling

The presence of buildings either side of a road can introduce 'street canyon' effects which result in pollutants becoming trapped, leading to increased pollutant concentrations. Several clusters of buildings in the model domain produce street canyons, which contribute to air quality issues.

Street canyon impacts were modelled using the AEOLIUS model, which is included in RapidAir. Street canyons were identified using building height data sourced from Ordnance Survey (OS) Mastermap data provided by the Council.[8] These canyon locations were checked using Google Street View and local knowledge. The locations of modelled street canyons are shown in Figure 2-4.

2.3.8 Gradients, tunnels and flyovers

Gradient effects were included for relevant road links during emissions calculations. LIDAR Composite Digital Terrain Model (DTM) datasets at 1m resolution are available over the model domain[9]. Link gradients across the model domain were calculated by extracting start and end node elevations for road links from the LIDAR DTM datasets.

The Emissions Factor Toolkit (EFT) v9.0, includes gradient effects in its emissions calculations, and was used in this assessment. The adjustment in the EFT applies to roads with gradients of 2.5% or greater. Figure 2-5 shows the roads where gradient effects were included during emission calculations.

No modelling of tunnels or flyovers is included in the modelling, in order to provide a worst-case estimation of air quality impacts at a height of 2m.

[8] https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html
[9] http://environment.data.gov.uk/ds/survey/#/survey

Figure 2-4: Modelled street canyons

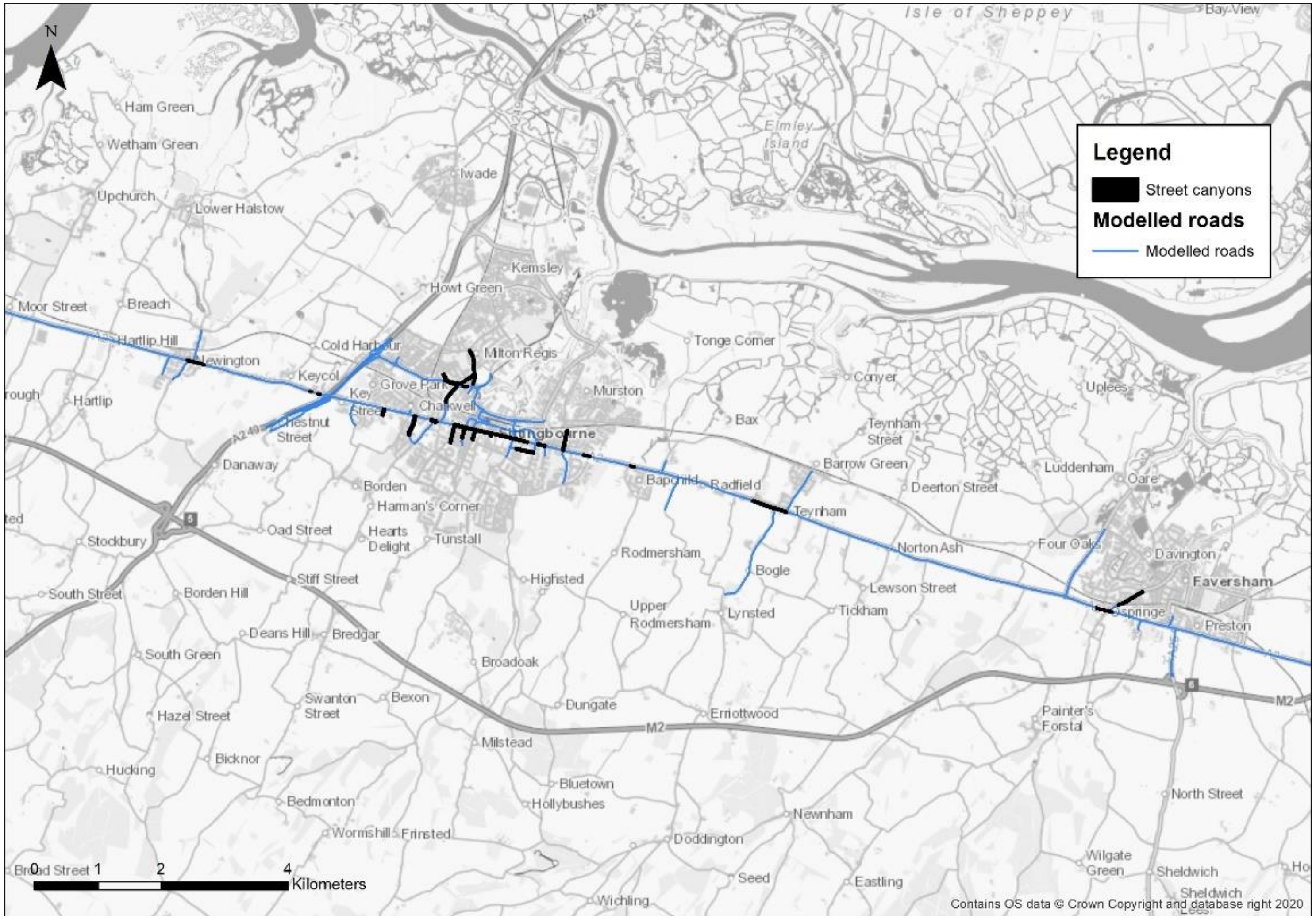
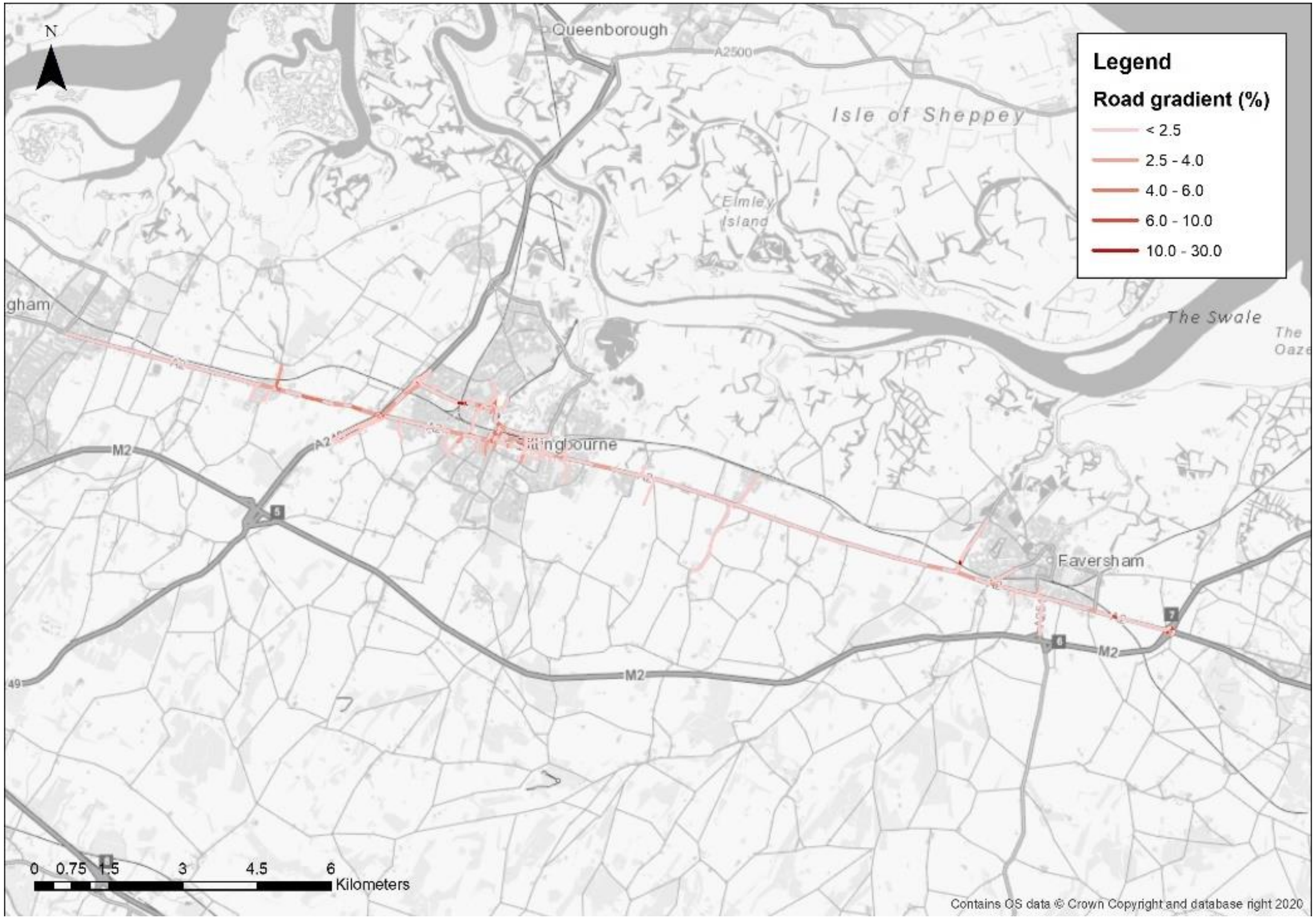


Figure 2-5: Modelled gradients



2.4 Road traffic modelling

The development of the emission inventories was carried out through the following process:

1. Collation of traffic activity data;
2. Traffic flow and fleet data were combined with emission factors from the most recent version of the Emission Factor Toolkit (EFT), version 9.1b[10] to provide total annual emissions for the modelled road links.

Each step is described below.

2.4.1 Emission factors

Emissions from all modelled road traffic sources were calculated using speed-dependent vehicle emission factors for NO_X and primary NO_2 from the latest version of the Emission Factor Toolkit (EFT), version 9.1b. The emission factors for NO_X are derived from COPERT, while the emission factors for primary NO_2 are derived from the National Atmospheric Emissions Inventory. COPERT is a European database of emission factors which is recommended for the quantification of road-transport emissions. These factors provide emission factors categorised by vehicle size, age, and Euro classification, taking into account average vehicle mileage and engine degradation.

The EFT uses these factors to calculate emissions along road links given traffic flow, vehicle split, speed, and gradient information.

2.4.2 Traffic flows and speeds

Traffic data for the study area was taken from the Swale Highway Model (SHM)[11]. This model was developed by Sweco on behalf of Kent County Council (KCC) in order to test the traffic impacts of both new developments and transport infrastructure across the area. The transport model results include traffic flows for the following periods for the years 2017 and 2027:

- AM peak (07:00 to 10:00);
- Interpeak (10:00 to 16:00);
- PM peak (16:00 to 19:00);
- Outside peak (19:00 to 07:00).

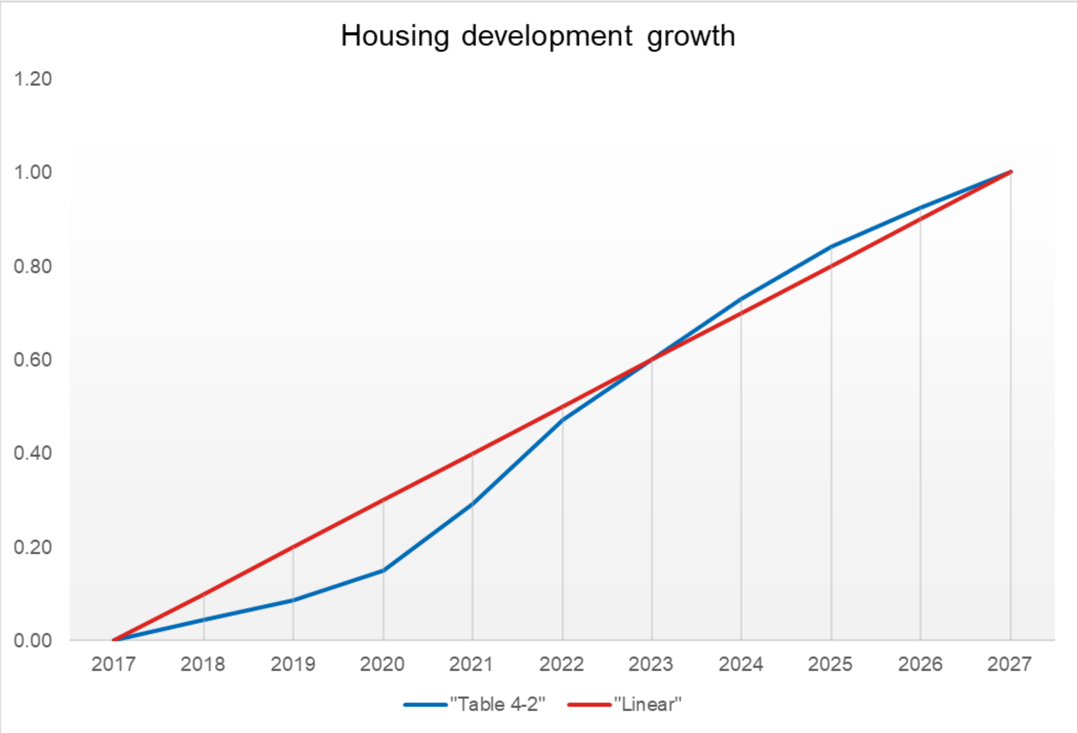
The 2017 transport model output was adjusted to represent the baseline year of 2019 and a CAZ implementation year of 2022. The housing development growth ratio from the Swale Highway Model, as illustrated Figure 2-6, was used to project traffic flows and speed for 2019 (ratio=0.09) and 2022 (ratio=0.47) from the 2017 traffic flows.

---

10 https://laqm.defra.gov.uk/review-and-assessment/tools/emissions-factors-toolkit.html

11 Sweco (2019), Swale Highway Model: Reference Case Forecasting Report

Figure 2-6 – Swale housing development growth from Swale Highway Model



2.4.3 Vehicle fleet composition

Results from an ANPR survey provided by Swale Borough Council were used to derive the vehicle fleet composition for 2019; the fleet projection tool in the Emissions Factors Toolkit published by Defra was then used to project this fleet to the 2022 future baseline year. This project is based on national assumptions to local fleet turnover may not necessarily be the same as this, but this is the best available approach to estimating future fleet composition.

Information on the baseline Euro standard mix (traffic composition & age) was collected in ANPR surveys at three locations along the A2 (London Road, Key Street, and Ospringe Street).

The Euro fleet composition for cars, LGVs, and HGVs were derived from the ANPR surveys, as sufficient data was available to derive a robust local fleet. For other vehicle types, the national average fleet split was used. Table 2-1 shows the Euro fleet distribution for cars, LGVs, and HGVs derived from the ANPR surveys. The projected 2022 fleet is presented in Table 2-2.

Table 2-1: Fleet age splits, ANPR

Vehicle type	Pre-Euro 1/I	Euro 1/I	Euro 2 / II	Euro 3 / III	Euro 4 / IV	Euro 5 / V	Euro 6 / VI	Euro 6c	Euro 6d
Petrol Car	-	0.2%	0.5%	4.5%	20.1%	46.8%	9.1%	18.8%	-
Diesel Car	-	0.2%	0.5%	4.5%	20.1%	46.8%	9.1%	18.8%	-
LGV	-	0.6%	0.5%	8.0%	18.1%	50.7%	22.1%	-	-
HGV	-	0.5%	0.6%	7.4%	7.5%	18.5%	65.5%	-	-

Table 2-2: Fleet age split projections, 2022

Vehicle type	Pre-Euro 1/I	Euro 1/I	Euro 2 / II	Euro 3 / III	Euro 4 / IV	Euro 5 / V	Euro 6 / VI	Euro 6c	Euro 6d
Petrol Car	-	-	-	0.9%	5.6%	19.2%	12.7%	61.6%	-
Diesel Car	-	-	-	0.6%	5.8%	27.7%	17.4%	24.2%	24.3%
LGV	-	-	-	0.8%	5.3%	19.2%	13.1%	28.5%	33.1%
Rigid HGV	-	-	-	1.4%	1.6%	9.1%	87.9%	-	-
Artic HGV	-	-	-	0.2%	0.3%	3.8%	95.8%	-	-

2.5 Model uncertainty, verification and adjustment

2.5.1 Model uncertainty

There were key uncertainties in the traffic data that could affect model results:

- The results of a transport model for traffic flows and speeds were used and projected to the relevant years, rather than using observed traffic data on the modelled road links in 2019.
- ANPR surveys were only available at three locations within the modelling domain and did not include taxis or buses. Details of fuel use were also not available, so national average statistics were used that may not be fully representative of the vehicle fleet in Swale.
- The impact of COVID-19 on traffic levels in the coming years is uncertain.

In light of this uncertainty, two approaches were taken to identifying locations at risk of exceedance:

- Concentrations at monitoring sites have been calculated using a site-specific adjustment factor, in order to ensure that maximum concentrations are captured;
- Any concentrations that are within 5.2 $\mu g.m^{-3}$ of the Air Quality Objective (the RMSE) are considered to be 'at risk' of exceeding due to uncertainty in the model, for example in the event that fleet turnover in the Swale area does not match the rapid turnover which is predicted to occur naturally.

The impact of Covid-19 on future air quality is difficult to quantify, and is a significant cause of additional uncertainty in the results of this study. In order to quantify the uncertainty associated with Covid-19, a simple sensitivity was carried out following guidance provided by the Joint Air Quality Unit (JAQU). JAQU recommend that sensitivity should be assessed by modelling the assumption that Covid-19 will delay fleet turnover by a year, i.e. that vehicle owners and businesses hold on to their existing vehicles for a year longer. This approach has been used in a number of other CAZ studies.

2.5.2 Model verification and adjustment

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations; this helps to identify how the model is performing and if any adjustments should be applied. The verification process involves checking and refining the model input data to try and reduce uncertainties and produce model outputs that are in better agreement with the monitoring results. This can be followed by adjustment of the modelled results if required. The LAQM.TG(16) guidance recommends making the adjustment to the road contribution of the pollutant only and not the background concentration these are combined with.

The approach outlined in LAQM.TG(16) section 7.508 – 7.534 (also in Box 7.14 and 7.15) has been used in this case. All roadside automatic and diffusion tube NO_2 measurement sites near modelled roads in Swale have been used for model verification with sufficient (> 75 %) data capture in 2019 (n = 51).

It is appropriate to verify the performance of the RapidAir© model in terms of primary pollutant emissions of nitrogen oxides (NOx = NO + NO_2). To verify the model, the predicted annual mean Road NOx concentrations were compared with concentrations measured at the various monitoring sites during 2019.

The model output of Road NOx (the total NOx originating from road traffic) was compared with measured Road NOx, where the measured Road NOx contribution is calculated as the difference between the total NOx and the background NOx value. Total measured NOx for each diffusion tube was calculated from the measured NO_2 concentration using the latest version of the Defra NOx/NO_2 calculator (v7.1).

The initial comparison of the modelled vs measured Road NOx identified that the model was under-predicting the Road NOx contribution at most locations. Refinements were subsequently made to the model inputs to improve model performance where possible.

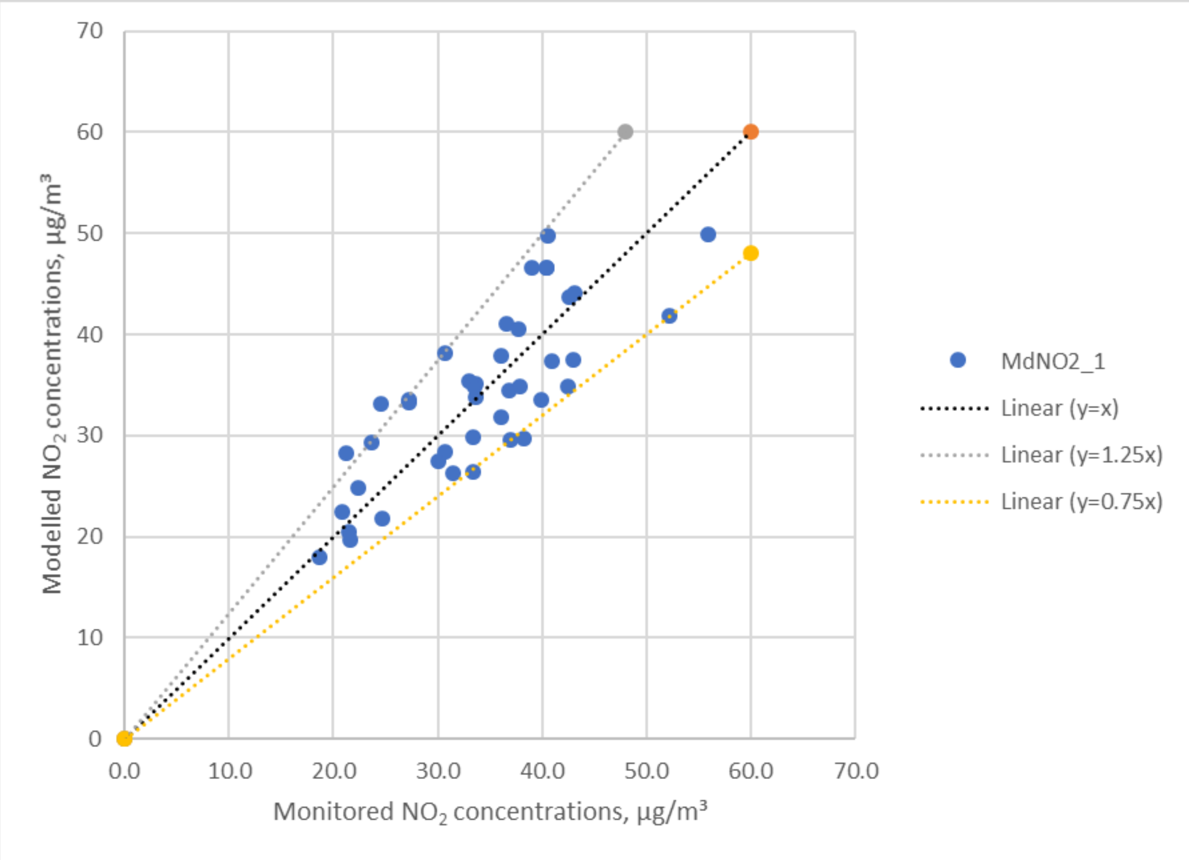
The gradient of the best fit line for the modelled Road NOx contribution vs. measured Road NOx contribution was then determined using linear regression and used as a global/domain wide Road NOx adjustment factor. This factor was then applied to the modelled Road NOx concentration at each discretely modelled receptor point to provide adjusted modelled Road NOx concentrations. The total annual mean NO_2 concentrations were then determined using the NOx/NO_2 calculator to combine background and adjusted road contribution concentrations.

Some clear outliers were apparent during the model verification process, whereby we were unable to refine the model inputs sufficiently to achieve acceptable model performance at these locations. There are a number of reasons why this could be the case e.g.

- A site located next to a large car park, bus stop, or additional emission source that has not been explicitly modelled due to unknown activity data.
- Sites located underneath trees or vegetation i.e. unsuitable locations for diffusion tubes to measure NO_2 concentrations effectively.
- No traffic model road link included where the NO_2 sampler is located, not all road links included e.g. at a junction, or insufficiently resolved traffic information at the junction e.g. resolution of speed information.

A number of sites were not used for verification because they were either outside of the modelling area or had poor data capture or missing data. In addition, 4 out of remaining 45 monitoring sites were considered as outliers and were therefore excluded from the verification process. Appendix 1 contains a table of outliers and reasons for exclusion. A primary NOx adjustment factor (PAdj) of 2.4882 was derived and applied to all modelled Road NOx data prior to calculating an NO_2 annual mean. Adjusted modelled and measured NO_2 concentrations are presented in Figure 2-7.

Figure 2-7 – Monitored vs. modelled NO_2 concentrations (µg m^{-3})



To evaluate the model performance and uncertainty, the Root Mean Square Error (RMSE) for the observed vs predicted NO_2 annual mean concentrations was calculated, as detailed in Technical Guidance LAQM.TG(16). These calculations are presented in Appendix 1. The RMSE is 5.2 µg.m^{-3} after the exclusion of outliers.

2.6 Baseline results

The modelling provides detailed NO_2 concentration data on a 1m x 1m grid over the study area and so allows the extraction of results for all relevant receptor location. In this case results have been extracted in 2 ways to provide an assessment of air quality along the A2 and related AQMAs:

- Compliance data in relation to the Air Quality Directive for all roads in the modelled area – this extracts results at a distance of 4m from the kerb and at 2m height were extracted at 10m intervals along each road and presents the highest concentration along each road link.

- Monitoring point location results – which provide relevant exposure for Local Air Quality Management purposes which is often closer to the kerb than the 4m criteria used above. These have been extracted both with the overall model adjustment factor (global) and adjusted to match the actual monitored value (site-specific) in 2019. These latter site-specific adjusted results are intended to reflect any specific conditions around the diffusion location that could be influencing the results.

The results in relation to road link compliance and monitoring sites are set out in the following sections.

2.6.1 Compliance results along road links

The road link based results are illustrated in Figure 2-8 through Figure 2-15 and present the maximum modelled concentrations at 4m from the kerb along each link in the study area, for comparison with the Air Quality Objective. These are all modelled results and cannot be compared directly with results at monitoring locations which may be nearer or further away from the road. However, they do provide a prediction of air quality compliance for all roads across the study area. Roads in red exceed the Objective; amber roads are classified as being 'at risk' of exceeding, given model uncertainty. For the 2022 reference and sensitivity results maps are not presented for the Faversham and Newington areas, as concentrations along all links in these regions are predicted to be below 35 $\mu g.m^{-3}$.

2019 base year

The base year data shows exceedances in the main AQMAs in Sittingbourne in St Paul's Street and East Street as would be expected. It also identifies the exceedance in Keycol Hill running up to the A249 which has now been declared an AQMA. However, the modelling also indicates other exceedances along a number of sections of the A2 in Sittingbourne, where no monitoring currently takes place, particularly around busy junctions along Key Street, London Road and Canterbury Road.

A single small section of the A2 in Faversham at the Ospringe Street/Ospringe Road junction is predicted to exceed the Objective. However, no exceedances are predicted to occur in the Teynham and Newington AQMA and more generally in Ospringe AQMA, and predicted concentrations in these areas are generally low. Most monitoring sites in these areas did not measure exceedances in 2019.

Exceedances are also predicted to occur along the majority of the A249. However, as this road is part of the Strategic Road Network and is managed by Highways England, concentrations along this road have not been considered further in this study.

2022 business as usual

Moving forward to 2022 the results show a significant improvement based on business as usual conditions, generated primarily by improvement to the vehicle fleet as vehicles renew and become cleaner. Road link based compliance results show that no roads were expected to exceed the objective value although there are roads in Sittingbourne, within the St Pauls Street and East Street AQMA's that are at risk of exceedance being above 35 $\mu g.m^{-3}$ which is within model error estimated from the model verification

However, there is level of uncertainty in the results particularly in relation to projected traffic flows and the turnover of the fleet, hence a sensitivity test was developed.

2022 COVID sensitivity

As described in Section 2.5.1 a sensitivity test was developed with a slower fleet turn over to represent what might be the impact of an economic slow down as a result of the COVID 19 situation. This assumes that fleet turnover is delayed by 1 year. These results indicate that under these conditions exceedances would remain in the St Paul's Street and East Street AQMAs. Also small exceedances are predicted to occur along the A2 near the two junctions between West Street/St. Michael's Road and London Road/Hawthorne Road, as the result of congestion and low traffic speeds associated with the junctions.

Figure 2-8: Modelled annual mean NO_2 concentrations, 2019

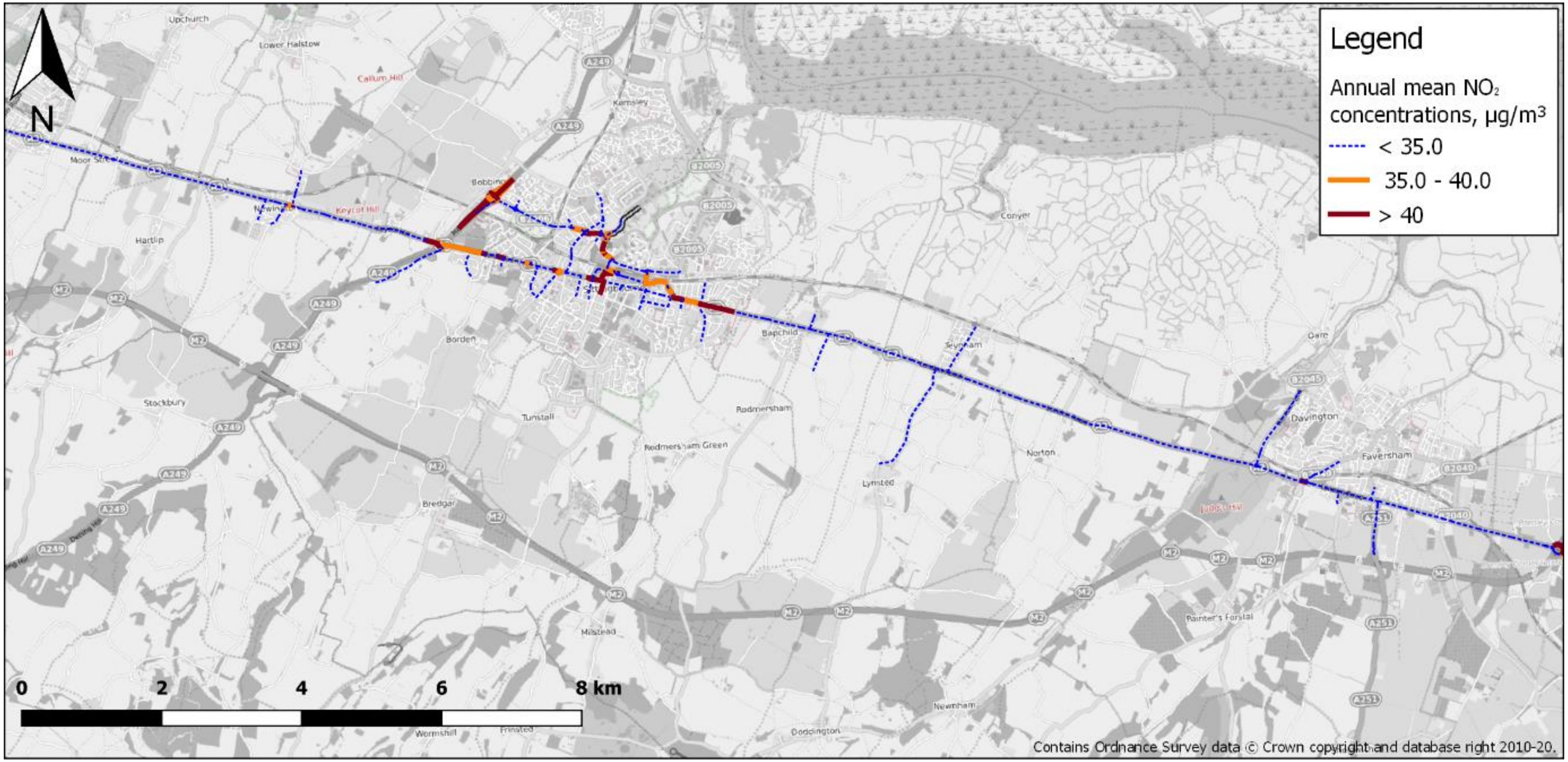


Figure 2-9: Modelled annual mean NO_2 concentrations, 2019, Sittingbourne

Figure 2-10: Modelled annual mean NO_2 concentrations, 2019, Faversham

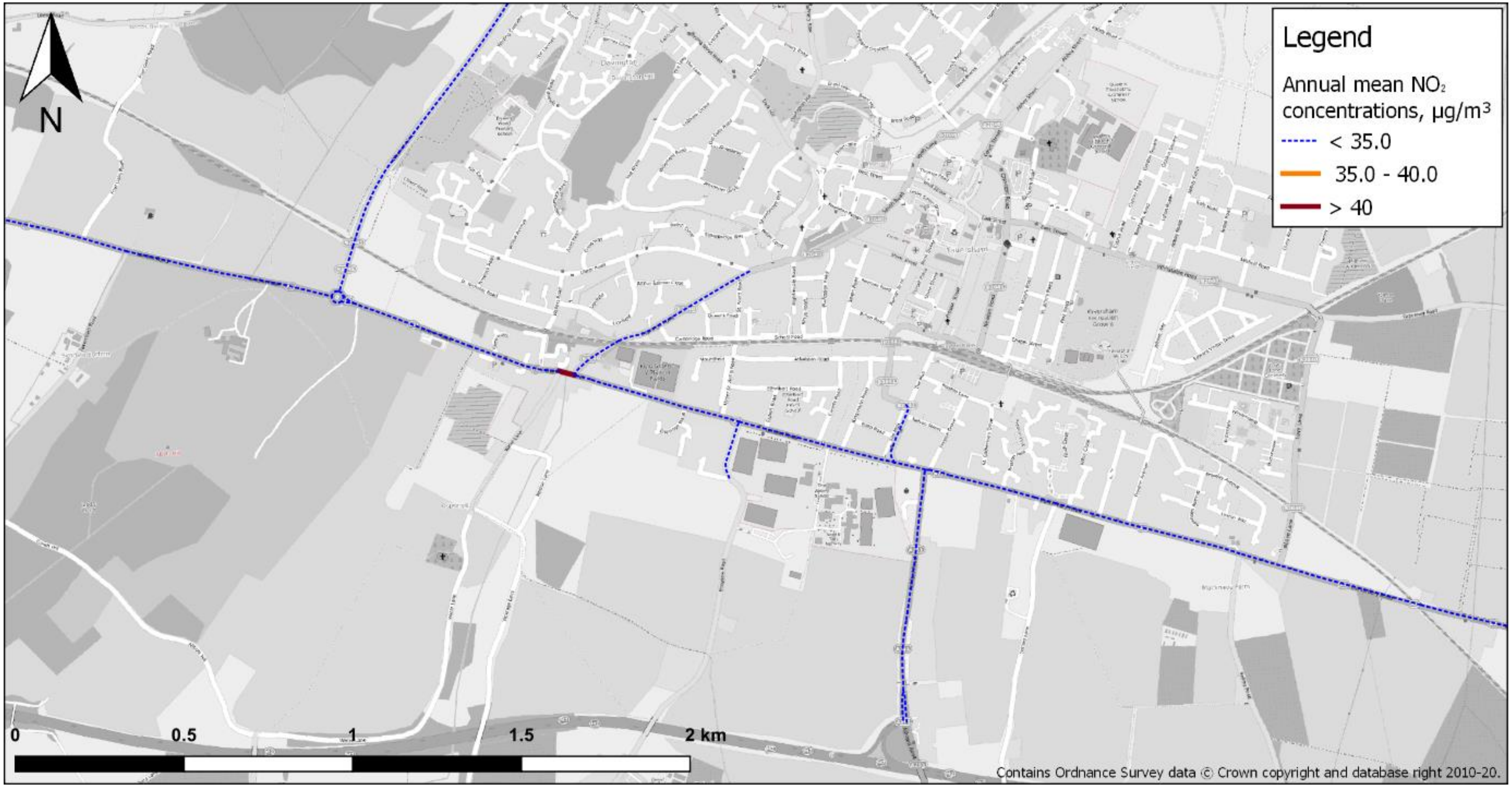


Figure 2-11: Modelled annual mean NO_2 concentrations, 2019, Newington

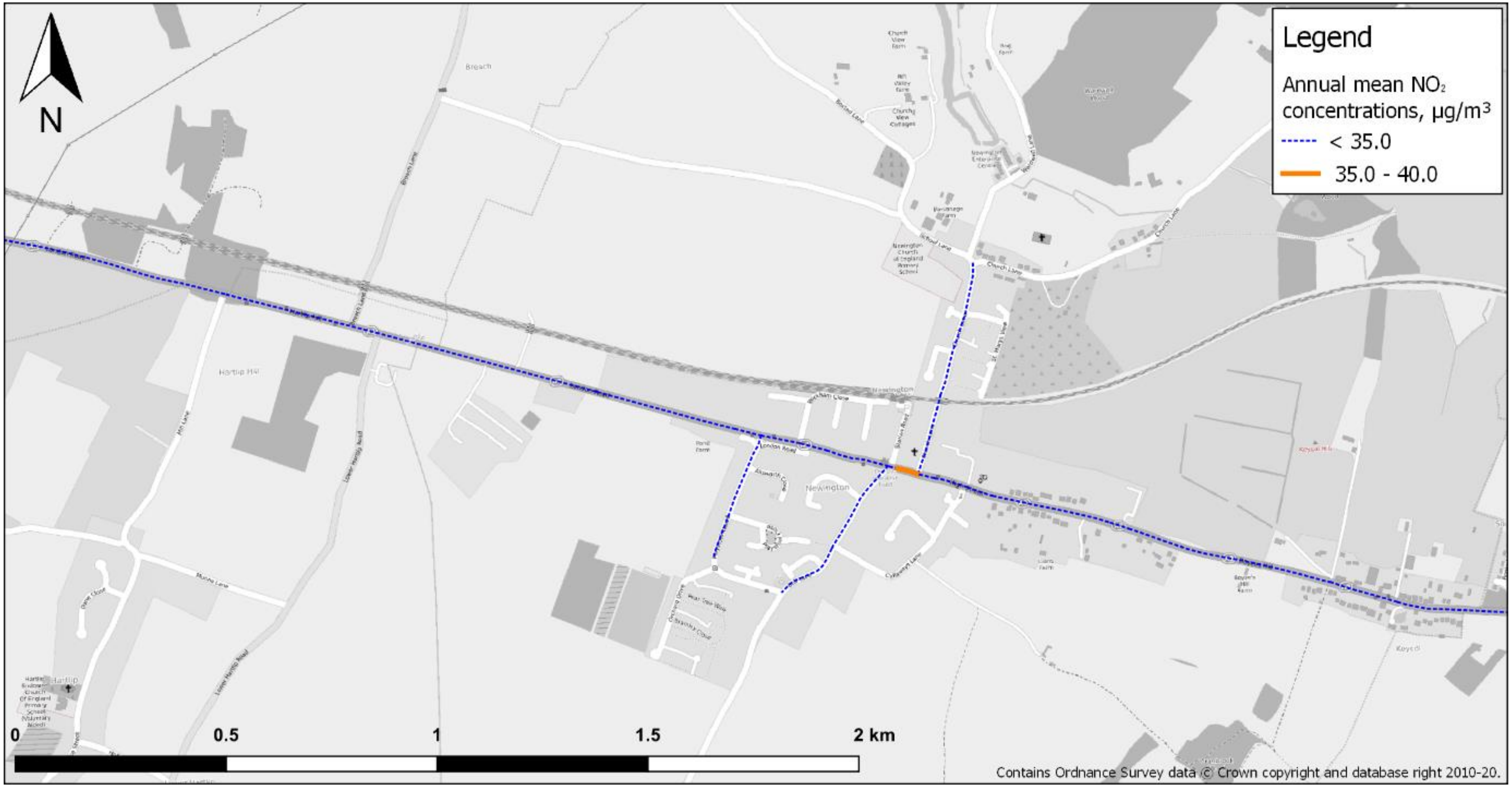


Figure 2-12: Modelled annual mean NO_2 concentrations, 2022 Reference case

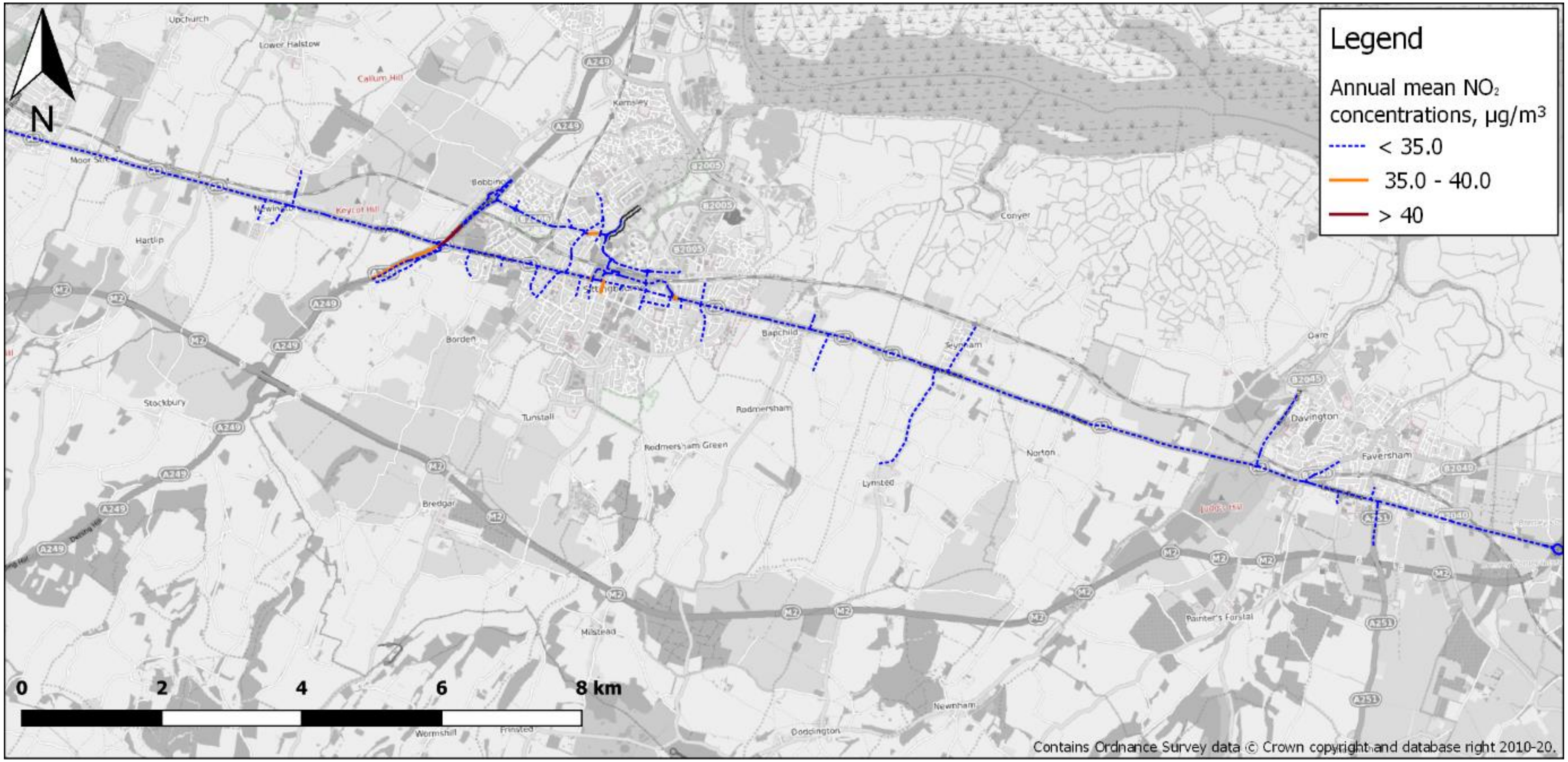


Figure 2-13: Modelled annual mean NO_2 concentrations, Sittingbourne area, 2022 Reference case

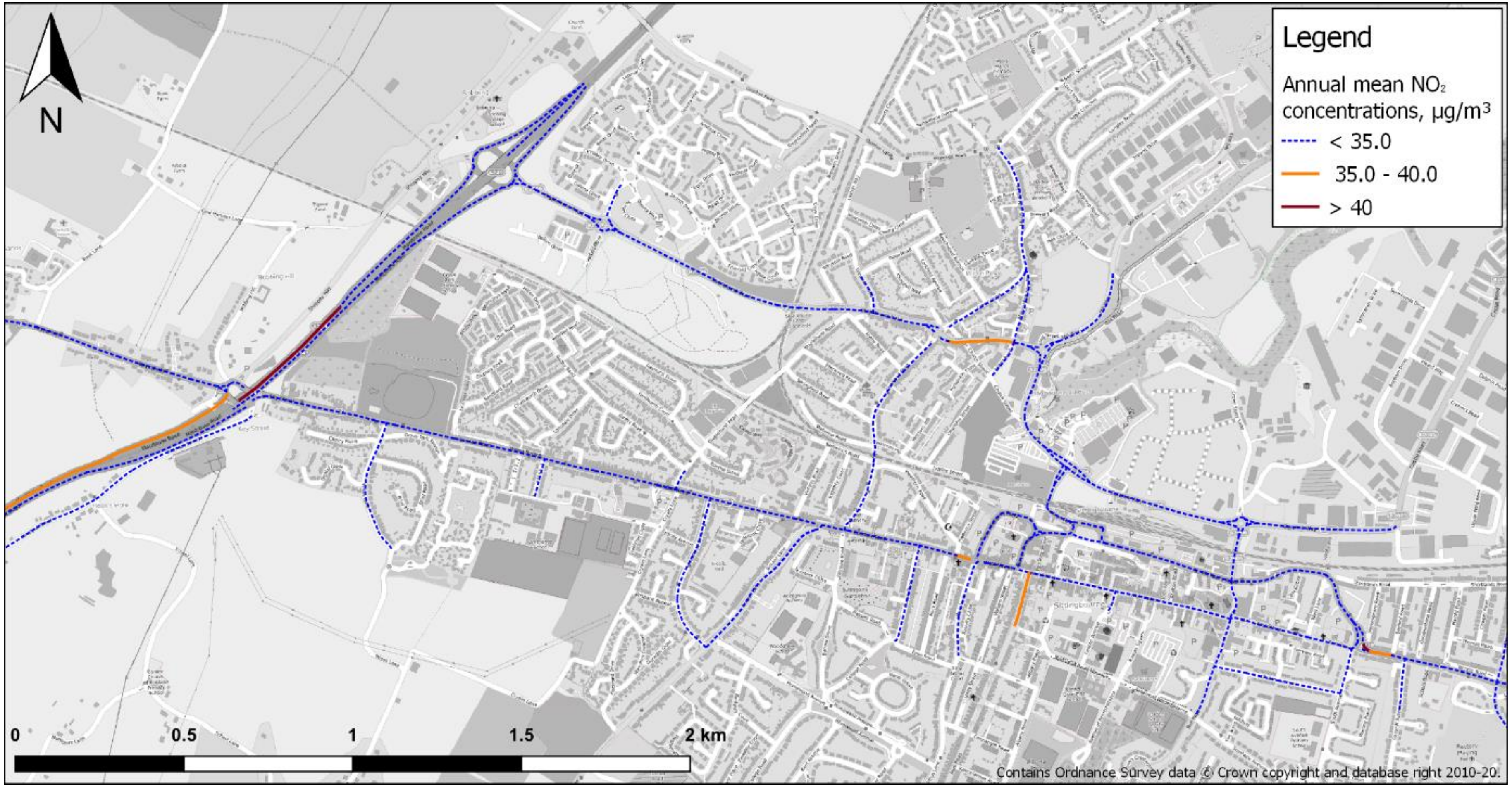


Figure 2-14: Modelled annual mean NO_2 concentrations, 2022, including Covid-19 sensitivity

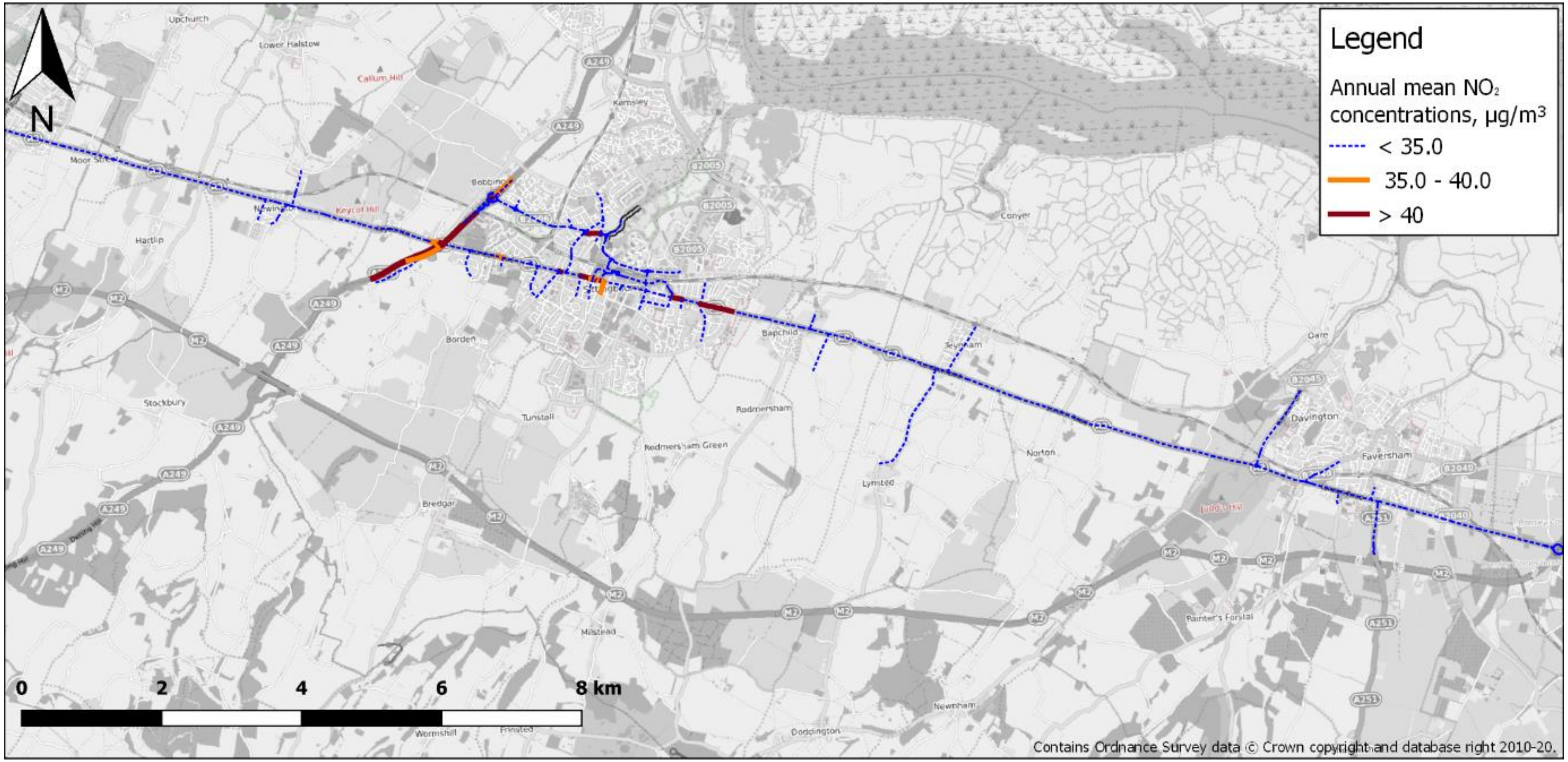
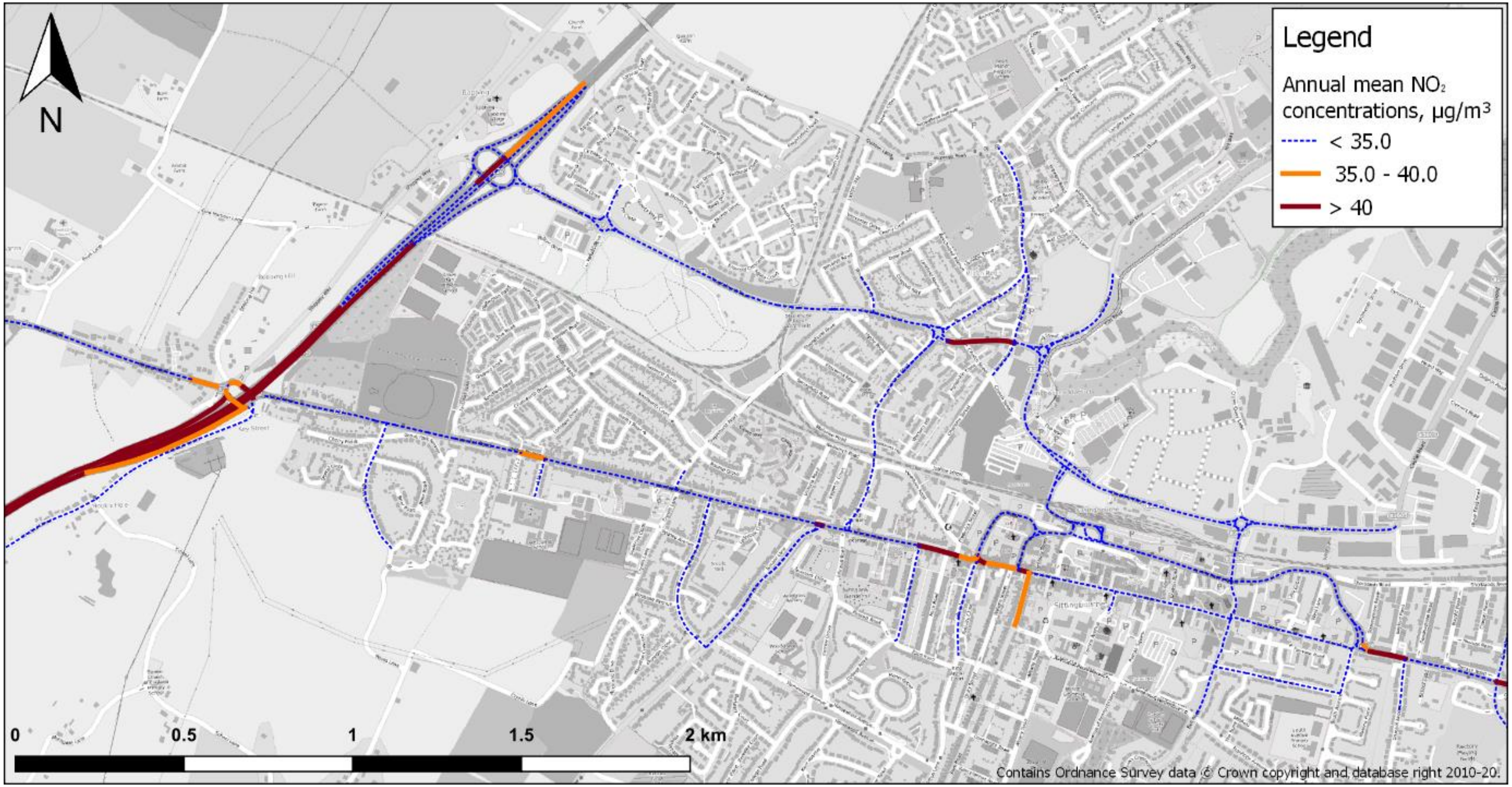


Figure 2-15: Modelled annual mean NO_2 concentrations, 2022, including Covid-19 sensitivity, Sittingbourne



2.6.2 Concentrations at monitoring locations

The modelled concentrations at monitoring site locations are shown in Table 2-3 for 2019, 2022, and the 2022 Covid-19 sensitivity test. The results are shown with both the global and local adjustment factors. The 2019 results are the actual monitored data, whereas 2022 results are modelled using both the site-specific and global adjustment factors. Red values indicate that the concentration exceeds the Air Quality Objective of 40 $\mu g.m^{-3}$; amber values indicate that location is classified as 'at risk' of exceeding within the model uncertainty. For the purposes of this study, at risk locations were defined as having a predicted concentration greater than 35 $\mu g.m^{-3}$, i.e. one RMSE from exceedance. The total number of monitoring locations exceeding or at risk in each of the three modelling baseline scenarios is also presented.

2019 baseline results

There are 9 exceedances of the Air Quality Objective of 40 $\mu g.m^{-3}$ for annual mean NO_2 concentrations at monitoring stations in Swale in 2019. These exceedances primarily occur along the A2 and the B2006 in the Sittingbourne area. Exceedances occur at the East Street, St. Paul's Street and Newington AQMAs. An additional exceedance is shown on Keycol Hill, where gradients and congestion near the junction with the A249 give rise to elevated emissions.

2022 reference case

No exceedances of the air quality objective are predicted to occur at monitoring sites when using the global adjustment factor. However, these predictions are subject to significant uncertainty and as such site-specific adjustment factors have been used at monitoring sites in order to account for local effects that may not be captured in the model. Using site-specific adjustment factors, one location is predicted to exceed the objective in 2022 without intervention; SW82, located in the St. Paul's Street AQMA.

The East Street and St. Paul's Street AQMAs are both predicted to remain at risk of exceeding in 2022 without intervention.

2022 Covid-19 sensitivity

The Covid-19 sensitivity test indicates that the impacts will lead to increased concentrations across all the monitoring locations. When using the global adjustment this does not result in any exceedances, but with the site-specific adjustment factor two exceedances are predicted one at SW82 in the St Paul's Street AQMA and SW124 in Keycol Hill.

Table 2-3: Modelled annual mean NO_2 concentrations at monitoring locations in the study area, $\mu g.m^{-3}$

Site	Road Name	Monitored data	Site-specific adjustment		Global adjustment	
		2019	2022	2022 (Covid-19 sensitivity)	2022	2022 (Covid-19 sensitivity)
ZW6	Newington 3	26.8	20.6	21.8	25.9	27.4
ZW8	St Paul's Street	39.1	29.2	31.1	34.9	37.2
ZW3	Ospringe Roadside	31.4	24	25.3	20.1	21.2
SW66	96/94High Street, Newington	33.7	25.6	27.1	25.7	27.2
SW45	64 High Street, Newington	36.1	27.5	29	24.2	25.6
SW35	60 High Street, Newington	42.5	32.2	34.1	26.4	28
SW42	High Street, Opp Church Lane	44.2	32.9	35.1	32.8	34.9
SW19	Newington Social Club	36.8	27.8	29.5	26	27.5
SW20	Newington Co Op	26.1	20.1	21.2	25.8	27.3
SW36	49 High Street, Newington	32.9	24.8	26.3	26.6	28.2
SW82	Conservative Club, St Paul's Street	55.9	41.6	44.4	37.1	39.6
SW51	14/16 St Paul's Street	40.5	30.2	32.2	37	39.5
SW89	St Paul's Air Quality Station	40.3	30.2	32.2	34.9	37.2
SW71	o/s 8 Staple Close, Staplehurst Road, Sittingbourne	36.1	27.4	29.3	28.8	30.8
SW73	14 Chalkwell Road, Sittingbourne	30.7	23.7	25.9	21.9	23.9
SW56	126 East Street, Sittingbourne	37.7	29.1	30.7	31.3	33
SW87	Canterbury Road AQ Station	30.7	24.2	25.2	30	31.3
SW99	A2 Frognal Lane, Teynham	24.7	20.1	21.2	21.5	22.7
SW91	Adj to 72 London Road, Teynham	33.4	25.5	26.9	20.2	21.3
SW101	A2 Lynsted Lane, Jct	22.4	18.2	19.2	20.2	21.3
SW28	Mayors Arms, Ospringe	43	31.9	34	27.9	29.7
SW30	ZW3 Ospringe Street	30.1	22.9	24.2	20.9	22.1
SW31	Site 7, 4 Ospringe Street	37.9	28	29.8	25.8	27.4
SW32	11 Ospringe Street, Ospringe	36.9	27.6	29.3	22.1	23.4
SW96	Maison Dieu, Ospringe Street	36.6	27	28.9	30.3	32.4
SW29	Opp Lions Yard, Ospringe Street	40.9	30.4	32.4	27.8	29.6
SW120	103 Ospringe Street, Ospringe, Faversham	39.9	29.6	31.4	24.9	26.4
SW117	Land Adj Orchard, Canterbury Road, Faversham	28.5	22.2	23.2	16.5	17.2

Site	Road Name	Monitored data	Site-specific adjustment		Global adjustment	
		2019	2022	2022 (Covid-19 sensitivity)	2022	2022 (Covid-19 sensitivity)
SW62	Key Street, Sittingbourne	33.7	24.9	26.4	25.9	27.6
SW110	2 Cherryfields, Sittingbourne	18.7	15	15.5	14.3	14.9
SW111	76A Key Street, Sittingbourne	38.2	28.9	30.6	22.4	23.7
SW112	56 Key Street, Sittingbourne	33.4	25.2	26.7	22.5	23.8
SW114	2 Florence Cottages, Chestnut Street	20.9	15.9	16.7	17.1	18
SW115	Cherry Tree Cottage, Chestnut Street	21.6	16.6	17.4	15.1	15.8
SW116	Bankside, Chestnut Street	21.5	16.4	17.2	15.6	16.4
SW124	31/33 Keycol Hill Sittingbourne Highest Point	52.3	39.2	41.7	31.4	33.4
SW121	Façade Squirrel Cottage, Keycol Hill	42.7	32.5	34.6	33.3	35.5
SW122	Façade 13 Key Street, Sittingbourne	21.2	15.8	16.8	21.1	22.3
SW123	12 Key Street, Sittingbourne	27.3	20.2	21.4	24.6	26.1
SW76	155 Canterbury Road, Sittingbourne	33.5	25.9	27.4	27	28.5
SW119	Flats, The Mount, Ospringe	24.7	19.2	20.2	17	17.8
SW83	Pembury Court, Dover Street	24.6	19	19.9	25.6	26.8
SW125	16/18 The Street, Bapchild	23.7	18.5	19.6	23	24.3

Note: Red cells are exceedances and yellow/amber cells are at risk sites

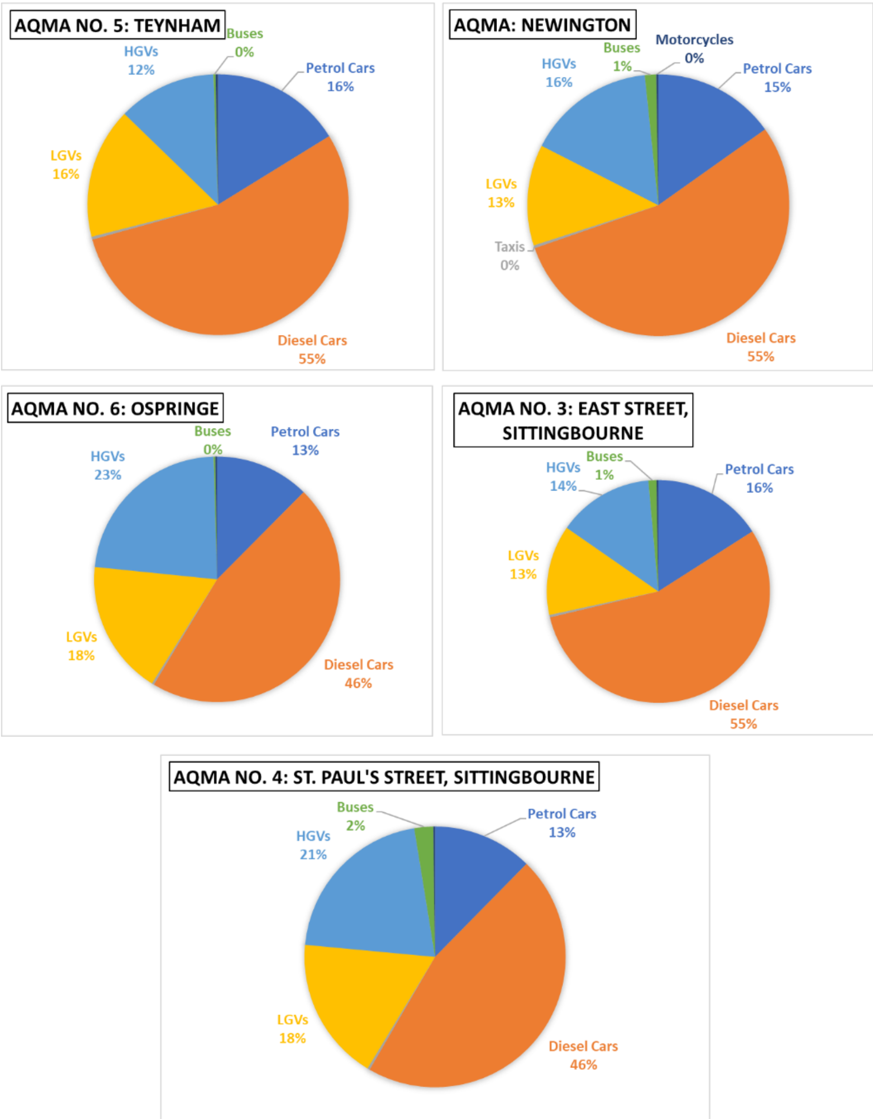
2.7 Source apportionment

A source apportionment analysis was carried out for roads in the five AQMAs in 2019 and 2022, in order to identify the primary contributors of air pollution hotspots in the city and inform potential policy development.

2.7.1 2019

The most important source of NO_X emissions in the AQMAs is diesel cars; this is a common trend seen across the United Kingdom, as cars comprise the majority of vehicle trips in the UK, and diesel cars have significantly higher NO_X emissions compared with petrol cars. In 2019, diesel cars were the largest contributors to NOx emissions in each of the AQMAs, ranging from 37-50%. The second most important source of NO_X emissions is HGVs, which contribute 22-36% of NOx emissions. LGVs contribute 13-19% of emissions, and petrol cars contribute 9-12%. The contributions of buses, motorcycles, and taxis are very low (<2%), which may reflect the limitations of the traffic data available for the project as described in Section 2.5. Figure 2-16 shows the source apportionment for all vehicle types in each AQMA.

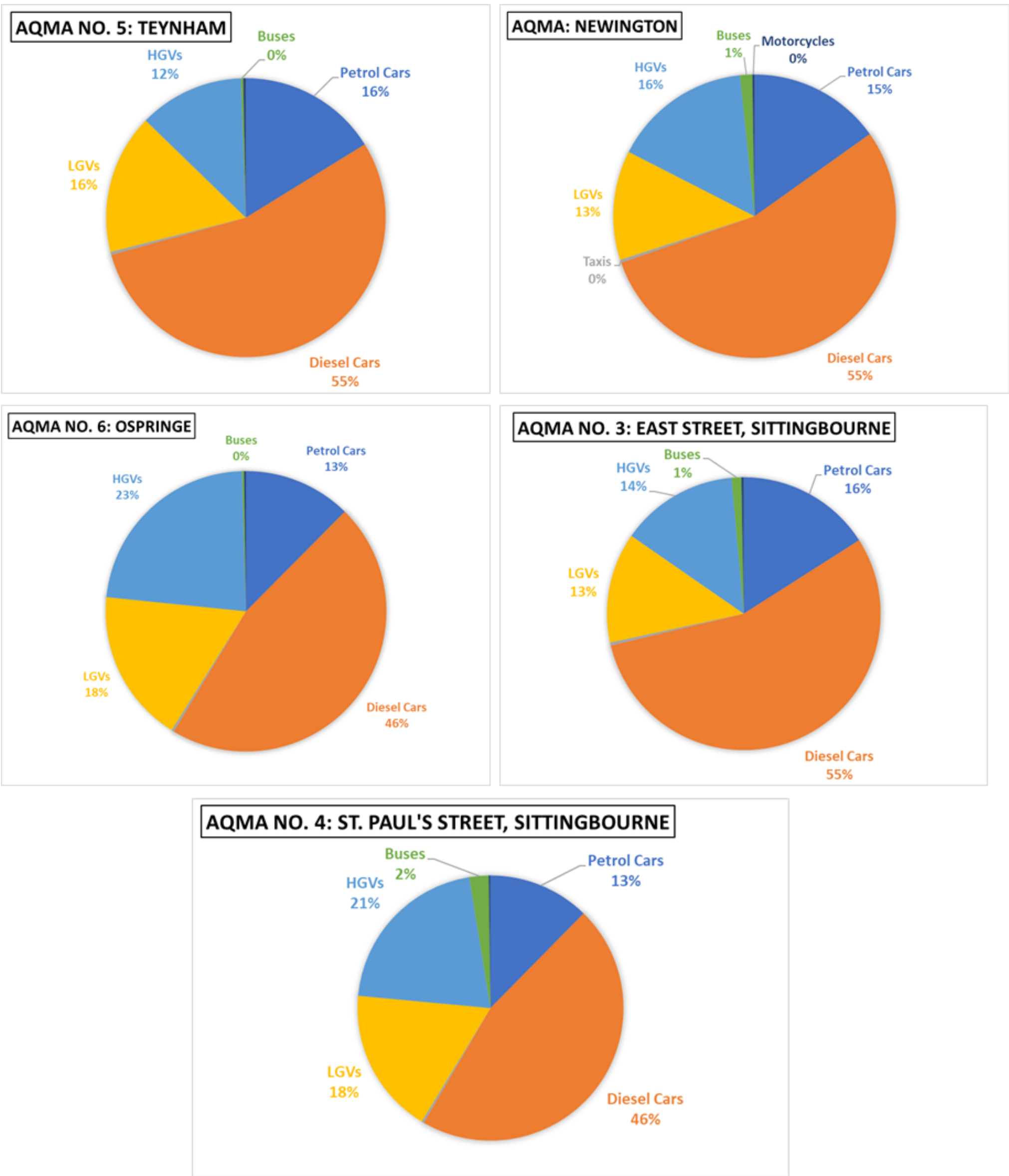
Figure 2-16 – Source apportionment in AQMAs in 2019



2.7.2 2022

In 2022, diesel cars are projected to be the largest contributor to NOx emissions in each AQMA, ranging from 46-55%. Compared to 2019, the contributions of HGVs decrease to 12-23% in each AQMA in 2022, while the contributions of both diesel and petrol cars increase in each AQMA. The contributions of LGVs remains approximately consistent compared to 2019. Figure 2-17shows the source apportionment for all vehicle types in each AQMA in 2022, and lists the percentages from both years.

Figure 2-17 – Source apportionment in AQMAs in 2022



3 Developing the mitigation options

There are a number of different mitigation options that could be applied that would have different impacts on both pollutant emissions and concentrations. In developing an initial list of options, we have considered both:

- Regulatory measures – primarily a charging Clean Air Zone, that requires people to action to reduce their emissions;

- Non-regulatory measures – where people are encourages or incentives to change behaviours to reduce emissions, for example supporting active travel to reduce car use

Alongside the impact on air quality it is also necessary to consider the costs of scheme implementation and the cost to the public. Generally, regulatory measures come with a high cost of enforcement, compliance and have lower public acceptability. Non-regulatory can have a range of costs to the local authority but are generally more accepted by the public and have lower costs to the public. Because of this, formal schemes such as a Charging CAZ are often considered only as a last resort or where the pollution problems are significant. Often a package of multiple softer non-regulatory measures is chosen in preference to the regulatory scheme, if the package of measures can provide the required emission reductions to result in acceptable concentrations.

For this project a long list of measures was created to identify potential solutions to the elevated NO_2 concentrations. From this long list, key themes were extracted and discussed with key stakeholders through engagement. Through this engagement a shortlist was created, as the long list was revised and refined to focus on the most appropriate measures for the Swale context. The shortlist of measures was refined further to create a final set of options that were taken through to the detailed air quality modelling and cost benefit analysis.

3.1 Option identification and longlist

The starting point for the long list was a review of existing plans and policies to identify existing and planned measures that would help to address the problem and then identify potential gaps where further action could be taken. To do this a thorough review of documents that could have any impact on emissions in Swale were assessed.

The review covered strategies and policies not just from Swale Borough Council (SBC) but also Kent County Council (KCC) and Transport for the South East (TfSE) as the key bodies responsible for transport in the area. The documents were evaluated looking at: air quality action plans, development plans, transportation strategy (incl. rail, active travel, taxi, parking) and sustainable growth, including any progress reports in these areas. The documents reviewed are listed in Table 3-1 below.

Table 3-1. List of documents reviewed to identify measures.

Document	Body
Swale Strategic AQAP 2018 - 2022	SBC
Swale Strategic AQAP 2018 – 2022, Report 1: Source Apportionment and Options Assessment. October 2018	Phlorum
Swale Strategic AQAP 2018 – 2022, Report 2: AQMA options assessment, October 2018	Phlorum
Swale - Cycling and walking Guidance Statement 2018-2022	SBC
2019 Air Quality Annual Status Report	SBC
Swale Borough Council - Parking Standards	SBC
Realising our ambitions for Swale - Partnership priorities for the borough to 2031	SBC
SWALE BOROUGH COUNCIL - PROCUREMENT STRATEGY (2013 – 2016)	SBC

Housing Strategy 2010-2015	SBC
HACKNEY CARRIAGE AND PRIVATE HIRE LICENSING POLICY 2018-2021	SBC
Air Quality Action Plan (2018 – 2022)	SBC
Swale Transportation Strategy 2014-2031 (Draft)	SBC
SWALE BOROUGH COUNCIL FREIGHT MANAGEMENT PLAN	SBC
Bearing Fruits 2031	SBC
The Swale Borough Local Plan	SBC
Digital Strategy	SBC
Housing Strategy 2010-2015	SBC
Kent County Council's Strategic Statement 2015-2020 (Annual Report 2019 County Council)	KCC
Rail Action Plan for Kent	KCC
SEA Environmental Report -LTP4 Strategic Environmental Assessment	KCC
Strategic Environmental Assessment – Non-Technical Summary [Local Transport Plan 4 (LTP4)]	KCC
SEA Adoption Statement - LTP4 Strategic Environmental Assessment	KCC
Local Transport Plan 4: Delivering Growth without Gridlock 2016–2031	KCC
KENT ENVIRONMENT STRATEGY INDICATORS JANUARY 2020	KCC
Kent ENVIRONMENT Strategy - A strategy for environment, health and economy - Impact Report 2018	KCC
KENT ENVIRONMENT STRATEGY IMPLEMENTATION PLAN - Year 2 activity monitoring report - August 2017 – July 2018	KCC
Kent County Council - Environment policy	KCC
KENT COUNTY COUNCIL HIGHWAYS TRACKER 2017 WRITTEN REPORT	KCC
KENT AND MEDWAY GROWTH AND INFRASTRUCTURE FRAMEWORK | 2018 UPDATE	KCC
Transport Strategy for the South East - Consultation Draft - October 2019	TfSE
TRANSPORT FOR THE South East - Draft Transport Strategy - October 2019 [Strategic Policy Context]	TfSE
TRANSPORT FOR THE South East - Priority scheme summaries	TfSE
TRANSPORT FOR THE South East - Future transport technology	TfSE
TRANSPORT FOR THE South East - Draft Transport Strategy - October 2019 [Freight, logistics and gateway review]	TfSE
Economic Connectivity Review	TfSE

From these documents an initial long list of measures was generated by collating similar and overlapping measures into key themes. These themes were then reviewed to identify any potential gaps building on experience from measures being implemented in other CAZ cities or through the concept of Low Emission Strategies such as those developed in Southampton, Leicester and York. This initial long list defined 25 key groups in 4 themes:

1. A formal charging CAZ and options on this;
2. Low emission vehicle measures to promote and support the uptake of low emission vehicles;
3. Traffic and travel management to promote mode shift and the efficient flow of vehicles;
4. Longer term development policy.

These measures are listed in Table 3-2 and described briefly below.

3.1.1 Charging CAZ

A charging CAZ is a measure that creates a financial incentive to change the emissions of a vehicle. Vehicles that enter the charging zone are required to pay a charge to enter if they do not meet a specific emission standard defined as Euro4 for petrol vehicles and Euro 6/VI for diesel vehicles. By charging vehicles not meeting these standards it is possible to provide a strong price signal to upgrade a vehicle.

The legal basis for a charging Clean Air Zone is road user charging powers as set out in the Transport Act 2000. Part III of the Act empowers local authorities (as "charging authorities") to make a local charging scheme in respect of the use or keeping of motor vehicles on roads. DEFRA and DfT has also provided a clear framework[12] on the design of CAZ scheme so that there is a consistent approach taken across the country.

This measure can be targeted at specific types of vehicles, with the DEFRA guidance defining 4 categories or 'Classes' of CAZ:

- Class A – covering buses and taxis;
- Class B – covering buses, taxis and HGVs;
- Class C – covering buses, taxis, HGVs and LGVs;
- Class D – covering all vehicles types.

In addition, it is necessary to consider:

- the CAZ boundary – does it cover the whole A2 corridor, the whole of Swale or just the AQMAS;
- The charging price – the starting point for this would be the levels used for the London ULEZ.

In theory the DEFRA/DfT framework is guidance only and the legislation would allow different approaches to a charging scheme, but to avoid confusion this would not be expected to be called a CAZ. An example of this is the developing Zero Emission Zone in Oxford that is using the same legislation to promote zero emission vehicle usage in the centre of the city.

3.1.2 Low emission vehicle measures

Taxi licencing

The current taxi licencing regulations are stipulated in Hackney Carriage and Private Hire Licensing Policy (2018-2021):

- **2.5.1** Vehicles licensed with 4 to 6 passengers, on first registration, will be less than 8 years old on the first date of the application and can be licensed up to 10 years old.
- **2.5.2** Vehicles licensed with 7 to 8 passengers, with wheelchair accessibility will be less than 12 years old on the first date of application and can be licensed for up to 15 years old.

There is potential to tighten the restrictions on the emissions from taxis. Taxis that are 10 years old are likely to be Euro V and taxis that are 15 years old are likely to be Euro IV. Although the current licencing rules stipulate age of taxis, it might make more sense to stipulate emission standards rather

[12] 'Clean Air Zone Framework, Principles for setting up Clean Air Zones in England', DEFRA/DfT, May 2017

than age in the licencing method. Through licencing in this way it is also possible to encourage taxis to become ULEV and hybrid vehicles.

Creating more stringent taxi licencing regulations will only be successful with the co-operation of adjoining boroughs. If licencing is more stringent in Swale then taxi drivers would licence in adjoining boroughs but continue to operate within Swale.

Taxi incentives

A taxi licencing scheme can also be complemented by grants or incentives as being developed in other authorities such as grant schemes for upgrades, loan schemes and try before you buy schemes.

It is also possible to use Traffic Regulation Orders (TROs) to set emission standards for vehicles using taxi ranks. This can help support licencing, provide an incentive to upgrade to use priority ranks and help with taxi coming in from other areas.

Eco Stars scheme for freight vehicles

The Kent Freight Action Plan highlights the Eco-Star scheme where large operators within SBC are provided with community recognition for high levels of environmental performance. The scheme provides support for operators in better fuel management and driver training. The result of the scheme is to help improve efficiency, reduce fuel consumption and reduce negative impact on local air quality.

According to the Energy Saving Trust, by taking Eco-driving training, an improvement of up to 15% MPG would be possible. However, the average improvement is close to 8% and this can tail off over time.

Low emission loading bays

To complement the Eco Stars and as an alternative to a CAZ charging scheme it would be possible to use TROs to set emission standards for vehicles using loading areas along the A2 and especially in the AQMAs. This would require deliveries to have vehicles that meet the given standards.

Improving bus fleet through a retrofit programme

This measure looks to reduce emissions from buses. As a modal shift away from private vehicles occurs, the need for clean buses further increases.

Reduced bus emissions can occur from retrofitting Selective Catalytic Reduction and particle Trap (SCRT) exhaust treatment old buses and provide thermal management for Euro V buses. Another option is to explore a change in vehicle power moving towards Compressed Natural Gas (CNG) or electric.

ULEV parking charges

This measure provides preferential parking charges for ULEVs. By providing better or cheaper parking for ULEV this measure will encourage the uptake of ULEVs. This measure can act either on residential parking permits or council owned public parking.

A recent trial in Winchester has seen some drivers of EVs being able to park for free in any local authority parking bays. In addition, a discount on parking charges is provided to those owner vehicles who have low CO_2 levels (according to vehicle excise duty band).

Two other examples of such schemes are in Richmond and Edinburgh. These were applied to the pricing of residents parking permits, but other authorities such as York have consider adjusting charges in in public car parks. In most cases the main assessment has been on impact of parking revenues with the current fleet rather than the likely change to that fleet. Clearly the impact will depend on the scale of the charges or indeed if only vehicles of a certain emission criteria can use the parking, but it seems likely to be small. In assessing a scheme of this nature some simple assumptions will need to be made on its likely impact on vehicle emission standards.

EV cars and vans - charging infrastructure

A key obstacle to overcome in the uptake of EVs is the provision of charging infrastructure. The perception of a lack of infrastructure stops people from making the leap to electric vehicles.

The range of modern electric vehicles are now well over 100 miles. Therefore, the majority of charging is usually done overnight for local commuting travel. It is therefore important that electric charging is available at home. This may be easier for people who have the ability to park off-road but more challenging for those who park on the road. There are potential health and safety issues with running cables across pavements. In these circumstances, provision of electric charging infrastructure built into the road would allow charging at the roadside.

Charging infrastructure can also be provided at places of work, where vehicles will typically sit for the duration of the day. Fleet vehicles are an area where EV uptake is expected to be high. Provision of EV infrastructure for fleet vehicles is important.

EV cars and vans – grants

This measure provides financial support to those who wish to make a change in vehicle from combustion to electric vehicle. Through car leasing or salary sacrifice it is possible to increase the uptake in electric vehicles. EV cars that are financed in this way would then gain some of the other benefits discussed in this list in relation to priority provision for EVs.

EV cars and vans - car clubs

The basic idea of a car club is that people can have access to a car in their neighbourhood without having to own it. With Electric car clubs, the idea is identical with the proviso being that only EVs are available for users.

Typically, car club members pay an annual membership fee to an operator (in the order of £100-£200) who provides and maintains a range of vehicles in their neighbourhood. Members then pay by the hour and mile when they use a vehicle. Some operators prefer to charge a higher hourly rate and do not ask for a membership or mileage fee.

The combined costs of membership and use are intended to be cheaper than personal car ownership, for car owners who do not do a high mileage, and to encourage the adoption of relatively diverse personal transport strategies.

Anti-idling

This measure looks to highlight the unnecessary emissions that are created during engine idling. There are two types of schemes, one which raises awareness and others which issue fixed penalty notices (FPN) in order to increase local authority revenue as well as improve air quality. The Council has already adopted and approved this action for use in the Borough.

Anti-idling campaigns are one approach to reduce vehicle emissions and fuel consumption, and improve air quality. They typically advise drivers to switch their engine off whenever it is likely to be idling for more than one minute. One of the key benefits of this measure is that it will be possible to target the pollution hot spots and areas of high exposure. Targeting bus drivers and taxis at train stations or parents at schools will greatly reduce exposure to large populations.

3.1.3 Traffic and travel management

Improve walking infrastructure

Improving walking infrastructure can increase the numbers of people walking. There are a number of key issues that need to be addressed:

- Safety
- Access
- Journey times

Additional safety can be provided to pedestrians via barriers alongside major roads and junctions. These provide a physical barrier which can increase the perception of safety. Separation from the traffic can also be provided by creating additional distance from the main carriageway. Where the pavements are wide enough, creation of a cycle path next to the road, and a walkway further away provides an additional buffer from the flow of traffic. Another safety element comes through the provision of lights to allow for walking at night and the feeling of safety.

To encourage walking it is important that at least one side of a carriageway has sufficient space to get a wheelchair or pram along the pavement. In locations where cars park mounted on the curb this is not always the case. Wide pavements allow for improved access allowing wheelchairs or pram users to pass one another with ease.

A key benefit that can be realised for walking is increased journey times over road users for short journeys. Due to the decreased space required to put a path in versus a road, it is possible to create walking cut throughs which will allow pedestrians to take more direct routes. This also has the added benefit of removing pedestrians from walking alongside roads. Another way to improve journey times is through priority signalling. This is where the traffic light signalling has been optimised in favour of pedestrians rather than cars.

Improve cycle infrastructure

Improving cycle infrastructure can improve the rates of cycling. Rates of cycling in Swale are low compared to the national average. Investment in cycle infrastructure can increase the appeal of cycling and therefore increase its uptake.

Key cycle infrastructure can be in relation to:

- Cycle routes
- Cycle safety
- Bicycle storage
- Post cycle facilities
- Journey times
- Bicycle rental schemes
- Training

An effective cycle network requires cycle routes which interlink and are direct between key destinations. For the more experienced cyclists cycling on main roads does not phase them, but this can be quite daunting for less experience cyclists. Provision of cycle routes that are off the main roads can be a great way to increase the numbers of cyclists. By providing routes that have low numbers of cars there is increased security for cyclists. Reducing the number of cars on cycle routes can be achieved via cycle cut throughs that cars cannot use. This can be achieved via something as simple as filtered permeability (where bollards across a restrict cars but bicycles can still get through).

Cycle safety can be achieved through a number of methods but safety of cyclists is a key barrier to new cyclists. Provision of visible cycle infrastructure can be a great way to encourage cyclists. This can be via road markings (e.g. cycle lanes and cycle boxes at lights) or via hard infrastructure (separating cyclist from the main carriageway).

Cycling requires physical effort and therefore the shortest routes are the best routes, with little slowing and accelerating for lights. It may be possible to tweak the road network to give priority at signals to cyclists and to create green-wave for lights so that cyclists can retain their momentum.

Another key to increase cycle numbers is the provision of cycle storage. At the end of a journey by bicycle it is important that the user can lock up their bike without the fear of it being stolen. At places of work and schools this is provision of storage facilities that are not accessible to the general public. In public locations this is provision of cycle storage in well light areas preferably with CCTV surveillance.

For those commuting longer distance by bicycle then they will likely require changing and shower facilities. Provision of these facilities will encourage a modal shift towards cycling. Following this, there is also need for cycle equipment storage (e.g. helmet). Provision of lockers can overcome this issue.

Many people do not feel comfortable cycling and are nervous about trying to cycle. There are a number of different schemes that are available to help overcome this. The KCC Adult Cycle Training provided training to 381 across 174 sessions in 2017/18. In Camden in London, to encourage cycling at the end of training sessions, the trainer agrees to cycle attendees' routes from home to work with them to help them gain confidence on the route they will take. Other schemes in Kent include Ride Social and Breeze Rides which provide residents to ride with cycle leaders and can be a good way to increase cycle confidence.

Short-term cycle hire schemes are now commonplace in many cities using either a docked or free-standing system. In the London Borough of Hackney, the council provide bicycles on loan for a month to help users determine whether or not cycling is the right option for them. There is also growing use of e-bikes and other micro-mobility solution as alternatives to the car for some longer journeys.

Pinch-point parking alternatives

Pinch-point parking is a measure that does not allow parking along key routes, especially where roads narrow. By removing parking along these routes, it is possible to improve the flow of traffic as parked cars do not create obstacles which can often lead to congestion, low-speeds and high acceleration passed the obstacle. By removing obstacles it will also improve active travel experience, especially cycling.

Through the removal of parking spaces to improve vehicular flow, it will be important to provide additional parking options to gain the support of the public.

Improve bus services for key routes

All key centres should be accessed by public transport. There are a number of potential bus routes which do not exist that could exist:

- Sittingbourne to Ashford
- Faversham to Maidstone

During rush hour, it is possible to run express bus services which make less stops and travel more directly from one economic hub to another. This type of service further improves reliability and reduces travel times.

Improve public transport scheduling

To create a modal shift away from cars to public transport, it is important that the journey times do not differ too much. If a journey is required to be multi-modal, long wait times can severely increase the overall journey time.

A key way of reducing overall journey times is to improve public transport scheduling. By providing public transport that allows for quick transitions from one form of public transport to another then it is possible to make public transport more appealing and create modal shift. Since train schedules are often fixed due to other users of the same trainlines, it will be the bus schedules which may need to change to optimise the public transport schedules.

It is also important to provide public transport that works to the schedules of workers. It is important to provide public transport services that get people to work or school before when they need to arrive, but not by too much.

Improve public transport infrastructure

It is possible to increase public transport ridership through the provision of improved infrastructure. Infrastructure could be in relation to: multi-modal journeys, bus lanes, better bus-stops, quick and easy journey payments.

Bus lanes are an excellent way to improve the reliability of bus services and therefore make bus travel more desirable. As a result of assigning space on the roads to buses, it increases congestion for private vehicles. This can increase journey times and encourage a modal shift. However, until the modal shift occurs, there is likely to be a spike in emissions.

Good bus stops can be a key factor in improving their ridership. By covered bus stops with up-to-date information makes bus travel a more pleasant experience. Bus stops that are in lay-bys allow for the flow of other traffic to continue whilst the bus is stopped and therefore this reduces any potential congestion that could occur in these locations. Provision of good services for multi-modal travel are also important (e.g. bike stands).

Kent connected Smartcard is the first step from KCC towards smart ticketing. Quick payment for journeys improves journey times and reduces the need for fiddly coins in payment.

School and business travel plans

Creating cohesive travel plans for schools and business may highlight key areas for improvements. Understanding the journeys that members of your organisation take it is possible to put into place actions to improve transportation.

Secondary schools in Swale have a below average active travel percentage, at 1.6% cycling to school rate compared to the national average of 2.2%[13]. A key question therefore should be why? Where pupils are too far to travel by active travel, it may be possible to reduce the number of vehicles by combining school journeys with others that live near-by.

For business it may be possible to reduce the number of car journeys by having colleagues come into work together or by improving at work bicycle facilities (e.g. shower, changing and bicycle storage).

[13] Swale cycling rate was provided by SBC in an unpublished rpeort, the national average is from the National Travel Survey published by DfT.

20 mph zones

Reduced speed zones are primarily designed as a safety measure - reducing the speed of vehicles, increases the safety of cyclist and pedestrians. This in itself can encourage more walking and cycling. Also, by reducing the speed limit to 20 mph reduce vehicle accelerations and so decrease emissions, but this is not always the case. However, another effect of reducing speeds on key road segments can be to cause changes to route selection for vehicles potentially taking longer route and therefore increase emissions. So the overall effect on these on emission is complicated and not always positive.

Freight management – consolidation centre

This measure aims to reduce the number of goods vehicles making deliveries into the town centre. A consolidation centre is usually a warehouse on the outskirts of town where LGVs deliver to and subsequently smaller goods vehicles do the final drop into the centre of town. This methodology reduces congestion and also provides an opportunity to make the final deliveries in low emission vehicles or EVs.

These can have a significant impact on the number of vehicles delivering to retail premises involved in the scheme, reducing them by some 60-70%. However, only a proportion of retailers will use the scheme (perhaps 20-30%), hence we might expect a 15% reduction in activity of freight vehicles servicing the area targeted by the consolidation centre.

Freight management – Delivery and servicing plans

Delivery and service plans - manage and co-ordinate deliveries to a given site. TfL in London has been working strongly on these and has seen delivery trips reduced by 15-20% for a given site when this approach has been implemented.

Improvement to current road network

These measures look to improve the flow of traffic across the road network. By improving the flow of traffic, it is possible to reduce the number of slow-moving, high-emitting vehicles.

There are a number of major road infrastructure projects that have been discussed both by Swale and Kent councils. The major road infrastructure projects are:

- A249 corridor capacity enhancements to support growth
- Sittingbourne town centre regeneration
- Improvements to Key Street junction
- Improvements to M2 Junction 5 – funding committed by Highways England
- A249/Grovehurst Road junction
- Improvements to M2 Junction 7 (Brenley Corner)

Major road infrastructure projects are extremely expensive but can be an effective measure to move vehicles from areas of high human exposure and improve the flow of the overall road network.

3.1.4 Development policy

Sustainable new development

This measure ensures that new developments, both residential and commercial do not negatively impact the environment. Through planning guidance documents developers are led towards technologies that are best for Swale. This can include:

- Energy efficiency
- Car parking spaces and type

- Provision of cycle storage
- Public transport provision
- Local amenities.

Through carefully planned new developments it is possible to develop in such a manner that is unlikely to have a negative impact on the environment and community.

Citizens of Swale seem to have reservations about new developments and their likely impacts on the roads in Swale. An increase in population does not need to have a negative impact on the roads of Swale but this requires provision of other transportation services. Provision of active travel and public transport will be required to increase the population of Swale without increasing congestion. A key factor is the location of new developments and the amenities provided in the development to reduce the need for travel.

High quality telecommunication service provision

This measure looks to capitalise on improve telecommunications software which increases individual's ability to work from home. By working from home it is possible to reduce journey and therefore the number of vehicles on the roads. Lots of families prefer the flexibility provided by the ability to work from home and with the COVID-19 pandemic it has proven to be successful for many people.

3.2 Initial review and consultation

The consultation and engagement was carried out in two stages:

- Initial review and discussion of the long list with SBC officers to focus down the long list to a draft short list for wider engagement;

- Two stakeholder engagement workshops to review and discuss the draft short list.

3.2.1 Initial review

The aim of stage in the process was to reduce the long list of measures for stakeholder engagement discussions. To refine the list of measures, discussions with SBC on each of the measures allowed for better understanding of the issues in Swale and the likely effectiveness of these measures. The long list of measures is presented in Table 3-2.

Table 3-2It should be also noted that a number of measures that potentially could have effective may have been removed from the list of measures to carry into the next stage for a number of other reasons, including:

- Measure would have been effective, but the impacts would only be felt outside the timeframe of this study e.g. sustainable new developments, high speed internet;

- Deemed to be outside the scope of the project e.g. improvements to road network

- They would only impact on a small source of emissions e.g. improvements to the buses or taxis;

- The impact of the measure could not be assessed in the model for example vehicle idling for which is not accounted for in the model, or traffic management schemes, such as 20 mph zones which would not affect average traffic speeds.

Table 3-2 indicates how the long list of 25 measures was reduced following these initial review discussions into a short list for wider stakeholder engagement.

Table 3-2. Long list of measures for initial review with SBC

Measure	Measure type	Initial review conclusions (green taken further; red excluded)
Charging CAZ		
Charging CAZ (Class B - HGVs, Bus and Taxi)	Clean air zone	Include
Charging CAZ (Class C - LGVs, HGVs, Bus and Taxi)	Clean air zone	Include
Charging CAZ (Class D - Cars, HGVs, LGVs, Bus and Taxi)	Clean air zone	Include
ULEV		
ULEV parking charges - residential	Low emission vehicle measures	Include as part of Non-Charging CAZ
ULEV parking charges - public	Low emission vehicle measures	Include as part of Non-Charging CAZ
EV cars and vans - infrastructure	Low emission vehicle measures	Charging infrastructure to be led by KCC
EV cars and vans - grants	Low emission vehicle measures	Include as part of Non-Charging CAZ
EV cars and vans - car clubs	Low emission vehicle measures	Include as part of Non-Charging CAZ
Freight		
Eco Stars scheme	Low emission vehicle measures	Currently in place for existing members, but stopped for new members. Has been hard to quantify improvements
Low emission freight bays	Low emission vehicle measures	Minimal locations for this measure (except Sittingbourne)
Freight management - consolidation centre	Traffic and travel management	Include as part of Non-Charging CAZ
Freight management - delivery service plans	Traffic and travel management	HGV drop offs are often determined by the route required by the company
Active travel		
Improve walking infrastructure	Traffic and travel management	Include as part of Non-Charging CAZ
Improve cycle infrastructure	Traffic and travel management	Include as part of Non-Charging CAZ
Taxi/Public transport		
Improve public transport services	Traffic and travel management	Include as part of Non-Charging CAZ
Improving bus fleet	Low emission vehicle measures	High financial burden to bus operating companies which may reduce services
Taxi licencing	Low emission vehicle measures	Minor source
Taxi incentives	Low emission vehicle measures	Minor source
Local emission reductions		
Anti-idling (Bus and Taxis)	Traffic and travel management	Local emission reductions hard to model
Improve traffic flow		
School and business travel plans	Traffic and travel management	Include as part of Non-Charging CAZ
20 mph zones	Traffic and travel management	Average road speeds in the model were already at 20 mph or blow in

		many places so measure difficult to assess arcuately.
Improvement to current road network	Traffic and travel management	Out of scope – would require additional transport modelling
Pinch-point parking alternatives	Traffic and travel management	Include as part of Non-Charging CAZ
Development		
Sustainable new development	Development policy	Reductions will occur over too long a time frame
High quality telecommunication service provision	Development policy	Reductions will occur over too long a time frame

3.2.2 Stakeholder engagement

The long list of measures was refined into a shortlist of measures for the stakeholder engagement. Stakeholder engagement was performed over the course of two separate workshops delivered as webinars. The presentations differed slightly between the two webinars, but the majority of content remained the same. The slides from the second workshop are provided in Appendix 2.

For the first consultation invitations were provided to Swale Cabinet and Deputy Members and KCC Highways Authority. The second consultation invitations included key internal and external stakeholder groups:

- All public transport sector (buses and trains)
- Relevant KCC departments i.e. KCC Highways; Transport Innovations; Public Transport; Transport and Development Planners
- Medway Council - Departments – Planning and Environmental protection
- All parish councils
- Swale Officers - Planning and Policy, Economy and Community Services, Environmental Protection, Environmental Services, Parking Services
- Relevant Swale Management Officers and Councillors

During the webinar a presentation of the baseline modelling results was followed by a presentation and discussion of the measures. During these discussions the relative strengths and weaknesses of each measure was discussed with particular focus on potential feasibility and political acceptance. The short list of measures discussed during stakeholder engagement is shown in Table 3-3 with the summarised feedback from the webinars.

Table 3-3. Short list of measures for engagement workshop

Measure	Measure type	Summary
Charging CAZ		
Charging CAZ (Class B - HGVs, Bus and Taxi)	Clean air zone	If a CAZ, Class B is most likely - to be modelled
Charging CAZ (Class C - LGVs, HGVs, Bus and Taxi)	Clean air zone	-
Charging CAZ (Class D - Cars, HGVs, LGVs, Bus and Taxi)	Clean air zone	Reference case as likely most impactful measure - to be modelled
Mode shift		
Improve walking infrastructure	Active travel	Great opportunity
Improve cycle infrastructure	Active travel	Great opportunity

Improve public transport services	Public transport	Significant improvements required
School and business travel plans	Traffic and travel management	Potential to do more
ULEV		
ULEV parking charges - residential	Low emission vehicle measures	Supported
ULEV parking charges - public	Low emission vehicle measures	Supported
EV cars and vans - grants	Low emission vehicle measures	Is there the demand? Can grid cope?
Freight		
Freight management - consolidation centre	Traffic and travel management	Generally positive
Freight management - delivery service plans	Traffic and travel management	Generally positive
Improve traffic flow		
Pinch-point parking alternatives	Traffic and travel management	Politically acceptable despite residential resistance
Car Clubs	Traffic and travel management	Supported

A couple of measures were mentioned in the webinars that did not make the short list of measures. One was the 20 mph zone measure which had a lot of interest and is being carried out in Faversham. This measure is typically a safety measure with focus on reducing the speed differential between active travel and cars. A 20 mph zone would however not show up in the modelling due to the low speeds in the model. However, it could work in conjunction with a Charging CAZ by increasing the journey times of taking back roads in an attempt to avoid the charge. The 20 mph zone concept also supports wider uptake of walking and cycling which will impact on air quality and this mode shift approach was taken through into the final modelling. The other measure raised but not taken forwards was to increase rail freight in an attempt to reduce road freight, but this measure had insufficient data to be modelled.

As a result of these discussions, the short list of measures was further refined into a selection of different modelling scenarios. The modelled scenarios are collections of measures that target specific sectors and the scenarios (including rationale) were:

1. **CAZ B** – This was determined to be the most likely charging CAZ option to be pursued. It was also proposed that buses and taxis should exempt for 3 years from the scheme as they were only a small source of emissions and it was felt it would be an unnecessary burden to this sector when trying to promote alternatives to the car. Also during (and before) this exemption period it would be the intention to work with the bus and taxi industry to support them in upgrading their vehicles to meet the CAZ standard.
2. **CAZ D** – It was agreed to be carried out as a reference CAZ as the likely to be the most impactful measures, but it was noted that the political acceptability would be very low. As with the CAZ B buses and taxis would be exempt for 3 years.
3. **Mode shift package** – This was a package of measures that look to target moving people out of private vehicles and included: travel plans, walking and cycling infrastructure, cycle parking, pilots/loans/trials with e-bikes/scooters and car clubs. It was felt, that in the current pandemic that an increase in personal mobility as people increase the amount they are working from home may make reductions in the need for personal car journeys with the right support.
4. **Freight measures package** – Eurolink causes high percentages of goods vehicles so a consolidation centre and delivery service plans could reduce the number of goods vehicles on the road.

5. **Electric vehicle incentives** – To encourage the uptake of electric vehicles, a package of actions were considered to create the incentives and knowledge to increase the electric vehicle percentage in the fleet. This could be to include parking charges that are cheaper for EVs, the use of car clubs (which would be electric vehicles) and informational measures promoting their use (especially in travel plans).
6. **Pinch point parking removal** – By removing obstacles from the road it is possible to increase speeds. Low modelled speeds along parts of the A2 is a sign of queueing traffic which have relatively high emissions, removing pinch point parking allows for traffic to flow freely in both directions, reducing emissions.
7. **Non-charging CAZ package** – This measure is a combination of the non-CAZ measures as a package to show the impact if all sectors were tackled without the use of a formal CAZ.

The assumptions used to model each of these scenarios are described in the following section.

4 Air quality modelling of short-listed measures

Air quality modelling was carried out for each of the shortlisted options outlined in Section 3, in order to allow the effectiveness of each option in improving air quality to be assessed. The assumptions used to represent the shortlisted options are described in this chapter, and predicted pollutant concentrations in each scenario are presented.

4.1 Modelling assumptions for options

Traffic flows and fleet data in the 2022 baseline model were adjusted to reflect each of the shortlisted options using the best available approach for each measure. Where official guidance was available which provides assumptions for a particular measure, this information was used; in the absence of guidance, suitable proxies from other studies were sought. Appropriate, expert judgement was used to assess the best way to model the measures. Table 4-1 presents the modelling assumptions followed for each of the short-listed measures, together with the data source for each assumption.

Table 4-1: Modelling assumptions for short-listed measures

Option	Description	Modelling assumptions	Data source for assumptions
Charging CAZ B HGVs Buses Taxis	CAZ B covering A2 from A249 to A299, including St Paul's Street AQMA. - Buses and taxis with proposed exemption for 3 years, so are unaffected by the CAZ in 2022.	JAQU behavioural response assumptions	JAQU assumptions Grant and exemption assumptions
Charging CAZ D HGVs Buses Taxis LGVs Cars	CAZ D covering A2 from A249 to A299, including St Paul's Street AQMA. - Buses and taxis with proposed exemption for 3 years, so are unaffected by the CAZ in 2022.	JAQU behavioural response assumptions	JAQU assumptions Grant and exemption assumptions
Mode shift	Mode shift package targeting Swale in general but focusing along the A2 including: - Travel plans – schools and businesses - Work with KCC in investment in walking and cycling infrastructure - Invest in secure cycle parking - Pilots/loans/trials with e-bikes/scooters - Car club in Sittingbourne and Faversham	3.5% reduction in traffic	Cardiff CAZ modelling from Motts - 3.5% reduction in car traffic for travel plan and cycle scheme based on previous pilot evaluation DfT Sustainable travel towns study investment of 4p per km removed
Freight	Package focused on freight, again covering the main swale towns but with focus along A2, including: - Delivery and servicing plans, link to travel plans - Consolidation centre servicing Sittingbourne and Faversham	3% reduction in freight traffic	Southampton LES/CAZ study, 7.5% reduction for DSP and consolidation centre based on 15% reduction for 50% of premises. Assume only 20% uptake as final CAZ was much lower gives 3% freight reduction.
EV	Package to promote electric cars and vans across Swale including: - Parking charge incentives - Charging infrastructure in Council car parks also working with businesses - Promotion – link to travel plans - E-car clubs linked to car clubs (could just shift car clubs here)	2% cars and vans EV	Derby EV strategy, 2% EV's in fleet by 2022. Check current EfT projections. Should be greater than these. Derby LES and EV strategy has costing info to use.

Option	Description	Modelling assumptions	Data source for assumptions
Pinch point	Remove pinch point parking on A2	Speed data adjusted upwards to link average at pinch points	Expert judgement
Non charging package	Bundle of mode shift, freight, electric vehicles and pinch point removal	All non-charging assumptions combined	
CAZ B plus non charging package	This was a simple addition of the benefits of the CAZ B and the non-charging package. This was only carried out for the monitoring site results.	Simple addition of benefits	

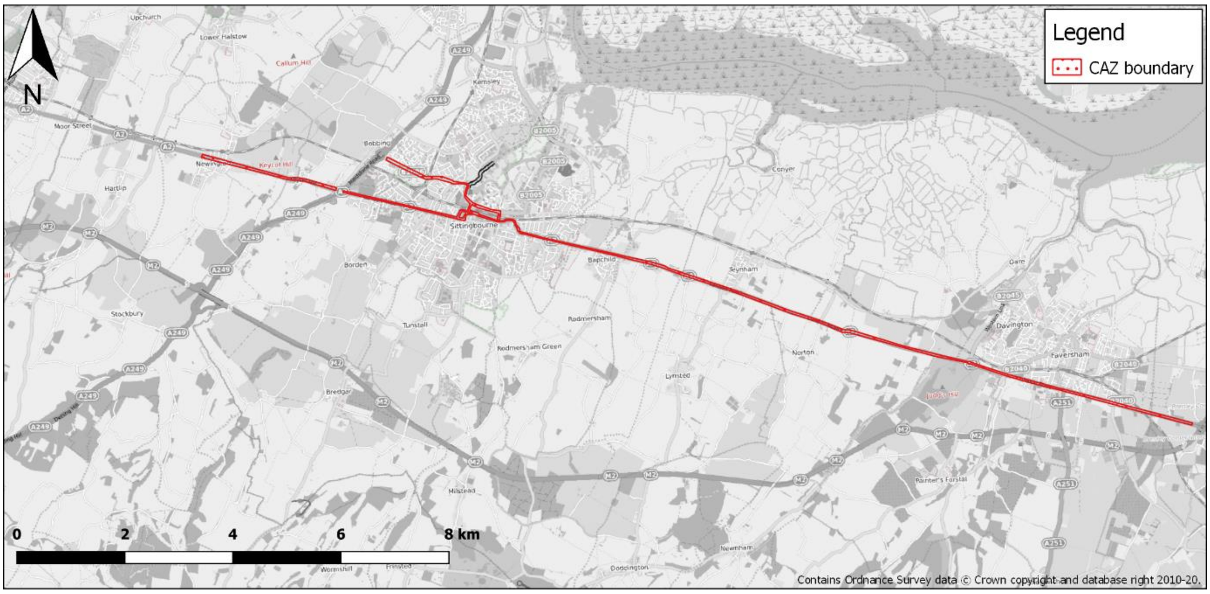
Driver response behaviour to the implementation of a charging Clean Air Zone was taken from the Third Wave Evidence Package document published by JAQU for use in Clean Air Zone studies. These statistics represent behavioural responses from the implementation of the ULEZ in London, and are therefore considered appropriate for this study. The behavioural responses are summarised in Table 4-2.

Table 4-2: Response behaviour assumptions to a charging CAZ (taken from Third Wave Evidence Package document from JAQU)

Response	Cars	LGV	HGV
Upgrade vehicle	64%	64%	83%
Cancel trip	7%	6%	4%
Change mode	11%	2%	0%
Avoid zone	11%	8%	4%
Pay charge	7%	20%	9%

Figure 4-1 presents the proposed charging CAZ boundary used in the modelling. This boundary encompasses the A2 running through Swale, and sections of roads with measured exceedances of the Air Quality Objective.

Figure 4-1: Proposed charging CAZ boundary



4.2 Air quality results for short-listed options

4.2.1 Summary of results

A summary of the results considering road link compliance and monitoring sites (both globally and locally adjusted) are shown in Table 4-3 below. This table shows the number of road links exceeding or at risk for each scenario, the average reduction in concentration resulting at monitoring sites across the study area, and the total number of monitoring sites predicted to exceed the objective or 'at risk' of exceeding the objective in 2022.

Table 4-3: Summary of air quality results for short listed options

Category	Reference Case	CAZ B	CAZ D	EV	Freight	Mode Shift	Pinch Point	All non-charging	CAZ B + non-charging
Average reduction concentration reduction across all monitoring sites									
Reduction	0%	1.7%	18.4%	1.2%	0.6%	2.1%	0.3%	3.0%	4.7%
Number of monitoring sites exceeding or at risk (global adjustment)									
Exceeding	0	0	0	0	0	0	0	0	0
At risk	2	2	0	2	2	2	2	2	2
Number of monitoring sites exceeding or at risk (site-specific adjustment)									
Exceeding	1	1	0	1	1	1	1	0	0
At risk	1	1	0	1	1	1	1	2	2

The charging class D CAZ is highly effective in reducing annual mean NO_2 concentrations in across all monitoring sites in Swale, reducing concentrations by 18.4% on average. Concentrations are reduced along all roads in the study area as the result of the expected fleet upgrades in response to the CAZ. This is to be expected, as the class D CAZ is the only charging measure to affect diesel cars, which account for the majority of NOx emissions in the area. The CAZ D is predicted to eliminate all exceedances including in the St. Paul's Street AQMA, and reduces concentrations along all road links to below 'at risk'.

As the charging class B CAZ is only designed to affect HGVs, the overall impact on predicted pollution levels is small compared to the class D CAZ; an average reduction of 1.7% is seen across monitoring sites, less than a tenth of the change from implementing the class D CAZ. This change is not sufficient to eliminate the exceedance in the St. Paul's Street AQMA when considering local adjustment.

Of the non-charging interventions the modal shift intervention delivers the largest average change in annual mean NO_2 concentrations across the study area, leading to a 2% reduction in concentrations. This corresponds to a 0.9 $\mu g.m^{-3}$ reduction in annual mean NO_2 concentrations at receptors 4m from the St. Paul's Street and East Street AQMAs. This measure just reduces the locally adjusted concentration in St Pauls to the limit value and so is technically in compliance.

Pinch point effects are highly localised, and as such the average effect across all roads in the study area is small; however, significant reductions are achieved along short sections of the A2. However, as the St. Paul's Street AQMA is not affected by the proposed changes, this exceedance is not affected by the measure.

The implementation of a package to promote electric cars and LGVs in the area and reduction in freight traffic lead to additional small reductions in NO_2 concentrations. However, these measures are not sufficiently effective to address air quality issues in the borough on their own.

Bundling all four non-charging measures together with the CAZ B leads to a 4.7% reduction in average predicted concentrations, and is predicted to address the potential air quality exceedance on St. Paul's Street. This road is therefore classified as 'at risk' in this scenario.

Maps showing modelled concentrations at receptors relevant to compliance of the Air Quality Directive along each road are presented in Section 4.3. These extract the highest concentration along each road link estimated at 4 m from the roadside. These plots give a fuller view of air quality across the study area beyond just the monitoring locations.

Predicted concentrations for all the shortlisted options at monitoring sites in the study area are presented in Section 4.4. Table 4-4 shows concentrations that have been adjusted to match the measurements at these locations, i.e. using local adjustment factors rather than the global adjustment factor described in section 2.6. Results using the global adjustment factor are provided in Table 4-5

4.3 Maps of results

4.3.1 Charging CAZ B

Figure 4-2 – The reduction in NO_2 concentrations along the A2 for the CAZ B option

Figure 4-3 – The reduction in NO_2 concentrations around Faversham for the CAZ B option

Figure 4-4 – The reduction in NO_2 concentrations around Newington for the CAZ B option

Figure 4-5 – The reduction in NO_2 concentrations around Sittingbourne for the CAZ B option

4.3.2 Charging CAZ D

Figure 4-6 – The reduction in NO_2 concentrations along the A2 for the CAZ D option

Figure 4-7 – The reduction in NO_2 concentrations around Faversham for the CAZ D option

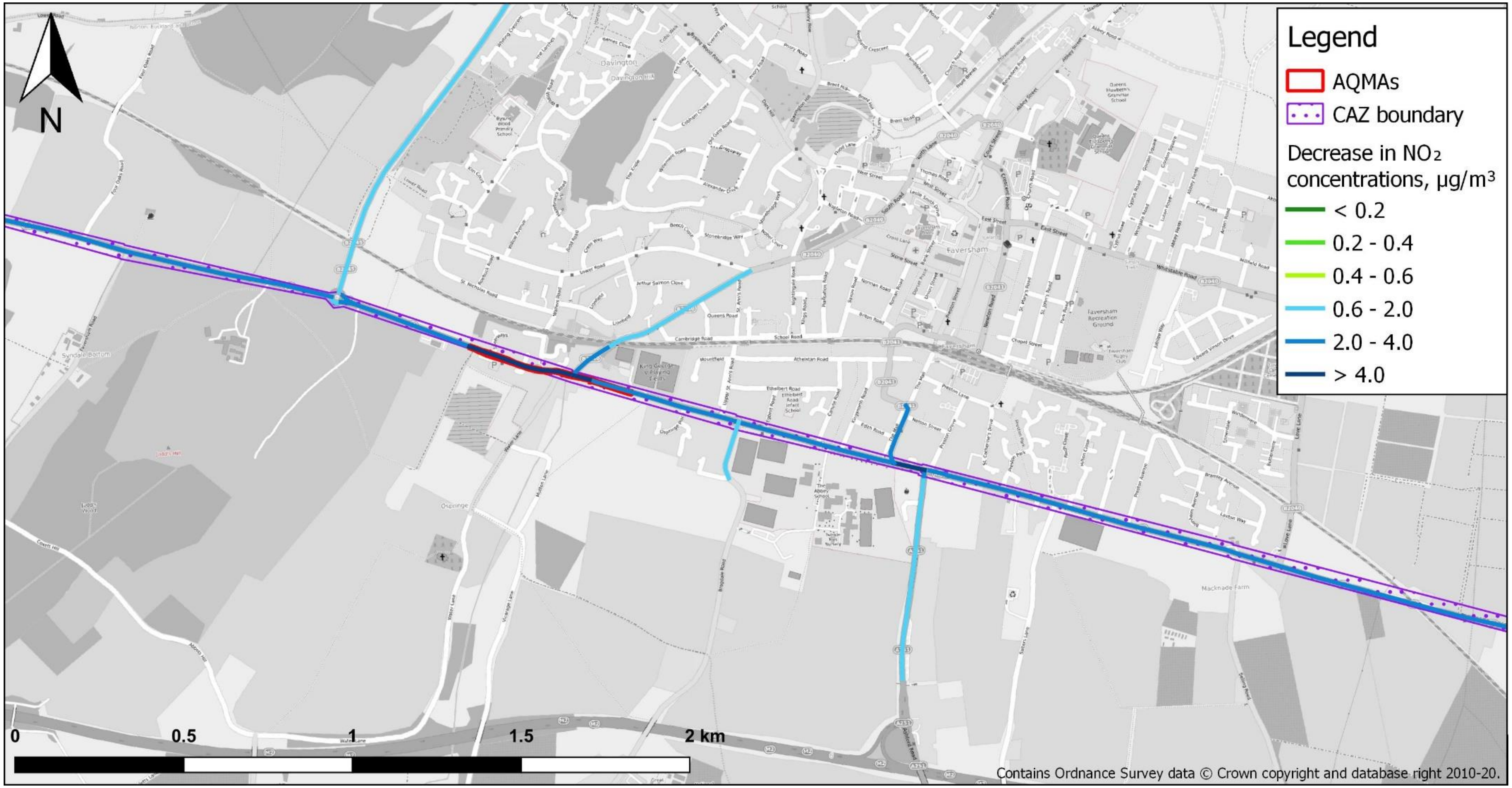


Figure 4-8 – The reduction in NO_2 concentrations around Newington for the CAZ D option

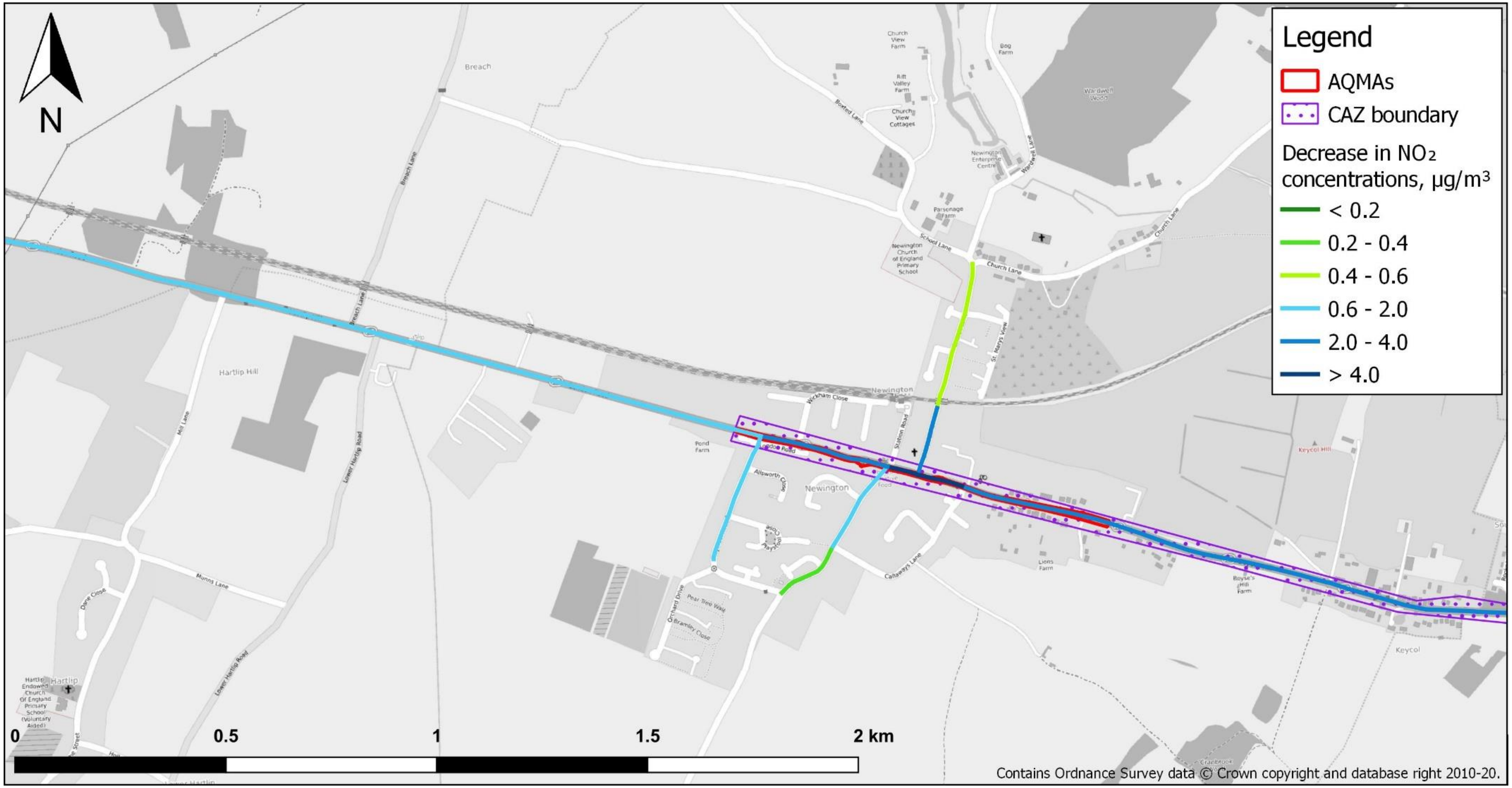
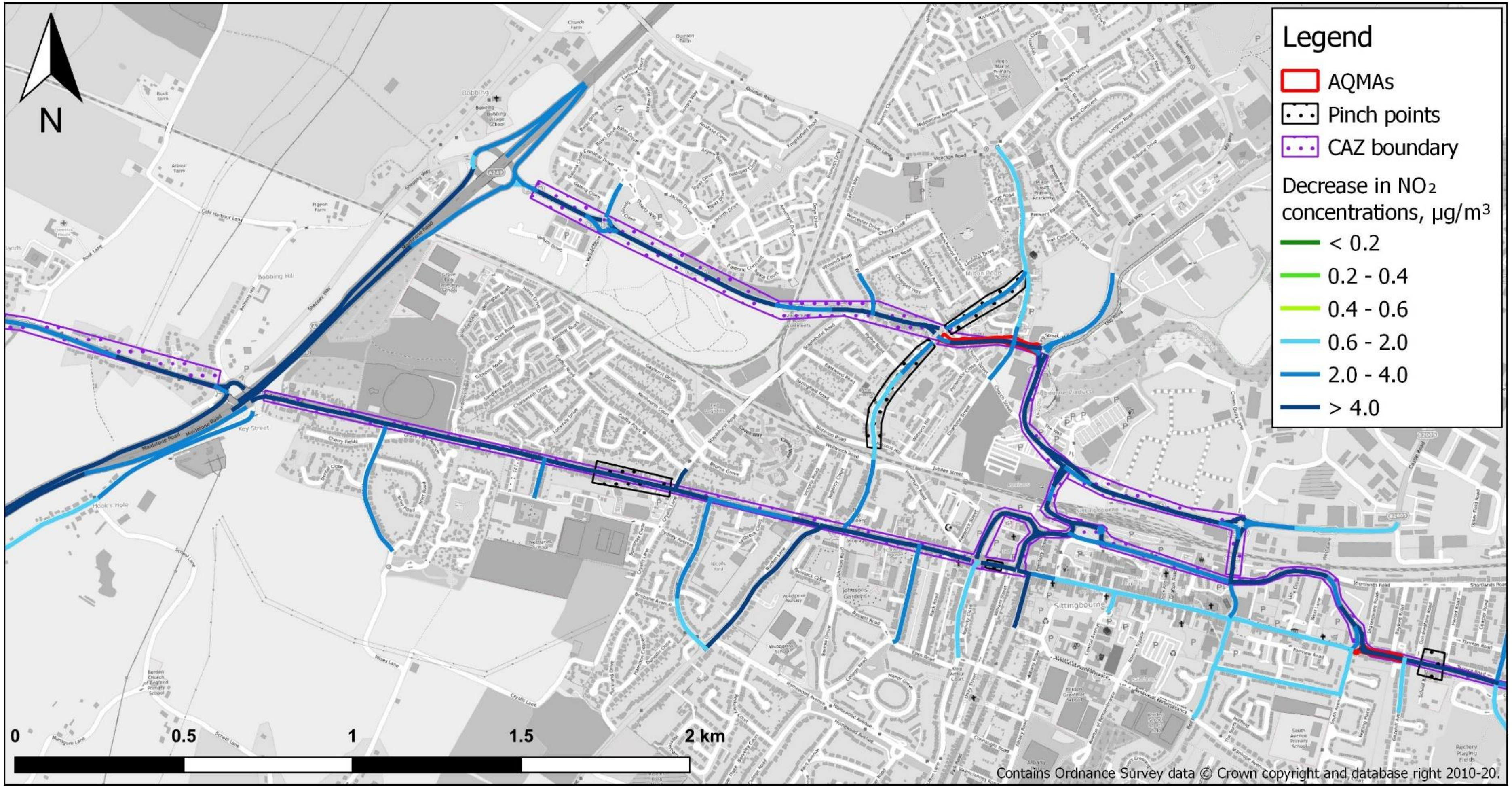


Figure 4-9 – The reduction in NO_2 concentrations around Sittingbourne for the CAZ D option



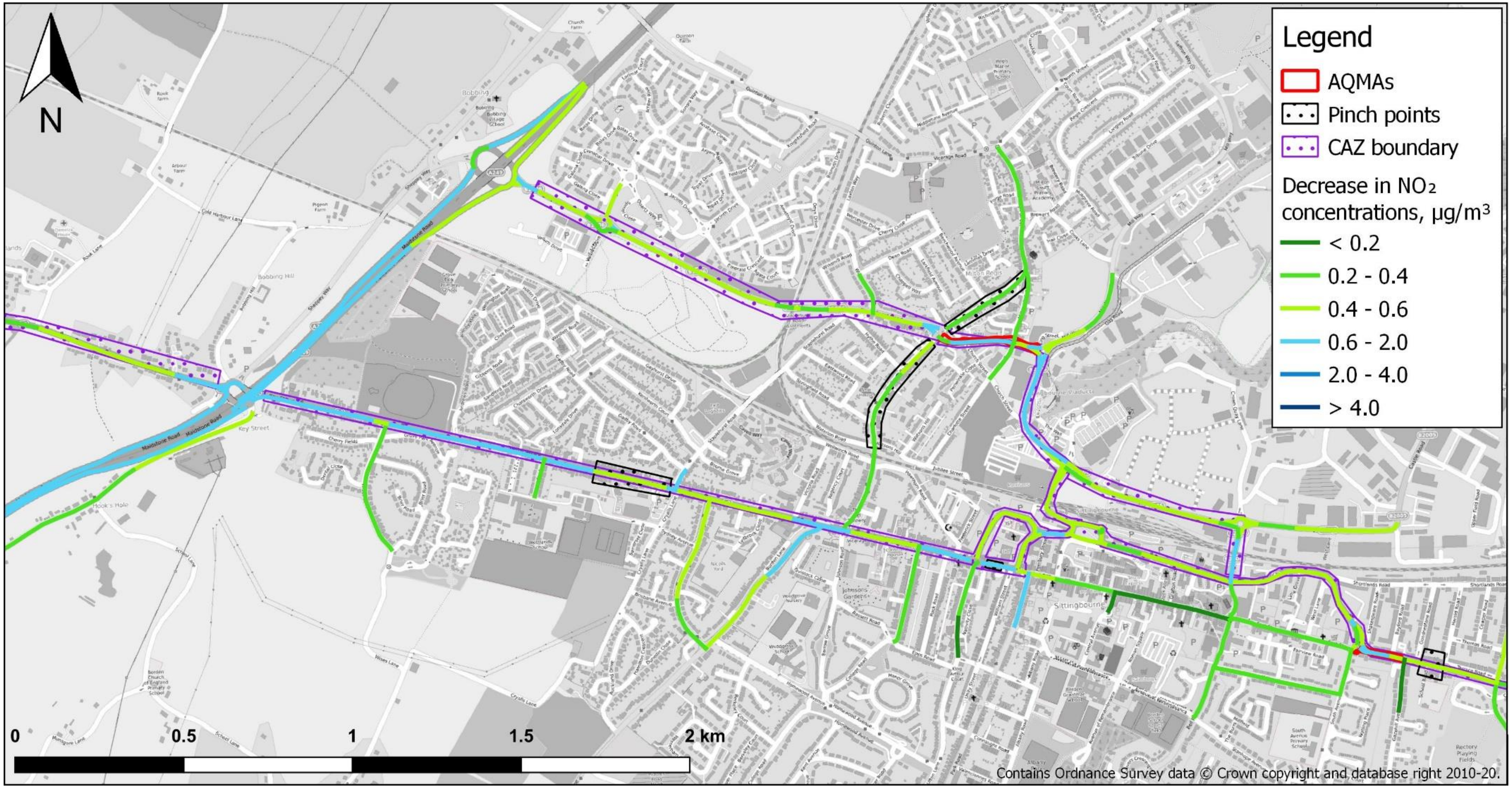
4.3.3 Mode shift

Figure 4-10 – The reduction in NO_2 concentrations along the A2 for the mode shift option

Figure 4-11 – The reduction in NO_2 concentrations around Faversham for the mode shift option

Figure 4-12 – The reduction in NO_2 concentrations around Newington for the mode shift option

Figure 4-13 – The reduction in NO_2 concentrations around Sittingbourne for the mode shift option



4.3.4 Freight

Figure 4-14 – The reduction in NO_2 concentrations along the A2 for the freight option

Figure 4-15 – The reduction in NO_2 concentrations around Faversham for the freight option

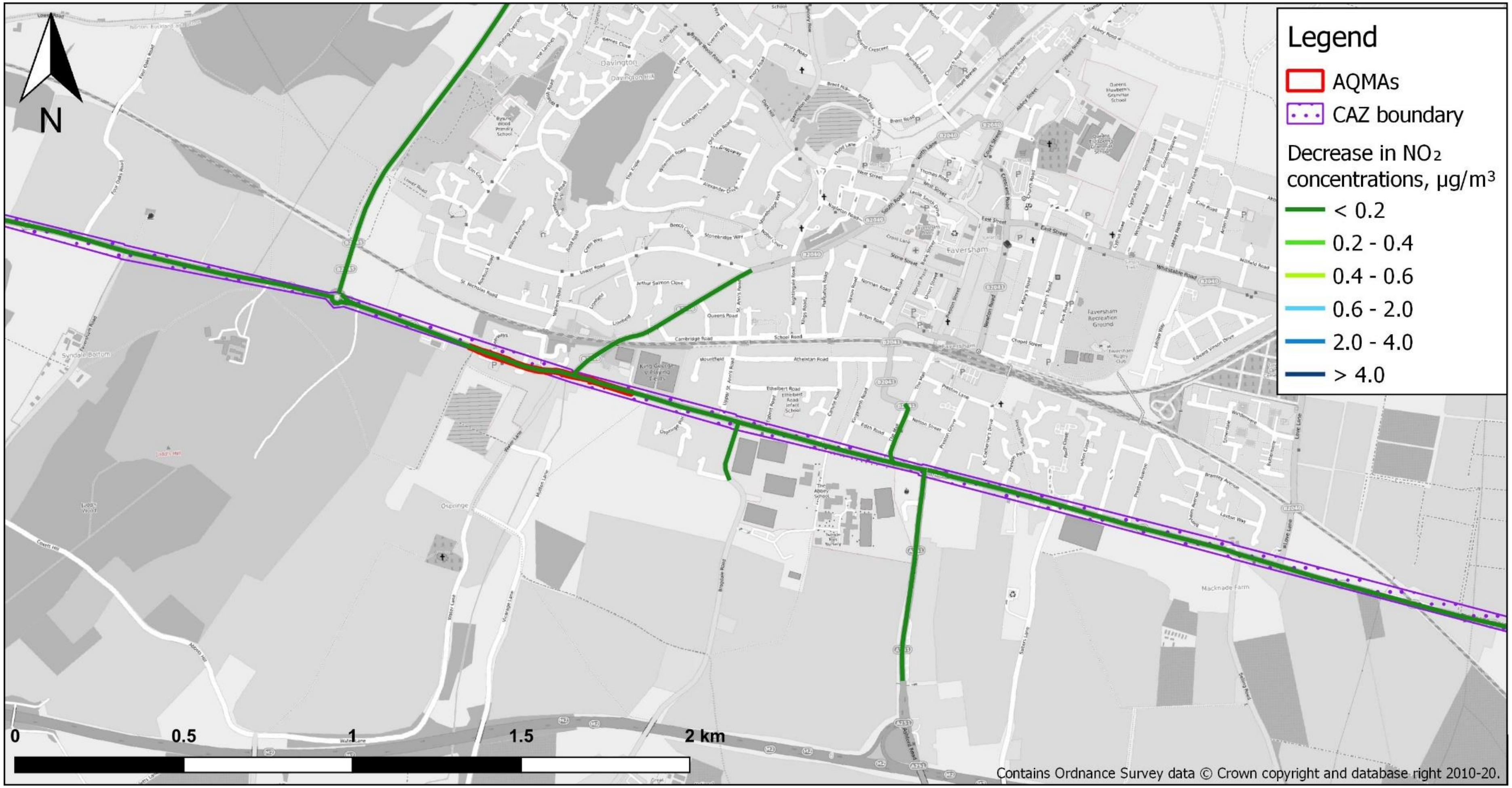
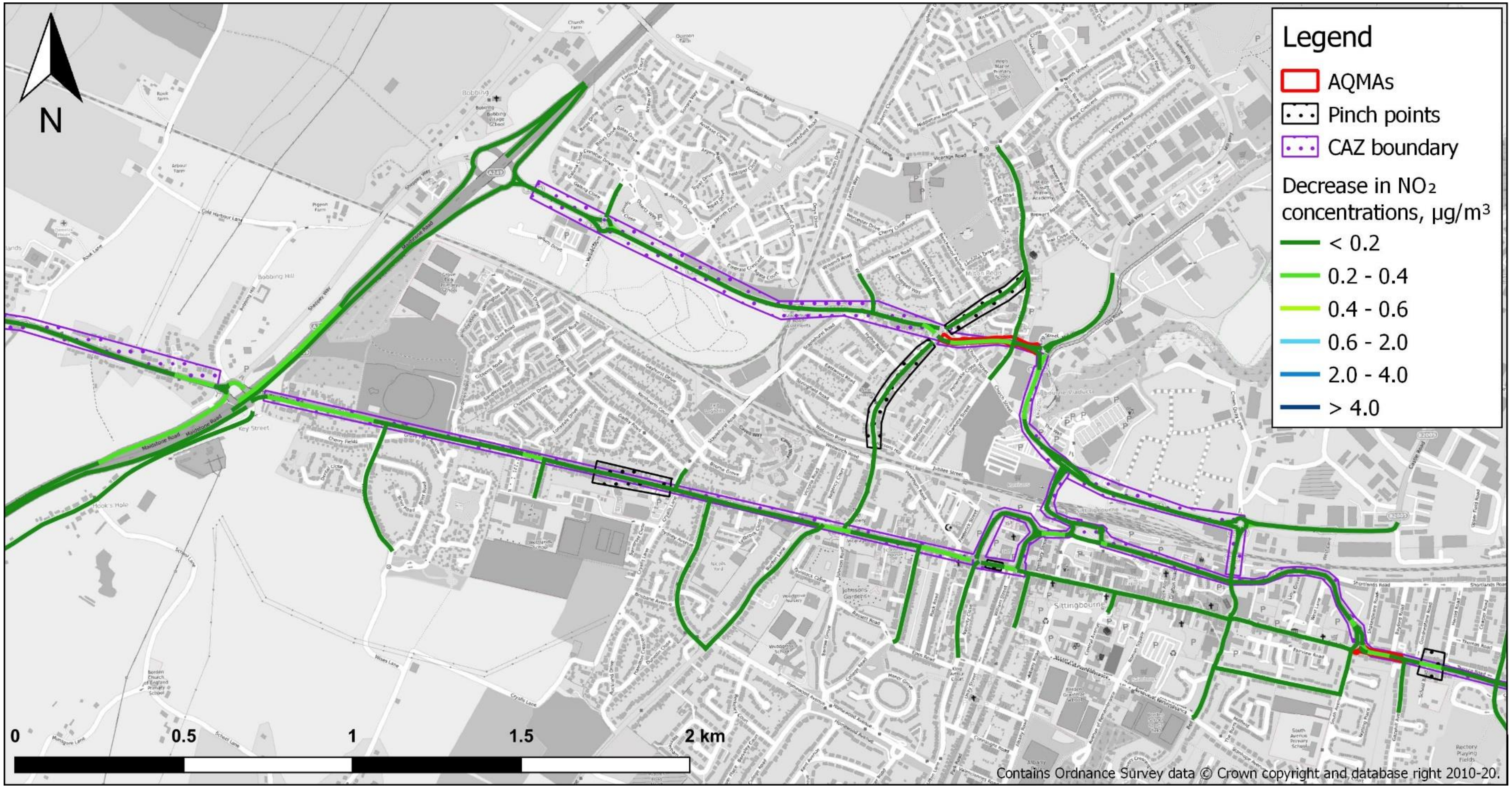


Figure 4-16 – The reduction in NO_2 concentrations around Newington for the freight option

Figure 4-17 – The reduction in NO_2 concentrations around Sittingbourne for the freight option



4.3.5 EV

Figure 4-18 – The reduction in NO_2 concentrations along the A2 for the EV option

Figure 4-19 – The reduction in NO_2 concentrations around Faversham for the EV option

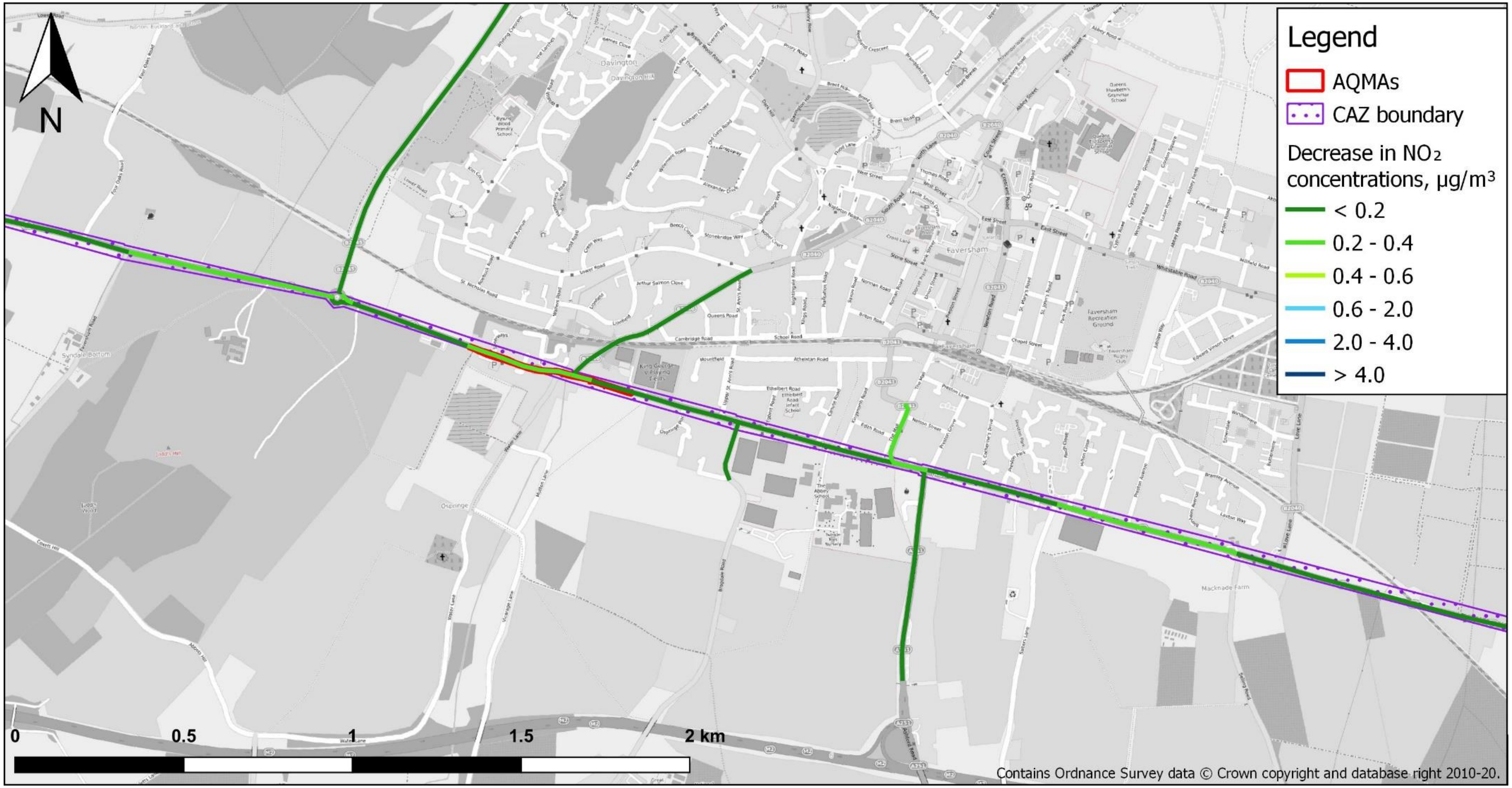


Figure 4-20 – The reduction in NO_2 concentrations around Newington for the EV option

Figure 4-21 – The reduction in NO_2 concentrations around Sittingbourne for the EV option

4.3.6 Pinch point

Figure 4-22 – The reduction in NO_2 concentrations along the A2 for the pinch point option

Figure 4-23 – The reduction in NO_2 concentrations around Faversham for the pinch point option

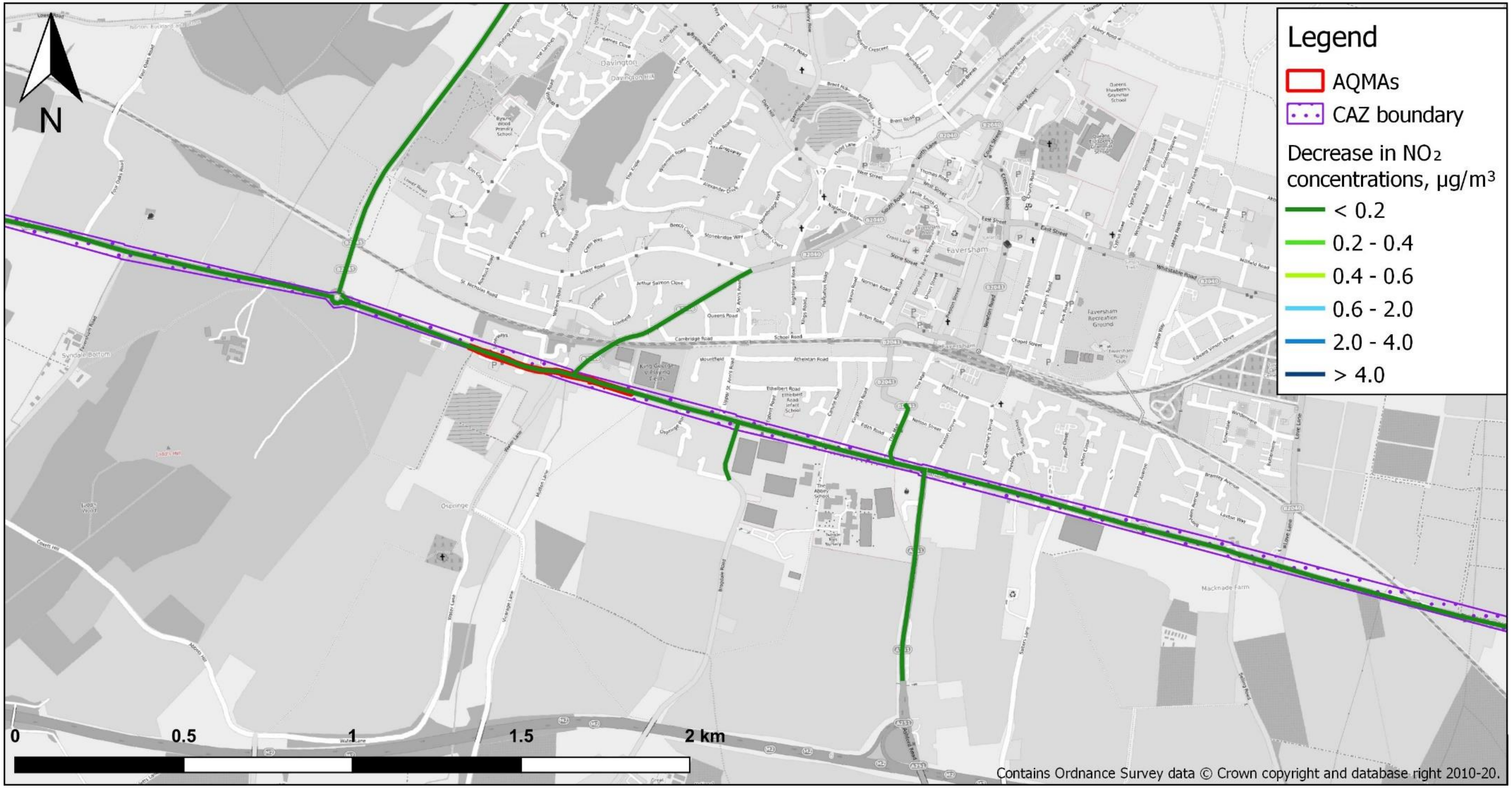
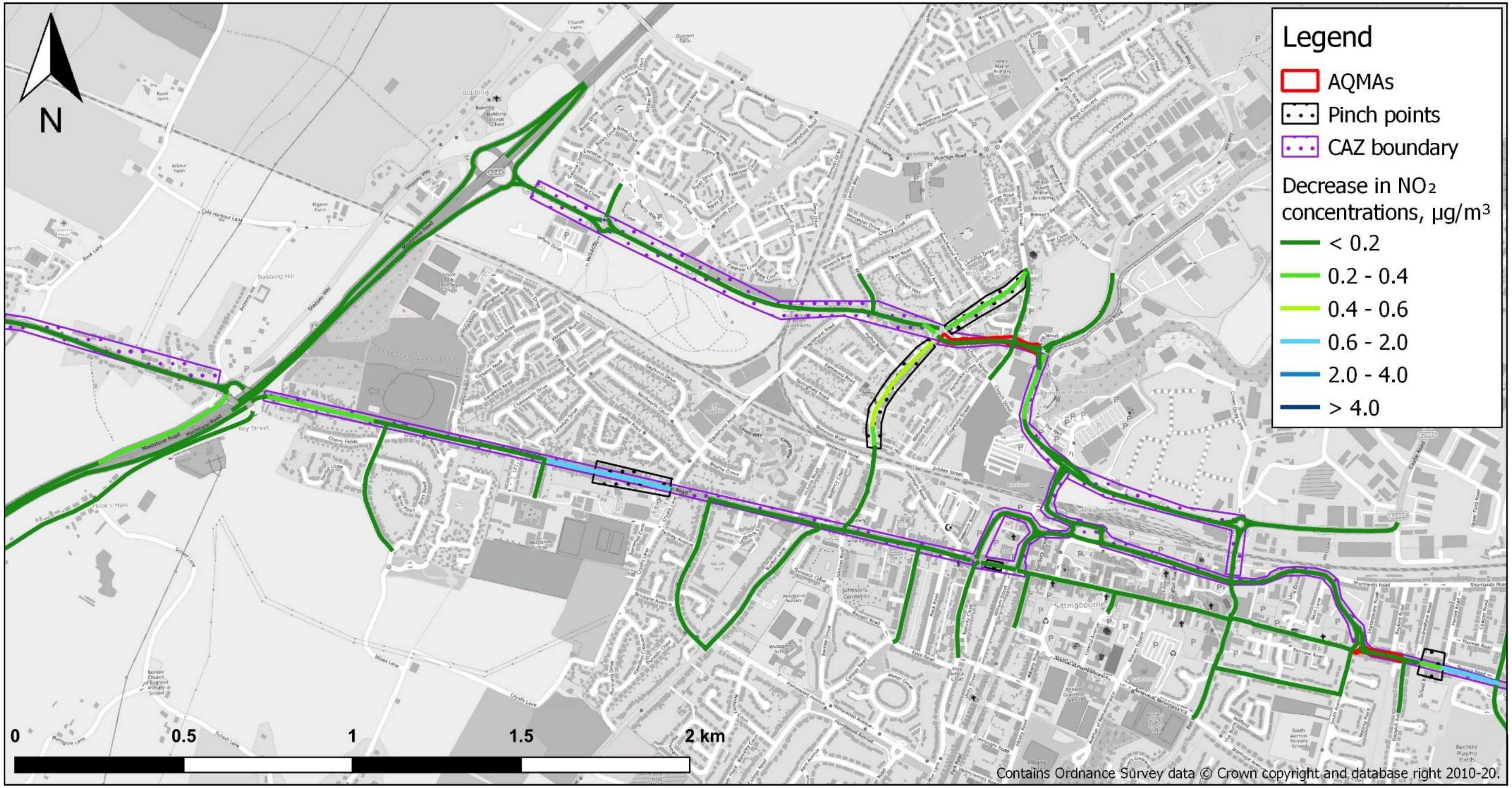


Figure 4-24 – The reduction in NO_2 concentrations around Newington for the pinch point option

Figure 4-25 – The reduction in NO_2 concentrations around Sittingbourne for the pinch point option



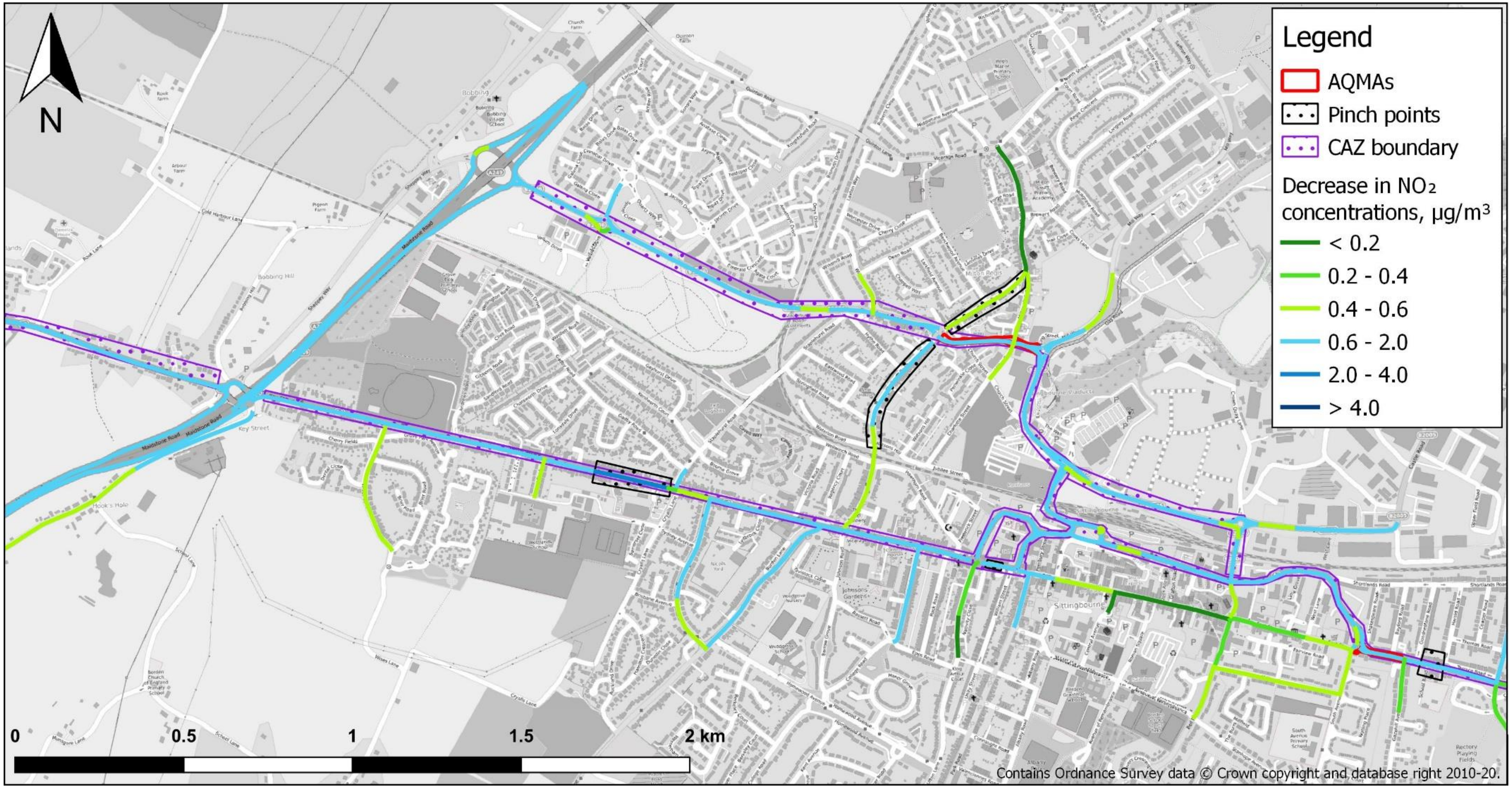
4.3.7 All non-charging measures combined

Figure 4-26 – The reduction in NO_2 concentrations along the A2 for the bundle combining all non-charging measures

Figure 4-27 – The reduction in NO_2 concentrations around Faversham for the bundle combining all non-charging measures

Figure 4-28 – The reduction in NO_2 concentrations around Newington for the bundle combining all non-charging measures

Figure 4-29 – The reduction in NO_2 concentrations around Sittingbourne for the bundle combining all non-charging measures



4.4 Results at monitoring locations

Table 4-4: Modelled annual mean NO_2 concentrations for the 2022 reference case and shortlisted options, local adjustment applied, µg.m^{-3}

Site	Road Name	Modelled annual mean NO_2 concentrations, 2022, µg.m^{-3}								
		Reference Case	CAZ B	CAZ D	EV	Freight	Mode Shift	Pinch Point	All non-charging	CAZ B + all non-charging
ZW6	Newington 3	20.6	20.3	16.7	20.4	20.5	20.2	20.6	20.0	19.8
ZW8	St Paul's Street	29.2	28.7	24.0	28.9	29.1	28.7	29.2	28.4	27.8
ZW3	Ospringe Roadside	24.0	23.5	19.2	23.7	23.8	23.5	24.0	23.2	22.7
SW66	96/94High Street, Newington	25.6	25.2	20.4	25.3	25.5	25.1	25.6	24.9	24.5
SW45	64 High Street, Newington	27.5	27.1	22.2	27.2	27.4	27.0	27.5	26.7	26.3
SW35	60 High Street, Newington	32.2	31.6	25.7	31.8	32.0	31.6	32.1	31.2	30.6
SW42	High Street, Opp Church Lane	32.9	32.2	25.2	32.4	32.7	32.1	32.8	31.8	31.1
SW19	Newington Social Club	27.8	27.3	22.0	27.4	27.6	27.2	27.7	27.0	26.4
SW20	Newington Co Op	20.1	19.8	16.2	19.8	19.9	19.7	20.0	19.5	19.2
SW36	49 High Street, Newington	24.8	24.3	19.6	24.5	24.6	24.3	24.7	24.0	23.6
SW82	Conservative Club, St Paul’s Street	41.6	40.8	33.8	41.1	41.3	40.7	41.5	40.3	39.5
SW51	14/16 St Paul’s Street	30.2	29.6	24.5	29.8	30.0	29.5	30.1	29.2	28.6
SW89	St Paul’s Street Air Quality Station	30.2	29.7	24.8	29.9	30.1	29.7	30.2	29.4	28.8
SW71	o/s 8 Staple Close, Staplehurst Road, Sittingbourne	27.4	27.1	22.4	27.1	27.3	26.8	27.3	26.6	26.2
SW73	14 Chalkwell Road, Sittingbourne	23.7	23.4	20.3	23.4	23.6	23.2	23.5	22.9	22.6
SW56	126 East Street, Sittingbourne	29.1	28.7	23.9	28.8	29.0	28.6	29.1	28.4	27.9

Site	Road Name	Modelled annual mean NO_2 concentrations, 2022, µg.m^{-3}								
		Reference Case	CAZ B	CAZ D	EV	Freight	Mode Shift	Pinch Point	All non-charging	CAZ B + all non-charging
SW87	Canterbury Road AQ Station	24.2	23.8	19.8	23.9	24.0	23.7	24.1	23.5	23.2
SW99	A2 Frognal Lane, Teynham	20.1	19.8	16.0	19.8	20.0	19.7	20.0	19.5	19.2
SW91	Adj to 72 London Road, Teynham	25.5	25.2	20.4	25.2	25.4	25.0	25.4	24.7	24.4
SW101	A2 Lynsted Lane, Jct	18.2	18.0	14.6	18.0	18.1	17.9	18.2	17.7	17.4
SW28	Mayors Arms, Ospringe	31.9	31.1	25.5	31.6	31.7	31.3	31.9	30.9	30.1
SW30	ZW3 Ospringe Street	22.9	22.4	18.2	22.6	22.8	22.4	22.9	22.1	21.6
SW31	Site 7, 4 Ospringe Street	28.0	27.5	22.5	27.6	27.8	27.4	27.9	27.1	26.6
SW32	11 Ospringe Street, Ospringe	27.6	27.2	22.8	27.3	27.5	27.1	27.6	26.9	26.4
SW96	Maison Dieu, Ospringe Street	27.0	26.3	21.3	26.7	26.8	26.4	27.0	26.1	25.4
SW29	Opp Lions Yard, Ospringe Street	30.4	29.7	24.4	30.1	30.2	29.8	30.4	29.5	28.7
SW120	103 Ospringe Street, Ospringe, Faversham	29.6	29.1	23.9	29.2	29.4	29.0	29.5	28.7	28.2
SW117	Land Adj Orchard, Canterbury Road, Faversham	22.2	22.0	18.7	21.9	22.1	21.8	22.1	21.6	21.4
SW62	Key Street, Sittingbourne	24.9	24.5	19.8	24.5	24.7	24.2	24.7	23.9	23.6
SW110	2 Cherryfields, Sittingbourne	15.0	14.8	13.4	14.8	14.9	14.8	14.9	14.6	14.5
SW111	76A Key Street, Sittingbourne	28.9	28.5	22.8	28.5	28.7	28.2	28.8	27.9	27.5
SW112	56 Key Street, Sittingbourne	25.2	24.8	19.9	24.8	25.0	24.6	25.1	24.3	24.0
SW114	2 Florence Cottages, Chestnut Street	15.9	15.8	14.3	15.7	15.8	15.6	15.9	15.5	15.3
SW115	Cherry Tree Cottage, Chestnut Street	16.6	16.5	15.0	16.4	16.5	16.3	16.5	16.2	16.1

Site	Road Name	Modelled annual mean NO_2 concentrations, 2022, µg.m^{-3}								
		Reference Case	CAZ B	CAZ D	EV	Freight	Mode Shift	Pinch Point	All non-charging	CAZ B + all non-charging
SW116	Bankside, Chestnut Street	16.4	16.3	14.9	16.2	16.3	16.1	16.3	16.0	15.9
SW124	31/33 Keycol Hill Sittingbourne Highest Point	39.2	38.4	31.2	38.7	38.9	38.3	39.2	37.9	37.1
SW121	Façade Squirrel Cottage, Keycol Hill	32.5	31.8	26.3	32.1	32.3	31.8	32.5	31.4	30.6
SW122	Façade 13 Key Street, Sittingbourne	15.8	15.6	13.2	15.6	15.8	15.5	15.8	15.3	15.1
SW123	12 Key Street, Sittingbourne	20.2	19.9	16.5	19.9	20.1	19.7	20.1	19.5	19.2
SW76	155 Canterbury Road, Sittingbourne	25.9	25.4	20.8	25.6	25.8	25.4	25.9	25.2	24.7
SW119	Flats, The Mount, Ospringe	19.2	18.9	15.9	19.0	19.1	18.8	19.2	18.7	18.4
SW83	Pembury Court, Dover Street	19.0	18.7	15.5	18.8	18.9	18.6	18.9	18.4	18.2
SW125	16/18 The Street, Bapchild	18.5	18.2	14.9	18.3	18.5	18.2	18.5	18.0	17.7

Table 4-5: Modelled annual mean NO_2 concentrations for the 2022 reference case and shortlisted options, no local adjustment applied, μg.m^{-3}

Site	Road Name	Modelled annual mean NO_2 concentrations, 2022, μg.m^{-3}								
		Reference Case	CAZ B	CAZ D	EV	Freight	Mode Shift	Pinch Point	All non-charging	CAZ B + all non-charging
ZW6	Newington 3	25.9	25.6	21.0	25.6	25.8	25.4	25.9	25.2	24.8
ZW8	St Paul's Street	34.9	34.2	28.7	34.5	34.7	34.2	34.8	33.9	33.2
ZW3	Ospringe Roadside	20.1	19.6	16.1	19.8	19.9	19.6	20.0	19.4	18.9
SW66	96/94High Street, Newington	25.7	25.3	20.5	25.4	25.6	25.2	25.7	24.9	24.5
SW45	64 High Street, Newington	24.2	23.9	19.6	24.0	24.1	23.8	24.2	23.5	23.2
SW35	60 High Street, Newington	26.4	25.9	21.1	26.1	26.3	25.9	26.4	25.6	25.1
SW42	High Street, Opp Church Lane	32.8	32.1	25.1	32.3	32.5	32.0	32.7	31.6	30.9
SW19	Newington Social Club	26.0	25.5	20.6	25.6	25.8	25.4	25.9	25.2	24.7
SW20	Newington Co Op	25.8	25.5	20.9	25.5	25.7	25.3	25.8	25.1	24.8
SW36	49 High Street, Newington	26.6	26.1	21.0	26.3	26.4	26.1	26.5	25.8	25.3
SW82	Conservative Club, St Paul's Street	37.1	36.4	30.1	36.7	36.9	36.3	37.0	35.9	35.2
SW51	14/16 St Paul's Street	37.0	36.3	30.1	36.6	36.8	36.2	36.9	35.9	35.1
SW89	St Paul's Street Air Quality Station	34.9	34.2	28.7	34.5	34.7	34.2	34.8	33.9	33.2
SW71	o/s 8 Staple Close, Staplehurst Road, Sittingbourne	28.8	28.4	23.5	28.4	28.6	28.2	28.7	27.9	27.5
SW73	14 Chalkwell Road, Sittingbourne	21.9	21.6	18.7	21.6	21.7	21.4	21.7	21.2	20.9
SW56	126 East Street, Sittingbourne	31.3	30.9	25.7	31.0	31.2	30.8	31.3	30.5	30.1
SW87	Canterbury Road AQ Station	30.0	29.5	24.5	29.6	29.8	29.4	29.9	29.2	28.7

SW99	A2 Frognal Lane, Teynham	21.5	21.2	17.2	21.2	21.4	21.1	21.4	20.9	20.6
SW91	Adj to 72 London Road, Teynham	20.2	19.9	16.1	19.9	20.1	19.8	20.1	19.6	19.3
SW101	A2 Lynsted Lane, Jct	20.2	19.9	16.2	19.9	20.1	19.8	20.1	19.6	19.3
SW28	Mayors Arms, Ospringe	27.9	27.2	22.3	27.6	27.7	27.3	27.9	27.0	26.3
SW30	ZW3 Ospringe Street	20.9	20.5	16.6	20.7	20.8	20.5	20.9	20.2	19.7
SW31	Site 7, 4 Ospringe Street	25.8	25.3	20.7	25.5	25.6	25.2	25.7	25.0	24.5
SW32	11 Ospringe Street, Ospringe	22.1	21.7	18.3	21.9	22.0	21.7	22.1	21.5	21.1
SW96	Maison Dieu, Ospringe Street	30.3	29.5	23.9	30.0	30.1	29.6	30.3	29.3	28.5
SW29	Opp Lions Yard, Ospringe Street	27.8	27.1	22.3	27.5	27.6	27.2	27.8	27.0	26.2
SW120	103 Ospringe Street, Ospringe, Faversham	24.9	24.4	20.1	24.6	24.7	24.4	24.8	24.1	23.7
SW117	Land Adj Orchard, Canterbury Road, Faversham	16.5	16.3	13.9	16.3	16.4	16.2	16.4	16.0	15.9
SW62	Key Street, Sittingbourne	25.9	25.5	20.6	25.5	25.7	25.3	25.8	24.9	24.6
SW110	2 Cherryfields, Sittingbourne	14.3	14.2	12.8	14.2	14.3	14.1	14.3	14.0	13.9
SW111	76A Key Street, Sittingbourne	22.4	22.1	17.7	22.1	22.3	21.9	22.3	21.7	21.3
SW112	56 Key Street, Sittingbourne	22.5	22.2	17.8	22.2	22.4	22.0	22.4	21.7	21.4
SW114	2 Florence Cottages, Chestnut Street	17.1	17.0	15.3	16.9	17.0	16.8	17.0	16.6	16.5
SW115	Cherry Tree Cottage, Chestnut Street	15.1	15.0	13.7	15.0	15.1	14.9	15.1	14.8	14.6
SW116	Bankside, Chestnut Street	15.6	15.5	14.2	15.5	15.6	15.4	15.6	15.2	15.1
SW124	31/33 Keycol Hill Sittingbourne Highest Point	31.4	30.8	25.0	31.0	31.2	30.7	31.4	30.3	29.7
SW121	Façade Squirrel Cottage, Keycol Hill	33.3	32.6	27.0	32.9	33.1	32.6	33.3	32.2	31.4

SW122	Façade 13 Key Street, Sittingbourne	21.1	20.9	17.6	20.9	21.0	20.7	21.1	20.4	20.2
SW123	12 Key Street, Sittingbourne	24.6	24.3	20.1	24.2	24.4	24.0	24.5	23.7	23.4
SW76	155 Canterbury Road, Sittingbourne	27.0	26.4	21.7	26.7	26.8	26.5	27.0	26.3	25.7
SW119	Flats, The Mount, Ospringe	17.0	16.7	14.0	16.8	16.9	16.6	16.9	16.5	16.2
SW83	Pembury Court, Dover Street	25.6	25.2	20.9	25.3	25.4	25.1	25.5	24.8	24.5
SW125	16/18 The Street, Bapchild	23.0	22.6	18.5	22.8	22.9	22.6	23.0	22.4	22.0

5 Cost Benefit Analysis

5.1 Introduction

The cost-benefit analysis comprises a high-level assessment of the key costs and benefits that can accrue to transport policies that impact air pollution. These are:

- Costs to vehicle users that are required to upgrade their vehicle
- Changes in operational expenditure to drivers with newer vehicles.
- Fuel costs from the change in vehicle fleet
- CO_2 savings from the change in fuel use
- Health benefits from the reduction in exhaust pollution
- The cost of implementing the different policies

Not all the costs set out here apply to all the measures assessed in this report. Principally, two Clean Air Zones that charge non-compliant vehicles to enter a designated area will encourage people to purchase new (cleaner) vehicles. The other policies assessed will have no impact on the overall makeup of the fleet, although they may reduce the number of vehicles entering the appraisal area.

5.1.1 Scope

The analysis includes all types of vehicles expected to be on the road, cars, taxis, private hire vehicles, LGVs, HGVs, buses and coaches. The nature of the ANPR data (automatic number plate registration) used in this analysis means that taxis and private hire vehicles are included in the 'car' analysis and buses and coaches are included in the 'HGV' analysis.

5.2 Assumptions

Several key assumptions were made as part of the cost benefit analysis conducted here. Firstly, it is assumed that all policies are implemented in 2022 and assessed over a 10 year appraisal period from 2022-2032. Any impacts that occur in the future are discounted to 2022 with a discount rate of 3.5%[14]. Moreover, all costs are calculated in a 2019 price year.

Several additional assumptions have been made to simplify the analysis undertaken.

1. A 3.5% discount rate has been used;
2. An 'urban medium' damage cost value has been used to value the air quality benefit[15];
3. For the CAZ B and D, vehicles will upgrade to a compliant vehicle of the same fuel type[16];
4. A 36% optimism bias has been added to capital expenditure (CAPEX) implementation costs[17];
5. Several assumptions about what the final measures in the 'modal shift' package will look like have been made to assess the implementation costs (these are presented in the section on implementation costs)[18];

[14] The 3.5% discount rate is determined by the UK Green Book Guidance. An analysis of how this discount rate is derived can be found in Annex 6 of the Green Book

[15] Pollutant damage costs are provided by DEFRA and vary depending on the population density of the appraisal area. Here an 'urban medium' setting was used to describe the appraisal area.

[16] This was assumed for simplicity of modelling.

[17] The requirement for optimism bias to be applied is set out by JAQU, however the exact level of optimism bias is not specified. 36% was used to be consistent with other scheme which in turn used WebTag guidance to determine the optimism bias.

6. Where possible damage costs and CO_2 costs have been based on webtag guidance and developed by DEFRA. Vehicle and related costs are primarily based on a Ricardo (2014) report[19];
7. The CAZ B and D do not capture the potential upgrades of non-compliant taxis or buses after the 3 year exemption period[20];
8. First order behavioural responses to the CAZ (upgrade assumption) are provided by JAQU[21].

5.3 Methodology

The methodology follows that set out in the webtag guidance[22]. Given the relatively small size and scope of the project some changes have been implemented to streamline the analysis and conduct individual assessment for a group of individual policy options (such as the mode shift package).

5.3.1 Vehicle upgrades

A vehicle owner upgrading to cleaner vehicles and the resultant impact on air quality is the key output of each charging CAZ scheme. The costs associated with this decision is a critical impact category. Our approach to estimating upgrade costs has been tested in a number of cities considering charging schemes and has been applied in Swale when considering the Charging Scheme and Fleet upgrades.

The approach starts by calculating the number of vehicles to be upgraded. For the CAZ this is defined by applying behavioural responses to the non-compliant vehicles in the baseline. It is assumed that the oldest vehicles are the first to upgrade. The number of vehicles upgrading is based on JAQU data and presented in Table 5-1

Table 5-1: Response behaviour assumptions to a charging CAZ (taken from Third Wave Evidence Package document from JAQU)

Response	Cars	LGV	HGV
Upgrade vehicle	64%	64%	83%
Cancel trip	7%	6%	4%
Change mode	11%	2%	0%
Avoid zone	11%	8%	4%
Pay charge	7%	20%	9%

The cost to an owner of a change in vehicle is then estimated through consideration of the following:

- The lost residual value from scrapped vehicles or the resale value of an unwanted vehicle based on the depreciated value of vehicle in 2022
- New or used vehicle purchase costs in 2022

These input values are combined to give the net cost. Resale costs (if applicable) are netted off the purchase costs and lost residual value associated with each upgrade.

Upgrades will also occur in the baseline and our approach to estimating these costs is very similar to what has been applied when considering the policy scenario. The general assumption in the baseline

[18] Given the early stage, the measures had not been finalised and therefore an indicative analysis of what the cost could look like given some potential modal shift measures has been conducted. The example measures are based off similar measures modelled or introduced in other UK cities.
[19] Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished).
[20] This is due to a lack of ANPR data on taxis and buses in the area.
[21] See **Error! Reference source not found.**
[22] https://www.gov.uk/guidance/transport-analysis-guidance-tag

is that the same upgrade decision will be undertaken as in the measure but at a later date (defined by useful lives and ownership profiles). This future net cost is discounted (according to how far in the future it occurs) to 2022 to allow comparison with option costs.

The upgrade costs are calculated taking the difference in aggregate upgrade costs for the option and baseline scenarios. The cost of upgrade is hence calculated as the marginal impact of people upgrading earlier than they would do if a CAZ was not in place. This is to say that a person would upgrade in the future anyway, what is the economic impact of the person upgrading in the implementation year relative to the cost in the future year.

5.3.2 Vehicle costs

Ricardo's model takes into account changes in fuel consumption (related to OPEX and GHG impacts)[23] associated with the upgraded fleet that has resulted from the option.

The estimation of operating costs and greenhouse gas emissions focused on capturing the effect of upgrading vehicles, which switches the distance travelled (measure in vehicle-km - vkm) from one Euro class of vehicles to another. The following approach was taken:

1. Take numbers of vehicles upgraded from fleet upgrade calculations
2. Combine numbers of vehicles upgraded by different vehicle type and Euro standards with data around the average annual fuel consumption and average annual operating costs per vehicle type and age[24]
    a. By applying average OPEX and fuel consumption over the full year and average vkm travelled per annum, this illustrative modelling will likely capture an even wider domain of impacts – i.e. will include the impacts where upgraded vehicles travel outside the AQ modelling domain.
3. Changes in fuel consumption are combined with changes in fuel prices.
4. Changes in fuel consumption are combined with emissions factors from BEIS' Green Book Supplementary Guidance to calculate changes in GHG emissions (tCO_2e)[25]
5. Changes in GHG emissions in each year are combined with carbon values from BEIS' Green Book Supplementary Guidance: Non-traded, Central[26].

Note: due to limitation in the model, only a single year analysis has been conducted. Typically analysis is conducted over the entire appraisal period and reflects the relative difference between the policy and baseline scenario. This has not been possible in this analysis and therefore an extrapolation factor has been applied. This assumes that benefits captured in the modelled implementation year decrease over time (in a linear fashion) as older vehicles are replaced with newer vehicles in the baseline scenario[27].

[23] Annual fuel consumption and opex source: Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished)

[24] Consumption and OPEX for general vehicle types came from: Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished). Data for hybrid vehicles came from: Ricardo Energy & Environment (forthcoming). Car Choice Model (CCM) summary report.

[25] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/602657/5._Data_tables_1-19_supporting_the_toolkit_and_the_guidance_2016.xlsx

[26] BEIS supplementary Green Book Guidance https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/602657/5._Data_tables_1-19_supporting_the_toolkit_and_the_guidance_2016.xlsx Tables 3: Carbon Prices and sensitivities Price Year 2016. Prices have been adjusted to 2019. Average carbon price for appraisal period: £76.81/tCO2e.

[27] The extrapolation factor was used to be consistent with the air quality analysis and is derived from JAQU data.
Given some limitation is the baseline scenario modelled this method may presented a more realistic approach to vehicle replacement as typically not all owners will wait until the end of the vehicle life to replace the vehicle.

5.3.3 Air pollutant emissions

The key objective of these policy options is to reduce the emission (and subsequently concentrations) of air pollutant emissions from road transport sources. Reducing air pollutant emissions will have a range of subsequent benefits on human and environmental health, productivity and amenity.

The following approach to valuing the impacts associated with reductions in emissions is as follows:

1. Take quantities (tonnes) of emissions from underlying air quality modelling undertaken by Ricardo for all option scenarios and do minimum baseline
2. Calculate total emissions impact relative to baseline
3. Value impact applying damage costs provided by JAQU
    a. The damage cost 'Urban medium' is applied to all emissions reductions

The change in the total output of emission in the implementation year is given by the air quality model which calculated the total emission (of NO_x $PM_{2.5}$ and PM_{10}) under a business as usual and the CAZ scenarios. The difference in emissions for each scenario is then determined.

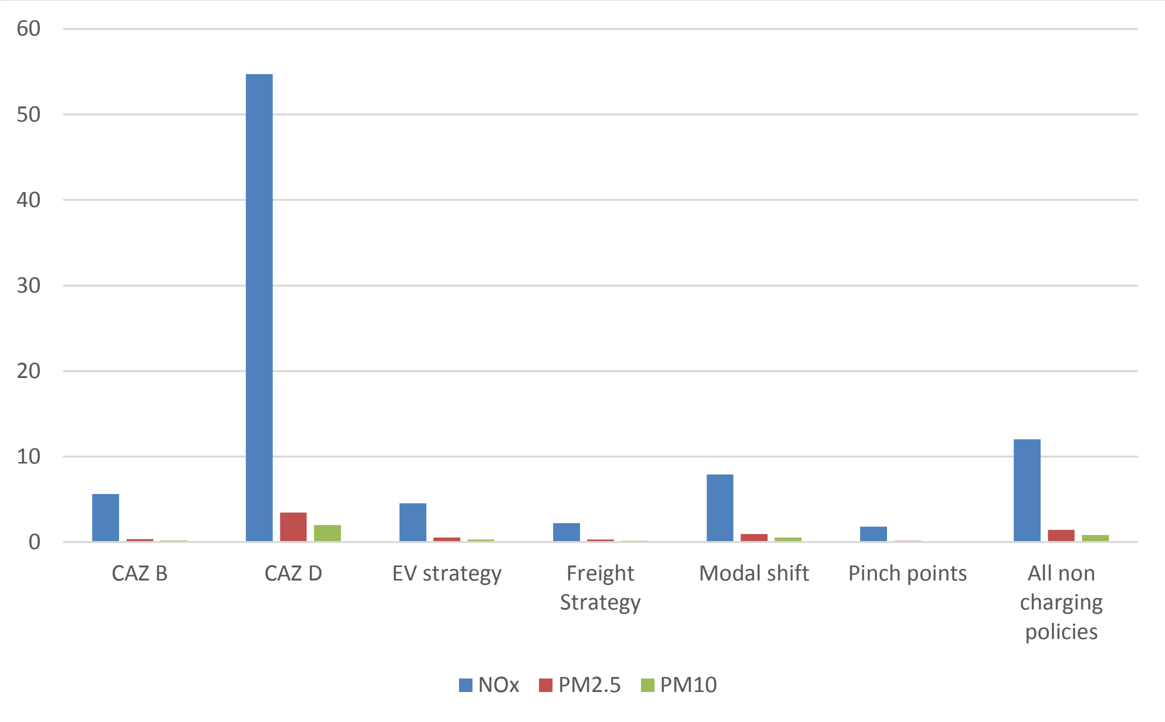
Damage cost values (based on recent Defra Guidance for Air Quality Damage Costs) are applied to calculate the monetary benefit of the change in emissions. It is assumed that the benefit reduces over time as the baseline scenario naturally catches up to the CAZ measure using an extrapolation factor based on JAQU data.

The results of the analysis for the implementation year 2022 are shown in Table 5-2 and the relative change in 2022 between the baseline and the various modelled policy options are shown graphically in Figure 5-1. It should be noted that these are only impacts for each single year, and there is no application of extrapolation factors.

Table 5-2: Air pollutant (NOx, PM2.5 and PM10) impacts of the measures in 2022 (tonnes)

	Net emission (tonnes)			Relative change (with baseline – tonnes)		
	NOx	PM2.5	PM10	NOx	PM2.5	PM10
Baseline	186.66	22.73	13.04			
CAZ B	181.02	22.38	12.85	5.63	0.34	0.19
CAZ D	131.95	19.25	11.04	54.71	3.47	2.00
EV strategy	182.11	22.18	12.73	4.55	0.54	0.31
Freight Strategy	184.43	22.43	12.87	2.23	0.30	0.17
Modal shift	178.76	21.76	12.49	7.90	0.97	0.55
Pinch points	184.85	22.55	12.94	1.80	0.18	0.11
All non charging policies	174.64	21.29	12.21	12.02	1.44	0.83

Figure 5-1: Relative change in emissions between the policies and baseline in 2022 (tonnes)



5.3.4 Implementation costs

The varied nature of the policy options considered in this analysis means that no consistent methodology has been developed for deriving the implementation costs. For each policy option we have referred to previous Clean Air Zones that have considered similar policies to benchmark the implementation costs and scaled them to reflect the size and traffic conditions in the Swale Borough area.

A 36% optimism bias is applied to all capital expenditures.

Clean Air Charging Zones (CAZ B and D)

Key costs of setting up and installing a charging area include signs, road markings, cameras and advanced warning. It is assumed that 8 sets of cameras will be use to capture vehicles assessing the CAZ area at key junctions. The majority of the cost is assumed to be capital expenditure (purchase of cameras etc) with some ongoing maintenance costs also required. The costs per camera have been used in a number of previous CAZ analyses and have been agreed with JAQU.

Mode shift (increasing active travel and reducing the use of private cars)

This policy includes a variety of different plans to reduce the amount of private vehicle use. The policies and costs are estimated below:

Table 5-3: Breakdown of mode shift policies modelled implementation costs (without optimism bias applied)

Policy	Cost	Rationale
Creation of travel plans	-	Travel plans will be created by schools and local communities and not require any financial investment
Investment in walking and cycling infrastructure	£11.12 million	This is the estimated cost of the creation of a cycle highway along the A2 between Newington and Faversham the cost per km is based on two estimates provided in DfT (2017) report[28]
Secure cycle parking	£10,000	Based on estimates of additional funding provided by TfL scaled down to estimate the installation of 20 bike storage units.
Car club	£ 5,000	Estimate – minimal costs expected.
Trial of e-bikes and scooters	£ 20,000	Estimations of a trial of 10 e-bikes, based on a similar trial in Leeds
Total	£11.5 million	

Note: as the exact form of several of these measures has not been agreed upon (such as the investment in walking and cycling infrastructure) indicative estimates have been used based off a potential final form. A more detailed assessment of the analysis will be required when these plans have been finalised. Moreover, the final implementation costs will be highly variable and location specific. The results presented here show the indicative scale of each plan rather than an opposed cost.

Freight consolidation plans

Previous analysis conducted for a port city provided an estimated cost for a freight consolidation centre, the size and cost has been scaled down to reflect the local environment in line with traffic modelling.

Increased use of electric vehicles

Based on electric vehicle strategies in different cities, we have estimated that an investment of £100,000 over the 10 year appraisal period is required to install the necessary infrastructure (charging and otherwise) to achieve the desired uptake in electric vehicles.

Removal of pinch points

The only cost to the council is understood to be a Traffic Regulation Order, required to change the layout of a road. A briefing paper produced by the House of Commons estimated the cost of a TRO to be between £1,000 and £3,000[29].

The cost is estimated to be £2,000 per annum, an average of the upper and lower boundary.

5.4 Results

Figure 5-2 and Table 5-4 provide a breakdown of the various costs and benefits we have assessed for the 6 different policy options included in the appraisal. We have also included an ‘all non-charging’ policy package which includes the 4 non-CAZ based policies which could be implemented together, and a package combining the CAZ B and all ‘non-charging’ measures.

[28] Department for Transport (2017) *Typical costs of cycling intervention* Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/742451/typical-costings-for-ambitious-cycling-schemes.pdf [Accessed October 2020)

[29] House of Commons Library (2020) *Traffic Regulation Orders (TROs) – Briefing Paper* No: CBP 6013 p.12

The results can broadly be assessed as falling in to 3 categories: a net cost due to the requirement for new vehicles to be purchased, a net cost due to high implementation costs[30] and policies with a net benefit. These last two, the freight policy and the removal of several pinch points[31], have a positive net present value (NPV)[32] but a very small overall impact. The nature of the policies means that while they have the benefit of reducing air pollution of several current exceeding locales, their overall impact is relatively small.

The policy with the largest impact is the CAZ D. This policy would require all non-compliant vehicles using the CAZ area to pay a charge. Given the inclusion of passenger cars in this charging measure there is an expected significant upgrade cost for the majority of non-compliant vehicles that will now upgrade. There is also a corresponding increase in fuel and CO_2 savings from the inclusion of passenger cars, however this does not negate the significant cost of requiring private vehicles to upgrade. Finally, its worth reiterating that the cost calculations for the CAZ B and D do not include the cost that non-compliant vehicles that choose to pay the charge will face, this is seen as a net transfer between the passenger and the local council and are therefore not considered a cost.

The costs presented here should be understood in relation to the Air Quality analysis presented previously and should not be used as the sole decision-making tool. While emission reductions are captured, the cost benefit analysis (CBA) does not take in to account if the pollution concentrations are sufficiently reduced in targeted area, nor does it capture any distributional elements of the policies, for example, which demographics would be impacted by the various options. The CBA presents one piece of evidence, amongst many, to support the introduction of new clean air policies.

[30] Note that the only policy here is the modal shift which has a very high implementation cost due to the inclusion of a cycle superhighway. If this was not included, it would likely have a net positive result

[31] Its worth reiterating that while this has a positive NPV in its current form. The costs here no not include the need to create additional parking space which would likely increase the overall cost of the policy. The cost could be significant if off-street parking needs to be produced.

[32] The NPV represents the total costs and benefits across the 10 year appraisal period, discounted to 2022 and summed.

Figure 5-2: Policy appraisal CBA results

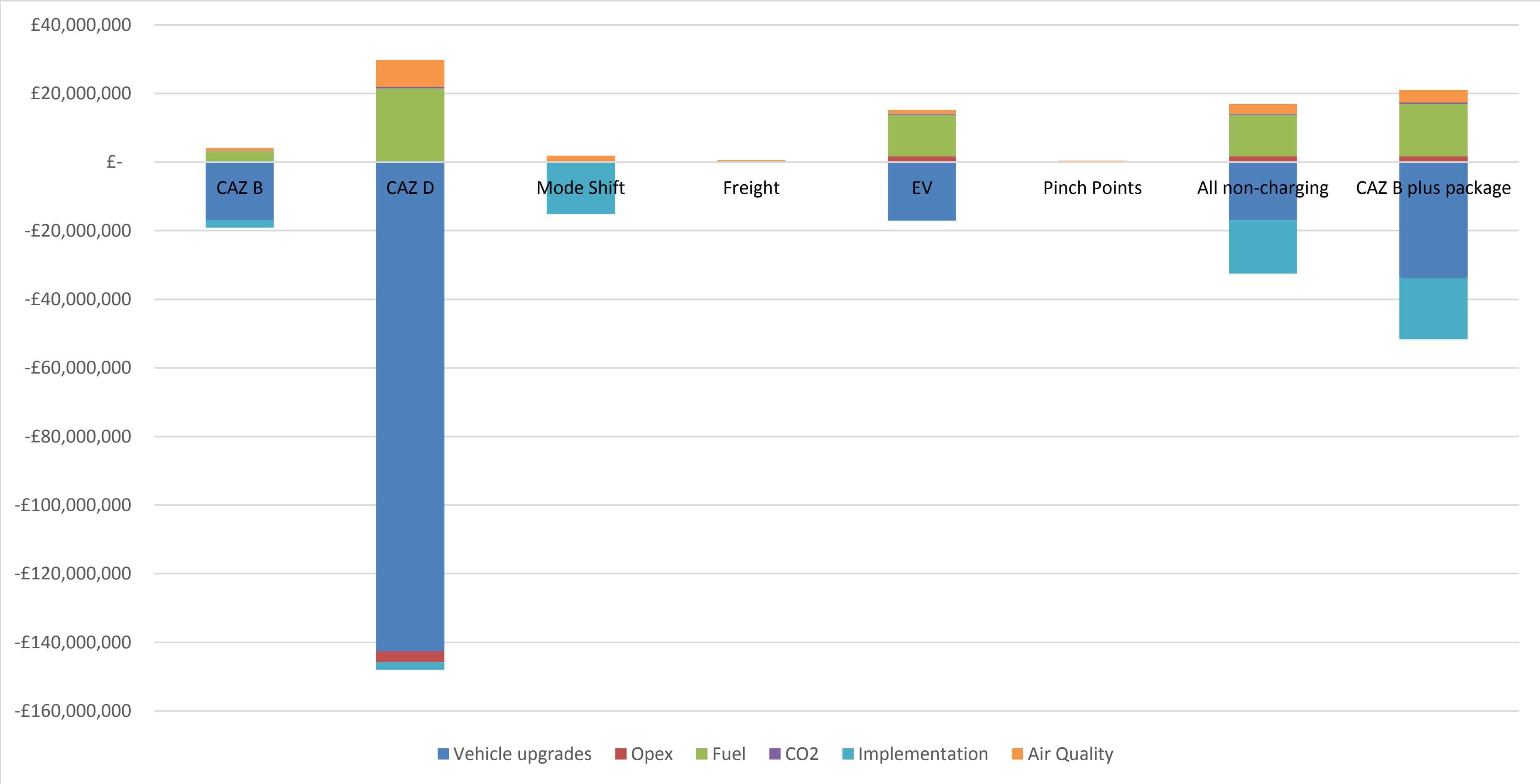


Table 5-4: Indicative breakdown of costs and benefits for all policy options

	CAZ B	CAZ D	Mode Shift	Freight policy	EV	Pinch Points	All non-charging	CAZ B plus all non-charging
Vehicle upgrades	- £16,857,000	- £142,584,000	£ -	£ -	- £16,929,000	£ -	- £16,929,000	- £33,785,000
Opex	£14,000	- £3,145,000	£ -	£ -	£1,616,000	£ -	£1,616,000	£1,631,000
Fuel	£3,184,000	£21,472,000	£ -	£-	£12,166,000	£ -	£12,166,000	£15,350,000
CO2	£82,000	£492,000	£ -	£-	£324,000	£-	£324,000	£407,000
Implementation	- £2,256,000	- £2,256,000	- £15,171,000	- £295,000	- £141,000	- £3,000	- £15,609,000	- £17,865,000
Air Quality	£783,000	£7,891,000	£1,867,000	£571,00	£1,053,000	£366,000	£2,797,000	£3,580,000
Total	**- £15,050,000**	**- £118,130,000**	**- £13,303,000**	**£276,000**	**- £1,909,000**	**£364,000**	**- £15,633,000**	**- £30,683,000**

Note: the CAZ B plus all non-charging has been estimated as a simple sum of the costs and benefits of these 2 scenarios
Numbers may not sum exactly due to rounding errors

5.4.1 CAZ B

The CAZ B is a relatively un-invasive charging policy that would only impact HGVs (with buses and taxis being initial except). Nevertheless, given the price of HGVs, there is a significant cost associated with requiring them to upgrade (totalling over £15 million). Moreover, JAQU assumptions state that 83% of non-compliant HGVs will choose to upgrade (although this may not reflect the actual behaviour response to the scheme in Swale). While there are additional benefits accrued as part of the policy (fuel savings, emission reduction) to policy results in a total NPV of -£15,259,113

5.4.2 CAZ D

As discussed above, a CAZ D is the most expansive and all-encompassing policy proposal as it requires all non-compliant vehicles, including private passenger cars to pay to enter the CAZ area. As demonstrated in Table 5-4 the most significant impact would be the requirement for a large number of non-compliant vehicle users to upgrade to a compliant vehicle, to the net cost of over £140 million. While this policy also results in significant savings (we see the largest pollution reduction and a significant fuel saving) these benefits are dwarfed by the upgrade costs. Overall we would see a net cost of over £116 million over the appraisal period.

5.4.3 Mode shift strategy

The mode shift strategy presents the most varied policy approach to reducing the number of private vehicles on the road and includes a number of different 'sub-measures' to achieve this. These include:

- The creation of travel plans for schools and businesses
- Additional investment in walking and cycling infrastructure
- Investment in secure cycle parking
- A pilot scheme for e-bikes and scooters
- A car club in Sittingbourne and Faversham.

As set out in the methodology, several assumptions have been made about what a modal shift strategy could look like, including potential investment for cycling infrastructure and a pilot scheme for e-bikes. This policy has the largest implementation cost of all the policies assessed including the two CAZs. This is primarily due to the estimated cost of creating a new cycle way along the A2.

The policy also results in the largest pollution reduction of all the non-charging mechanism, recognising the success of the modal shift policy.

5.4.4 Freight policy

The freight policy aims to remove a significant proportion of the HGV traffic entering the towns in the area under consideration, particularly in Sittingbourne. The policy will likely have a targeted impact on the commercial area of Sittingbourne and have limited wider impact. Moreover, as no fleet upgrades are expected to result from the policy, the overall impact is expected to be minimal.

While this policy has a larger impact on pollutant reductions than the pinch point policy it also has greater implementation costs therefore having the smallest magnitude impact of all the policies assessed. The total net benefit over the 10 year appraisal period is £282,163.

5.4.5 EV Strategy

The EV strategy assumes that 2% of all passenger cars and LGVs will upgrade to electric vehicles through the introduction of more EV charging and other supporting infrastructure. The measure has the potential for significant savings, particularly from the reduced fuel use and subsequent CO_2

savings, however the cost of 2% of vehicles upgrading to electric is also significant. The impacts captured here may slightly overestimate the true economic impact as it currently assumes that all new EV's will be purchased in 2022. More likely, the increase in EV uptake will happen gradually over the appraisal period.

The total modelled impact of NPV of -£1,909,262

5.4.6 Pinch points

The removal of several pinch points in and around Sittingbourne will improve the air quality in these immediate areas and have a small impact on driver speeds however it will have very limited overall economic effect.

While it will improve air quality in the immediate area around the current pinch points it will have the small impact of all options assessed on the total reduction of emissions (tonnes). There will also be a small cost to the council associated with removing the current parking spaces which will take place through the introduction of new TROs.

This does not include the creation of alternative parking to offset the removal on pinch point parking as specified previously. Additional work is required to assess the type of new parking required and the associated cost. This cost could be substantial if it is decided that new off-street parking is required to replace the parking spaced lost via the removal of these pinch points.

Overall, the modelled net benefit is £352,960

5.4.7 All non-charging measures

The package of non-charging measures has a greater air quality benefit than the CAZ B, driven mainly by the mode shift policy but increased by the other measures, but is less impactful that the CAZ D. The net cost of the package is about same as the CAZ B at £15,289,174 for greater impact, but an order of magnitude less than the CAZ D.

5.4.8 CAZ B plus all non-charging measures

This package simply summed the costs and benefits of the CAZ B and the all non-charging measures package. This combination is obviously more impactful then either on its own, but less than the CAZ D. It has a net cost of just over £30 million which is still significantly less than the CAZ D.

5.5 Conclusion

The policies appraised in this analysis form a wider spectrum of approaches to reducing air pollution. Moreover, while the cost-benefit analysis is a useful tool in understanding some of the impacts of each policy it provides no insight into the key metric of the policy, reducing air pollution concentration in current areas of exceedance.

Nevertheless, there is significant variation in the scope and economic impact of the policies assessed. The freight policy has the smallest NPV while the removal of key pinch points has the smallest overall impact. By far the most impactful policy would be the introduction of the CAZ D. While it would have a significant impact on improving air pollution in the local area, these benefits are dwarfed by the upgrade costs associated.

Each policy offers its own pros and cons to implementing and the NPV alone should not be used to decide the 'best' policy. Regardless, they offer a useful insight into understanding the impacts of each policy option.

6 Conclusions and recommendations

This study has set out to assess the feasibility and practicality of implementing a formal Charging Clean Air Zone to mitigate air quality issues along the A2. In addition, further non-charging measuring measures have been considered as an alternative or as a complement to a formal CAZ. The study initially established current air pollution levels along the A2 for a base year in 2019 and a future year in 2022 to assess the level of challenge that needed to be addressed. The improvements in air quality that could be gained from a set of CAZ and non-charging measures were assessed along with an indicative cost benefit analysis of implementing these measures. This final section combines these analyses to set out our recommendations for a practical approach to improving air quality along the A2 and associated AQMAs.

6.1 Current air quality along the A2

Air quality along the A2 was modelled using traffic data from the existing regional traffic model, fleet composition data collected from the previous source apportionment study, that latest emissions factors from DEFRA's Emission Factor Toolkit and our in-house dispersion model RapidAir®. The model was then verified and adjusted against 2019 monitoring data.

The modelling provides detailed NO_2 concentration data on a 1m x 1m grid over the study area and so allows the extraction of results for all relevant receptor location. In this case results have been extracted in 2 ways to provide an assessment of air quality along the A2 and related AQMAs:

- Compliance data in relation to the air quality limit values for all roads in the modelled area – this extracts results at 4m from the roadside and presents the highest concentration along each road link.

- Monitoring point location results – which have been extracted both with the overall model adjustment factor (global) and adjusted to match the actual monitored value (site-specific) in 2019. These latter site-specific adjusted results are intended to reflect any specific conditions around the diffusion tube location that could be influencing the results.

The baseline compliance air quality results in 2019 indicated a number of areas where the NO_2 limit value is being exceeded principally in Sittingbourne at Keycol Hill (this area has now been formally declared as an AQMA on 23rd October 2020) and in the St Paul's Street and East Street AQMAs. There is also a slight exceedance in Ospringe. In relation to the monitoring locations, 9 of the locations are showing exceedances of the 40 μgm^{-3} limit value.

Moving forward to 2022 the results show a significant improvement based on business as usual conditions, generated primarily by improvement to the vehicle fleet as vehicles renew and become cleaner. Road link based compliance results showed that no roads were expected to exceed the limit value although there are roads in Sittingbourne, again within the St Paul's Street and East Street AQMAs that are at risk of exceedance being above 35 μgm^{-3} which is within model error estimated from the model verification. The monitoring location results with the global adjustment reflect the same picture showing no monitoring sites expected to exceed in 2022. However, when using the local adjustment factor one monitoring site in St Paul's Street AQMA (SW82) is showing an exceedance and one location at Keycol Hill (SW124) is very close to exceedance.

For the 2022 year a sensitivity test was also carried out to assess the impact of a slower fleet turnover potentially from an economic slow-down related to COVID 19. This sensitivity suggested that there could potentially be exceedances remaining in Sittingbourne in the St Paul's Street and East Street AQMAs.

This analysis suggested that although a standard business as usual assessment in 2022 indicated that there would be no exceedances, sensitivity assessment using site-specific adjustment at monitoring locations and slower fleet turnover could well result in exceedances in Sittingbourne. The highest level of NO_2 under these tests was 44 μgm^{-3} estimated at monitoring location SW82 in the St Paul's Street AQMA. So, the aim of any mitigation measures should to reduce the risk of these potential exceedances occurring, especially in St Paul's Street AQMA.

6.2 Clean Air Zone mitigation measures

The earlier AQAP assessment work carried out in 2019 by Phlorum recommended the assessment of a Clean Air Zone as a potential measure to manage air pollution along the A2. The charging CAZ option was assessed in this study along with 'softer' non-charging measures as an alternative or complement to a charging CAZ. A summary of the key air quality and cost benefit results associated with the modelled options is set out in Table 6-1 below and discussed in the following sections

Table 6-1: Summary results for the mitigation options

Category	Reference Case	CAZ B	CAZ D	EV	Freight	Mode Shift	Pinch Point	All non-charging	CAZ B + non-charging
Average reduction concentration reduction across all monitoring sites									
Reduction	0%	1.7%	18.4%	1.2%	0.6%	2.1%	0.3%	3.0%	4.7%
Number of monitoring sites exceeding or at risk (global adjustment)									
Exceeding	0	0	0	0	0	0	0	0	0
At risk	2	2	0	2	2	2	2	2	2
Number of monitoring sites exceeding or at risk (site-specific adjustment)									
Exceeding	1	1	0	1	1	1	1	0	0
At risk	1	1	0	1	1	1	1	2	2
Summary cost benefit analysis results (Million £)									
Total NPV	N/A	-15.0	-118.1	-1.9	0.3	-13.3	0.4	-15.6	-30.6
Implementation only	N/A	2.26	2.26	0.14	0.29	15.17	<0.01	15.63	17.86

6.2.1 Charging Clean Air Zones

Two formal CAZ options were assessed in terms of a full CAZ D covering all vehicle types and a CAZ B targeted at HGV's as described in section 3. These would both be enforced in the same way with a set of ANPR cameras along the A2 and hence would have similar direct implementation costs to the Council estimated at about £2.2 million.

Clearly the CAZ D would generate the greatest air quality benefit as more vehicles are being targeted. On average it would reduce concentrations by some 18% resulting in no areas with exceedances of the NO_2 limit value or even at risk of exceeding. The CAZ B has a much smaller impact as it is only targeting HGVs. Many of which already meet the standard, and reduced concentrations on average by about 2%. However, this will still remove all exceedances with the possible exception of monitoring location SW82 in the St Paul's Street AQMA.

On the face of it this might indicate that the CAZ D would provide the greatest benefit for a similar cost. However, just implementation costs ignore the wider costs to vehicle owners for upgrading their vehicles. Taking these costs into account the CAZ D would cost local businesses and residents some £142 million in compliance costs to upgrade vehicles and have an overall negative net present value (NPV) from the CBA of £118 million over 10 years. This compares to the CAZ B which would have some £17 million in compliance costs borne by freight companies and an overall negative NPV of £15 million.

So both are costly measures to society as a whole but the CAZ B has a significantly lower cost while still largely mitigating any air quality limit value exceedance risk.

6.2.2 Non-charging measures

Four non-charging measures were assessed: a mode shift package, a freight package, support for electric vehicles and removal of pinch point parking. Of these the mode shift package was estimated to have the largest impact on air quality reducing concentrations by an average of 2.1% which is in fact a greater impact than the CAZ B. The EV measures had the next largest impact at a 1.2% average reduction in concentrations, followed by the freight measures at only a 0.6% average reduction. The smallest average impact was from the removal of pinch point parking, as might be expected, as the benefits of this measure are greatest at these specific points.

The costing of these measures was carried out in a fairly generic way as the specific details of what would be included was not developed and so the CBA can only be considered indicative. The mode shift package was the costliest as it assumed a significant investment in walking and cycling infrastructure of some £15 million. However, this provides a better, though still negative, overall NPV than a CAZ B of £13 million. This suggests it would be a better option for society in general than the CAZ B though it has higher direct costs to the public sector (in this case the County Council). It should also be noted that the mode shift CBA does not include the assessment of any wider health or congestion benefits.

The EV measure is the next most costly with a negative NPV of some £1 million overall, but with a potential implementation cost to the borough and county councils in terms of supporting charging infrastructure of some £137,000. The freight measures could potentially cost the councils some £300,000 but this would be outweighed by the air quality benefit to give a positive NPV for the measure. The pinch point parking removal is likely to fairly low cost and have air quality benefits that again outweigh the costs to give a positive NPV.

All the non-charging measures have a better overall NPV than either of the CAZ measures with two being positive. The mode shift measure also has a greater air quality impact than the CAZ B though not the CAZ D. The other measures all have lower, but still positive impacts on air quality.

6.2.3 A package approach

Two packages of measures were also considered: a combination of all the non-charging measures, and the CAZ B combined with the all of the non-charging measures. The impact of the latter package was not formally modelled but estimated by simply adding the impacts (and costs and benefits) of the CAZ B and package of non-charging measures.

The package of non-charging measures generated an average reduction in NO_2 concentrations of some 3%, about twice that of the CAZ B on its own. It also removes all exceedances of the limit value even the site-specific adjusted monitoring locations in St Paul’s Street AQMA (though only just). The CBA indicates that it has a negative NPV of around £15million which is the same of the CAZ B but with about twice the benefit to air quality.

Combining CAZ B with the package of non-charging measures gives an estimated reduction in concentrations of some 4.7% which is clearly better than either on their own, but less than the CAZ D. This combined package also removes all exceedances even for the site-specific adjusted monitoring location in St Pauls Street AQMA at SW82. It has a negative NPV of some £30 million (basically twice that of the CAZ B and Non-charging package individually), but this is an order of magnitude less than the cost of the CAZ D.

6.3 Recomendations

Air quality along the A2 is expected to improve significantly over the next 3 years out to 2022 as the vehicle fleet renews and the proportion of vehicles of the latest Euro emission standard increases significantly. As such by 2022 a standard reference forecast suggests the NO_2 limit values will be achieved. However, there is clearly uncertainly in the modelling and exploring this through site-specific adjustment at monitoring locations and a sensitivity test with a slower fleet turn over indicates that there is a risk of remaining exceedances especially in the St Pauls Street AQMA. As such there is still a need to take further action to reduce transport related emissions and concentrations along the A2.

The implementation of a Charging Clean Air Zone would reduce concentrations and manage the risk of further exceedances. However, the overall economic cost of these measures would be high (£30 million for a CAZ B and £118 million for a CAZ D) and likely to be politically challenging to implement. As such given the scale of the air quality challenge, largely around managing risk rather than tackling significant exceedances, these would appear to be a disproportionate response.

This suggests that a more appropriate approach is to implement a package of non-charging measures which have been shown to have about twice the benefit of the CAZ B, in terms of air quality, but at a similar economic cost. It is also clear that there would be further benefits for example in terms of health from active travel that have not been accounted for here.

Moving forward we would recommend that the Swale Borough Council work with the Kent County Council, who are the highways authority and so largely responsible for implementing transport measures, to develop in more detail a package of measures to reduce traffic, improve flow and improve the vehicle fleet operating along the A2 comprising:

- The removal of key pinch point parking areas – which is likely to be low cost (dependant on whether alternative parking locations are required), have both air quality and traffic flow benefits and is already being explored by the County Council.

- Assessment of the feasibility of a freight consolidation centre serving Sittingbourne (and potentially other areas) along with developing Delivery and Servicing Plans (DSPs) with local business to reduce freight movements in the area.

- Further work on the development of EV charging infrastructure and other incentives to accelerate the uptake of EVs in the area.

- Significant investment in walking and cycling schemes, travel plans and other information campaigns, as well as exploring micro-mobility options to manage traffic growth and congestion. This could also be an important element of economic recovery following the COVID 19 pandemic and would support wider public health in the area.

Appendix 1 – Air quality model verification and adjustment

A1.1 Exclusion of monitoring sites

Several diffusion tubes were excluded from the model verification and adjustment process because they were outside of the modelling domain or had insufficient data capture in 2019 (missing data from one or more months). These diffusion tubes are listed in Table A1.1.

Table A1.1 – Monitoring sites excluded from model

Site	Site Name	Reason for exclusion
SW37	32 High Street, Newington	Missing data for one or more months
SW38	15a High Street, Newington	Missing data for one or more months
SW78	55057 High Street, Newington	Low data capture 67%
SW129	55/57 High Street, Newington EOB	Low data capture 33%
SW52	20/22 St Paul's Street	Missing data for one or more months
SW90	Junction of Canterbury Road Goodnestone Road	Missing data for one or more months
SW133	159 High Street, Sheerness Lampost	Outside of modelling domain
SW134	12/14 High Street Sheerness Post	Outside of modelling domain
SW127	Halfway Road (14) Halfway, Sheerness	Outside of modelling domain
SW128	Queenborough Road (12/14) Halfway, Sheerness	Outside of modelling domain
SW85	Sheerness College 2, Bridge Road, Sheerness	Outside of modelling domain
SW86	Swale Foyer, Bridge Road, Sheerness	Outside of modelling domain
SW80	A2 Teynham, 107 London Road	Missing data for one or more months
SW92	FJ Williams, London Road	Located at bus stop
SW30	ZW3 Ospringe Street	Missing data for one or more months
SW95	The Mount, London Road, Ospringe	Low data capture 67%
SW22	35 Ospringe Street, Ospringe	Missing data for one or more months
SW98	Canterbury Road, Preston, Faversham	Missing data for one or more months
SW107	110 Borden Lane, Sittingbourne	Outside of modelling domain
SW108	1 Oak House, Wises Lane	Outside of modelling domain
SW109	39 Wises Lane, Sittingbourne	Outside of modelling domain
SW130	31/33 Keycol Hill Sittingbourne Mid Point	Low data capture 50%
SW131	31/33 Keycol Hill Sittingbourne Lowest Point	Low data capture 50%
SW132	Fountain Street, Sittingbourne	Low data capture 42%
SW53	114 East Street, Sittingbourne	Outside of modelling domain
SW77	Kemsley Fields, Swale Way, Sittingbourne	Outside of modelling domain
SW88	Sonara Way, Sonara Fields, Sittingbourne	Outside of modelling domain
SW118	Opp Fruit Stall, 9 Fox Hill, Bapchild	Missing data for one or more months, located next to car park and bus stop
SW58	Dover Street	Outside of modelling domain
SW126	Fox & Goose, The Street, Bapchild	Missing data for one or more months
SW34	Hernhill Village Hall, Hernhill	Outside of modelling domain
SW07	Capel Hill Farm, Harty	Outside of modelling domain

Some clear outliers were also apparent during the model verification process, whereby we unable to refine the model inputs sufficiently to achieve acceptable model performance at these locations. There are a number of reasons why this could be the case e.g.

- A site located next to a large car park, bus stop, petrol station, or taxi rank that has not been explicitly modelled due to unknown activity data.
- Sites located underneath trees or vegetation i.e. unsuitable locations for diffusion tubes to measure NO_2 concentrations effectively
- No traffic model road link included where the NO_2 sampler is located, or not all road links included e.g. at a junction.
- Uncertainties in the traffic model outputs.
- Uncertainties in the background maps, and the uncertainties introduced by modelling background concentrations over such a wide area at 1km resolution i.e. the mapped background concentrations change very suddenly at the edges of each 1km background map square. In reality annual average background concentrations would change gradually over an urban area. A possible solution to this issue would be to interpolate the 1km background maps to a finer resolution e.g. 200m; this would have the effect of smoothing out the sudden changes in background concentrations at the 1km square edges of the background maps

Table A1.2 lists the monitoring locations that were excluded as outliers from the verification process. For monitoring locations that contained multiple diffusion tubes, only one measurement was used in verification.

Table A1.2 – Monitoring sites excluded from verification

Site	Site name	Reason for exclusion
ZW6	Newington 3	Monitoring site is located in a passageway, which limits dispersion.
SW99	A2 Frognal Lane, Teynham	Monitoring site is adjacent to a car park which is not included in the model.
SW117	Land Adj Orchard, Canterbury Road, Faversham	Monitoring site is located at the entrance of a building site, and this road is not included in the model.
SW113	Squirrel Cottage, Keycol Hill	Overgrown vegetation is present at the monitoring site.

A1.2 Verification and adjustment results

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations; this helps to identify how the model is performing and if any adjustments should be applied. The verification process involves checking and refining the model input data to try and reduce uncertainties and produce model outputs that are in better agreement with the monitoring results. This can be followed by adjustment of the modelled results if required. The LAQM.TG(16) guidance recommends making the adjustment to the road contribution of the pollutant only and not the background concentration these are combined with.

The approach outlined in LAQM.TG(16) section 7.508 – 7.534 (also in Box 7.14 and 7.15) has been used in this case. All roadside automatic and diffusion tube NO_2 measurement sites near modelled roads in Swale have been used for model verification with sufficient (> 75 %) data capture in 2019. It is appropriate to verify the performance of the RapidAir© model in terms of primary pollutant emissions of nitrogen oxides ($NOx = NO + NO_2$). To verify the model, the predicted annual mean Road NOx concentrations were compared with concentrations measured at the various monitoring sites during 2019.

The model output of Road NOx (the total NOx originating from road traffic) was compared with measured Road NOx, where the measured Road NOx contribution is calculated as the difference between the total NOx and the background NOx value. Total measured NOx for each diffusion tube was calculated from the measured NO_2 concentration using the latest version of the Defra NOx/NO_2 calculator (v7.1).

The initial comparison of the modelled vs measured Road NOx identified that the model was under-predicting the Road NOx contribution at most locations. Refinements were subsequently made to the model inputs to improve model performance where possible.

The gradient of the best fit line for the modelled Road NOx contribution vs. measured Road NOx contribution was then determined using linear regression and used as a global/domain wide Road NOx adjustment factor. This factor was then applied to the modelled Road NOx concentration at each discretely modelled receptor point to provide adjusted modelled Road NOx concentrations. A linear regression plot comparing modelled and monitored Road NOx concentrations before and after adjustment is presented in Figure A1.1.

The total annual mean NO_2 concentrations were then determined using the NOx/NO_2 calculator to combine background and adjusted road contribution concentrations.

A primary NOx adjustment factor (PAdj) of 2.4882 based on model verification (Figure A1.1) using the remaining 2018 NO_2 measurements was derived and applied to all modelled Road NOx data prior to calculating an NO_2 annual mean. Adjusted modelled and measured NO_2 concentrations are presented in Figure A1.2.

Figure A1.1- Monitored vs. modelled NOx concentrations (µg m^{-3})

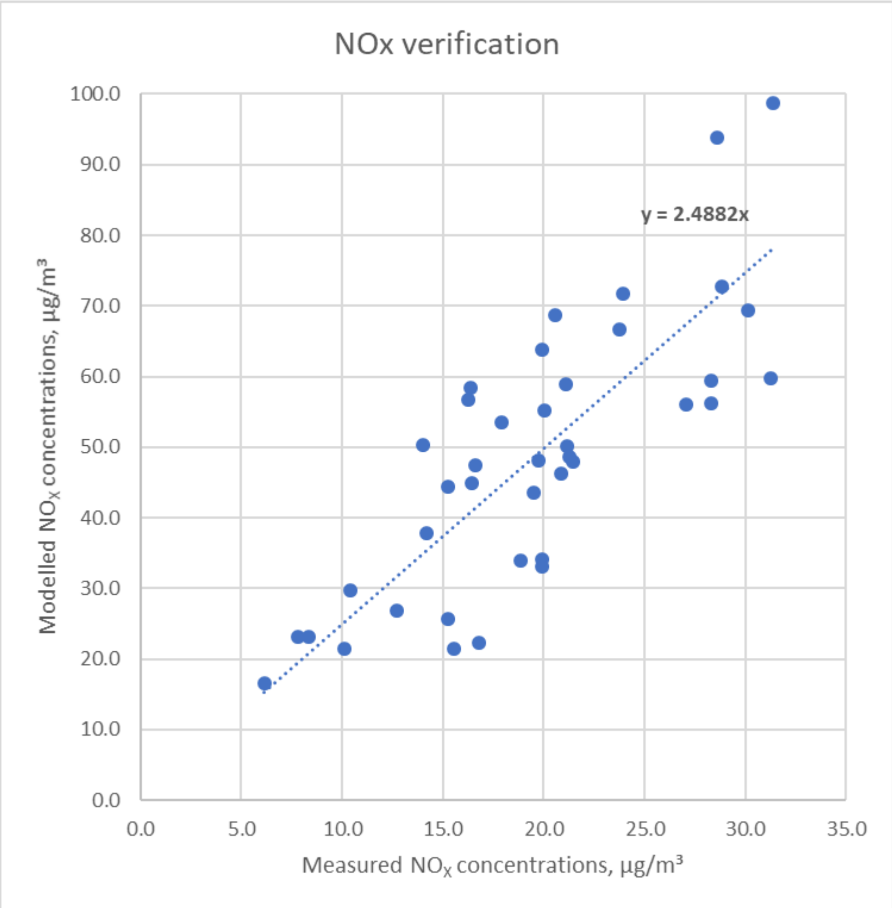
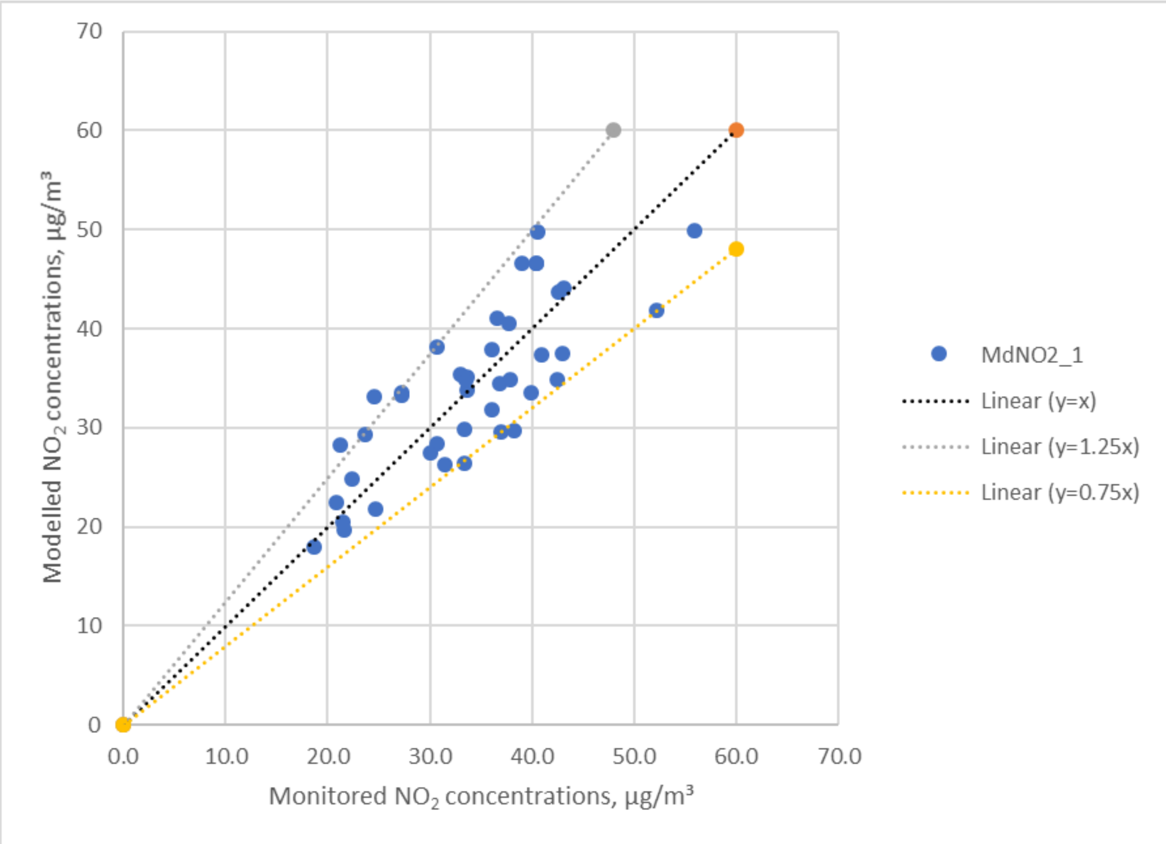


Figure A1.2- Monitored vs. modelled NO2 concentrations (µg m^{-3})



To evaluate the model performance and uncertainty, the Root Mean Square Error (RMSE) for the observed vs predicted NO_2 annual mean concentrations was calculated, as detailed in Technical Guidance LAQM.TG(16). The calculated RMSE is presented in Table A1.1. In this case the RMSE when outliers were excluded was calculated at 5.2 µg.m^{-3}.

Table A1.1 – Measured and modelled NO2 concentrations (µg.m^{-3})

Site	Site Name	Monitoring Type	Measured NO_2 annual mean concentration 2019	Modelled NO_2 annual mean concentration 2019	Difference measured – modelled
ZW8	St Paul's Street	Auto	39	47	-7.6
ZW3	Ospringe Roadside	Auto	31	26	5.2
SW66	96/94High Street, Newington	DT	34	34	-0.1
SW45	64 High Street, Newington	DT	36	32	4.3
SW35	60 High Street, Newington	DT	43	35	7.6
SW42	High Street, Opp Church Lane	DT	43	44	-0.9
SW19	Newington Social Club	DT	37	34	2.4
SW20	Newington Co Op	DT	27	34	-6.4
SW36	49 High Street, Newington	DT	33	35	-2.4
SW82	Conservative Club, St Paul's Street	DT	56	50	6.1
SW51	14/16 St Paul's Street	DT	41	50	-9.2
SW89	St Paul's Street Air Quality Station	DT	40	47	-6.2
SW71	o/s 8 Staple Close, Staplehurst Road, Sittingbourne	DT	36	38	-1.8
SW73	14 Chalkwell Road, Sittingbourne	DT	31	28	2.4
SW56	126 East Street, Sittingbourne	DT	38	41	-2.8
SW87	Canterbury Road AQ Station	DT	31	38	-7.4
SW91	Adj to 72 London Road, Teynham	DT	33	26	7
SW101	A2 Lynsted Lane, Jct	DT	22	25	-2.4
SW28	Mayors Arms, Ospringe	DT	43	38	5.4
SW30	ZW3 Ospringe Street	DT	30	28	2.6
SW31	Site 7, 4 Ospringe Street	DT	38	35	3
SW32	11 Ospringe Street, Ospringe	DT	37	30	7.4
SW96	Maison Dieu, Ospringe Street	DT	37	41	-4.4
SW29	Opp Lions Yard, Ospringe Street	DT	41	37	3.5
SW120	103 Ospringe Street, Ospringe, Faversham	DT	40	34	6.3

Site	Site Name	Monitoring Type	Measured NO_2 annual mean concentration 2019	Modelled NO_2 annual mean concentration 2019	Difference measured – modelled
SW62	Key Street, Sittingbourne	DT	34	35	-1.4
SW110	2 Cherryfields, Sittingbourne	DT	19	18	0.8
SW111	76A Key Street, Sittingbourne	DT	38	30	8.5
SW112	56 Key Street, Sittingbourne	DT	33	30	3.5
SW114	2 Florence Cottages, Chestnut Street	DT	21	22	-1.6
SW115	Cherry Tree Cottage, Chestnut Street	DT	22	20	1.9
SW116	Bankside, Chestnut Street	DT	21	20	1
SW124	31/33 Keycol Hill Sittingbourne Highest Point	DT	52	42	10.4
SW121	Façade Squirrel Cottage, Keycol Hill	DT	43	44	-1
SW122	Façade 13 Key Street, Sittingbourne	DT	21	28	-7.1
SW123	12 Key Street, Sittingbourne	DT	27	33	-6
SW76	155 Canterbury Road, Sittingbourne	DT	33	35	-1.4
SW119	Flats, The Mount, Ospringe	DT	25	22	2.9
SW83	Pembury Court, Dover Street	DT	25	33	-8.5
SW125	16/18 The Street, Bapchild	DT	24	29	-5.7
RMSE (excluding clear outliers)					**5.2**

Appendix 2 – RapidAir street canyon equations

AEOLIUS/OSPM

There are three principal contributions in the AEOLIUS model, a direct contribution from the source to the receptor, a recirculating component within a vertex caused by winds flowing across the top of the canyon, and the urban background. The RapidAir model only take the recirculating component from the canyon and sums this with the kernel derived concentrations.

The RapidAir implementation of AEOLIUS is written in python 2.7 and uses the same equations described in the referenced Met Office papers.

During the coding of the canyon model we tested the outputs of our code with calibration data provided with the FORTRAN version of AEOLIUS. Our implementation agrees almost perfectly (R^2 = 0.97) with the version supplied by the Met Office (which is in any case now out of circulation).

The AEOLIUS model is more complex than the STREET model. Concentrations are calculated for the windward and leeward sides of the road using the equations detailed below (based on equations from the Met Office). The leeward and windward concentrations described below are only calculated for streets that are perpendicular to the direction of the wind. Concentrations are calculated in ppb, and for NOx/NO_2 models are converted to µg/m^3 by multiplication by 1.91. The system of equations in Rapid Air's implementation of the AEOLIUS model are shown below.

Inputs:

Emission rates (*Q*, µg/m/s); traffic speeds (v_t, mph), traffic density (*f*, vehicles per hour), % of cars and heavy good vehicles (f_c and f_h respectively), wind speed at roof level (u_r, m/s), street canyon width (*w*, m), street canyon height (*h*, m), and angle of street (*θ*).

Leeward concentrations:

The leeward concentrations = sum(C_{dlee} + C_{rec}) where C_{dlee} is the direct contribution from vehicles and C_{rec} is the pollution associated with recirculation.

Direct contribution (C_{dlee}):

$$Recirculation\ zone\ (l_r) = \min(w, l_v * \sin(\theta)) \qquad \text{(meters)}$$

Where:

$$vortex\ length\ (l_v) = 2 * r * h \qquad \text{(meters)}$$

And r = wind speed dependence factor = 1 if u_r > 2 m/s and = u_r/2 otherwise.

If the recirculation zone is greater than the width of the canyon:

$$C_{dlee} = \sqrt{\frac{2}{\pi} * \frac{Q}{(w * \sigma_w)} * \ln\left[\left(\frac{\sigma_w * w}{h_o * u_s}\right) + 1\right]}$$

Where:

σ_w = mechanical turbulence from wind and traffic (m/s) = $\sqrt{(\lambda * u_s)^2 + {\sigma_{wo}}^2}$

λ = constant for removal at the top of the canyon = 0.1

σ_{wo} = traffic-created turbulence (m/s) = $b * \sqrt{\frac{v_t * f_c * s_c + v_t * f_h * s_h}{w}}$

where s_c = mean surface area of cars (4 m^2), s_h = mean surface area of heavy vehicles (16 m^2) and b = aerodynamic constant (0.18)

u_s = wind speed at street level (m/s) = $u_r \left(\frac{\ln\left(\frac{h_o}{z_o}\right)}{\ln\left(\frac{h}{zo}\right)} \right) (1 - d * \sin(\theta))$

h_o = effective height of emissions (2 m)

z_o = effective roughness length (0.6 m)

d = model dependence (0.45)

If the recirculation zone is less than the width of the canyon:

$$C_{dlee} = \sqrt{\frac{2}{\pi}} \frac{Q}{(w * \sigma_w)} \left[ln\left[\left(\frac{\sigma_w * d_1}{h_o * u_s} \right) + 1 \right] + R * \ln \left(\frac{h_o + \sigma_w * \frac{d_6}{u_s}}{\frac{\sigma_w * l_r}{u_s} + h_o} \right) + \frac{\sigma_w}{\omega_t} \left[1 - e^{\left(\frac{-\omega_t d_7}{u_s h} \right)} \right] \right]$$

Where:

d_1 (m) = min(w, l_r)

R = max(0, C_{ang})

C_{ang} = cos(2*r* θ)

d_6 (m)= min(max(l_{max}, l_r), x_1)

l_{max} = w/sin(θ)

x_1 = vertical distance (m) at which pollutants can escape canyon = $\frac{u_s(h - h_o)}{\sigma_w}$

ω_t = removal at top of the canyon (m/s) = $\sqrt{(\lambda * u_r)^2 + 0.4(\sigma_{wo})^2}$

d_7 (m) = max(l_{max}, x_1)-x_1

Recirculation contribution (C_{rec}):

$$C_{lee} = \frac{\left[\left(\frac{Q}{W} \right) d_1 \right]}{\omega_t * d_2 + \omega_s * d_3}$$

Where

d_2 (m) = min(w, 0.5*l_r)

d_3 (m) = $l_s \left(\max(0, \frac{2w}{l_r} - 1 \right)$

l_s (m) = $\sqrt{(0.5 * l_r)^2 + h^2}$

ω_s = removal speed at the side of the canyon (m/s) = $\sqrt{{u_s}^2 + {\sigma_{wo}}^2}$

Windward concentrations (C_{dwind}):

Final windward concentrations = C_{dwind} + C_{rec}. C_{dwind} = 0 if $l_r \geq w$, else:

$$C_{dwind} = \sqrt{\frac{2}{\pi}}\frac{Q}{w * \sigma_w}\left[ln\left(\frac{\sigma_w + d_4}{u_s + h_o} + 1\right) + \frac{\sigma_w}{\omega_t}\left[1 - e^{\left(\frac{-\omega_t d_5}{u_s h}\right)}\right]\right]$$

d_4 (m) = min[(w – l_r), x_1]

d_5 (m) = [max[(w – l_r),x_1]]-x_1

Ricardo
Energy & Environment

The Gemini Building
Fermi Avenue
Harwell
Didcot
Oxfordshire
OX11 0QR
United Kingdom

t: +44 (0)1235 753000
e: enquiry@ricardo.com

ee.ricardo.com