Cambridge
Environmental
Research
Consultants

Walworth Streetspace air quality modelling

Final report

Prepared for
London Borough of Southwark

14th October 2021

CERC

Report Information

CERC Job Number:	FM1339
Job Title:	Walworth Streetspace air quality modelling
Prepared for:	London Borough of Southwark
Report Status:	Draft
Report Reference:	FM1339/R1/21
Issue Date:	14th October 2021

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Reviewer(s):	Sarah Strickland

Issue	Date	Comments
1	13/10/21	Draft report
2	14/10/21	Final report

Main File(s):	FM1339_CERC_LBSouthwark_R2_14Oct21.pdf

Contents

1. Executive Summary

Southwark Council commissioned Cambridge Environmental Research Consultants Ltd (CERC) to carry out air quality modelling to assess the impact of Walworth Low Traffic Neighbourhood (LTN).

Two scenarios, pre-scheme and post-scheme, were modelled to assess the current air quality impact of Walworth LTN, based on 2021 traffic monitoring. Concentrations of NO_2, PM_{10} and $PM_{2.5}$ were modelled for assessment against national air quality objectives.

For both scenarios, the air quality objectives are met throughout the scheme area with the exception of parts of the A3 and road junctions along Walworth Road, which are predicted to exceed the air quality objective of 40 µg/m³ for annual average NO_2 concentrations.

The expected change in concentrations due to the implementation of the LTNs was assessed using significance criteria from Environmental Protection UK (EPUK) and Institute of Air Quality Management (IAQM) guidance for Land-Use Planning & Development Control. This is a widely used method for assessing air quality impacts for planning purposes.

Using the EPUK IAQM criteria, the changes in concentrations at school locations in the scheme area are classed as *Negligible* for all pollutants.

For the majority of building façade locations along scheme roads, the changes in concentration are classed as *Negligible*. Non-negligible impacts at building façade locations are predicted for annual average NO_2 concentrations in areas shown in Figure 1.1.

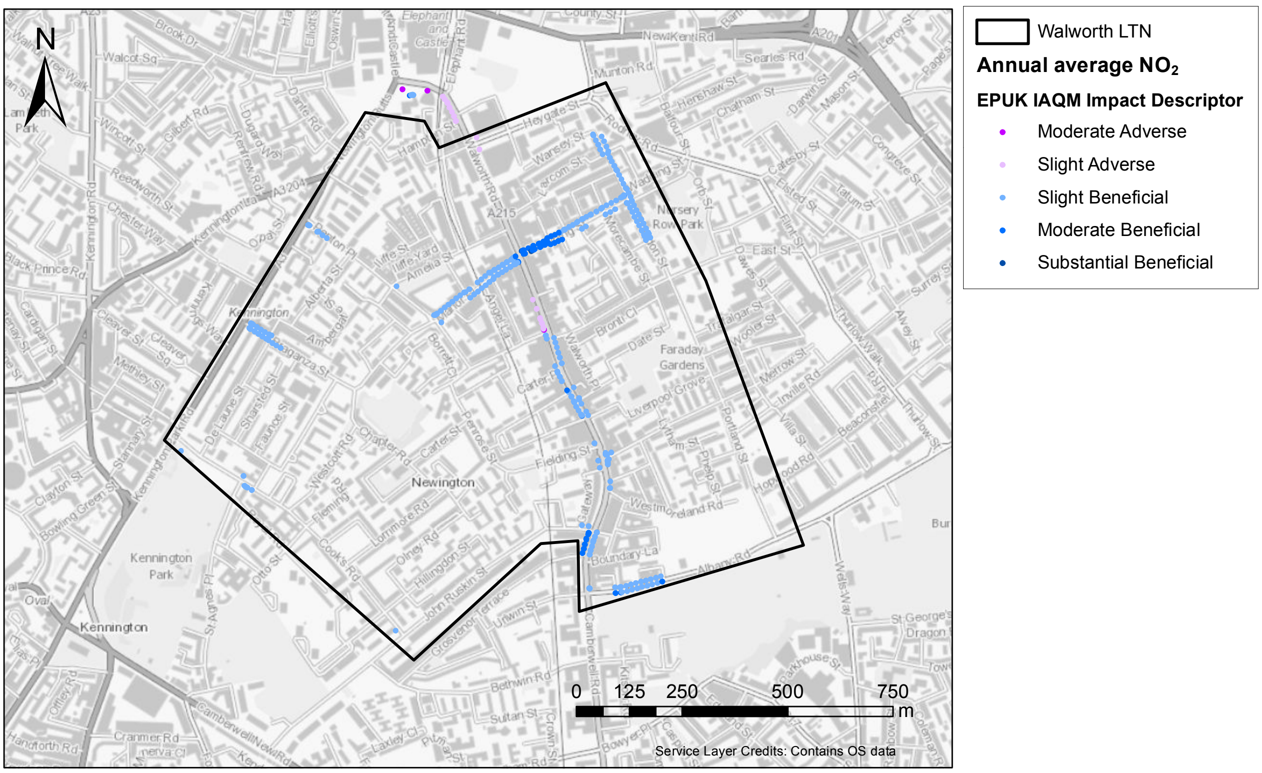

Figure 1.1: Impact descriptors for change in annual average NO_2 concentrations at building façade locations for Walworth LTN

Areas where *Beneficial* impacts (air quality improves) or *Adverse* impacts (air quality worsens) are predicted include:

- *Moderate Beneficial* impact on Browning Street and the south section of Walworth Road from Penrose Street to Albany Road;
- *Slight Beneficial* impact on Albany Road, Braganza Street, Brandon Street, Browning Street, Manor Place, Penton Place and the south section of Walworth Road; and
- *Slight Adverse and Moderate Adverse* impact on the north section of Walworth Road from Penrose Street to the Elephant and Castle junction.

Note that pre-scheme and post-scheme traffic monitoring were not available for the A3 and A202 boundary roads, therefore the air quality modelling has not assessed potential scheme-related changes along these roads.

All ground-level building façades were included in the assessment, regardless of whether or not the locations are relevant for long-term exposure; annual average air quality objectives only apply at locations such as residential settings, hospitals and schools and are not relevant for retail premises.

Using modelled annual average NO_2 and $PM_{2.5}$ concentrations, local mortality burdens were calculated using the approach set out in Appendix A of the Public Health England guidance *Estimating local mortality burdens associated with particulate air pollution (April 2014)*; the approach used concentration response function (CRF) pairs for NO_2 and $PM_{2.5}$ from the 2018 COMEAP report *Associations of long-term average concentrations of nitrogen dioxide with mortality.*

The health impacts of air pollution in the scheme area are calculated to be in the range of 175 and 205 life-years lost, which equates to an economic cost of between £6 million and £10 million. The LTN scheme is predicted to have a marginal positive impact on health, in the range of 0.3 and 0.4 life-years, equating to an economic benefit of between £11,000 and £18,000.

1.1. Summary of model set-up

The model was set up for a 2019 base year and was modified to include traffic and emissions data for 2021, to provide an estimate of the current air quality impact of the scheme.

Pollutant emissions from vehicles were calculated using activity data from traffic monitoring sites located within the LTN areas and on the boundary roads. Traffic data were provided for pre-scheme and post-scheme scenarios. For other roads in the area, London Atmospheric Emissions Inventory (LAEI 2016) data were used, adjusted to 2019 using DfT traffic counts.

These data were used with emission factors taken from the latest Department for Environment, Food and Rural Affairs (Defra) Emission Factor Toolkit (EFT v 10.1), modified to account for emission factor uncertainty in urban driving conditions. Baseline modelling was carried out using 2019 road traffic emissions and emission calculations for the scheme scenarios used road traffic fleet projections for 2021, in order to represent the current air quality impact of the LTNs.

The South East London CHP Energy Facility industrial source was explicitly included in the modelling. Emission rates for all other sources were taken from the LAEI 2016 and modelled as aggregated grid sources for the whole of London.

The modelling used meteorological data from Heathrow Airport and background pollutant data obtained from rural monitoring sites. The variation in emissions during the day was taken into account by applying a set of diurnal profiles to the road and grid sources. These profiles consider higher emissions during peak /congested periods, but will not consider detailed localised changes in the variation in emissions due to the implementation of the scheme.

The Advanced Street Canyon and Urban Canopy options in ADMS-Urban were used to take into account the impact of buildings on the dispersion of pollutants.

Using the pre-scheme traffic flows, model verification was carried out by comparing modelled concentrations with measured data at locations within the scheme area for 2019. Good agreement was achieved between modelled and measured concentrations, providing confidence in the modelling of scheme scenarios.

Following model verification, the model set-up was updated to use 2021 road traffic emission factors alongside pre-scheme and post-scheme traffic flows, to assess the impact of the LTN on current air quality levels.

Concentrations of NO_2, PM_{10} and $PM_{2.5}$ were modelled at receptor locations representing schools and on a grid of receptor points, to generate pollution maps for the scheme area. The modelled concentrations represent the pre-scheme and post-scheme (2021) scenarios.

2. Introduction

Low Traffic Neighbourhoods (LTNs) involve the closure of residential roads to motor vehicles at specific locations. With significantly less traffic in residential areas, LTNs become far easier and attractive to walk and cycle in, with improved air quality amongst a range of benefits; however, they also have the potential to worsen traffic and hence air quality on boundary roads.

Southwark Council commissioned Cambridge Environmental Research Consultants Ltd (CERC) to carry out an air quality modelling to assess the impact of Walworth LTN.

The model was set up for a 2019 base year to determine the current baseline levels of NO_2, PM_{10} and $PM_{2.5}$ across the scheme area. Once good agreement was achieved, the model set-up was updated to use 2021 traffic emission factors alongside pre-scheme and post-scheme traffic flows, to assess the impact of the LTN on current air quality levels. The pre-scheme and post-scheme scenarios are expected to provide the best estimate for the impact of the LTN schemes on current air quality levels.

This report describes the air quality modelling carried out. Section 3 presents the air quality standards, with which the calculated concentrations are compared, and Section 4 provides the criteria used to carry out the impact magnitude assessment of the LTN scheme. A summary of the site location and a review of existing air quality data are given in Section 5. The model set-up and emissions data are summarised in Sections 6 and 7. Section 8 presents the model verification for 2019, the baseline year. Section 9 presents modelled concentrations for the pre-scheme and post-scheme scenarios and air pollution mortality burden calculations are shown in Section 10. A discussion of the results is provided in Section 11. Appendix A includes a description of ADMS-Urban as a modelling tool.

3. Air quality standards

The EU *Ambient Air Quality Directive* (2008/50/EC) sets binding limits for concentrations of air pollutants, which take into account the effects of each pollutant on the health of those who are most sensitive to air quality. The Directive has been transposed into English legislation as the *Air Quality Standards Regulations 2010* [1] [2], which also incorporates the provisions of the *Fourth Daughter Directive* (2004/107/EC).

The *Air Quality Standards Regulations 2010* include limit values and target values. Local authorities are required to work towards air quality objectives. In doing so, they assist the Government in meeting the limit values. The limit values are presented in Table 3.1.

Table 3.1: Air quality objectives (µg/m³)

	Value	Description of standard
NO_2	200	Hourly mean not to be exceeded more than 18 times a calendar year (modelled as 99.79th percentile)
	40	Annual average
PM_{10}	50	24-hour mean not to be exceeded more than 35 times a calendar year (modelled as 90.41st percentile)
	40	Annual average
$PM_{2.5}$	25	Annual average

The short-term objectives, i.e. those measured hourly or over 24 hours, are specified in terms of the number of times during a year that a concentration measured over a short period of time is permitted to exceed a specified value. For example, the concentration of NO_2 measured as the average value recorded over a one-hour period is permitted to exceed the concentration of 200 µg/m³ up to 18 times per year. Any more exceedences than this during a one-year period would represent a breach of the objective.

It is convenient to model objectives of this form in terms of the equivalent percentile concentration value. A percentile is the concentration below which lie a specified percentage of concentration measurements. For example, consider the 98th percentile of one-hour concentrations over a year. Taking all of the 8760 one-hour concentration values that occur in a year, the 98th percentile value is the concentration below which 98% of those concentrations lie. Or, in other words, it is the concentration exceeded by 2% (100 – 98) of those hours, that is, 175 hours per year. Taking the NO_2 objective considered above, allowing 18 exceedences per year is equivalent to not exceeding for 8742 hours or for 99.79% of the year. This is therefore equivalent to the 99.79th percentile value. It is important to note that modelling exceedences of short term averages is generally not as accurate as modelling annual averages.

[1] http://www.legislation.gov.uk/uksi/2010/1001/contents/made

[2] Note limit and target values are not affected by *The Air Quality Standards (Amendments) Regulation 2016*.

Table 3.2 gives examples from the London Local Air Quality Management technical guidance (LLAQM.TG(19))[3] of where the air quality objectives should apply. Note that this table differs from the equivalent table in Defra's national (outside London) guidance, LAQM. TG(16), includes clarifications that the annual average objective applies to school playgrounds and the grounds of hospitals and care homes.

Table 3.2: Examples of where the air quality objectives should apply, as provided in the technical guidance LLAQM.TG(19)

Averaging period	**Objectives should apply at:**	**Objectives should generally not apply at:**
Annual average	All locations where members of the public might be regularly exposed. Building facades of residential properties, schools (including all of playgrounds), hospitals (and their grounds), care homes (and their grounds) etc.	Building facades of offices or other places of work where members of the public do not have regular access. Hotels, unless people live there as their permanent residence. Gardens of residential properties Kerbside sites (as opposed to locations at the building facade), or any other location where public exposure is expected to be short term.
24-hour mean	All locations where the annual mean objective would apply, together with hotels. Gardens of residential properties (where relevant for public exposure e.g. seating or play areas)	Kerbside sites (as opposed to locations at the building facade), or any other location where public exposure is expected to be short term.
Hourly average	All locations where the annual mean and 24-hour mean objectives apply and: Kerbside sites (for example pavements of busy shopping streets). Those parts of car parks, bus stations and railway stations etc. Which are not fully enclosed, where members of the public might reasonably be expected to spend one hour or longer. Any outdoor locations where members of the public might reasonably expected to spend one hour or longer.	Kerbside sites where the public would not be expected to have regular access.

[3] https://www.london.gov.uk/sites/default/files/llaqm_technical_guidance_2019.pdf

4. Significance criteria

The significance of the air quality impacts as a result of the LTN schemes was assessed using The Environmental Protection UK (EPUK) and Institute of Air Quality Management (IAQM) guidance for Land-Use Planning & Development Control[4].

The impact magnitude criteria presented in the EPUK and IAQM guidance can be applied to any Air Quality Assessment Level (AQAL), such as the air quality objectives considered in this assessment.

Table 4.1 (reproduced from Table 6.3 of the IAQM document[4]) sets out the impact descriptors for annual average NO_2 and particulate concentrations. A concentration decrease of 0.5% or more from the baseline is considered a *Beneficial* impact and an increase of 0.5% or more is considered an *Adverse* impact. The equivalent concentrations ranges when comparing annual average NO_2 air quality objective of 40 µg/m^3 are shown in Table 4.2.

Table 4.1: Impact descriptors

Long term average concentration at receptor in assessment year	**% change in concentration relative to Air Quality Assessment level (AQAL)**			
	1	2-5	6-10	>10
75% or less of AQAL	Negligible	Negligible	Slight	Moderate
76-94% of AQAL	Negligible	Slight	Moderate	Moderate
95-102% of AQAL	Slight	Moderate	Moderate	Substantial
103-109% of AQAL	Moderate	Moderate	Substantial	Substantial
110% or more of AQAL	Moderate	Substantial	Substantial	Substantial

Note percentages used in defining these descriptors are rounded to the nearest whole number

Table 4.2: Impact descriptor concentration ranges for annual average NO_2

Annual average NO_2 concentration at receptor in assessment year (µg/m^3)	**Change in concentration (µg/m^3)**			
	0.2 – 0.6	0.6 – 2.2	2.2 – 4.2	≥ 4.2
Less than 30.2	Negligible	Negligible	Slight	Moderate
30.2 – 37.8	Negligible	Slight	Moderate	Moderate
37.8 – 41.0	Slight	Moderate	Moderate	Substantial
41.0 – 43.8	Moderate	Moderate	Substantial	Substantial
43.8 or more	Moderate	Substantial	Substantial	Substantial

[4] Land-Use Planning & Development Control: Planning for Air Quality (January 2017) http://www.iaqm.co.uk/text/guidance/air-quality-planning-guidance.pdf

5. Site location and local air quality

5.1. Site location

Figure 5.1 shows the location of the Walworth Low Traffic Neighbourhood (LTN) within the London Borough of Southwark.

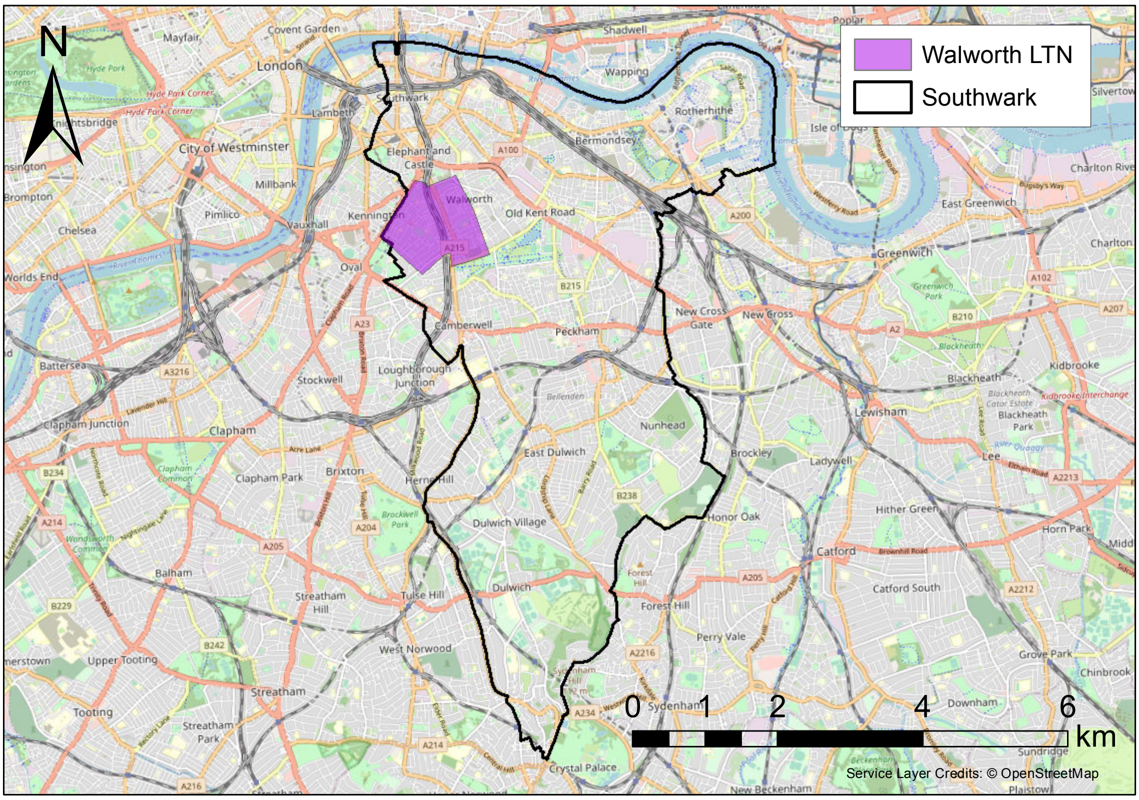

Figure 5.1: Location map of Walworth Low Traffic Neighbourhood

5.2. Local Air Quality Management

Part IV of the Environment Act 1995[5] prescribes the Local Air Quality Review and Assessment process for local authorities. The Review and Assessment process requires local authorities to review local air quality and assess whether or not air quality objectives will be achieved. If it is predicted that these will not be achieved, an Air Quality Management Area must be designated and an Air Quality Action Plan put in place to improve air quality to acceptable levels.

Southwark Council declared the northern part of the borough as an Air Quality Management Area (AQMA) in 2003, due to concentrations of NO_2 and PM_{10} exceeding the air quality objectives. The AQMA encompasses the entire northern part of the borough, extending from Rotherhithe to Walworth and Camberwell and up to the boundary on the River Thames. The Walworth LTN is within Southwark's AQMA.

5.3. Air quality monitoring

This section presents a summary of the monitoring sites operational in 2019 in the vicinity of Walworth LTN.

In 2019, in the vicinity of Walworth LTN, Southwark measured air pollutant concentrations at the automatic monitoring site SWK6, providing hour by hour measurements of NO_2 and PM_{10}, and at 13 diffusion tube locations, providing monthly measurements of NO_2. The automatic monitoring site SWK6 is an urban background location and all diffusion tube sites are classed as kerbside locations.

Table 5.1 provides details of the monitoring sites and Figure 5.2 provides their locations. The data were taken from Southwark Council's 2020 Air Quality Annual Status Report[6].

Concentrations monitored at these sites for the years 2019 and 2020, and the first eight months of 2021, are provided in the following sections.

[5] http://www.legislation.gov.uk/ukpga/1995/25/pdfs/ukpga_19950025_en.pdf
[6] https://www.southwark.gov.uk/assets/attach/49745/Air-Quality-Status-Report-2020.pdf

Table 5.1: Summary of Southwark monitoring sites in the vicinity of the Walworth LTN

Site ID	Site name	Site type	Location (X, Y)	Pollutants monitored	Distance to kerb of nearest road (m)	Height (m)
SWK 6	AQMS Elephant & Castle - Tube 1	Urban background	531893, 178846	NO_2, O_3, PM_{10} and $PM_{2.5}$	25	3.5
SDT 37	Lamppost 1068/09 Wansey Street	Kerbside	532340, 178711	NO_2	0.5	2.5
SDT 38	Walworth Road opposite junction to Elephant Road	Kerbside	532074, 178825	NO_2	0.5	2.5
SDT 104	Lamppost 08 Newington Causeway	Kerbside	531835, 178686	NO_2	0.5	2.5
SDT 106	Post adjacent to 80 Camberwell Road	Kerbside	532409, 177597	NO_2	0.5	2.5
SDT 107	Lamppost 1045/45 adjacent to 351 Walworth Road	Kerbside	532426, 178051	NO_2	0.5	2.5
SDT 111	Lamppost 31A/239 Walworth Road	Kerbside	532294, 178354	NO_2	0.5	2.5
SDT 147	Lamppost 1515 13 John Ruskin Street	Kerbside	532230, 177756	NO_2	0.5	2.5
SDT 148	Lamppost 1515 34 John Ruskin Street	Kerbside	532002, 177578	NO_2	0.5	2.5
SDT 149	Lamppost 1436L03 Kennington Park Place	Kerbside	531479, 177990	NO_2	0.5	2.5
SDT 154	Lamppost (1125 - L37) at the junction of Portland Street / Albany Road	Kerbside	532836, 177844	NO_2	0.5	2.5
SDT 155	Junction of East Street / Portland Street	Kerbside	532597, 178433	NO_2	0.5	2.5
SDT 156	Lamppost (1107 - L07)Junction of Stead Street / Flint Street	Kerbside	532643, 178677	NO_2	0.5	2.5
SDT 157	Lamppost (1027 - L03) adjacent to Braganza Street	Kerbside	531648, 178257	NO_2	0.5	2.5

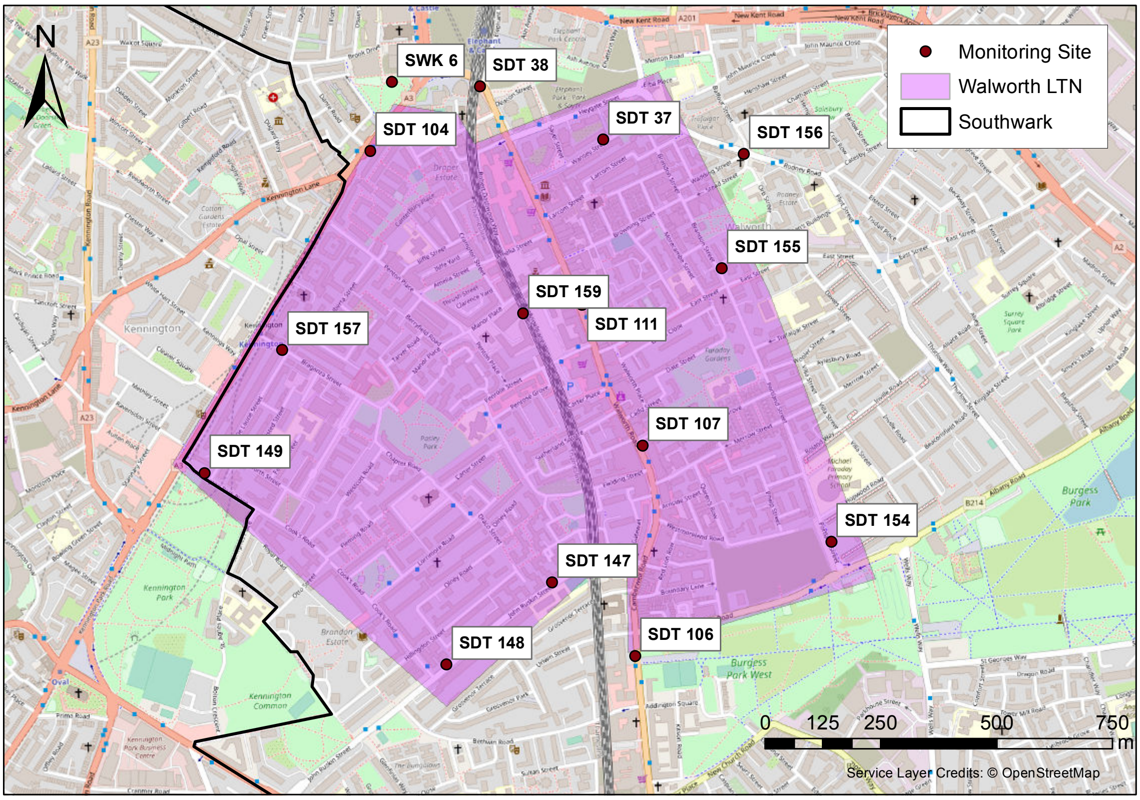

Figure 5.2: Southwark monitoring sites in the vicinity of Walworth LTN schemes

5.3.1. NO_2 concentrations

Table 5.2 shows NO_2 concentrations measured at the automatic monitor and diffusion tube sites for the years 2019 and 2020, and the first eight months of 2021. The values for 2019 and 2020 are fully ratified and bias adjusted, whereas 2021 values are raw values that are subject to change in 2022, when the measurements will be ratified and bias adjusted. Exceedences of the annual average air quality objective of 40 µg/m³ for 2019 and 2020 are highlighted in **bold**; the eight month averages for 2021 are shown in *grey italics*.

The concentration data for the automatic monitor site was taken from the London Air Quality Network[7] run by the ERG Imperial College London. The concentration data for the diffusion tube sites was provided by Southwark Council.

At the automatic monitoring site, there were no exceedences of the annual average air quality objective of 40 µg/m³ and there were no measured exceedences of the hourly averages over the permitted 18 hours per year for NO_2.

[7] https://www.londonair.org.uk/LondonAir/Default.aspx

At the diffusion tube sites, in 2019, annual average NO_2 concentrations exceeded the air quality objective at six of the thirteen considered sites. The air quality objective was not exceeded at diffusion tube locations in 2020. The NO_2 concentrations in 2020 were lower than 2019 concentrations, in part due to the reduced traffic flows associated with Covid-19 pandemic lockdown measures.

The average concentrations for the first eight months of 2021 are higher than 2020 levels, but it should be noted that these are raw concentrations before ratification and bias adjustment. For context, the bias adjustment factors applied to 2019 and 2020 concentrations are respectively 0.91 and 0.81, i.e. "true" values 9% and 19% lower than the measured diffusion tube results.

Table 5.2: NO_2 concentrations at monitoring sites($\mu g/m^3$)

Site ID	Site Name	Site Type	2019[a]	2020[b]	*2021[c]*
SWK 6	AQMS Elephant & Castle	Urban background	30	21	*23*
SDT 37	Lamppost 1068/09 Wansey Street	Kerbside	27	19	*35*
SDT 38	Walworth Road opposite junction to Elephant Road	Kerbside	**44**	30	*37*
SDT 104	Lamppost 08 Newington Causeway	Kerbside	**59**	37	*37*
SDT 106	Post adjacent to 80 Camberwell Road	Kerbside	**46**	34	*39*
SDT 107	Lamppost 1045/45 adjacent to 351 Walworth Road	Kerbside	36	23	*29*
SDT 111	Lamppost 31A/239 Walworth Road	Kerbside	**41**	28	*29*
SDT 147	Lamppost 1515 13 John Ruskin Street	Kerbside	35	23	*40*
SDT 148	Lamppost 1515 34 John Ruskin Street	Kerbside	37	22	*30*
SDT 149	Lamppost 1436L03 Kennington Park Place	Kerbside	34	22	*30*
SDT 154	Lamppost (1125 - L37) at the junction of Portland Street / Albany Road	Kerbside	**40**	23	*27*
SDT 155	Junction of East Street / Portland Street	Kerbside	31	20	*25*
SDT 156	Lamppost (1107 - L07)Junction of Stead Street / Flint Street	Kerbside	**40**	25	*30*
SDT 157	Lamppost (1027 - L03) adjacent to Braganza Street	Kerbside	33	19	*27*

[a] 2019 annual average, fully ratified and diffusion tube data bias adjusted using a factor of 0.91
[b] 2020 annual average, fully ratified and diffusion tube data bias adjusted using a factor of 0.81
[c] Eight-month average until the end of August 2021, unratified values without diffusion tube bias adjustment. Subject to change in 2022. For previous years the bias adjustment led "true" values that are lower than the measured diffusion tube results

5.3.2. PM_{10} and $PM_{2.5}$ concentrations

Table 5.3 and Table 5.4 show the measured annual average PM_{10} and $PM_{2.5}$ concentrations at the automatic monitor SWK6 for the years 2019 and 2020, and the first eight months of 2021. Note that $PM_{2.5}$ monitoring commenced during 2020 for SWK6.

There were no exceedences of the annual average air quality standard of 40 µg/m³ for PM_{10} or the annual average air quality standard of 25 µg/m³ for $PM_{2.5}$.

In addition, there were no measured exceedences of the hourly averages over the permitted 35 days per year for PM_{10}.

Table 5.3: Annual average PM_{10} concentrations at automatic monitors (µg/m³)

Site ID	Site Name	Site Type	2019	2020	2021
SWK6	Elephant & Castle	Urban Background	17	16	15

Table 5.4: Annual average $PM_{2.5}$ concentrations at automatic monitors (µg/m³)

Site ID	Site Name	Site Type	2019	2020	2021
SWK6	Elephant & Castle	Urban Background	-	9	9

6. Model set-up

Modelling was carried out using the ADMS-Urban [8] model (version 5.0.0.1). The model uses the detailed emissions data described in Section 7, together with a range of other input data, to calculate the dispersion of pollutants. This section summarises the data and assumptions used in the modelling.

6.1. Surface roughness

A length scale parameter called the surface roughness length is used in the model to characterise the study area in terms of the effects it will have on wind speed and turbulence, which are key factors in the modelling. A value of 1 m was used to represent the modelled area, representing the built-up nature of the area.

6.2. Monin-Obukhov length

In urban and suburban areas, a significant amount of heat is emitted by buildings and traffic, which warms the air within and above a city. This is known as the urban heat island and its effect is to prevent the atmosphere from becoming very stable. In general, the larger the urban area the more heat is generated and the stronger the effect becomes.

In the ADMS-Urban model, the stability of the atmosphere is represented by the Monin-Obukhov parameter, which has the dimension of length. In very stable conditions it has a positive value of between 2 metres and 20 metres. In near neutral conditions its magnitude is very large, and it has either a positive or negative value depending on whether the surface is being heated or cooled by the air above it. In very convective conditions it is negative with a magnitude of typically less than 20 metres.

The effect of the urban heat island is that, in stable conditions, the Monin-Obukhov length will never fall below some minimum value; the larger the city, the larger the minimum value. A value of 75 metres was used in the modelling.

6.3. Urban canopy flow

The ADMS-Urban spatially-varying urban canopy flow option calculates changes in the vertical profiles of velocity and turbulence caused by the presence of buildings in an urban area, allowing the flow field within urban areas to be characterised on a neighbourhood-by-neighbourhood basis. The velocity and turbulence profiles are displaced by the building height, and flow within the

[8] http://www.cerc.co.uk/environmental-software/ADMS-Urban-model.html

building canopy is slowed by the buildings. Note that modelling spatially-varying urban canopy flow does not influence the urban heat island calculations described in Section 6.2.

6.4. Street canyons

The presence of buildings either side of a road can introduce street canyon effects that result in pollutants becoming trapped, leading to increased pollutant concentrations. Street canyon effects were taken into account using the ADMS Advanced Canyon option, which makes use of detailed information for roadside buildings.

6.5. Meteorological data

A year of hourly sequential meteorological data measured at Heathrow in 2019 was used in the modelling. Table 6.1 shows the proportion of useable data and Table 6.2 summarises the data used in the modelling. To take account of the different surface characteristics at Heathrow, a surface roughness of 0.2 m was used for the meteorological site.

Table 6.1: Hours of meteorological data used in the modelling

Total number of hours used	8760
Number of hours with missing data	94
Percentage of hours used	98.9%

Table 6.2: Summary of meteorological data

	Minimum	Maximum	Mean
Temperature (°C)	-4.4	37.2	11.9
Wind speed (m/s)	0	16.5	4.0
Cloud cover (oktas)	0	8	5

The ADMS meteorological pre-processor, written by the Met Office, uses the data provided to calculate the parameters required by the program. Figure 6.1 shows a wind rose for the site showing the frequency of occurrence of wind from different directions for a number of wind speed ranges.

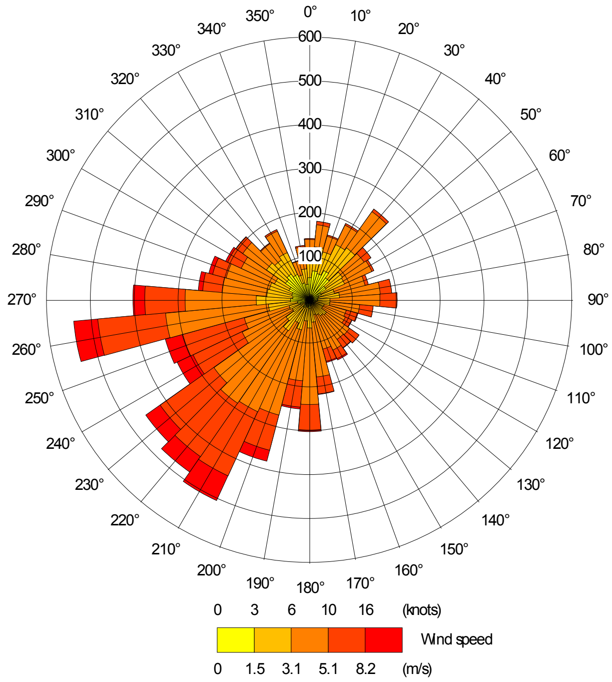

Figure 6.1: Wind rose for Heathrow 2019

6.6. Background data

The air entering from outside of London contains a concentration of each pollutant being modelled. These background concentrations were estimated using measured data from the monitoring sites at Wicken Fen, Chilbolton Observatory, Lullington Heath and Rochester Stoke.

Nitrogen dioxide (NO_2) results from direct emissions from combustion sources together with chemical reactions in the atmosphere involving NO_2, nitric oxide (NO) and ozone (O_3). The combination of NO and NO_2 is referred to as nitrogen oxides (NO_x).

The chemical reactions taking place in the atmosphere were taken into account in the modelling using the Generic Reaction Set (GRS) of equations. These use hourly average background concentrations of NO_x, NO_2 and O_3, together with meteorological and modelled emissions data to calculate the NO_2 concentration at a given point.

Hourly background data were input to the model to represent the concentrations in the air being blown into the city. NO_x, NO_2, O_3 and SO_2 concentrations were obtained from Rochester, Chilbolton Observatory, Lullington Heath and Wicken Fen. PM_{10}, $PM_{2.5}$ concentrations were obtained from Rochester and Chilbolton Observatory. The monitored concentration used for each hour is based upon the wind direction for that hour , as shown in Figure 6.2.

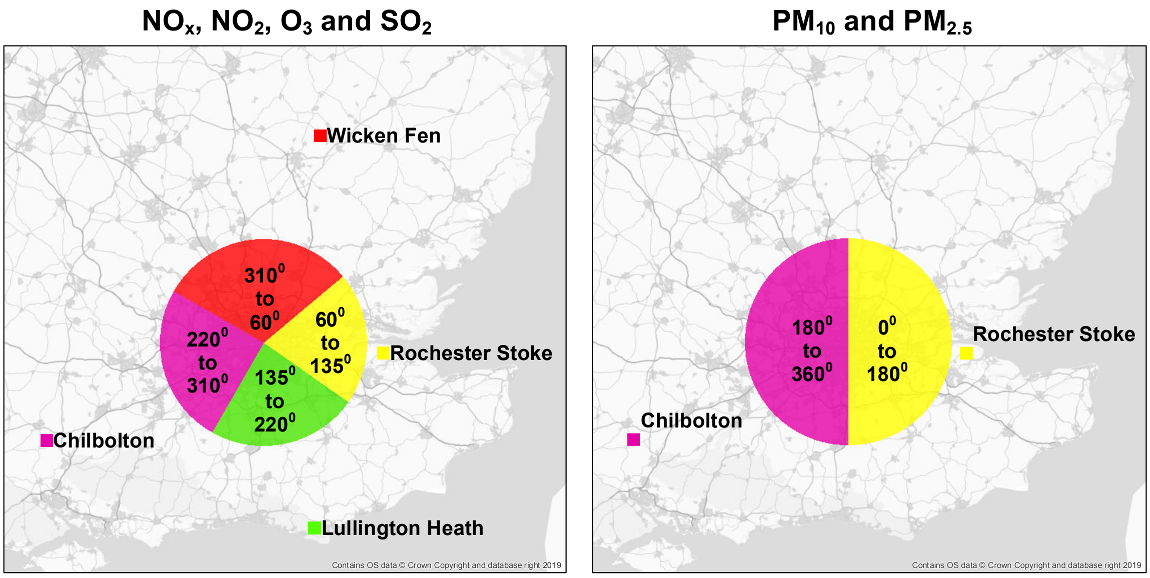

Figure 6.2: Wind direction segments used to calculate background concentrations

Table 6.3 summarises the annual statistics of the resulting background concentrations used in the modelling.

Table 6.3: Summary of 2019 background data used in the modelling (µg/m³)

Statistic	NO_x	NO_2	O_3	PM_{10}	$PM_{2.5}$	SO_2
Annual average	9.1	7.3	55.1	13.4	9.5	0.9
Maximum	175	107	205	272	191	12

7. Emissions data

Emissions inventories for oxides of nitrogen (NO_x), nitrogen dioxide (NO_2) and particulates (PM_{10} and $PM_{2.5}$) were compiled in CERC's emissions inventory toolkit, EMIT.

7.1. Traffic data

As part of the monitoring programme for Walworth LTN, data collection of traffic flows was carried out at 18 survey sites using Automatic Traffic Counters (ATCs). Traffic flow data for the ATC sites was provided by SYSTRA. The ATC sites are located within and on the immediate boundary roads that surround the LTN area. Note that the pre-scheme and post-scheme traffic monitoring were not available for the A3 and A202 boundary roads.

Calculated flow data was provided for each ATC site for pre and post-scheme scenarios in AADT (Annual Average Daily Traffic) format, based on SYSTRA's pre-implementation and post-implementation traffic monitoring in 2021.

The ATC traffic data were split into Motorcycles, Cars, LGV and HGV flows. To match the eleven vehicle categories used for emission calculations, Car flows were split into Cars and Taxis and HGV flows were split into Bus, Rigid HGV and Articulated HGV flows. The vehicle split was taken from LAEI 2016 data.

Figure 7.1 shows the network of explicitly modelled roads in the scheme area. Scheme roads use ATC site traffic flows and all other roads use LAEI 2016 traffic data. To maintain detail at junctions, the major roads in this network were mapped onto LAEI geometry. Note, that the LAEI network does not reflect recent changes to the road network in the wider area, for example the removal of the road through Burgess Park between New Church Road and Wells Way.

Major roads within 800 m of the scheme area were modelled in detail and emissions from other minor roads and more distant major roads were modelled as a part of the aggregated grid source described in Section 7.7. The widths for all roads were based on OS Mastermap data.

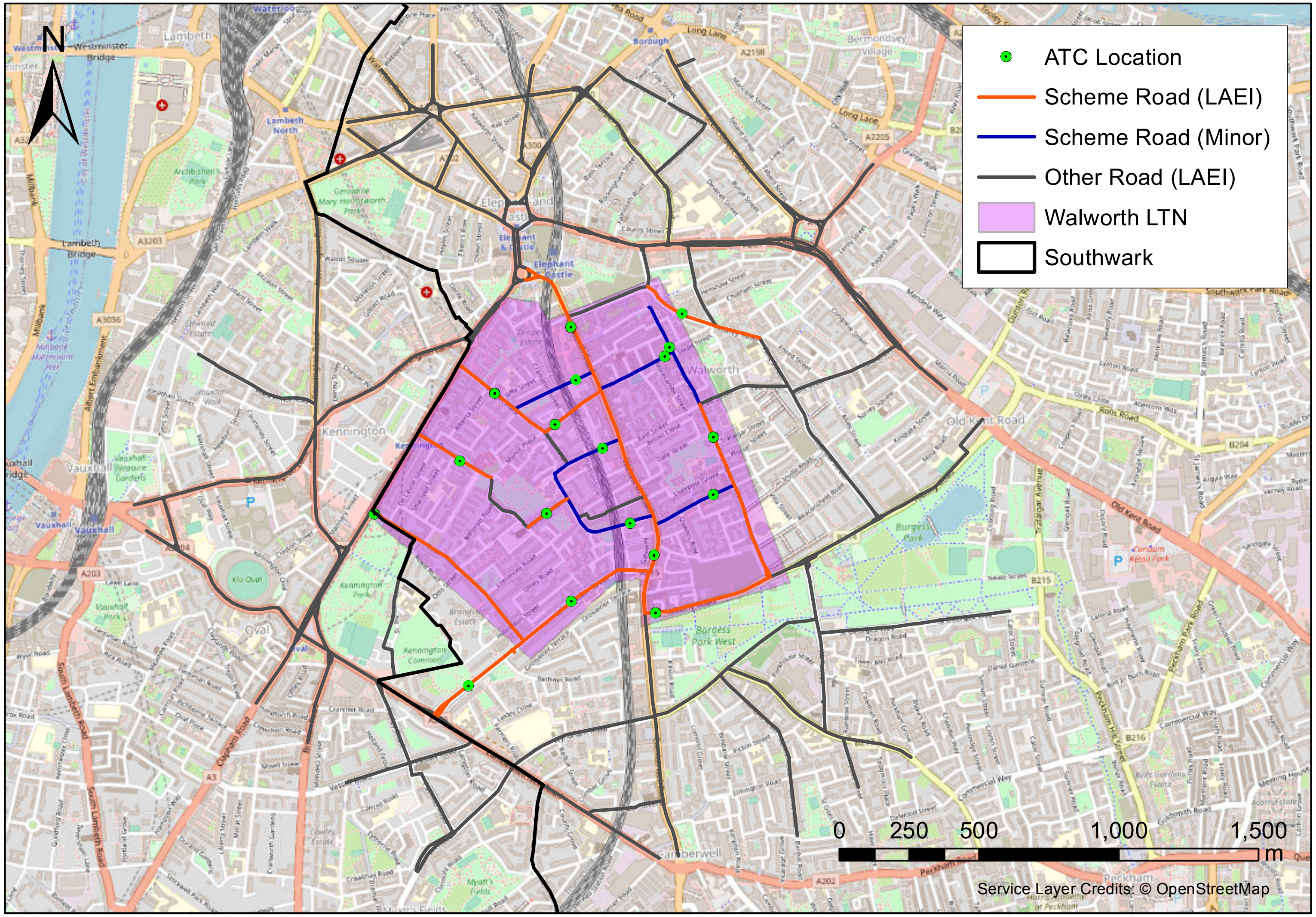

Figure 7.1: Map of explicitly modelled roads

7.2. Traffic speeds

Road speeds for pre-scheme and post-scheme scenarios were provided at each ATC site. On scheme roads where LAEI 2016 speed data were also available, the lower of the two speeds was used for each link, to maintain a good level of speed detail at junctions.

Where only ATC speeds were available, these speeds were used for the entire length of the road link. For other major roads (non-scheme), LAEI 2016 speeds were used.

On minor roads, the following speed assumptions were used for the emission calculations[9]:

- 11 km/h in Central London;
- 19 km/h in Inner London; and
- 31 km/h in Outer London.

These speeds were the basis of road traffic emission calculations. The variation of emissions across a day was considered by applying the time-varying emission profiles shown in Section 7.5.

7.3. Traffic emission factors

Traffic emissions of NO_x, NO_2 and PM_{10} were calculated from traffic flows and speeds using EFT v10.1 published by Defra[10]. This dataset comprises speed-emissions emission factors based on Euro vehicle emissions categories.

Note that there is uncertainty surrounding the current emissions estimates of NO_x in these factors. In order to address this discrepancy, the NO_x emission factors were modified based on published Remote Sensing Data (RSD) [11] [12] for vehicle NO_x emissions. Scaling factors were applied to each vehicle category and Euro standard.

Concentrations of PM_{10} at roadside locations are affected by brake, tyre and road-wear, and concentrations of PM_{10} are also affected by resuspension. With the exception of resuspension, these non-exhaust road traffic emissions were calculated using EFT v10.1 emission factors. Resuspension emission factors were taken from a report produced by TRL Limited on behalf of Defra [13].

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[9] https://www.london.gov.uk/questions/2019/19767

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

[11] Carslaw, D and Rhys-Tyler, G 2013: New insights from comprehensive on-road measurements of NO_x, NO_2 and NH_3 from vehicle emission remote sensing in London, UK. *Atmos. Env.* **81** pp 339–347.

[12] Davison, J., Rose, R.A., Farren, N.J., Wagner, R.L., Murrells, T.P. and Carslaw, D.C., 2021. Verification of a National Emission Inventory and Influence of On-road Vehicle Manufacturer-Level Emissions. Environmental Science & Technology, 55(8), pp.4452-4461.

[13] *Road vehicle non-exhaust particulate matter: final report on emission modelling*, TRL Limited Project Report PPR110 https://uk-air.defra.gov.uk/assets/documents/reports/cat15/0706061624_Report2__Emission_modelling.PDF

7.4. Road traffic fleet assumptions

The EFT v10.1 uses fleet data separated by the regions and road types. London roads were classified by region using definitions provided in LAEI 2016, shown in Figure 7.2, with the M25 treated separately (London Motorway fleet). For non-GLA roads within the M25, Outer London fleet data were used.

The borough of Southwark forms part of Inner London. With the exception of the bus fleet assumptions outlined in Section 7.4.1, the Inner London fleets were used, in line with the regions defined in the LAEI. This is expected to give a good representation of the fleet on a borough-wide basis but may not be representative of the fleet operating on particular roads.

Pre-scheme and post-scheme scenarios were modelled using road traffic fleet assumptions for 2021. In addition, a baseline model for 2019 was set-up using 2019 fleet data.

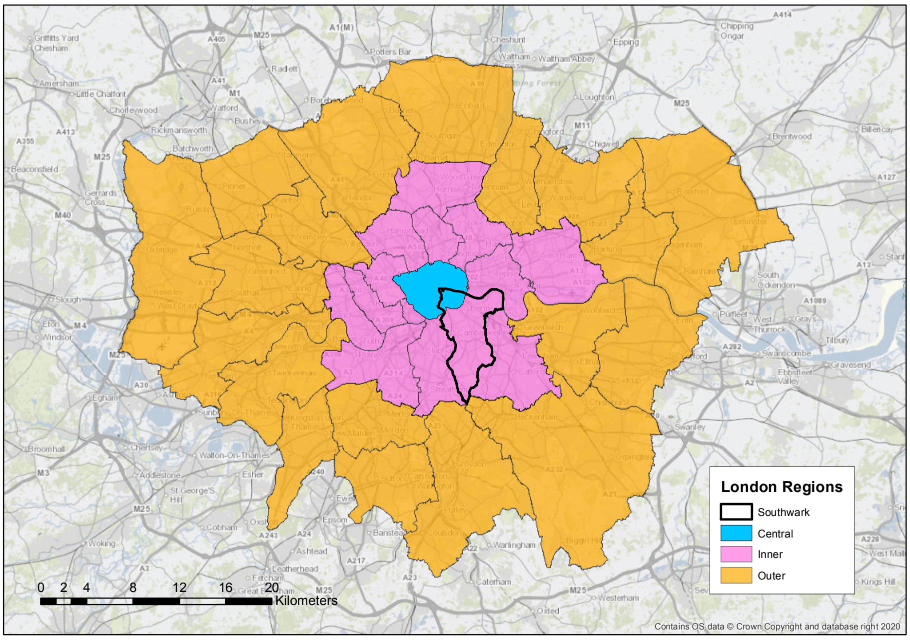

Figure 7.2: London regions

7.4.1. Bus fleet assumptions

Bus fleet projections in EFT 10.1 are shown in Figure 7.3. The projections for 2019 assume 100% buses operating in Central London, 77% in Inner London and 66% in Outer London are Euro VI or better. The projections show a step change in 2020, where all buses across London become Euro VI or better.

According to TfL's bus fleet audit[14], by the end of the 2018/2019 financial year, 77.5% of buses across the whole of London were Euro VI standard or better, increasing to 93.4% by the end of 2019/2020.

To account for the accelerated uptake of newer bus technology, the following assumptions were applied to the modelled bus fleet for 2019:

- Use an average of the respective EFT 2019 and 2020 bus projections for roads in Inner and Outer London; and
- For Central London, use the EFT projection without modifications for 2019 since it is in line with TfL's bus fleet audit.

For 2021 emissions, the EFT fleet for 2021 was used without modifications.

[14] https://tfl.gov.uk/corporate/publications-and-reports/bus-fleet-data-and-audits

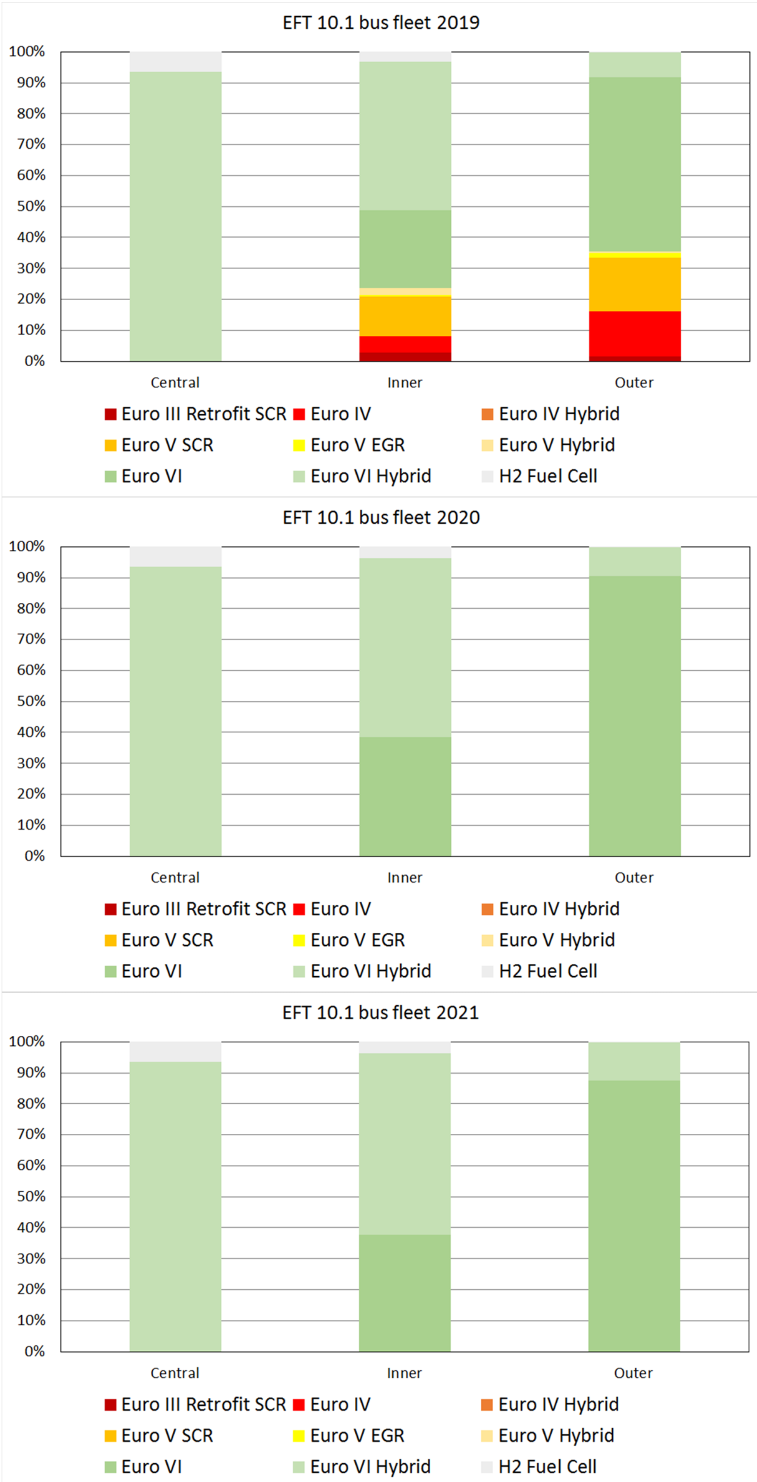

Figure 7.3: EFT 10.1 bus fleet projections for London regions for 2019 (top), 2020 (middle) and 2021 (bottom). Projections for Central, Inner and Outer London are shown

7.5. Time-varying emissions profiles

The variation in emissions during the day was taken into account by applying a set of diurnal profiles to the road and grid sources. Time-varying emissions profiles were based on road traffic emissions in *Air pollution and emissions trends in London* [15], used in the compilation of the LAEI, and are shown in Figure 7.4.

These emission profiles are expected to capture the changes in traffic volume, composition and speed throughout the day. In the absence of more detailed data, these profiles were used for all scheme roads in both the pre-scheme and post-scheme scenarios.

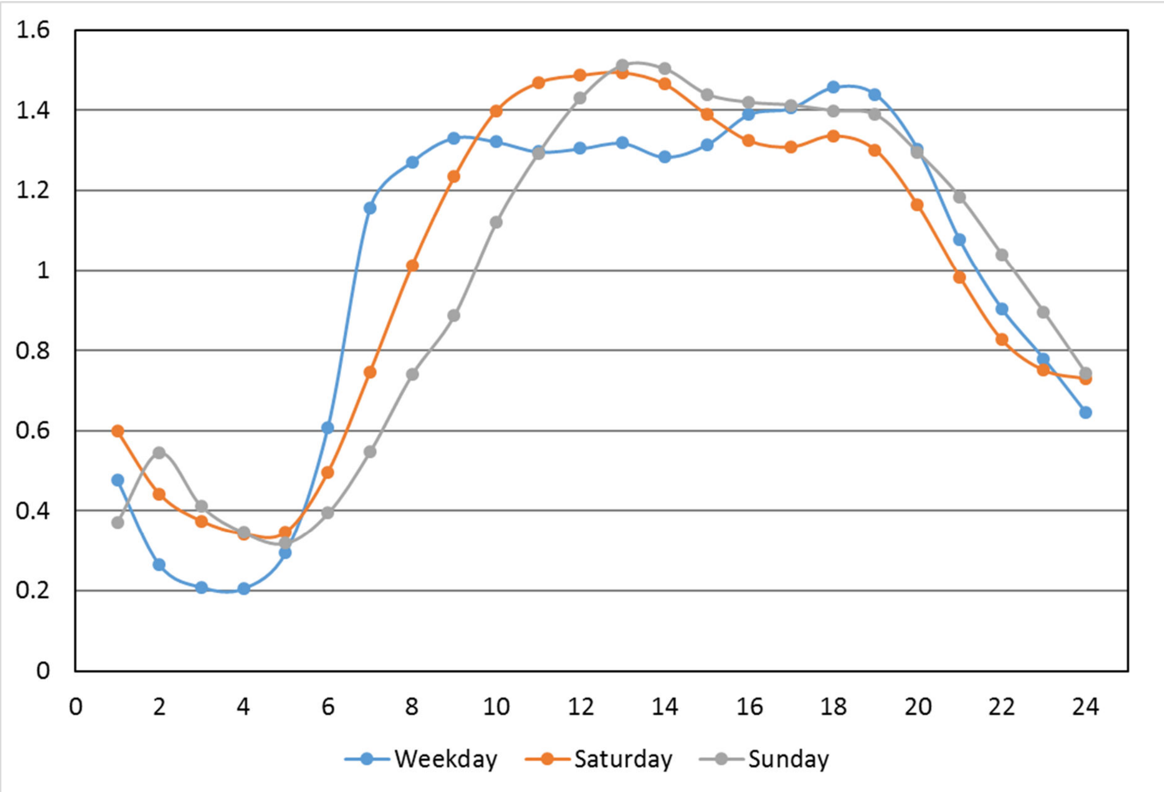

Figure 7.4: Diurnal profiles for road traffic emissions

Profiles for grid sources, as described in Section 7.7, were derived from European Monitoring and Evaluation Programme (EMEP) emissions data, and are shown in Figure 7.5.

[15] *Air pollution and emissions trends in London*, King's College London, Environmental Research Group and Leeds University, Institute for Transport studies https://uk-air.defra.gov.uk/assets/documents/reports/cat05/1004010934_MeasurementvsEmissionsTrends.pdf

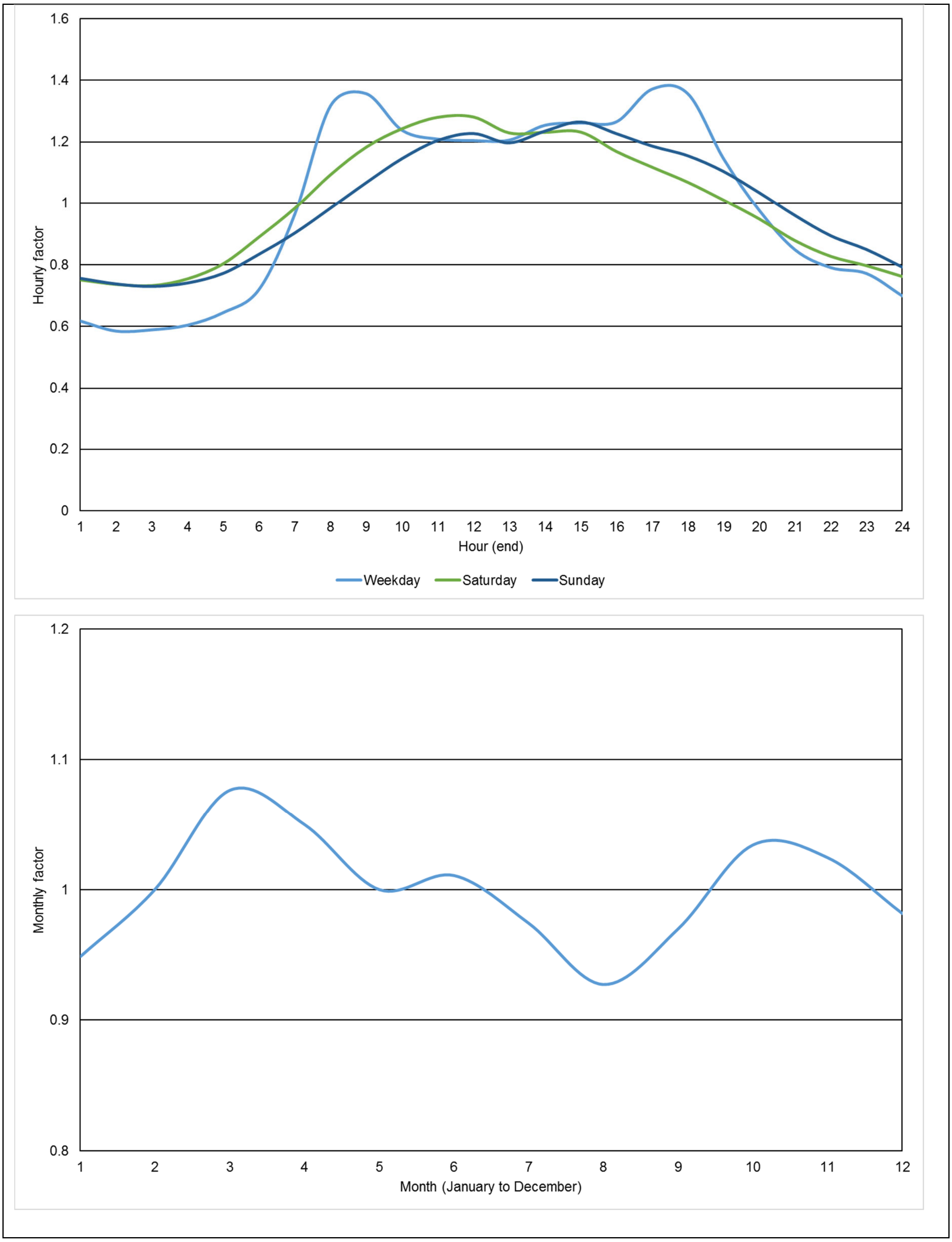

Figure 7.5: Diurnal (top) and monthly profiles (bottom) for grid source emissions

7.6. Industrial sources

One industrial source was explicitly included in the modelling due to its proximity to the scheme area and relatively high emission rates. The model parameters for South East London Combined Heat and Power (SEL CHP) are summarised in Table 7.1. The source is located in north Lewisham, approximately 3 km north-east of the scheme area.

Stack parameters were estimated based on the type of source and emission rates were obtained from the LAEI 2016, for the grid square in which the industrial source is located (535500, 178500).

Table 7.1: SEL CHP model parameters and emission rates

Location (x, y)	Height (m)	Diameter (m)	Exit velocity (m/s)	Temperature (°C)	NO_2 (g/s)	NO_x (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)
535700, 178120	61	1.6	13.7	134	1.0	20.0	0.1	0.1

7.7. Other emissions

Emission rates for all other sources were taken from the LAEI 2016 and modelled as aggregated 1-kilometre resolution grid sources covering the whole of London.

Hourly and monthly emissions profiles for the grid sources were derived from European Monitoring and Evaluation Programme (EMEP) emissions data and are shown in Section 7.5.

8. Model verification

The first stage of a modelling study is to verify that the input data and model set-up are representative of the area. This was done by calculating annual average concentrations of NO_2 and PM_{10} at the locations of monitoring sites at which they are measured. The monitoring site locations provided in Section 5 were fully reviewed as part of model verification and adjusted with respect to the distance from modelled roads and location within street canyons.

8.1. NO_2

Figure 8.1 and Table 8.1 summarise the measured and modelled annual average NO_2 concentrations for 2019. In the table exceedences of the air quality objective of 40 µg/m^3 are shown in **bold**.

The modelled concentrations show generally good agreement with the measured data, providing confidence for the modelling of the scheme scenarios. The modelled concentrations are within 25 % of the measured data all 14 sites and the modelled concentrations are within 10 % of monitored values at 9 sites (64 % of the sites).

The largest percentage model over-predictions, for SWK 6 and SDT 37, indicate some uncertainty with regard to the modelled urban background pollution levels in the area.

The largest percentage model under-prediction, for SDT 154, may reflect the impact of long-term building works close to monitoring site. Although the model under-predicts concentrations at SDT 104, in line with measurements the model predicts an exceedence of the air quality objective in 2019. Note that the diffusion tube is located along the A3, scheme ATC data were not available for this road, therefore LAEI traffic data were used.

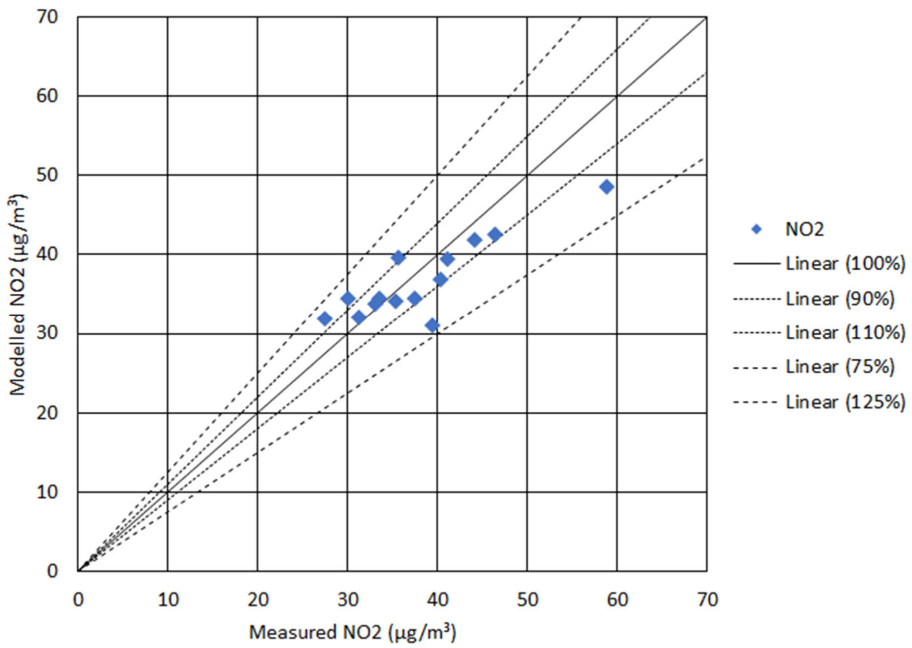

Figure 8.1: Measured and modelled annual average NO_2 concentrations

Table 8.1: Measured and modelled NO_2 concentrations (µg/m³)

Site ID	Site Name	Measured	Modelled	Modelled /Measured (%)
SWK 6	AQMS Elephant & Castle	30	34	113
SDT 37	Lamppost 1068/09 Wansey Street	27	32	119
SDT 38	Walworth Road opposite junction to Elephant Road	**44**	**42**	95
SDT 104	Lamppost 08 Newington Causeway	**59**	**49**	83
SDT 106	Post adjacent to 80 Camberwell Road	**46**	**43**	93
SDT 107	Lamppost 1045/45 adjacent to 351 Walworth Road	36	**40**	111
SDT 111	Lamppost 31A/239 Walworth Road	**41**	**40**	98
SDT 147	Lamppost 1515 13 John Ruskin Street	35	34	97
SDT 148	Lamppost 1515 34 John Ruskin Street	37	35	95
SDT 149	Lamppost 1436L03 Kennington Park Place	34	35	103
SDT 154	Lamppost (1125 - L37) at the junction of Portland Street / Albany Road	**40**	31	78
SDT 155	Junction of East Street / Portland Street	31	32	103
SDT 156	Lamppost (1107 - L07)Junction of Stead Street / Flint Street	**40**	37	93
SDT 157	Lamppost (1027 - L03) adjacent to Braganza Street	33	34	103

8.2. PM_{10}

Table 8.2 shows the measured and modelled annual average PM_{10} concentration for 2019 at the automatic monitoring sites.

Table 8.2: Measured and modelled PM_{10} concentrations at SWK6 for 2019 ($\mu g/m^3$)

Site ID	Site Name	Site Type	Measured	Modelled	Modelled /Measured (%)
SWK 6	AQMS Elephant & Castle	Urban background	17	21	124

9. Modelled concentrations

This section presents modelled NO_2, PM_{10} and $PM_{2.5}$ concentrations for the pre-scheme and post-scheme scenarios.

As described in the previous section, the modelling uses road traffic emissions calculated using fleet projections for 2021 and scheme traffic data based on monitoring from 2021. All other model inputs are for 2019, including meteorological and background (contribution from outside London).

9.1. School locations

Concentrations were calculated at school locations in the scheme area, chosen by Southwark Council. Figure 9.1 provides the locations of the schools and Table 9.1 provides the average modelled roadside façade(s) concentrations for schools or, where the nearby roads are not modelled scheme roads, a single location representing the centre of the school.

Modelled concentrations of NO_2, PM_{10} and $PM_{2.5}$ at these school locations are all below the relevant air quality objectives.

The change in annual average NO_2 concentrations between the post-scheme and pre-scheme scenarios range between a 0.01 $\mu g/m^3$ and 0.6 $\mu g/m^3$ reduction. For the majority of school locations, the change in concentration represents 1% or less of the annual average NO_2 air quality objective.

The changes in annual average PM_{10} and $PM_{2.5}$ concentrations are small, representing less than 1% of the relevant air quality objective.

Using the EPUK IAQM significance criteria matrix reproduced in Table 4.1, the impact of the scheme at all school locations, for all pollutants, is classed as *Negligible*.

In addition to small changes in concentrations, this significance classification represents the relatively low pollution concentrations across the scheme area. At all but one of the school locations, long term average concentrations fall into the *75% or less of AQAL* category of the significance criteria matrix.

Table 9.1: Average modelled concentrations at roadside façades of selected schools (μg/m³)

ID	School	Modelled Road	Pre-Scheme					Post-Scheme				
			Annual average NO_2	99.79th %ile of 1-hour NO_2	Annual average PM_{10}	90.41st %ile of 24-hour PM_{10}	Annual average $PM_{2.5}$	Annual average NO_2	99.79th %ile of 1-hour NO_2	Annual average PM_{10}	90.41st %ile of 24-hour PM_{10}	Annual average $PM_{2.5}$
1	St Joseph's Catholic Infants School	*School Centre Point*	27.4	98	20.3	36	12.8	27.4	98	20.3	36	12.8
2	St Joseph's Catholic Junior School	*School Centre Point*	27.4	98	20.3	36	12.8	27.4	98	20.3	36	12.8
3	The Highshore School	*School Centre Point*	27.9	99	21.0	37	13.0	27.9	99	21.0	37	13.0
4	Ark All Saints Academy	*School Centre Point*	28.0	99	20.9	37	13.0	28.0	99	20.9	37	13.0
5	John Ruskin School	JOHN RUSKIN STREET	30.0	101	20.6	37	13.1	29.6	100	20.6	36	13.1
6	St Paul's CoE Primary School	PENROSE STREET	28.5	98	20.6	37	13.1	28.4	98	20.6	37	13.1
7	The Park College	KENNINGTON PARK PLACE	29.7	101	20.4	36	13.3	29.1	99	20.3	36	13.2
8	Keyworth Primary School	*School Centre Point*	28.1	97	20.1	36	13.1	28.1	97	20.1	36	13.1
9	Crampton Primary School	*School Centre Point*	28.6	98	20.6	37	13.3	28.5	98	20.6	37	13.3
10	St John's Walworth CoE Primary School	*School Centre Point*	28.9	98	21.3	37	13.4	28.8	98	21.3	37	13.4
11	St Peter's CoE Primary School and Nursery	*School Centre Point*	27.6	96	20.7	37	13.1	27.6	96	20.7	37	13.1

ID	School	Modelled Road	Pre-Scheme					Post-Scheme				
			Annual average NO_2	**99.79^{th} %ile of 1-hour NO_2**	**Annual average PM_{10}**	**90.41^{st} %ile of 24-hour PM_{10}**	**Annual average $PM_{2.5}$**	**Annual average NO_2**	**99.79^{th} %ile of 1-hour NO_2**	**Annual average PM_{10}**	**90.41^{st} %ile of 24-hour PM_{10}**	**Annual average $PM_{2.5}$**
12	Michael Faraday Primary School	PORTLAND STREET	28.1	97	20.3	36	12.9	27.9	97	20.2	36	12.9
13	Robert Browning Primary School	*School Centre Point*	28.0	97	21.2	37	13.3	27.9	97	21.2	37	13.3
14	University Academy of Engineering South Bank	*School Centre Point*	27.8	97	20.9	37	13.2	27.7	97	20.9	37	13.2
15	English Martyrs' Catholic Primary School	*School Centre Point*	28.7	100	21.2	37	13.4	28.7	100	21.2	37	13.4
16	Townsend School	*School Centre Point*	29.4	101	21.0	37	13.4	29.4	101	21.0	37	13.4
17	Victory Primary School and Children's Centre	RODNEY ROAD	31.9	106	22.1	38	13.8	31.8	106	22.1	38	13.8
18	Liral Veget College London	*School Centre Point*	29.6	102	21.1	37	13.5	29.6	102	21.1	37	13.5

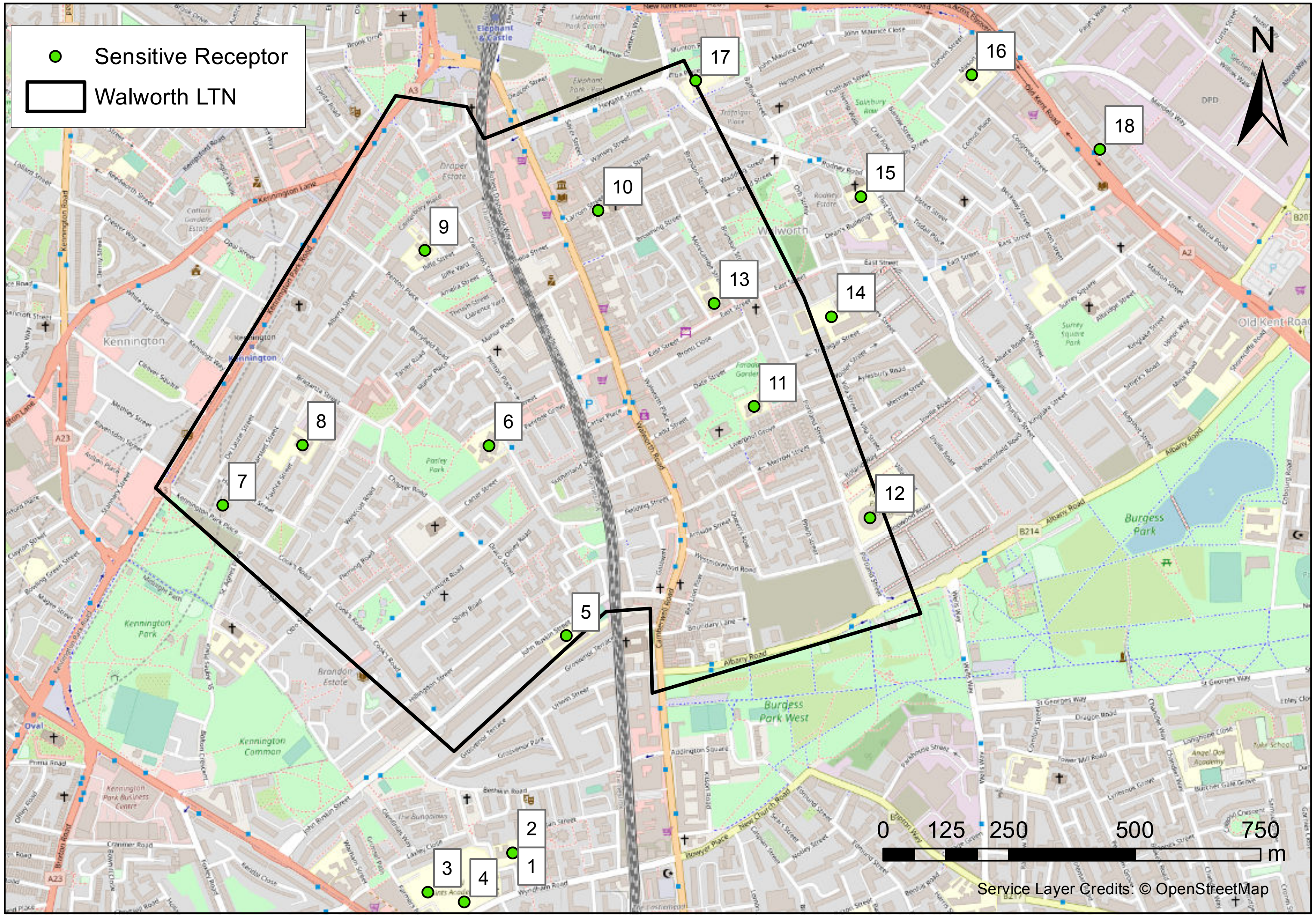

Figure 9.1: Locations of modelled sensitive receptors

9.2. Contour maps

Concentrations were calculated on a regular grid of receptors on a 20 m resolution and a dense network of roadside, kerbside and building façade points. The additional set of receptors was used to represent the steep concentration gradient from the roadside to the building facades. The model output was used to generate 5 m resolution contour maps across the scheme area using the natural neighbour interpolation method.

Figure 9.2 and Figure 9.3 show modelled annual average NO_2 concentrations for the pre-scheme and post-scheme scenarios, respectively. These maps use the same colour scale as the GLA's LAEI 2016 concentration maps.

Modelled annual average NO_2 concentrations meet the air quality objective of 40 µg/m³ throughout the scheme area, with the exception of some locations close to busy road junctions. Modelled concentrations exceed the air quality objective along the A3 (Newington Butts and Kennington Park Road) and parts of Walworth Road.

For context, Figure 9.4 shows modelled annual average NO_2 concentrations from a 2019 baseline model, using 2019 road traffic emission factors and pre-scheme traffic flows normalised to 2019 levels. Comparing this figure against the scheme scenarios that use 2021 traffic emission factors, provides an indication of the expected change in concentrations due to recent changes in the traffic fleet composition, partly driven by measures such as the Ultra Low Emission Zone. The area exceeding the annual average NO_2 air quality objective in 2019 has a much wider extent than for the scheme scenarios, encompassing most of the length of Walworth Road, and parts of Albany Road and Heygate Street.

Figure 9.5 and Figure 9.6 show the modelled 99.79th percentile of hourly average NO_2 concentrations for the pre-scheme and post-scheme scenarios, respectively. Modelled concentrations meet the air quality objective of 200 µg/m³ across the scheme area.

Figure 9.7 and Figure 9.8 shows the modelled annual average PM_{10} concentrations for the pre-scheme and post-scheme scenarios, respectively. Modelled concentrations meet the air quality objective of 40 µg/m³ across the scheme area.

Figure 9.9 and Figure 9.10 shows the modelled 90.41st percentile of 24-hour average PM_{10} concentrations for the pre-scheme and post-scheme scenarios, respectively. Modelled concentrations meet the air quality objective of 50 µg/m³ across the scheme area.

Figure 9.11 and Figure 9.12 show modelled annual average $PM_{2.5}$ concentrations for the pre-scheme and post-scheme scenarios, respectively. Modelled concentrations meet the air quality objective of 25 µg/m³ across the scheme area.

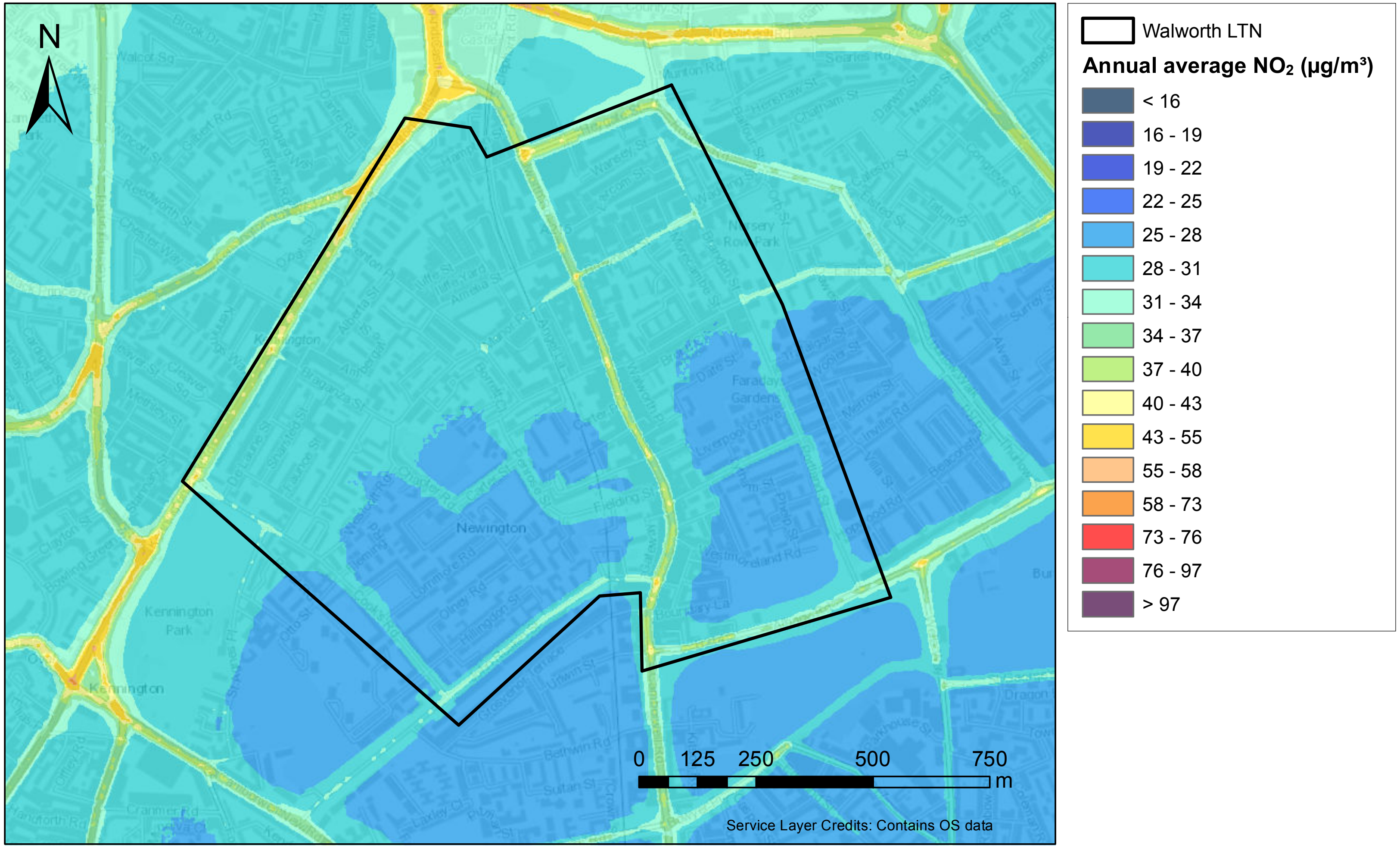

Figure 9.2: Pre-scheme annual average NO_2 concentrations (2021 road traffic emission factors)

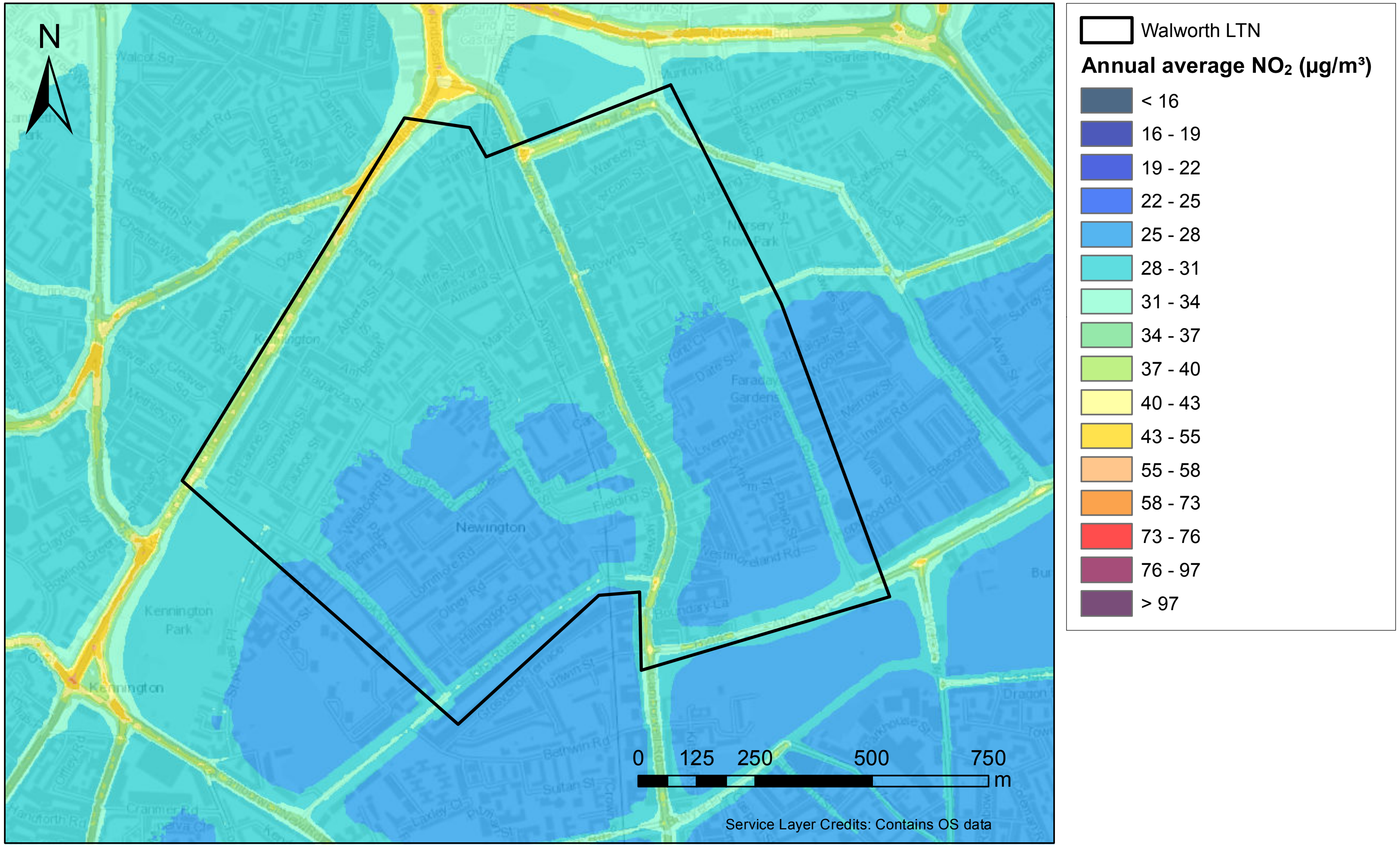

Figure 9.3: Post-scheme annual average NO_2 concentrations (2021 road traffic emission factors)

Figure 9.4: 2019 annual average NO_2 concentrations

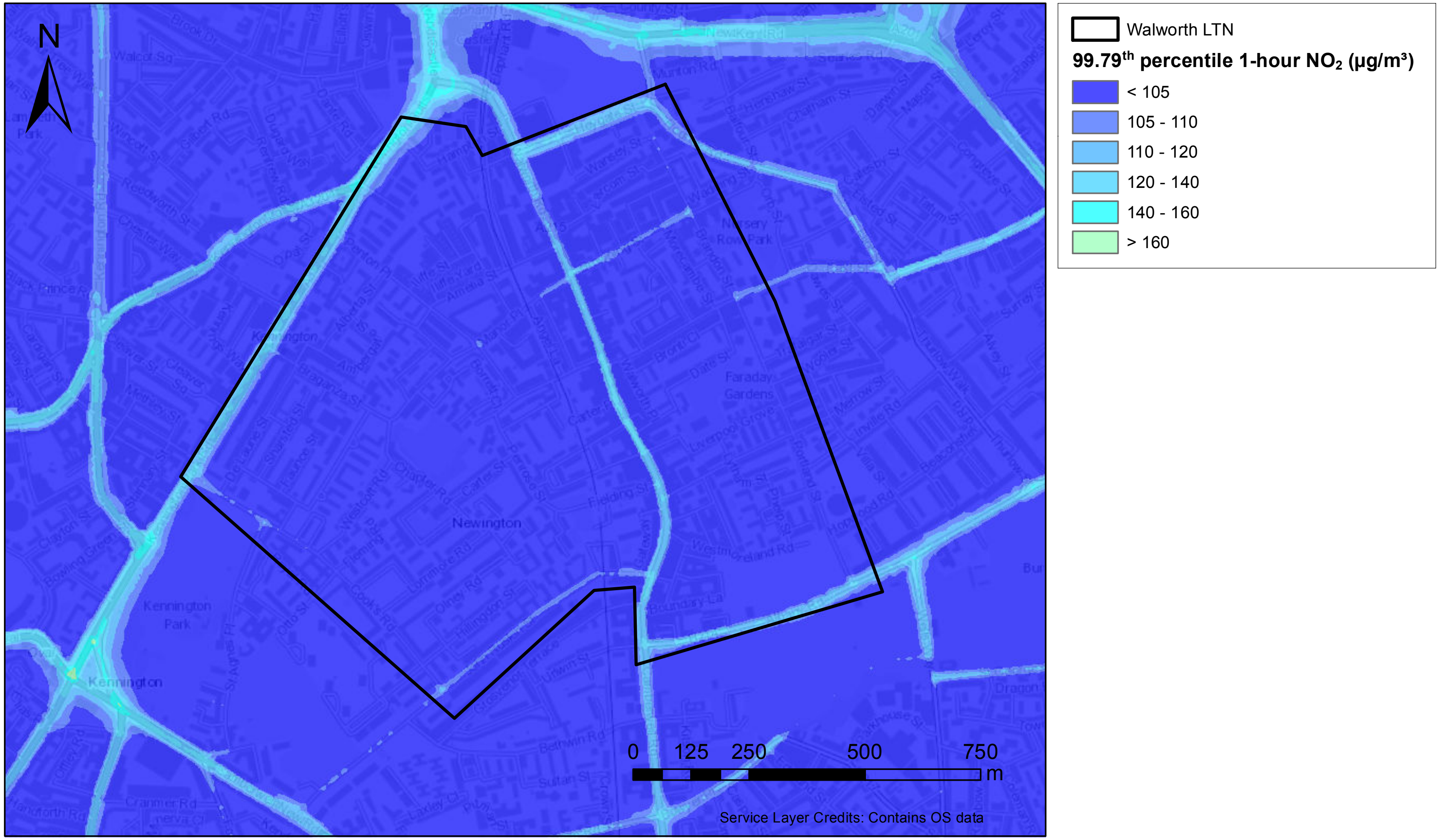

Figure 9.5: Pre-scheme 99.79th percentile of hourly average NO_2 concentrations (2021 road traffic emission factors)

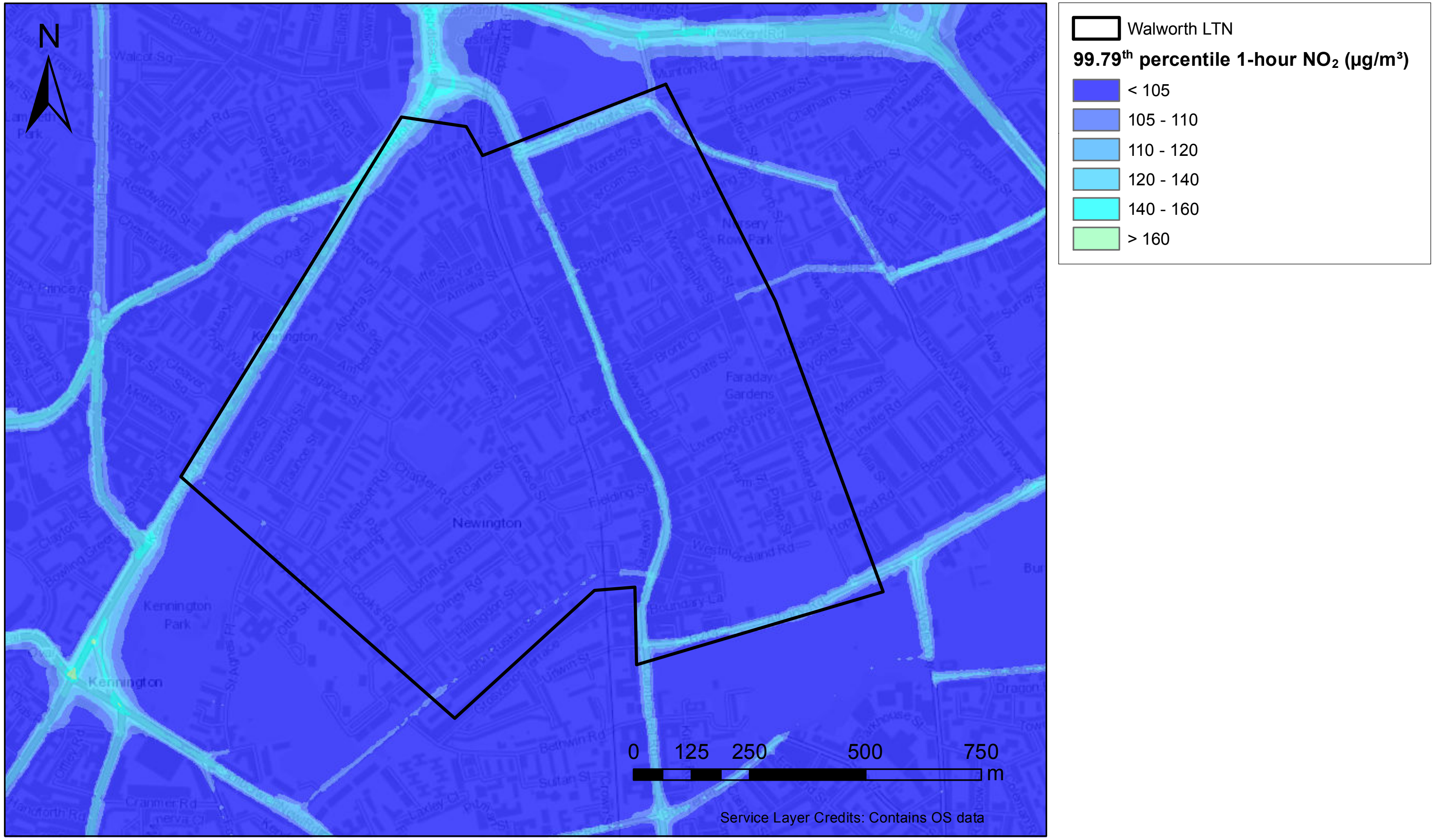

Figure 9.6: Post-scheme 99.79th percentile of hourly average NO_2 concentrations (2021 road traffic emission factors)

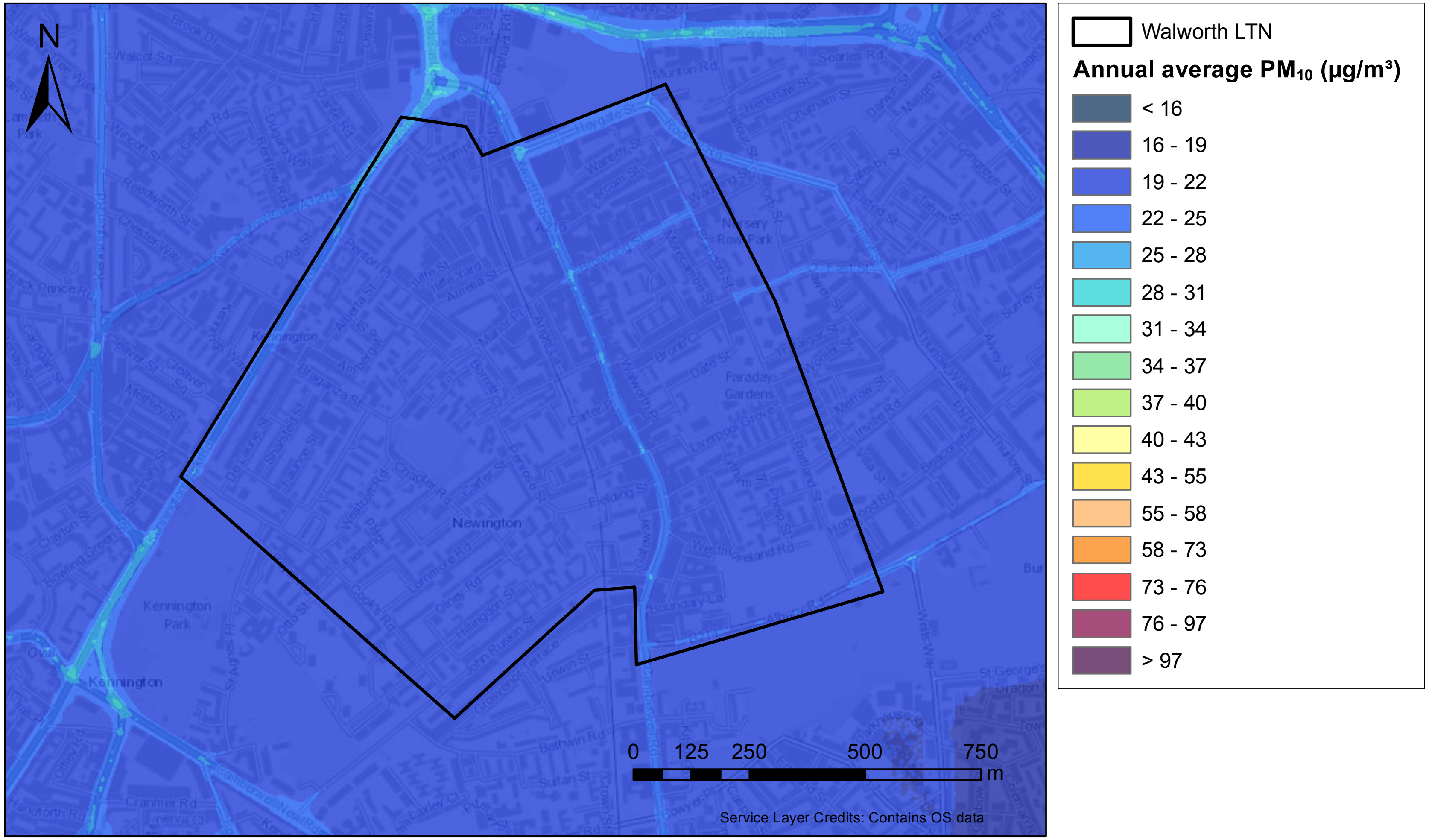

Figure 9.7: Pre-scheme annual average PM_{10} concentrations (2021 road traffic emission factors)

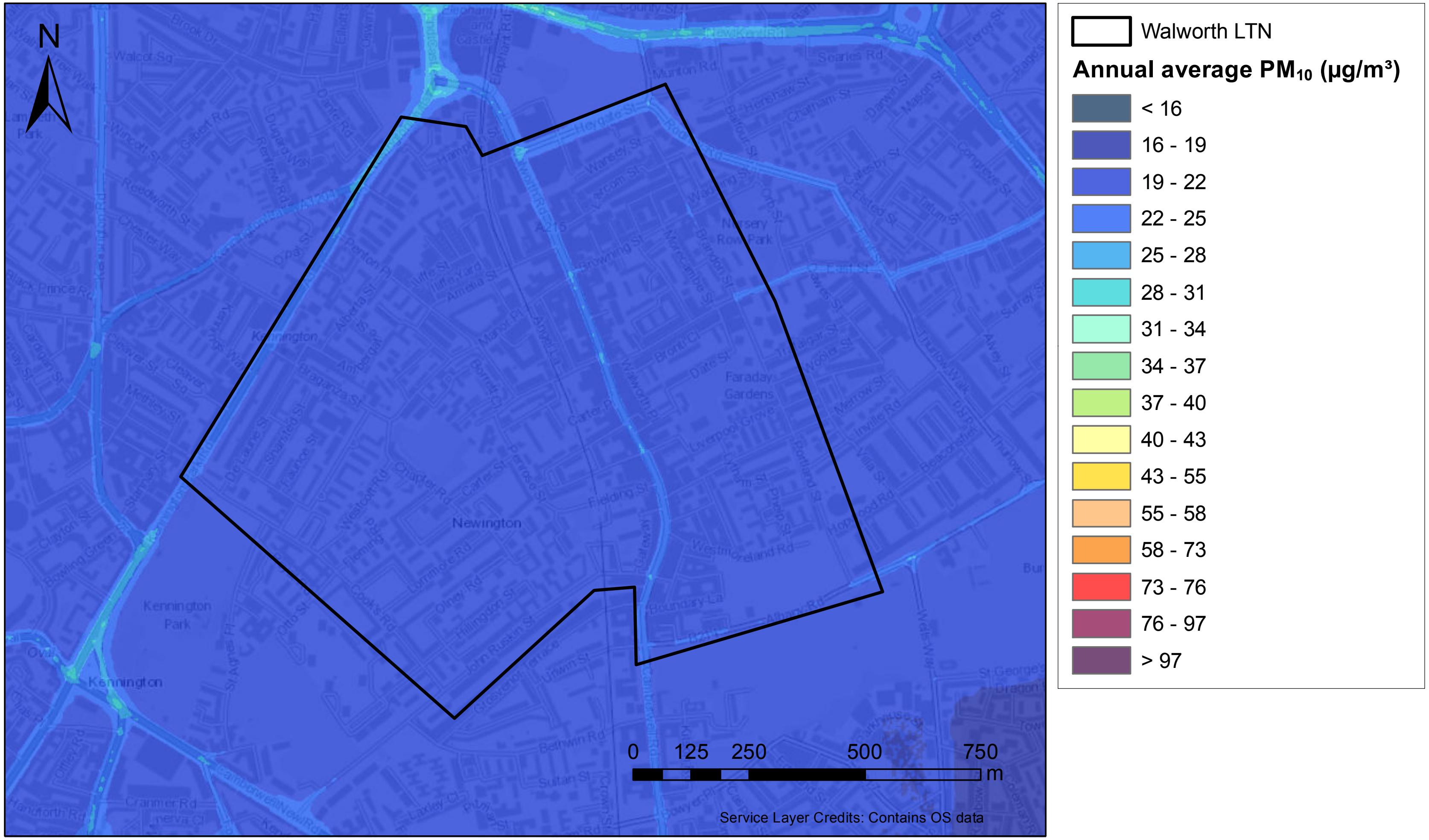

Figure 9.8: Post-scheme annual average PM_{10} concentrations (2021 road traffic emission factors)

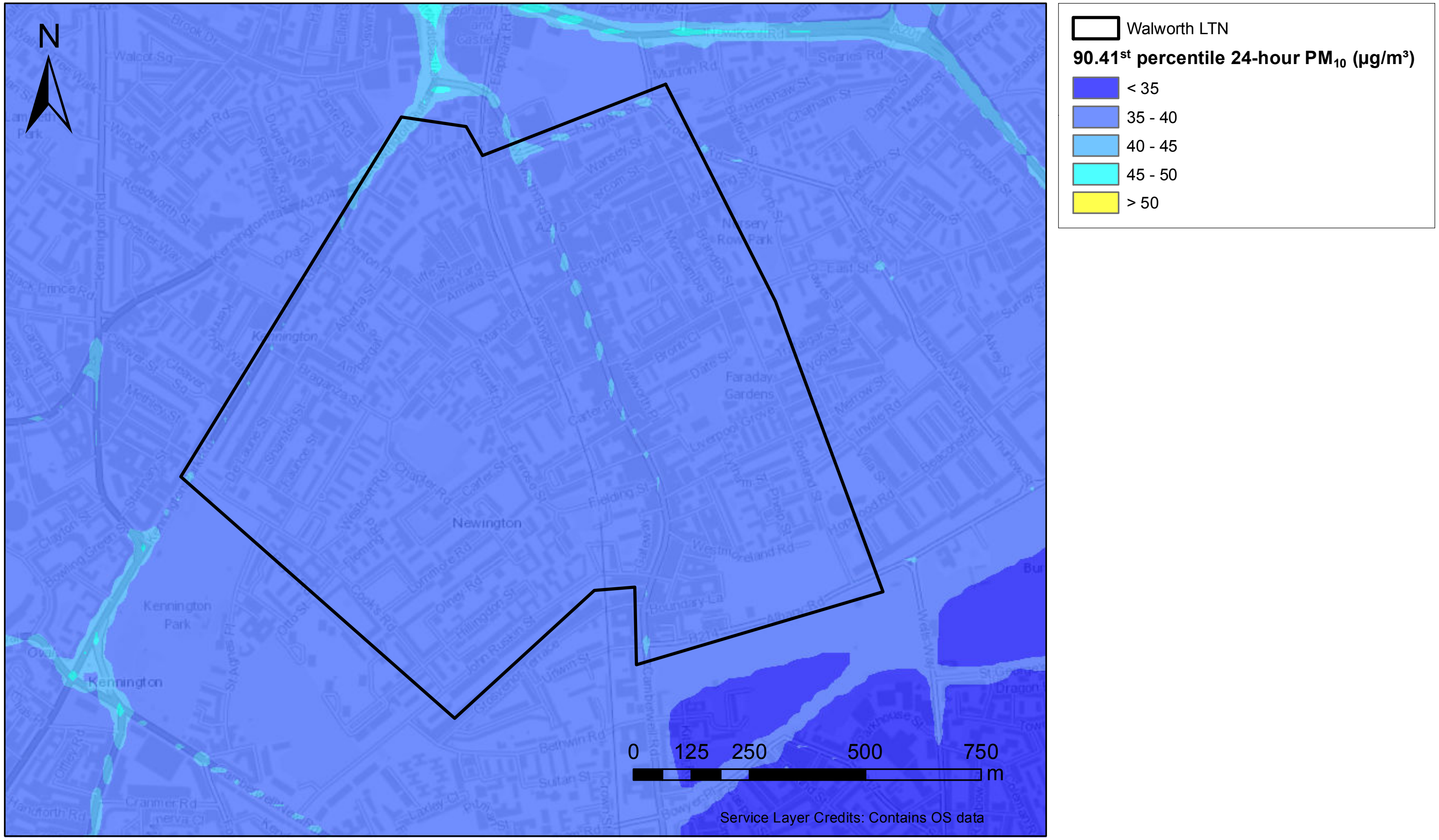

Figure 9.9: Pre-scheme 90.41st percentile of 24-hour average PM_{10} concentrations (2021 road traffic emission factors)

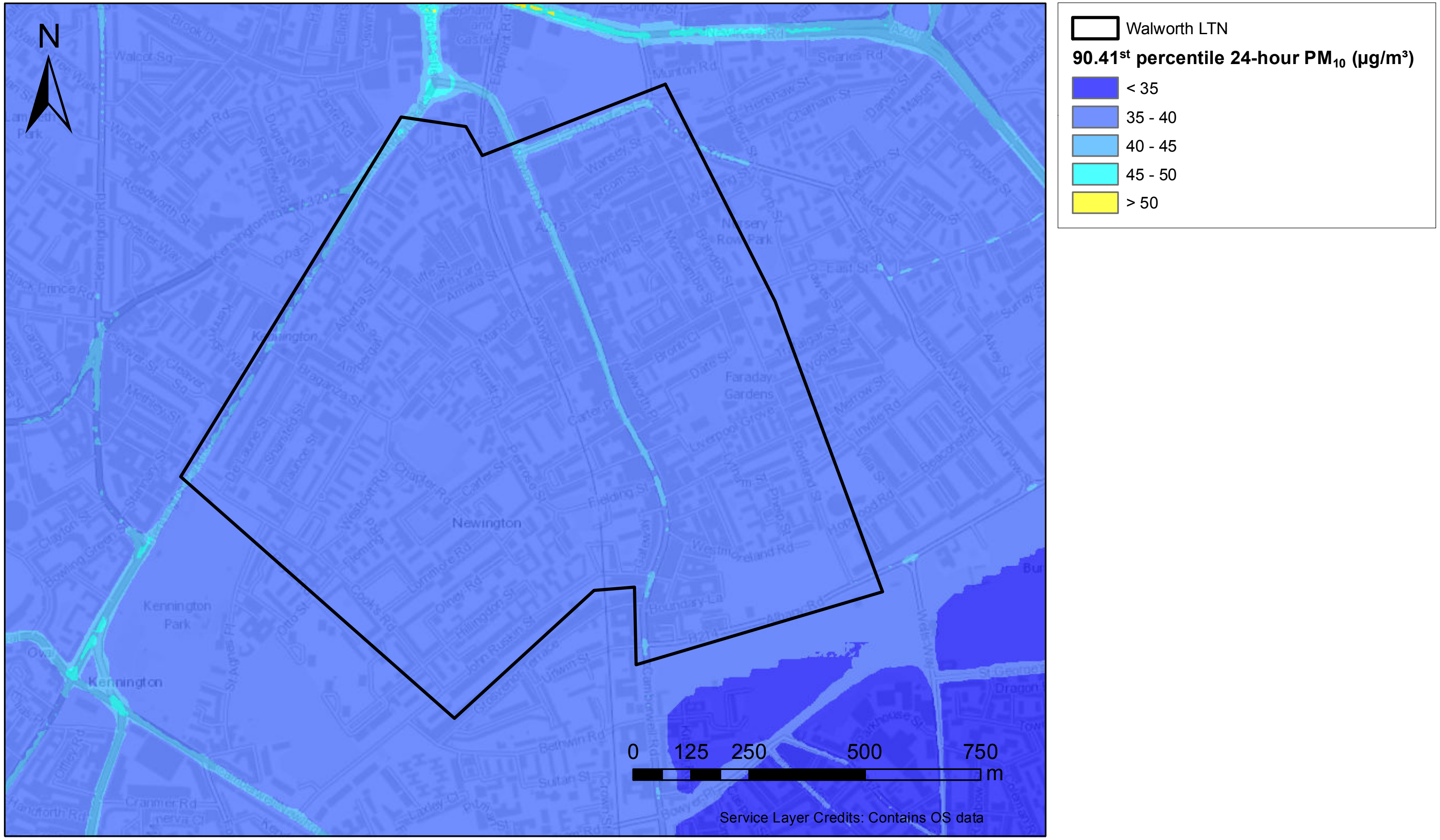

Figure 9.10: Post-scheme 90.41st percentile of 24-hour average PM_{10} concentrations (2021 road traffic emission factors)

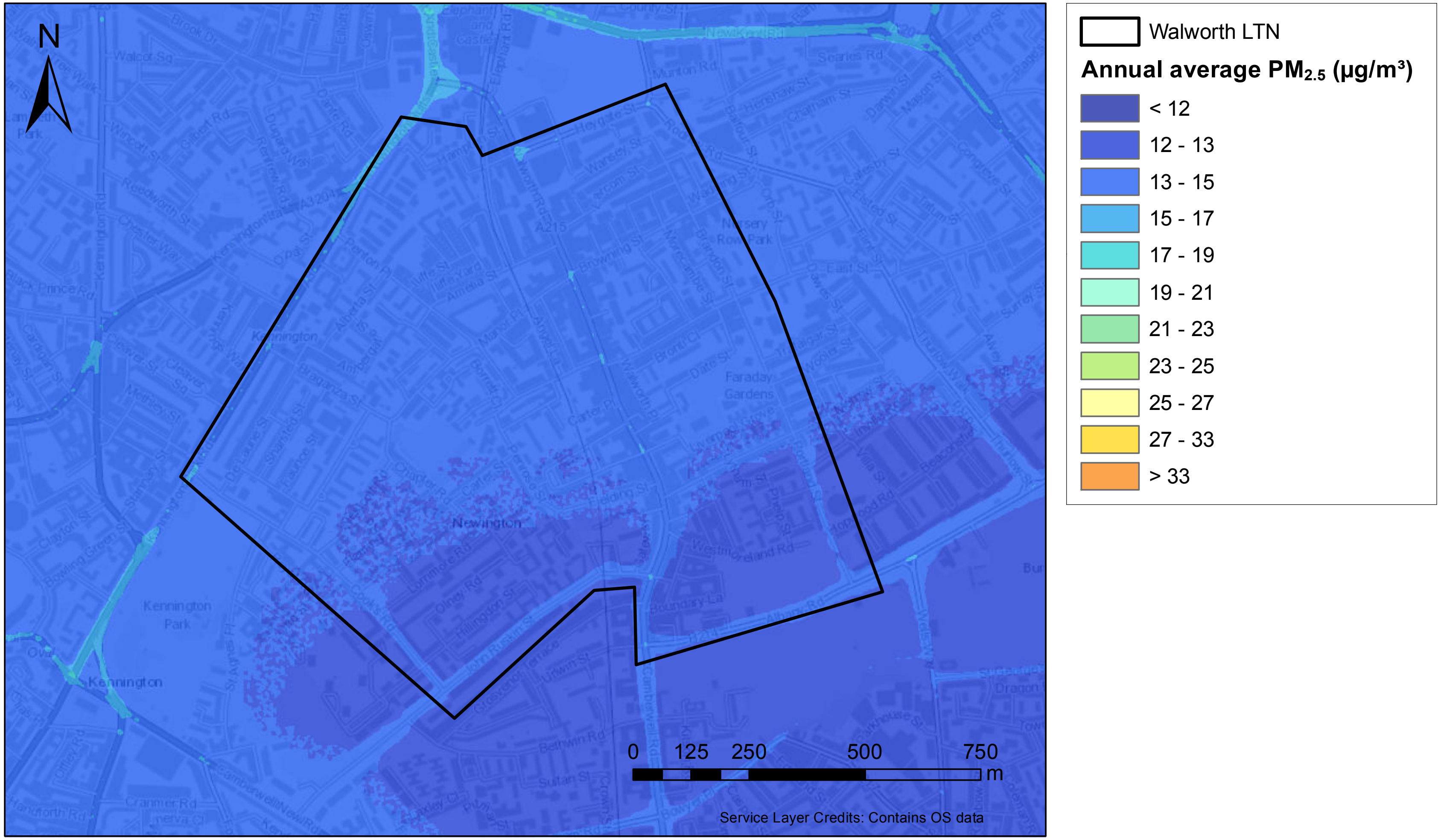

Figure 9.11: Pre-scheme annual average $PM_{2.5}$ concentrations (2021 road traffic emission factors)

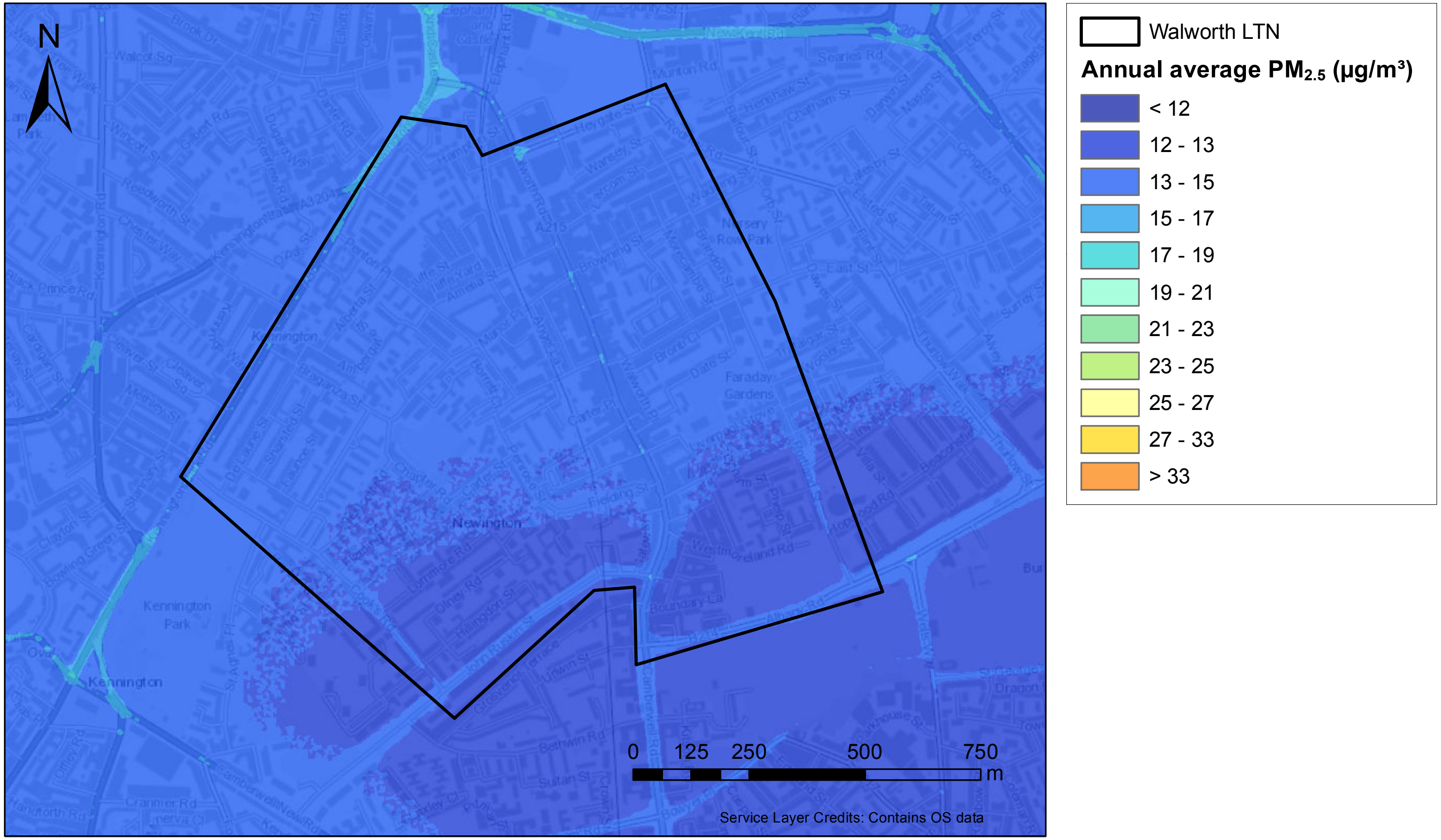

Figure 9.12: Post-scheme annual average $PM_{2.5}$ concentrations (2021 road traffic emission factors)

9.3. Significance criteria maps

Figure 9.13 and Figure 9.14 show pre-scheme and post-scheme annual average NO_2 concentrations coloured by long term concentration bands used in the EPUK IAQM significance criteria described in Section 4.

A difference plot showing the predicted change in annual average NO_2 concentrations due to the scheme is shown in Figure 9.15, using a colour scale reflecting the percentage change used in the EPUK IAQM significance criteria.

This difference plot was calculated by subtracting the modelled annual average concentrations of the pre-scheme scenario from the post-scheme scenario. The resulting concentrations are shown on a map where: areas coloured purple show an increase in concentrations with the scheme in place; areas coloured blue show a decrease in concentrations; and areas with no colour show no significant change in concentrations.

Annual average NO_2 concentrations for the majority of the scheme area fall into the lowest *75% or less of AQAL* long term concentration band, the exception being some locations close to busy roads. For most of the scheme area, concentrations are predicted to change by 5% or less of the air quality objective of 40 $\mu g/m^3$. As a consequence, the impact descriptor for the scheme is classed as *Negligible* for the majority of the scheme area.

The EPUK IAQM significance criteria are intended for the assessment of air quality impacts at locations relevant for long term exposure. Therefore, the model results were used to assess the air quality impacts at ground-floor building façade locations along scheme roads. As some of these buildings may represent retail premises, not all of the building façade locations assessed will be relevant for long term exposure.

Table 9.2 and Table 9.3 summarise average concentrations at building façade locations along key scheme roads. At building façade locations, increases in annual average NO_2 concentrations due to the scheme are up to 1.1 $\mu g/m^3$, or 3 % of the air quality objective. Reductions in concentrations are up to 5.8 $\mu g/m^3$, or 15 % of the air quality objective.

This is confirmed by Figure 9.16 which shows impact descriptors for only those building façade locations where a significant impact is predicted, i.e. locations of where the impact is negligible are omitted.

Areas where *Beneficial* impacts (air quality improves) or *Adverse* impacts (air quality worsens) are predicted include:

- *Moderate Beneficial* impact on Browning Street and the south section of Walworth Road from Penrose Street to Albany Road;
- *Slight Beneficial* impact on Albany Road, Braganza Street, Brandon Street, Browning Street, Manor Place, Penton Place and the south section of Walworth Road; and
- *Slight Adverse and Moderate Adverse* impact on the north section of Walworth Road from Penrose Street to the Elephant and Castle junction

Note that pre-scheme and post-scheme traffic monitoring were not available for the A3 and A202 boundary roads. Since the same LAEI traffic flows were used for both scenarios for these roads, the modelling shows no change in concentrations.

All ground-level building façades were included in the assessment, regardless of whether the locations are relevant for long-term exposure; annual average air quality objectives only apply to locations such as residential settings, hospitals and schools and are not relevant for retail premises.

Due to significantly lower concentrations, relative to the relevant air quality objectives, the impact of the predicted changes in annual average PM_{10} and $PM_{2.5}$ concentrations are classed as *Negligible* throughout the scheme area.

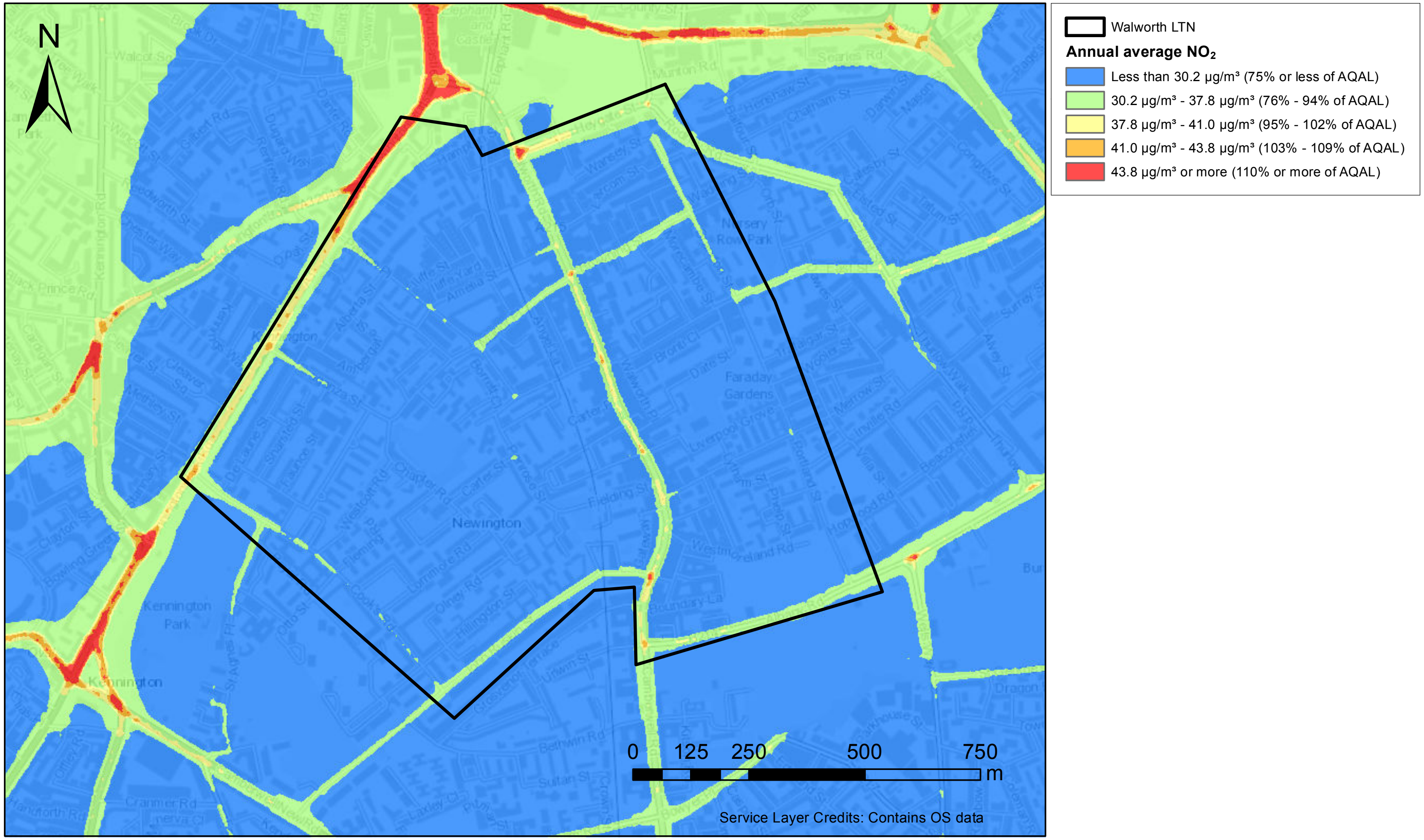

Figure 9.13: Pre-scheme annual average NO_2 concentrations categorised by AQAL levels used in EPUK IAQM significance criteria calculations

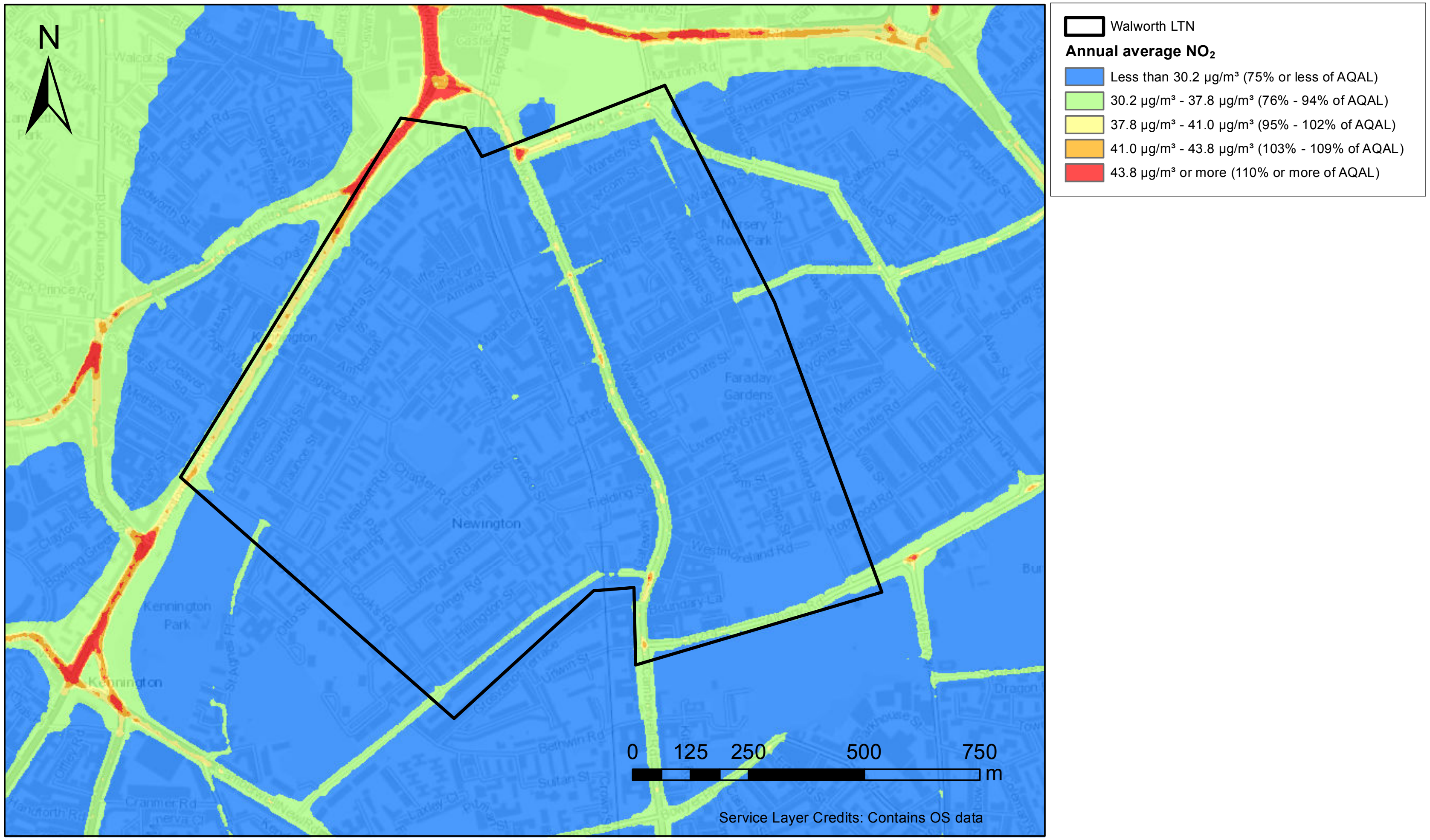

Figure 9.14: Post-scheme annual average NO_2 concentrations categorised by AQAL levels used in EPUK IAQM significance criteria calculations

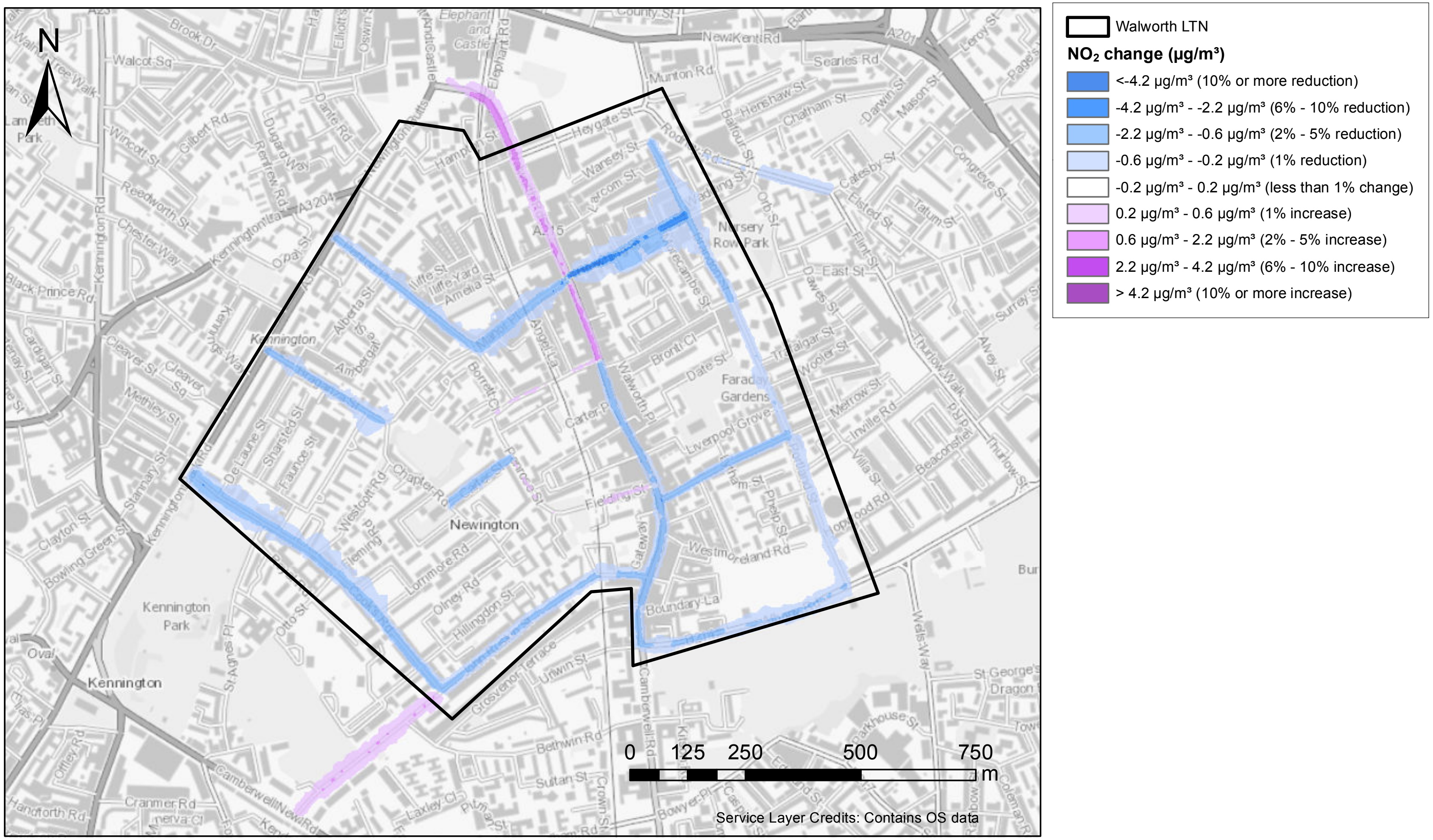

Figure 9.15: Difference plot (post-scheme minus pre-scheme) of annual average NO$_2$ concentrations, coloured by EPUK IAQM significance criteria concentration change bands

Table 9.2: Predicted annual average NO_2, PM_{10} and $PM_{2.5}$ concentrations at building façades along scheme roads

Air quality metric	Scenario	Statistic	Albany Road	Amelia Street	Braganza Street	Brandon Street	Browning Street	Camberwell Road	Carter Street	Fielding Street	John Ruskin Street (east)
Annual average NO_2	Pre-Scheme	Average	33.7	29.3	30.8	30.6	30.7	34.2	28.8	28.2	30.0
		Minimum	28.1	28.6	28.4	29.2	29.4	28.8	28.0	28.0	27.8
		Maximum	42.9	30.1	38.1	34.5	32.4	44.7	31.0	29.0	31.8
	Post-Scheme	Average	33.2	29.1	29.9	29.6	29.0	33.8	28.5	28.3	29.6
		Minimum	28.0	28.4	28.2	28.8	28.5	28.1	27.9	28.0	27.7
		Maximum	41.8	29.9	37.1	31.0	29.5	43.5	30.5	29.3	30.9
	Change[1]	Average	-0.6	-0.2	-0.9	-1.1	-1.7	-0.4	-0.3	0.1	-0.4
		Minimum[2]	-1.1	-0.8	-1.3	-3.5	-2.9	-2.1	-1.1	-0.1	-1.1
		Maximum[3]	0.0	-0.1	-0.2	-0.1	-0.8	1.1	0.2	0.3	0.3
Annual average PM_{10}	Pre-Scheme	Average	21.6	21.0	20.7	22.0	22.0	22.4	20.6	20.5	20.6
		Minimum	20.3	20.6	20.3	21.5	21.5	20.6	20.4	20.3	20.1
		Maximum	24.8	21.5	22.5	23.0	22.3	26.6	21.2	20.6	21.2
	Post-Scheme	Average	21.5	21.0	20.5	21.8	21.5	22.4	20.5	20.5	20.6
		Minimum	20.3	20.6	20.2	21.5	21.4	20.6	20.3	20.4	20.1
		Maximum	24.6	21.4	22.2	22.3	21.6	26.6	21.1	20.7	21.2
	Change[1]	Average	-0.2	0.0	-0.2	-0.2	-0.4	-0.1	-0.1	0.0	-0.1
		Minimum[2]	-0.3	-0.1	-0.3	-0.7	-0.7	-0.5	-0.4	0.0	-0.3
		Maximum[3]	0.0	0.0	0.0	0.0	-0.1	0.1	0.1	0.1	0.1
Annual average $PM_{2.5}$	Pre-Scheme	Average	13.7	13.4	13.4	13.6	13.7	13.9	13.2	13.0	13.1
		Minimum	12.9	13.2	13.1	13.5	13.4	13.1	13.0	13.0	12.9
		Maximum	15.0	13.5	14.3	14.2	13.9	15.8	13.5	13.2	13.4
	Post-Scheme	Average	13.6	13.4	13.3	13.5	13.5	13.8	13.1	13.0	13.1
		Minimum	12.9	13.2	13.1	13.4	13.4	13.0	13.0	13.0	12.9
		Maximum	14.9	13.5	14.1	13.8	13.5	15.7	13.4	13.2	13.3
	Change[1]	Average	-0.1	0.0	-0.1	-0.1	-0.2	0.0	0.0	0.0	0.0
		Minimum[2]	-0.2	-0.1	-0.2	-0.4	-0.4	-0.3	-0.2	0.0	-0.2
		Maximum[3]	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0

[1] Post-scheme concentrations minus pre-scheme concentrations
[2] Minimum change represents the largest reduction in pollutant concentrations
[3] Maximum change represents the largest increase in pollutant concentrations or the smallest reduction

Table 9.3: Predicted annual average NO_2, PM_{10} and $PM_{2.5}$ concentrations at building façades along scheme roads (continued)

Air quality metric	Scenario	Statistic	John Ruskin Street (west)	Kennington Park Place	Manor Place	Merrow Street	Penrose Street	Penton Place	Portland Street	Rodney Road	Walworth Road
Annual average NO_2	Pre-Scheme	Average	29.2	30.1	32.0	28.8	28.9	30.3	29.0	32.8	35.6
		Minimum	28.1	28.4	29.6	28.5	28.2	28.6	27.7	29.5	28.7
		Maximum	37.0	44.1	40.9	29.0	30.8	37.8	37.6	40.4	53.2
	Post-Scheme	Average	29.3	29.2	30.8	27.9	29.0	29.6	28.5	32.7	35.4
		Minimum	28.1	28.0	28.8	27.8	28.2	28.3	27.6	29.4	28.6
		Maximum	37.2	43.2	39.7	28.0	31.0	37.4	37.4	40.2	53.3
	Change[1]	Average	0.2	-0.9	-1.3	-0.9	0.1	-0.7	-0.4	-0.2	-0.2
		Minimum[2]	0.0	-1.8	-2.0	-1.0	-0.1	-1.7	-1.6	-0.3	-5.8
		Maximum[3]	0.5	-0.1	0.6	-0.7	0.2	-0.1	-0.1	-0.1	0.9
Annual average PM_{10}	Pre-Scheme	Average	21.0	20.7	21.9	20.8	20.8	20.9	20.9	22.5	23.3
		Minimum	20.2	20.2	20.9	20.7	20.6	20.6	20.0	21.5	20.8
		Maximum	24.2	25.6	25.2	20.9	21.3	22.9	24.0	24.7	30.0
	Post-Scheme	Average	21.1	20.5	21.6	20.6	20.8	20.8	20.8	22.4	23.1
		Minimum	20.2	20.2	20.8	20.5	20.6	20.5	20.0	21.5	20.8
		Maximum	24.3	25.4	24.9	20.6	21.3	22.8	23.9	24.7	30.0
	Change[1]	Average	0.1	-0.2	-0.3	-0.2	0.0	-0.2	-0.1	-0.1	-0.2
		Minimum[2]	0.0	-0.4	-0.6	-0.3	0.0	-0.3	-0.4	-0.2	-1.5
		Maximum[3]	0.1	0.0	-0.1	-0.1	0.1	0.0	0.0	0.0	0.0
Annual average $PM_{2.5}$	Pre-Scheme	Average	13.2	13.3	13.7	13.1	13.2	13.4	13.2	13.9	14.3
		Minimum	12.9	13.0	13.3	13.1	13.1	13.2	12.8	13.5	13.3
		Maximum	14.5	15.6	15.0	13.1	13.5	14.4	14.7	15.0	17.4
	Post-Scheme	Average	13.2	13.2	13.6	13.0	13.3	13.4	13.1	13.9	14.3
		Minimum	12.9	12.9	13.2	13.0	13.1	13.2	12.8	13.5	13.3
		Maximum	14.5	15.5	14.9	13.0	13.5	14.4	14.7	15.0	17.4
	Change[1]	Average	0.0	-0.1	-0.1	-0.1	0.0	-0.1	-0.1	0.0	-0.1
		Minimum[2]	0.0	-0.2	-0.3	-0.1	0.0	-0.2	-0.3	-0.1	-0.8
		Maximum[3]	0.1	0.0	0.1	-0.1	0.1	0.1	0.0	0.0	0.1

[1] Post-scheme concentrations minus pre-scheme concentrations
[2] Minimum change represents the largest reduction in pollutant concentrations
[3] Maximum change represents the largest increase in pollutant concentrations or the smallest reduction

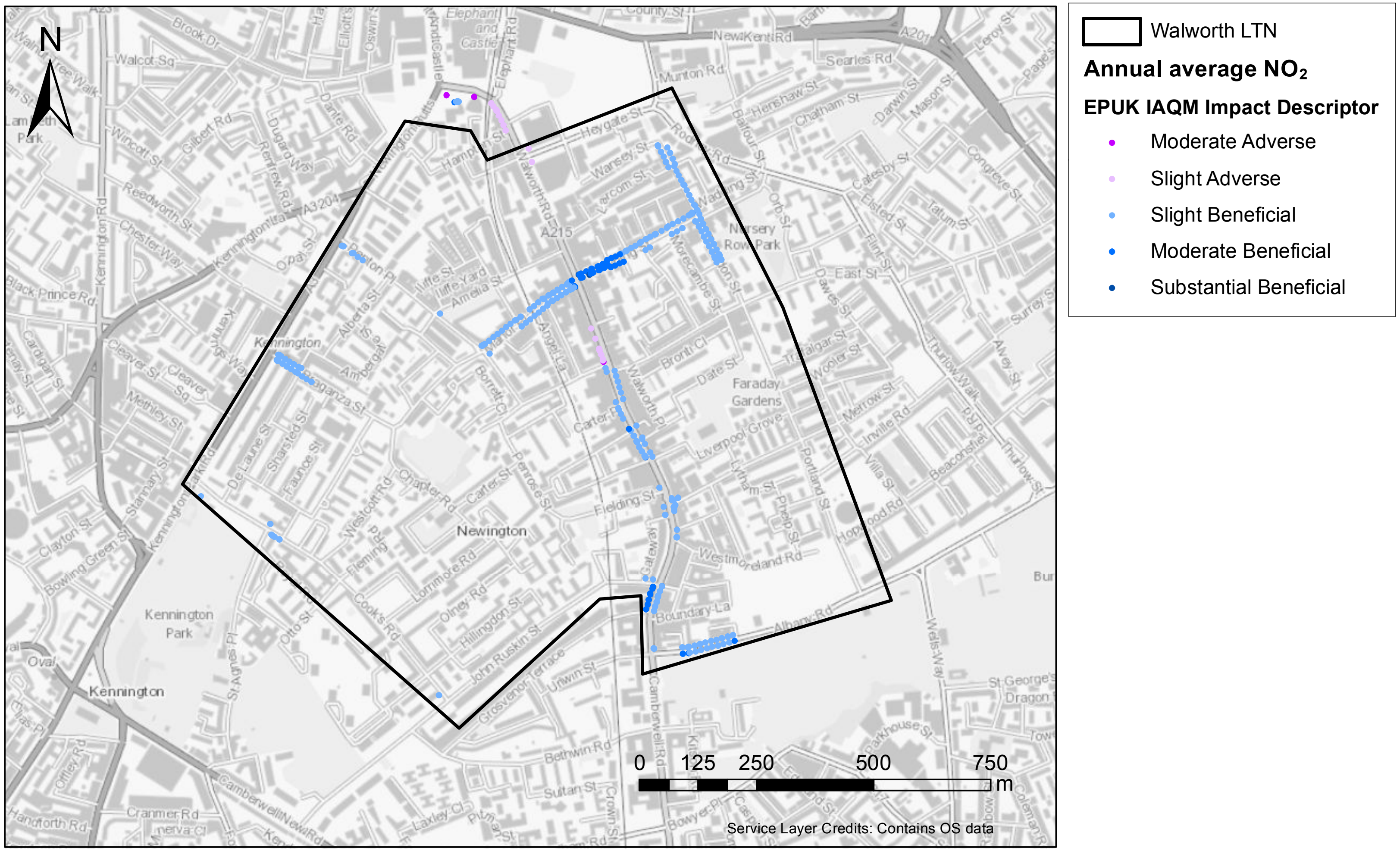

Figure 9.16: EPUK IAQM impact descriptors for change in annual average NO_2 concentrations at building façade locations

10. Local mortality burden of air pollution

This section summarises calculations of the local mortality burden of air pollution. It includes the calculation of the number of deaths attributable to air pollution, the associated life-years lost and economic cost. The calculations were carried out for the pre-scheme and post-scheme scenarios in order to estimate the health impact of the scheme.

The mortality burden was assessed using the approach set out in Appendix A of the Public Health England guidance *Estimating local mortality burdens associated with particulate air pollution (April 2014)*[16]. This guidance uses concentration response functions (CRFs) which relate the increased risk of mortality to a given change in pollutant concentrations; specifically, it assumes that an increment of 10 µg/m³ in the annual concentration of $PM_{2.5}$ will increase the mortality risk by 6%.

The mortality burden of air quality will actually be a consequence of exposure to both NO_2 and $PM_{2.5}$. The 2018 COMEAP report *Associations of long-term average concentrations of nitrogen dioxide with mortality*[17] recommends revised CRFs for anthropogenic $PM_{2.5}$ and NO_2 which are adjusted from the single-pollutant CRFs to avoid double counting air quality effects from different pollutants. The report recommends using pairs of CRFs for $PM_{2.5}$ and NO_2 taken from four studies, as shown in Table 10.1, with the results from the two pollutants added for each study.

Table 10.1: Coefficients for use in burden calculations

Pollutant	Jerrett et al (2013)	Fischer et al (2015)	Beelen et al (2014)	Crouse et al (2015)
NO_2	1.019	1.016	1.011	1.020
$PM_{2.5}$	1.029	1.033	1.053	1.019

Mortality burden calculations were carried out for Lower Layer Super Output Areas (LSOAs), each representing an area with a population of approximately 1,500. There are 14 LSOAs covering the scheme area. The Office for National Statistics (ONS) publishes population[18] and death[19] data split by age for each LSOA; data for 2019 were used for the calculations.

[16] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/332854/PHE_CRCE_010.pdf
[17] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734799/COMEAP_NO2_Report.pdf
[18] https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/lowersuperoutputareamidyearpopulationestimates
[19] https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/009235numberofdeathsregisteredineachlowersuperoutputareabysexandagedeathsregisteredin2017

For each LSOA, the relative risk for each pollutant is calculated as

$$RR(c) = R^{c/10}$$

where *R* is the relative risk, as given in Table 10.1, and *c* is the average pollutant concentration for that LSOA calculated from the concentration contour maps, presented in Section 9.2.

The attributable fraction is then calculated as

$$AF = (RR-1)/RR$$

The number of attributable deaths in each LSOA was then calculated by multiplying the attributable fraction by the number of deaths over 30 years of age. The total number of attributable deaths for the scheme area is the sum of the attributable deaths in each LSOA.

The total loss in life-years due to air pollution for each LSOA was calculated by multiplying the attributable deaths for each 5-year age band by the corresponding expected life expectancy for each age group. The 2017-2019 life expectancy data for Southwark were taken from the ONS[20].

The economic cost is calculated by multiplying the life-years lost by a value for a life year lost. The recommended value in the Defra guidance[21] of £42,780 at 2017 prices. The economic costs were calculated at 2017 and 2021 prices assuming a 2% annual uplift, in line with Defra recommendations for damage costs appraisals[22].

Table 10.2 summarises mortality burden estimates for the pre-scheme and post-scheme scenarios. For the scheme area between 8 and 12 deaths are attributable to air pollution, equivalent to between 175 and 205 life-years lost. The economic costs range between £6 million and £10 million.

The calculated mortality burden for the post-scheme scenario is slightly lower than the pre-scheme scenario, indicating that the scheme provides a marginal benefit of between 0.1% and 0.2%. This is a reduction in life-years lost of between 0.3 and 0.4 life-years (three to five life-months), equivalent to an economic 'saving' of between £11,000 and £18,000.

[20] https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/datasets/lifeexpectancyestimatesallagesuk

[21] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/770649/impact-pathway-approach-guidance.pdf

[22] https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance

Table 10.2: Summary of mortality burden calculations for scheme area

Scenario	Metric	Air pollution burden coefficients			
		Beelan *et al* (2014)	**Crouse *et al* (2015)**	**Fischer *et al* (2015)**	**Jerrett *et al* (2013)**
Pre-scheme	Attributable Deaths	11.63	8.93	10.01	10.24
	Life-years lost	204.1	157.1	176.0	179.9
	Economic cost (£, 2017 prices)	8,730,626	6,719,252	7,527,545	7,697,824
	Economic cost (£, 2021 prices)	9,450,310	7,273,134	8,148,056	8,332,372
Post-scheme	Attributable Deaths	11.61	8.91	10.00	10.22
	Life-years lost	203.8	156.7	175.6	179.6
	Economic cost (£, 2017 prices)	8,718,851	6,702,674	7,513,087	7,681,392
	Economic cost (£, 2021 prices)	9,437,565	7,255,190	8,132,407	8,314,586
Difference	Attributable Deaths	-0.02	-0.02	-0.02	-0.02
	Life-years lost	-0.3	-0.4	-0.3	-0.4
	Economic cost (£, 2017 prices)	-11,775	-16,578	-14,458	-16,432
	Economic cost (£, 2021 prices)	-12,745	-17,945	-15,650	-17,786

11. Discussion and conclusions

Southwark Council commissioned Cambridge Environmental Research Consultants Ltd (CERC) to carry out air quality modelling to assess the impact of Walworth Low Traffic Neighbourhood (LTN).

Two scenarios, pre-scheme and post-scheme, were modelled to assess the current air quality impact of Walworth LTN, based on 2021 traffic monitoring. Concentrations of NO_2, PM_{10} and $PM_{2.5}$ were modelled for assessment against national air quality objectives.

Concentrations of NO_2, PM_{10} and $PM_{2.5}$ were modelled for assessment against national air quality objectives. Concentrations were calculated at school locations and on a grid of receptor points, to generate pollution maps for the scheme area.

For both scenarios, the air quality objectives are met throughout the scheme area with the exception of some areas along two roads, the A3 and Walworth Road, predicted to exceed the air quality objective of 40 $\mu g/m^3$ for annual average NO_2 concentrations. Along Walworth Road traffic volumes are predicted increase in some areas and decrease in others with the scheme in place; scheme traffic monitoring was not available for the A3, therefore the modelling shows no change in concentrations along this road.

The modelled concentrations based on 2021 traffic emissions predict smaller areas exceeding the air quality objective when compared to the 2019 baseline model.

Typically, pollution levels across the scheme are relatively low; with the exception of roadside locations concentrations are 75% or less than the air quality objectives. The largest predicted changes in concentrations due to the scheme are predicted at roadside locations; at locations relevant for long term exposure the predicted changes in concentrations are much lower.

Using the EPUK IAQM significance criteria, the predicted changes in concentrations at school locations in the scheme area are classed as *Negligible* for all pollutants. In addition, for the majority of building façade locations along scheme roads the predicted changes in concentrations are classed as *Negligible*. The EPUK IAQM criteria identifies seven roads where the model predicted improvement in air quality at building façades is classed as significant, and one area where the predicted worsening of air quality is classed as significant.

Air pollution mortality burden calculations estimate that the Walworth LTN schemes have a marginal positive health impact.

APPENDIX A: Summary of ADMS-Urban

ADMS-Urban is a scientifically advanced but practical air pollution modelling tool, which has been developed to provide high resolution calculations of pollution concentrations for all sizes of study area relevant to the urban environment. The model can be used to look at concentrations near a single road junction or over a region extending across the whole of a major city. ADMS-Urban is used worldwide to assess air quality impact for a wide range of planning and policy studies, incorporating elements such as Low Emission Zones, traffic management, clean vehicle technologies and modal shift. In the UK, it is used extensively for air quality review and assessment carried out by local government.

The following is a summary of the capabilities and validation of ADMS-Urban. More details can be found on the CERC web site[23].

ADMS-Urban is a development of the Atmospheric Dispersion Modelling System (ADMS), which has been developed to investigate the impacts of emissions from industrial facilities. ADMS-Urban allows full characterisation of the wide variety of emissions in urban areas, including an extensively validated road traffic emissions model. It also includes a number of other features, which include consideration of:

- the effects of vehicle movement on the dispersion of traffic emissions;
- the behaviour of material released into street-canyons;
- the chemical reactions occurring between nitrogen oxides, ozone and Volatile Organic Compounds (VOCs);
- the pollution entering a study area from beyond its boundaries;
- the effects of complex terrain on the dispersion of pollutants;
- the effects of the urban canopy on the dispersion of pollutants; and
- the effects of a building on the dispersion of pollutants emitted nearby.

Further details of these features are provided below.

Studies of extensive urban areas are necessarily complex, requiring the manipulation of large amounts of data. To allow users to cope effectively with this requirement, ADMS-Urban runs in Windows 10 and Windows 8 environments. The manipulation of data is further facilitated by the ADMS-Urban Mapper, which allows for the visualisation and manipulation of geospatial information, and by the CERC Emissions Inventory Toolkit, EMIT.

[23] https://www.cerc.co.uk/environmental-software/ADMS-Urban-model.html

Dispersion Modelling

ADMS and ADMS-Urban use boundary layer similarity profiles to parameterise the variation of turbulence with height within the boundary layer, and the use of a skewed-Gaussian distribution to determine the vertical variation of pollutant concentrations in the plume under convective conditions.

The main dispersion modelling features of ADMS-Urban are as follows:

- ADMS-Urban is an **advanced dispersion model** in which the boundary layer structure is characterised by the height of the boundary layer and the Monin-Obukhov length, a length scale dependent on the friction velocity and the heat flux at the surface. This method supersedes methods based on Pasquill Stability Categories, as used in, for example, the US models Caline and ISC. Concentrations are calculated hour by hour and are fully dependent on prevailing weather conditions.
- For convective conditions, a **non-Gaussian vertical profile of concentration** allows for the skewed nature of turbulence within the atmospheric boundary layer, which can lead to high concentrations near to the source.
- A **meteorological processor** calculates boundary layer parameters from a variety of input data, typically including date and time, wind speed and direction, surface temperature and cloud cover. Meteorological data may be raw, hourly averaged or statistically analysed data.

Emissions

Emissions into the atmosphere across an urban area typically come from a wide variety of sources. There are likely to be emissions from road traffic, as well as from domestic heating systems and industrial emissions from chimneys. To represent the full range of emissions configurations, the explicit source types available within ADMS-Urban are:

- **Roads**, for which emissions are specified in terms of vehicle flows and the additional initial dispersion caused by moving vehicles is also taken into account.
- **Industrial points**, for which plume rise and stack downwash are included in the modelling.
- **Areas**, where a source or sources is best represented as uniformly spread over an area.
- **Volumes**, where a source or sources is best represented as uniformly spread throughout a volume.

In addition, sources can also be modelled as a regular grid of emissions. This allows the contributions of large numbers of minor sources to be efficiently included in a study while the majority of the modelling effort is used for the relatively few significant sources.

ADMS-Urban can be used in conjunction with CERC's Emissions Inventory Toolkit, EMIT, which facilitates the management and manipulation of large and complex data sets into usable emissions inventories.

Presentation of Results

The results from the model can be based on a wide range of averaging times, and include rolling averages. Maximum concentration values and percentiles can be calculated where appropriate meteorological input data have been input to the model. This allows ADMS-Urban to be used to calculate concentrations for direct comparison with existing air quality limits, guidelines and objectives, in whatever form they are specified.

ADMS-Urban has an integrated Mapper which facilitates both the compilation and manipulation of the emissions information required as input to the model and the interpretation and presentation of the air quality results provided. ADMS-Urban can also be integrated with ArcGIS or MapInfo.

Complex Effects - Street Canyons

ADMS-Urban incorporates two methods for representing the effect of street canyons on the dispersion of road traffic emissions: a basic canyon method based on the *Operational Street Pollution Model (OSPM)*[24], developed by the Danish National Environmental Research Institute (NERI); and an advanced street canyon module, developed by CERC. The basic canyon model was designed for simple symmetric canyons with height similar to width and assumes that road traffic emissions originate throughout the base of the canyon, i.e. that the emissions are spread across both the road and neighbouring pavements.

The advanced canyon model[25] was developed to overcome these limitations and is our model of choice. It represents the effects of channelling flow along and recirculating flow across a street canyon, dispersion out of the canyon through gaps in the walls, over the top of the buildings or out of the end of the canyon. It can take into account canyon asymmetry and restricts the emissions area to the road carriageway.

Complex Effects - Chemistry

ADMS-Urban includes the *Generic Reaction Set (GRS)*[26] atmospheric chemistry scheme. The original scheme has seven reactions, including those occurring between nitrogen oxides and ozone and parameterisations of the large number of reactions involving a wide range of Volatile Organic Compounds (VOCs). In addition, an eighth reaction has been included within ADMS-Urban for

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[24] Hertel, O., Berkowicz, R. and Larssen, S., 1990, 'The Operational Street Pollution Model (OSPM).' *18th International meeting of NATO/CCMS on Air Pollution Modelling and its Applications.* Vancouver, Canada, pp741-749.

[25] Hood C, Carruthers D, Seaton M, Stocker J and Johnson K, 2014. *Urban canopy flow field and advanced street canyon modelling in ADMS-Urban.* 16th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Varna, Bulgaria, September 2014. http://www.harmo.org/Conferences/Proceedings/_Varna/publishedSections/H16-067-Hood-EA.pdf

[26] Venkatram, A., Karamchandani, P., Pai, P. and Goldstein, R., 1994, 'The Development and Application of a Simplified Ozone Modelling System.' *Atmospheric Environment,* Vol 28, No 22, pp3665-3678.

the situation when high concentrations of nitric oxide (NO) can convert to nitrogen dioxide (NO_2) using molecular oxygen.

In addition to the basic GRS scheme, ADMS-Urban also includes a trajectory model[27] for use when modelling large areas. This permits the chemical conversions of the emissions and background concentrations upwind of each location to be properly taken into account.

Complex Effects - Terrain

As well as the effect that complex terrain has on wind direction and, consequently, pollution transport, it can also enhance turbulence and therefore increase dispersion. These effects are taken into account in ADMS-Urban using the FLOWSTAR[28] model developed by CERC.

Complex Effects – Urban Canopy

As wind approaches an urban area of relatively densely packed buildings, the wind profile is vertically displaced. The wind speed and turbulence levels are also reduced within the area of buildings. These effects are taken into account in ADMS-Urban by modifying the wind speed and turbulence profiles based on parameters describing the amount and size of buildings within an urban area.

Data Comparisons – Model Validation

ADMS-Urban is a development of the Atmospheric Dispersion Modelling System (ADMS), which is used throughout the UK by industry and the Environment Agency to model emissions from industrial sources. ADMS has been subject to extensive validation, both of individual components (e.g. point source, street canyon, building effects and meteorological pre-processor) and of its overall performance.

ADMS-Urban has been extensively tested and validated against monitoring data for large urban areas in the UK and overseas, including London, Birmingham, Manchester, Glasgow, Riga, Cape Town, Hong Kong and Beijing, as part of projects supported by local governments and research organisations. A summary of model validation studies is available online[29]. CERC have co-authored[30] a number of papers presenting results from ADMS-Urban, and other organisations have published the outcomes of their applications of the model[31].

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[27] Singles, R.J., Sutton, M.A. and Weston, K.J., 1997, 'A multi-layer model to describe the atmospheric transport and deposition of ammonia in Great Britain.' In: *International Conference on Atmospheric Ammonia: Emission, Deposition and Environmental Impacts. Atmospheric Environment*, Vol 32, No 3.
[28] Carruthers D.J., Hunt J.C.R. and Weng W-S. 1988. 'A computational model of stratified turbulent airflow over hills – FLOWSTAR I.' Proceedings of Envirosoft. In: *Computer Techniques in Environmental Studies,* P. Zanetti (Ed) pp 481-492. Springer-Verlag.
[29] www.cerc.co.uk/Validation
[30] www.cerc.co.uk/CERCCoAuthorPublications
[31] www.cerc.co.uk/CERCSoftwarePublications