

**Detailed air quality modelling
and source apportionment**

Final report

Prepared for
Surrey Local Authorities

23rd August 2019

Report Information

CERC Job Number: FM1183

Job Title: Detailed air quality modelling and source apportionment

Prepared for: Surrey Local Authorities

Report Status: Final

Report Reference: FM1183/R5/19

Issue Date: 23rd August 2019

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Issue	Date	Comments
1	20/02/19	Draft, verification only
2	26/02/19	Draft, verification only, with minor amendments
3	04/04/19	Full draft report
4	24/05/19	Final report
5	23/08/19	Final report with additions to Section 9

Main File(s): FM1183_Surrey_CERC_R5_23August19.pdf

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Glossary

AADTs	Annual Average Daily Traffic
AF	Attributable fraction
ATC	Automatic Traffic Count
AQAP	Air Quality Action Plan
AQMA	Air Quality Management Area; places designated by local authorities where statutory air quality objectives are not likely to be achieved
CRF	concentration response function
Defra	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
DT	Diffusion tube
EFT	Emission Factors for Transport
LAQM	Local Air Quality Management; local authorities' process for reviewing and assessing air quality
LSOA	Lower Layer Super Output Area
NAEI	National Atmospheric Emissions Inventory
NO	nitric oxide
NO ₂	nitrogen dioxide
NO _x	nitrogen oxides (nitrogen dioxide plus nitric oxide)
O ₃	ozone
ONS	Office for National Statistics
PM ₁₀	particulates of less than 10µm effective diameter
PM _{2.5}	particulates of less than 2.5µm effective diameter
SO ₂	sulphur dioxide
TPM	Total Particulate Matter
VOC	Volatile Organic Compound

1 Summary

CERC was commissioned to carry out county-wide air pollution dispersion modelling, source apportionment and local mortality burden calculations for the combined local authorities of Surrey.

The main source of air pollution across Surrey is road traffic emissions from major roads. Eight of the eleven local authorities have declared Air Quality Management Areas (AQMAs) for annual average NO₂ concentrations. Two of these AQMAs are also declared for PM₁₀ concentrations, in Runnymede (annual mean and 24-hour mean PM₁₀) and Surrey Heath (annual mean PM₁₀).

The main air quality modelling was carried out with ADMS-Urban (version 4.2) dispersion modelling software, using meteorological data from the Heathrow Airport meteorological station. Additional sensitivity analysis was carried out using meteorological data from the Gatwick Airport meteorological station.

Road traffic emissions input to the dispersion model were calculated from traffic flows provided from the Surrey Traffic Model, supplemented by Department for Transport (DfT) count data and local data from borough council detailed and further assessments. The Emission Factor Toolkit version 8.0.1, published by Defra, was used to calculate emissions from traffic flows. All other emissions data were taken from the NAEI.

Detailed model verification was carried out by comparing modelled concentrations against monitored data across Surrey for the year 2017, with iterative improvements to the model set-up to ensure acceptable agreement between modelled and monitored concentrations.

High resolution air quality maps for concentrations of nitrogen dioxide (NO₂) and particulate matter (PM₁₀ and PM_{2.5}) across Surrey were then generated to determine the extent to which the air quality objectives for these pollutants are exceeded. With exception of some locations close to major roads, the air quality objectives are met throughout the county. There are modelled exceedences of the annual mean NO₂ objective of 40 µg/m³ along motorways and other busy roads. Exceedences of short-term NO₂ and PM₁₀ objectives are less extensive. The annual mean PM_{2.5} objective of 25 µg/m³ is met throughout the county.

Source apportionment was carried out to calculate relative contributions of each source group to pollutant emissions and concentrations. The following source groups were included: road sources, by vehicle type and non-exhaust component for PM; large industrial sources; other emissions sources; and background. Road transport is typically the largest contributor to NO_x concentrations; diesel cars and LGVs are the largest contributors to the road transport NO_x concentrations. Background concentrations, from outside Surrey, are the most significant contributors to concentrations of PM₁₀ and PM_{2.5}; sources inside Surrey contribute on an average 21% of total PM₁₀ concentrations and 24% of total PM_{2.5} concentrations.

Local mortality burden calculations were carried out by coupling population data, by Lower Layer Super Output Areas (LSOA), with the modelled annual mean concentrations of NO₂ and PM_{2.5}. This includes deaths attributable to air pollution, the associated life-years lost and economic cost. This was done 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 NO₂ and PM_{2.5}, these CRFs have been taken from the 2018 COMEAP report *Associations of long-term average concentrations of nitrogen dioxide with mortality*.

The combined health impacts of NO₂ and PM_{2.5} for the whole of Surrey have been calculated to be in the range of 6,610 and 8,059 life-years lost, which equates to an economic cost of between £283 million and £345 million in 2017. Using the unadjusted value, the lowest life years lost were calculated to be 5,233, resulting from NO₂ concentrations. This equates to an economic cost of £224 million.

2 Introduction

The combined local authorities of Surrey commissioned CERC to carry out detailed air quality modelling, source apportionment and local mortality burden calculations across the county.

The modelling methodology and county-wide results, including air quality maps, are presented in this report.

Separate accompanying reports present the results for individual boroughs, including: air quality maps; source apportionment; and mortality burden by ward.

The air quality limit values and target values with which the calculated concentrations are compared are presented in Section 3. Section 4 summarises local air quality across the Surrey boroughs. The model setup and emissions data are described in Sections 5 and 6, respectively.

The results of the modelling are then presented: the model verification in Section 7; and the concentration maps for the year 2017 in Section 8. Mortality burden calculations are described in Section 9. Source apportionment is presented in Section 10. A discussion of the results is presented in Section 11.

Model verification was carried out using meteorological data from both Heathrow Airport and Gatwick Airport. The model set-up using Heathrow Airport was used for the main modelling and included in the main section of the report. Appendix A includes a comparison of the model verification using Heathrow Airport against the alternative set-up using Gatwick Airport data, with a summary of this alternative set-up using Gatwick Airport data in Appendix B.

Finally, a summary of the ADMS-Urban model is included as Appendix C.

3 Air quality standards and guidance

The EU *ambient air quality directive* (2008/50/EC) sets binding limits for concentrations of air pollutants. The directive has been transposed into English legislation as the *Air Quality Standards Regulations 2010*¹, which also incorporates the provisions of the *4th air quality daughter directive* (2004/107/EC).

The *Air Quality Standards Regulations 2010* include limit values and target values. The NO₂, PM₁₀ and PM_{2.5} Air Quality Objectives are presented in Table 3-1.

Table 3-1: Air quality objectives

	Value (µg/m ³)	Description of standard
NO ₂	200	Hourly mean not to be exceeded more than 18 times a year (modelled as 99.79 th percentile)
	40	Annual average
PM ₁₀	50	24-hour mean not be exceeded more than 35 times a year (modelled as 90.41 st percentile)
	40	Annual average
PM _{2.5}	25	Annual average

The short-term standards considered 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 NO₂ measured as the average value recorded over a one-hour period is permitted to exceed the concentration of 200µg/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 NO₂ 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.

Table 3-2 gives examples from the Defra TG(16) guidance of where the air quality objectives should apply.

¹ <http://www.legislation.gov.uk/ukxi/2010/1001/contents/made>

Table 3-2: Examples of where the air quality objectives should apply

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, hospitals, care homes etc	Building facades of offices or other places of work where members of the public do not have regular access. Hotels, unless people live there as their permanent residence. Gardens of residential properties Kerbside sites (as opposed to locations at the building 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.	Kerbside sites where the public would not be expected to have regular access.

4 Local air quality

The Local Air Quality Management (LAQM) process, as set out in Part IV of the Environment Act (1995), the Air Quality Strategy for England, Scotland, Wales and Northern Ireland 2007 and the relevant Policy and Technical Guidance documents places an obligation on all local authorities to regularly review and assess air quality in their areas, and to determine whether or not the air quality objectives are likely to be achieved. Where exceedences are considered likely, the local authority must then declare an Air Quality Management Area (AQMA) and prepare an Air Quality Action Plan (AQAP) setting out the measures it intends to put in place in pursuit of the objectives.

Figure 4.1 shows the eleven local authorities in Surrey. The following subsections describe the AQMAs and monitoring data for each of the local authorities, in alphabetical order.

All monitoring data presented in this section were provided by individual boroughs, with diffusion tube concentrations presented as bias adjusted values. A 0.91 bias adjustment factor was applied to raw diffusion tube data of all boroughs except Spelthorne, for which a bias adjustment factor of 0.99 was used.

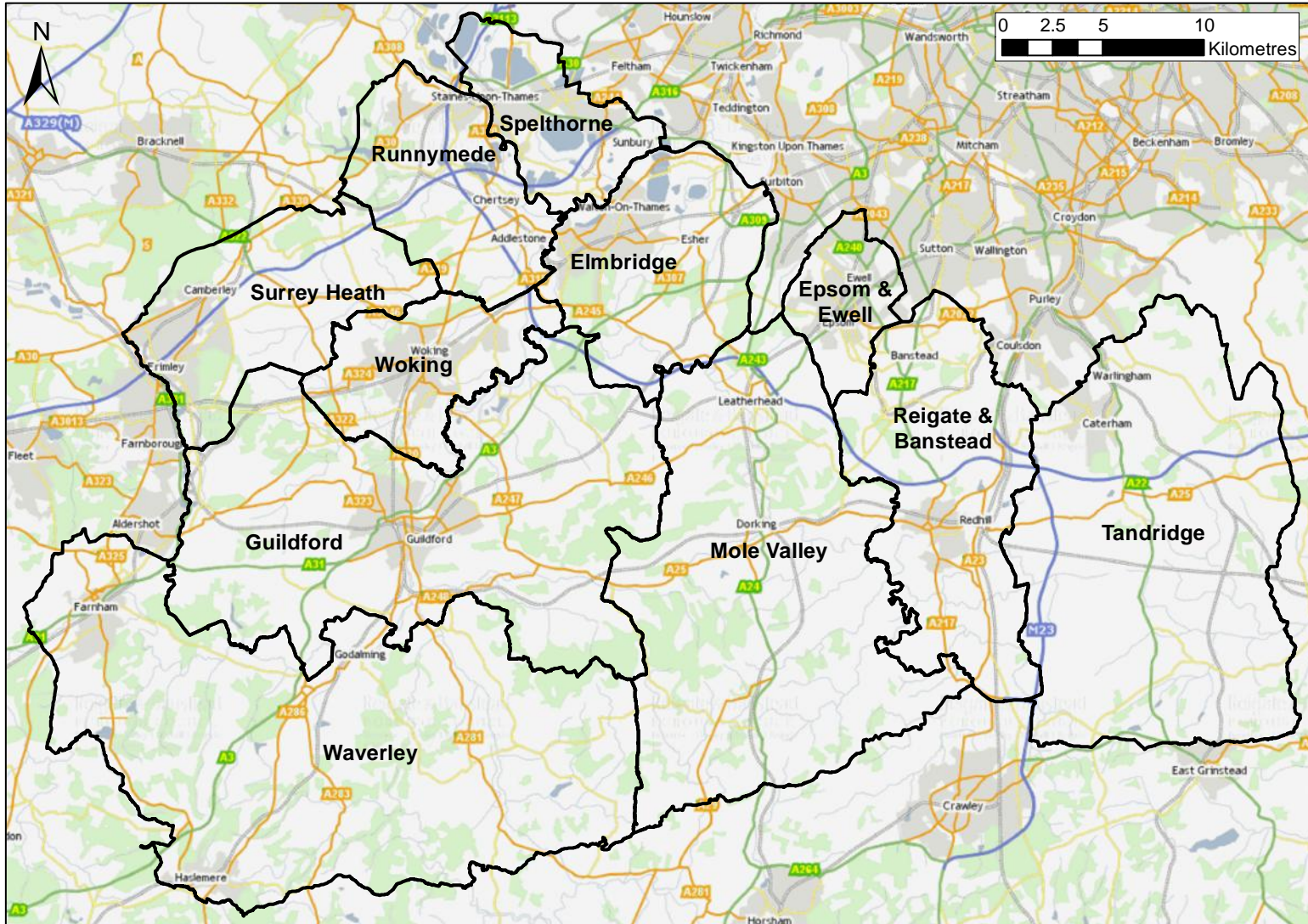


Figure 4.1: Locations of Surrey local authorities

4.1 Elmbridge Borough Council

Figure 4.2 presents the locations of monitoring sites and AQMAs in Elmbridge, comprising 40 diffusion tubes, two continuous monitors and seven AQMAs. The AQMAs are:

- Walton-on-Thames High Street;
- Weybridge High Street;
- Hampton Court;
- Cobham High Street;
- Hinchley Wood;
- Esher High Street; and
- Walton Road, Molesey.

All seven AQMAs were declared for annual mean NO₂ concentrations.

Table 4-1 presents the monitored annual average NO₂ concentrations for Elmbridge in 2017. The table includes annual average NO_x concentrations for continuous monitors. Exceedences of the air quality objective of 40µg/m³ for annual average NO₂ concentrations are highlighted in **bold**.

Two sites include triplicate diffusion tubes, collocated with continuous monitors: Hampton Court 2/3/4 are collocated with Hampton Court Parade; and Weybridge 10/11/12 are collocated with Weybridge High Street.

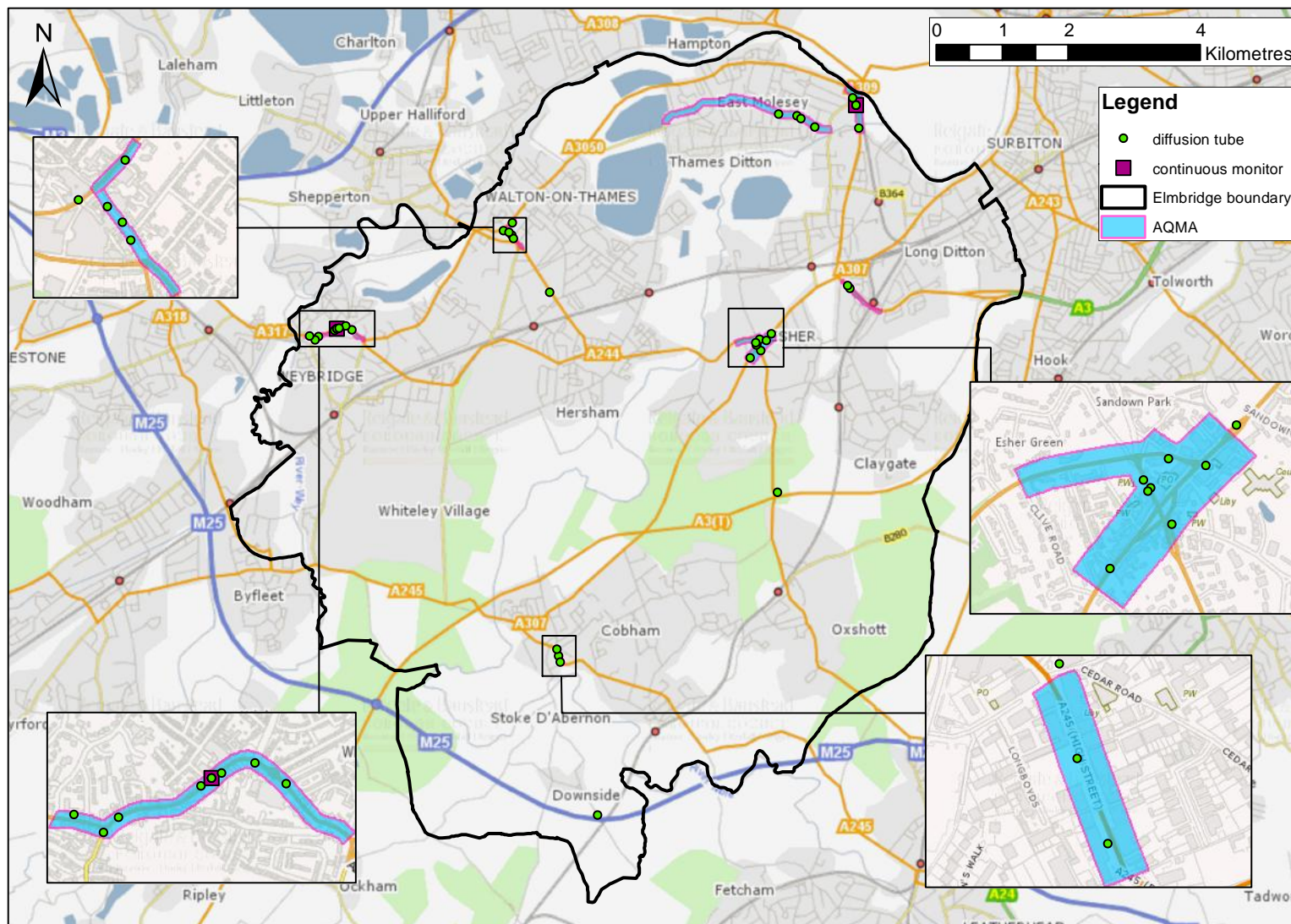


Figure 4.2: Continuous monitoring stations, diffusion tubes and AQMA locations in Elmbridge

Table 4-1: Monitored annual average NO₂ concentrations at Elmbridge continuous monitoring stations and diffusion tubes, 2017

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration (µg/m ³)
Hampton Court Parade	Continuous	515342, 168292	1.8	2	41 [NO _x 108]
Weybridge High Street	Continuous	507480, 164923	1.8	0.6	34 [NO _x 78]
Cobham 1	DT	510833, 159998	2.4	0.6	30
Cobham 6	DT	510814, 160098	2.4	6	25
Cobham 7	DT	510866, 159908	2.4	3.1	33
Downside 3	DT	511429, 157606	2.3	1.1	19
Esher 1	DT	513841, 164693	2.6	1.5	38
Esher 4	DT	514060, 164853	2.4	4.7	34
Esher 5	DT	514148, 162467	2.4	1.4	43
Esher 7	DT	513981, 164750	2.3	0.6	40
Esher 8	DT	513834, 164685	2.4	3.2	39
Esher 9	DT	513822, 164713	2.6	0.6	29
Esher 10	DT	513886, 164767	2.4	2.1	29
Esher 11	DT	513896, 164600	2.6	5.1	33
Esher 13	DT	513737, 164488	2.4	0.9	32
Hampton Court 1	DT	515384, 167947	2.2	0.9	36
Hampton Court 2	DT				35
Hampton Court 3	DT	515342, 168292	1.7	1.9	35
Hampton Court 4	DT				35
Hampton Court 5	DT	515292, 168406	2.5	0.4	26
Hinchley Wood 1	DT	515247, 165535	2.4	4.5	36
Hinchley Wood 2	DT	515217, 165577	1.9	9.8	31
Molesey 1	DT	514449, 168132	2.5	1.1	29
Molesey 8	DT	514716, 167960	2.5	2.6	32
Molesey 9	DT	514508, 168088	2.4	2.6	33
Molesey 10	DT	514170, 168156	2.4	4.9	28
Walton 3	DT	510132, 166336	2.6	0.4	30
Walton 5	DT	510704, 165473	2.3	0.9	28
Walton 8	DT	510156, 166282	2.6	2.9	31
Walton 9	DT	510086, 166382	2.5	2.6	30
Walton 10	DT	510140, 166522	2.6	3.3	34
Walton 11	DT	509999, 166402	2.4	2.3	31
Weybridge 1	DT	507448, 164900	2.5	1	30
Weybridge 4	DT	507704, 164906	2.4	2	31
Weybridge 5	DT	507610, 164968	2.3	1.6	34
Weybridge 6	DT	507510, 164937	2.3	0.5	28
Weybridge 7	DT	507199, 164805	2.4	1.5	41
Weybridge 8	DT	507153, 164760	2.4	4.6	36
Weybridge 9	DT	507065, 164813	1.6	13.1	23
Weybridge 10	DT				32
Weybridge 11	DT	507480, 164923	1.8	0.6	31
Weybridge 12	DT				32

4.2 Epsom and Ewell Borough Council

Figure 4.3 presents the locations of monitoring sites and the AQMA in Epsom and Ewell, comprising 20 diffusion tubes and one AQMA in High Street, Ewell. The AQMA was declared on the basis of annual mean NO₂ concentrations.

Table 4-2 presents the monitored annual average NO₂ concentrations for Epsom and Ewell in 2017. Exceedences of the UK Air Quality Objective of 40µg/m³ for annual average NO₂ concentrations are highlighted in **bold**.

Table 4-2: Monitored annual average NO₂ concentrations at Epsom and Ewell diffusion tubes, 2017

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration (µg/m ³)
EE1	DT	520732, 160765	2.1	2.5	34
EE3	DT	519293, 160026	2	2	17
EE6	DT	520528, 165045	2.1	6.8	32
EE7	DT	520919, 164643	2.3	6.8	36
EE9	DT	519829, 163738	2.4	3.2	23
EE10	DT	521998, 162633	2.1	1.3	45
EE14	DT	520887, 161309	2	1.6	26
EE16	DT	522026, 162624	1.7	1.1	31
EE17	DT	522025, 162563	2.2	2	31
EE22	DT	520968, 160864	2.3	0.5	40
EE36	DT	521072, 160820	2.1	9.2	27
EE38	DT	520722, 160866	1.8	2.8	25
EE39	DT	520842, 160729	2.1	3.3	28
EE42	DT	521008, 160901	2.1	7.7	29
EE43	DT	521483, 161454	2.3	5.5	29
EE45	DT	522208, 163100	2.1	8.3	23
EE47	DT	520713, 162968	1.9	4.7	25
EE48	DT	522016, 162504	2.1	1.7	29
EE49	DT	520577, 160586	2.2	3.5	29
EE50	DT	521974, 162676	2.1	0.9	37

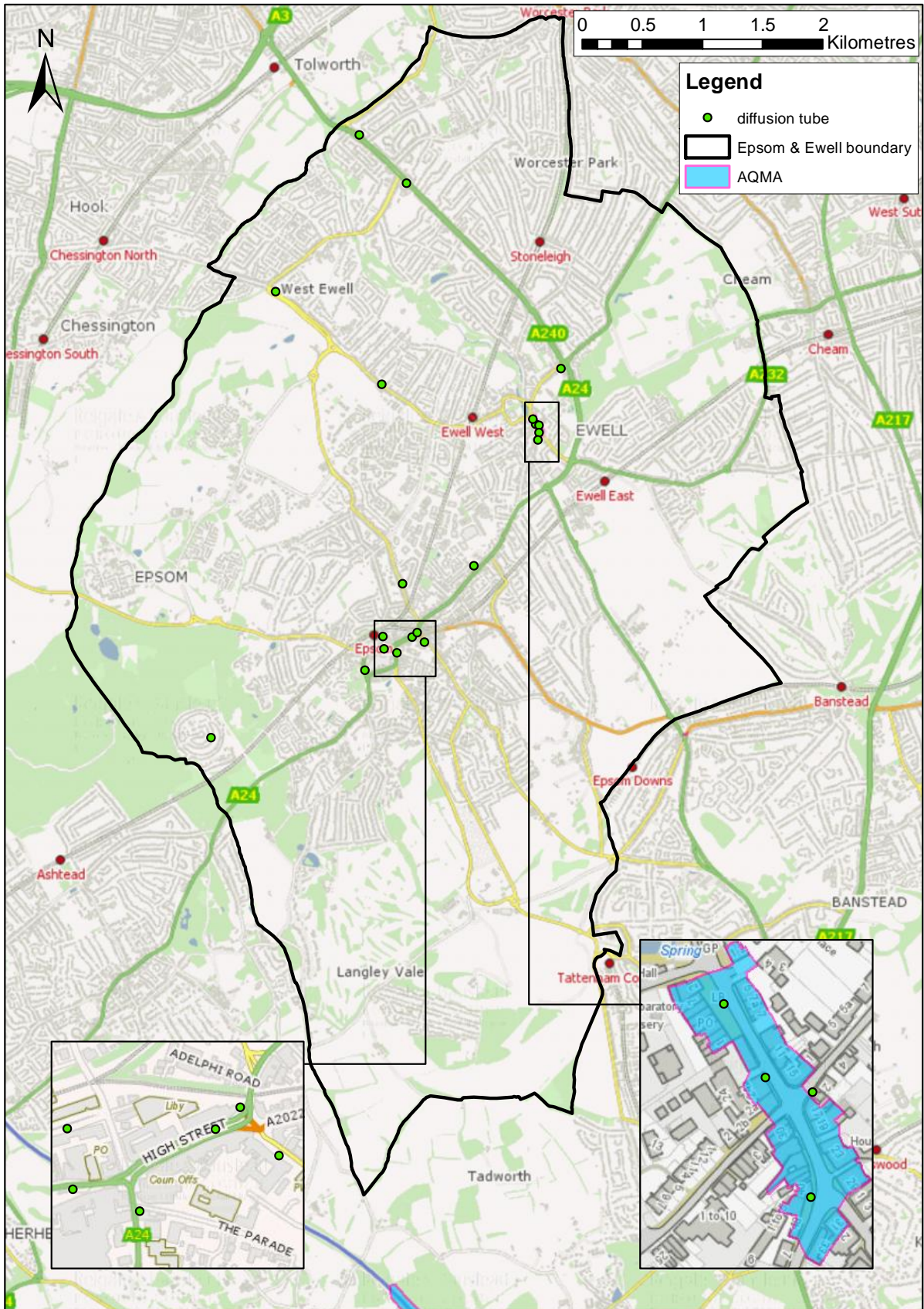


Figure 4.3: Diffusion tube and AQMA locations, Epsom and Ewell

4.3 Guildford Borough Council

Figure 4.4 presents the locations of monitoring sites in Guildford, comprising 26 diffusion tubes. Guildford Borough Council has not declared any AQMAs.

Table 4-3 presents the monitored annual average NO₂ concentrations for Guildford in 2017. Exceedences of the UK Air Quality Objective of 40µg/m³ for annual average NO₂ concentrations are highlighted in **bold**.

Table 4-3: Monitored annual average NO₂ concentrations at Guildford diffusion tubes, 2017

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration (µg/m ³)
GUL_ASH1	DT	489885, 150767	2.5	10	18
GUL_ASH2	DT	488350, 150078	2.5	N/A	22
GUL_C4	DT	495440, 147289	2.5	1.5	40
GUL_C9	DT	495446, 147271	2.5	1	44
GUL_C10	DT	495440, 147291	2.5	1	32
GUL_FRH1	DT	499024, 149402	2.5	N/A	34
GUL_GD1	DT	499272, 149524	2.5	5	29
GUL_GD2	DT	499799, 149932	2.5	5	31
GUL_GD3	DT	499658, 150732	2.5	5	17
GUL_GD6	DT	500385, 148342	2.5	120	10
GUL_GD9	DT	488276, 149859	2.5	5	17
GUL_GD10	DT	488629, 150032	2.5	5	15
GUL_GD11	DT	498133, 150648	2.5	8	24
GUL_GD13	DT	499300, 149514	2.5	1	31
GUL_GD14	DT	499800, 149912	2.5	5	32
GUL_GD15	DT	499806, 150792	2.5	8	28
GUL_RP1	DT	505242, 156820	2.5	5	28
GUL_RP2	DT	505090, 156776	2.5	1	24
GUL_send1	DT	502860, 155420	2.5	5	22
GUL_send2	DT	502173, 155846	2.5	1	21
GUL_SH1	DT	500045, 147603	2.5	1	36
GUL_STN	DT	498831, 151473	2.5	1	25
GUL_T1	DT	488637, 148845	2.5	N/A	23
GUL_WCL	DT	504476, 151404	2.5	1	20
GUL_WP1	DT	497971, 152575	2.5	1	25
GUL_WS1	DT	507346, 158005	2.5	NA	14

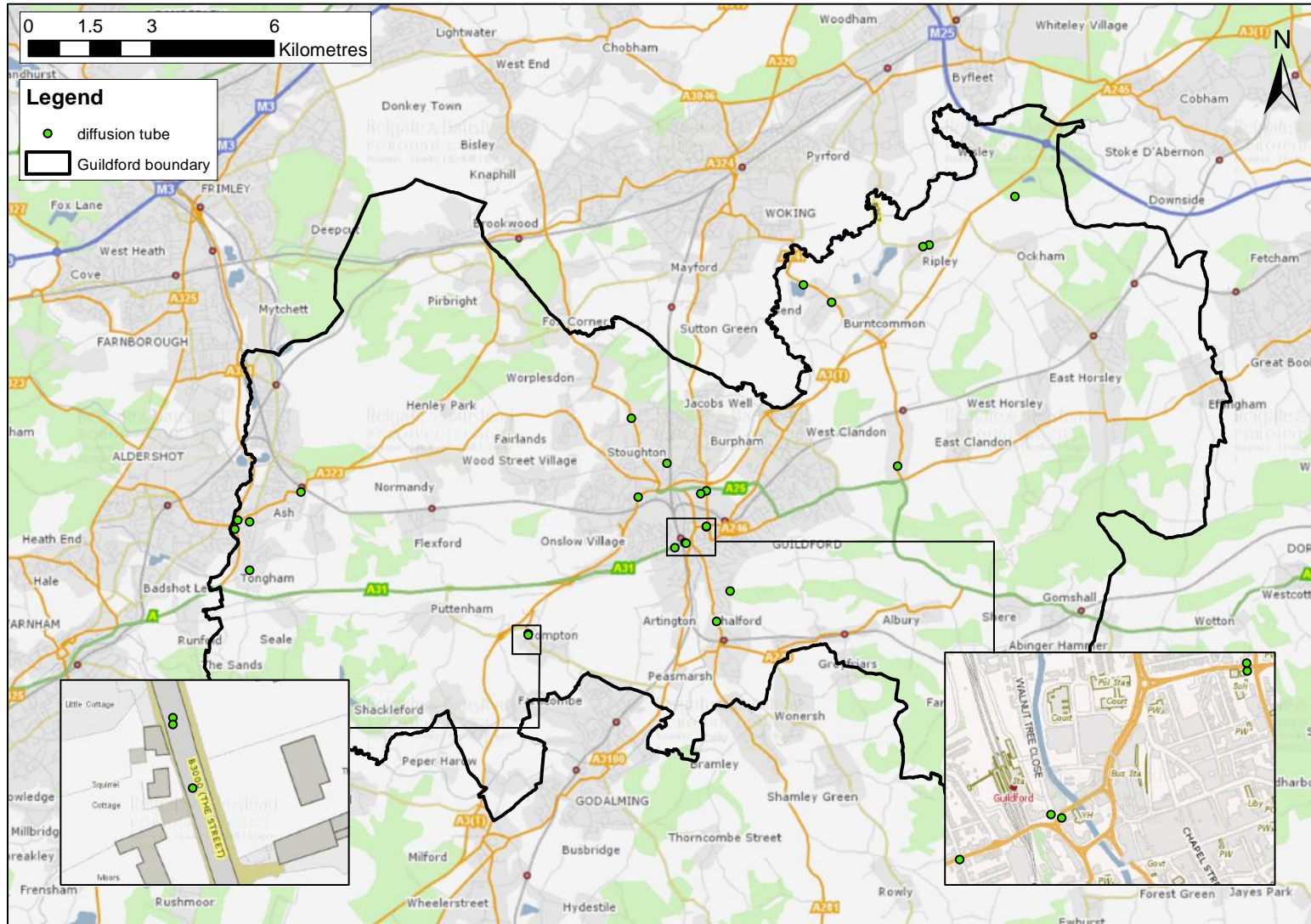


Figure 4.4: Diffusion tubes locations, Guildford

4.4 Mole Valley District Council

Figure 4.5 presents the locations of monitoring sites in Mole Valley, comprising 12 diffusion tubes. Mole Valley District Council has not declared any AQMAs.

Table 4-4 presents the monitored annual average NO₂ concentrations for Mole Valley in 2017. There were no monitored exceedences of the air quality objective of 40µg/m³ for annual average NO₂ concentrations in 2017.

Table 4-4: Monitored annual average NO₂ concentrations at Mole Valley diffusion tubes, 2017

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration (µg/m ³)
MV1	DT	516388, 149369	2.5	2	24
MV2	DT	516256, 148882	2.5	2	20
MV3	DT	516867, 149800	2.5	27	17
MV4	DT	514123, 155336	2.5	17	14
MV6	DT	517214, 157204	2.5	28	30
MV7	DT	520210, 150565	2.5	13	17
MV8	DT	523419, 140580	2.5	36	18
MV9	DT	526906, 142368	2.5	55	11
MV10	DT	517712, 156744	2.5	2	33
MV12	DT	517674, 156840	2.5	2	30
MV13	DT	516125, 149357	2.5	1	33
MV14	DT	517037, 149800	2.5	15	18

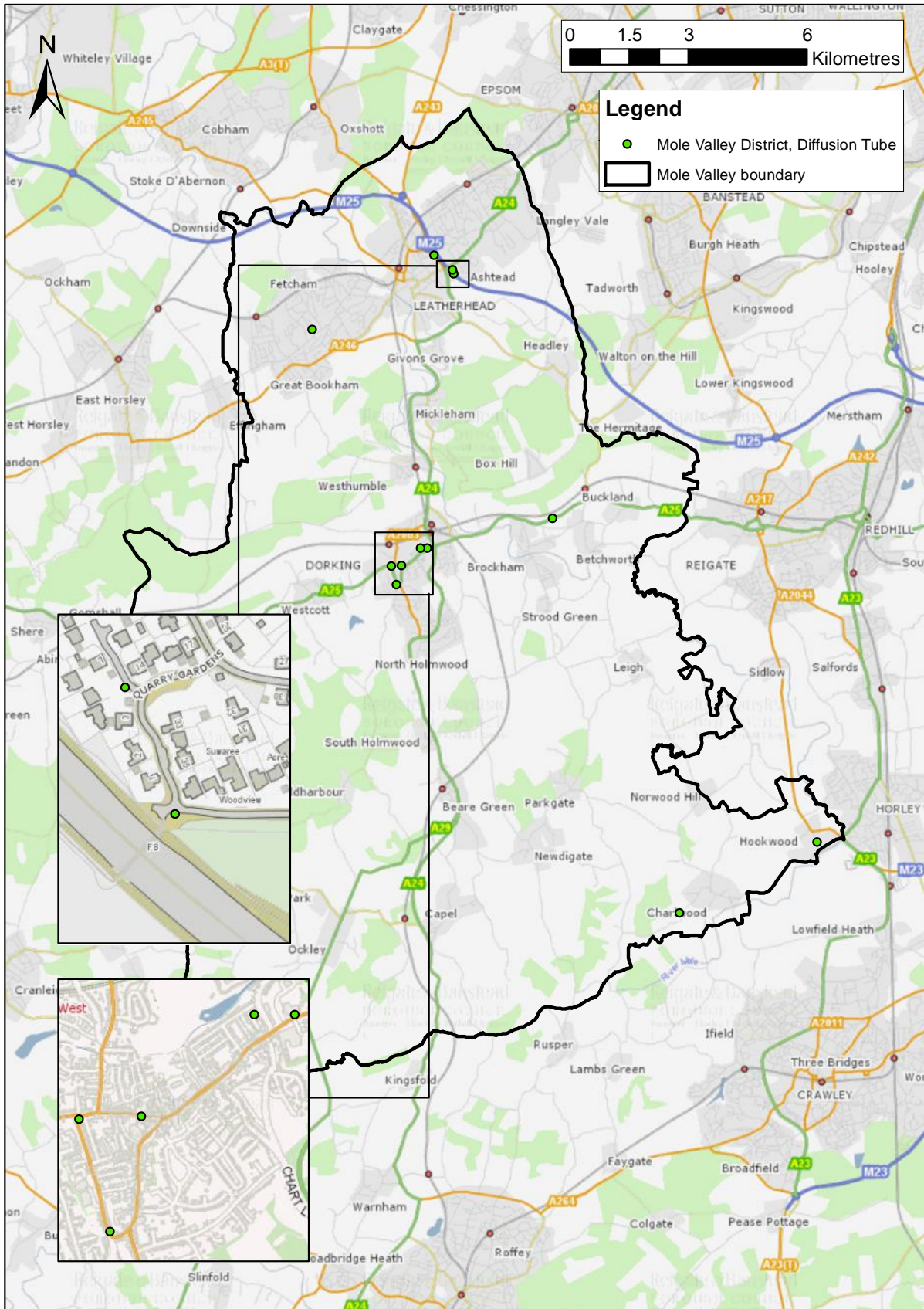


Figure 4.5: Diffusion tubes, Mole Valley

4.5 Reigate and Banstead Borough Council

Figure 4.6 presents the locations of monitoring sites in Reigate and Banstead, comprising 104 diffusion tubes, three continuous monitors and nine AQMAs. The AQMAs are:

- AQMA No. 1 (M25)
- AQMA No. 3 (Horley)
- AQMA No. 6 (Blackhorse Lane)
- AQMA No. 8 (Drift Bridge)
- AQMA No. 9 (Reigate High Street, West Street and Bell Street)
- AQMA No. 10 (Merstham)
- AQMA No. 11 (Reigate Hill)
- AQMA No. 12 (Redhill)
- AQMA No. 13 (Hooley)

All nine were declared on the basis of annual mean NO₂ concentrations.

Table 4-5 presents the monitored annual average NO₂ concentrations for Reigate and Banstead in 2017. The table includes annual average NO_x concentrations for continuous monitors. Exceedences of the air quality objective of 40µg/m³ for annual average NO₂ concentrations are shown in **bold**.

Three sites include triplicate diffusion tubes collocated with continuous monitors:

- RB24, RB25 and RB26 are collocated with RG1;
- RB99, RB100 and RB101 are collocated with RG3.
- RB178, RB179 and RB180 are collocated with RG6; and

Note that RG3, and collocated RB99, RB100 and RB101 diffusion tubes fall outside of Surrey but are managed by Reigate and Banstead. One diffusion tube, RB102 is managed by Reigate and Banstead but falls within Tandridge District Council.

Table 4-6 presents the monitored annual average PM₁₀ concentrations at two continuous monitors in Reigate and Banstead in 2017. At the same location, PM₁₀ concentrations are measured using both Tapered Element Oscillating Microbalance (TEOM) and Filtered Dynamic Measurement System (FDMS) instruments, at RG1 and RG5 respectively.

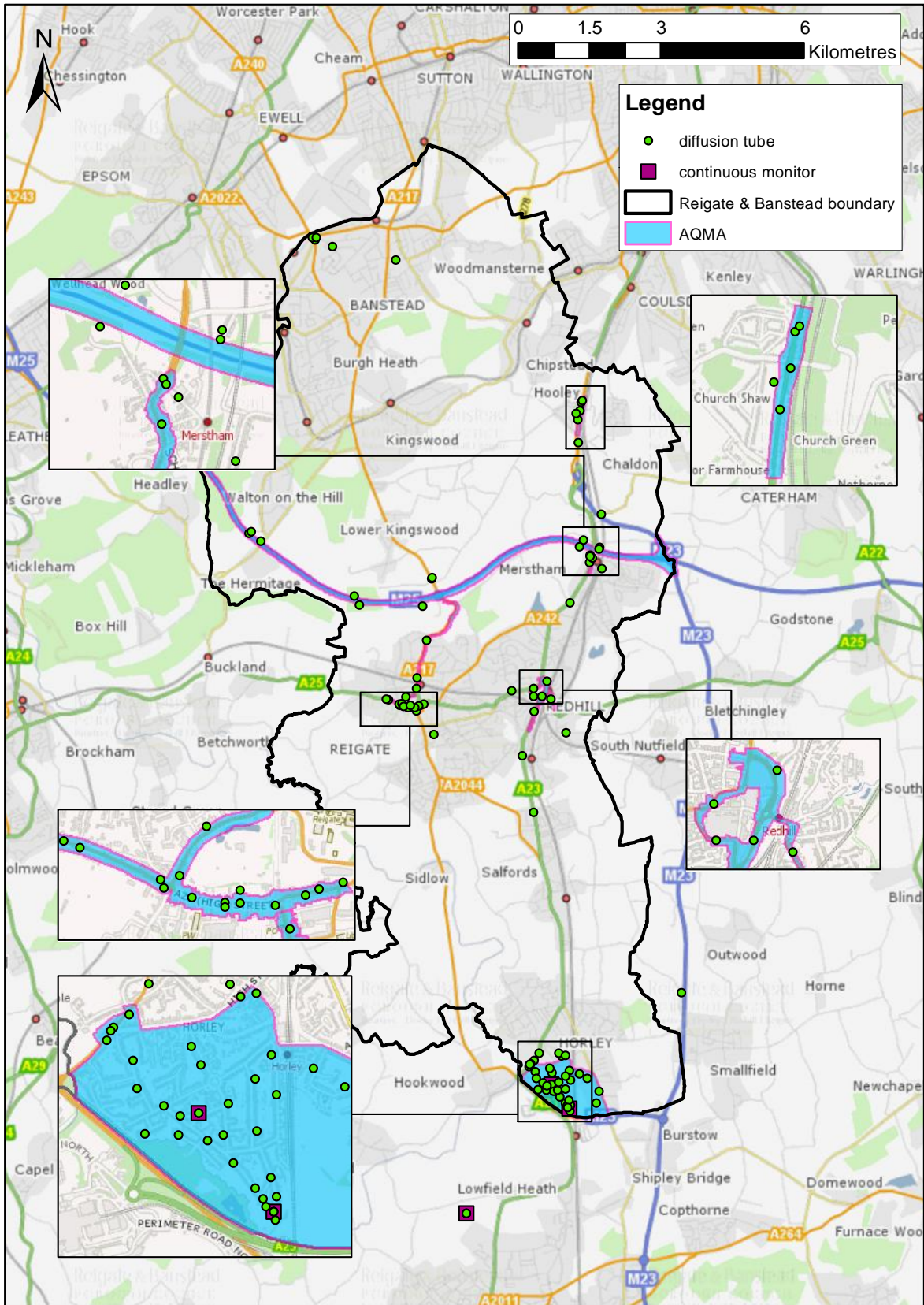


Figure 4.6: Diffusion tubes, continuous monitoring sites and AQMAs, Reigate and Banstead

Table 4-5: Monitored annual average NO₂ concentrations at Reigate and Banstead continuous monitoring stations and diffusion tubes, 2017

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration (µg/m ³)
RG1	Continuous	528208, 142337	3.5	19.1	20 [NO _x 34]
RG6	Continuous	528591, 141830	1.5	0.7	27 [NO _x 46]
RG3	Continuous	526421, 139639	2	12.6	14 [NO _x 19]
RB1	DT	525246, 150251	3.1	5.1	32
RB3	DT	524944, 159630	3	0.7	18
RB8	DT	525246, 150287	3.7	39.2	18
RB9	DT	525749, 149677	2.5	24.9	17
RB11	DT	528104, 142226	3	1.4	23
RB12	DT	528423, 142935	2.9	0.4	28
RB13	DT	528368, 142996	2.9	30	20
RB17	DT	528511, 149715	2.9	1.7	14
RB18	DT	529262, 153156	3	1.3	23
RB19	DT	529067, 153375	2.9	0.7	24
RB20	DT	529025, 153419	2.9	2.6	33
RB21	DT	523198, 160095	2.9	1.7	34
RB22	DT	523279, 160101	2.9	1.1	20
RB23	DT	523613, 159906	2.7	2.3	16
RB24	DT				21
RB25	DT	528208, 142337	3.5	19.1	22
RB26	DT				21
RB27	DT	521873, 153896	3	5.6	25
RB29	DT	521921, 153937	3	11.7	25
RB30	DT	522112, 153728	3	18.9	24
RB31	DT	525506, 152366	3	19.5	16
RB33	DT	524081, 152580	3	0	21
RB34	DT	524177, 152393	3	45.6	24
RB36	DT	528885, 153759	3	74.8	20
RB37	DT	529217, 153605	3	12	24
RB39	DT	529211, 153572	3	10.9	25
RB40	DT	529252, 154290	3	15	20
RB43	DT	528799, 153616	3	52.4	23
RB44	DT	525534, 150308	3	14.6	31
RB45	DT	525430, 150273	3	0.1	28
RB46	DT	525344, 150245	3	0.4	36
RB47	DT	525111, 150267	3	0.5	35
RB49	DT	525698, 152943	3	3.5	42
RB50	DT	525708, 152969	3	24	26
RB51	DT	527873, 142606	3.5	15.1	21
RB52	DT	527893, 142463	3.5	13.7	25
RB53	DT	528030, 142374	3.5	4.3	25
RB54	DT	528112, 142321	3.5	4.2	23
RB55	DT	528254, 142196	3.5	1.1	23
RB56	DT	528386, 142080	3.5	2.6	24
RB57	DT	528499, 141953	3.5	2.6	26

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration ($\mu\text{g}/\text{m}^3$)
RB58	DT	528538, 141897	3.5	2.6	27
RB59	DT	528602, 141789	3.5	2.2	28
RB60	DT	528607, 141910	3.5	2.8	27
RB61	DT	528578, 142006	3.5	1	23
RB64	DT	528608, 142432	3.5	1.6	22
RB65	DT	528581, 142635	3.5	16.8	22
RB66	DT	528499, 142512	3.5	18.5	22
RB68	DT	528505, 142246	3.5	18.5	24
RB69	DT	528335, 142224	3.5	14	26
RB70	DT	528360, 142384	3.5	17.8	24
RB72	DT	528219, 142583	3.5	19.2	22
RB73	DT	528172, 142679	3.5	17.8	22
RB74	DT	529149, 141953	3.5	15.1	23
RB75	DT	529210, 142195	3.5	12.4	24
RB76	DT	528957, 142471	3.5	20.7	20
RB77	DT	528797, 142567	3.5	13	21
RB78	DT	528553, 141857	3.5	2.7	27
RB81	DT	527595, 149235	3.5	5.5	31
RB82	DT	528770, 155798	3.5	18.3	34
RB95	DT	525382, 150639	2	5.9	25
RB98	DT	527931, 142231	2	1	26
RB99	DT				14
RB100	DT	526421, 139639	2	12.4	14
RB101	DT				14
RB102	DT	530936, 144271	2	19.1	21
RB104	DT	525204, 150252	2	4.9	35
RB105	DT	525203, 150240	2	2.8	39
RB106	DT	523254, 160055	2	2.1	29
RB107	DT	525467, 150290	2	2.3	26
RB109	DT	525385, 150178	2	3.6	32
RB110	DT	529016, 153439	2	4.3	29
RB111	DT	525032, 150293	2	4.3	30
RB113	DT	524795, 150406	2	2.1	27
RB115	DT	524750, 150425	2	0.6	30
RB116	DT	525022, 150317	2	2.3	32
RB117	DT	525075, 150327	2	2.9	35
RB118	DT	525152, 150466	2	14.2	31
RB120	DT	528195, 150421	2	2.2	33
RB122	DT	528014, 150475	2	2.9	32
RB123	DT	527838, 150475	2	0.5	36
RB124	DT	529009, 153283	2	1.8	35
RB125	DT	525590, 151655	2	2.7	35
RB136	DT	528812, 156473	2	1	49
RB137	DT	528833, 156648	2	6	42
RB140	DT	528122, 150799	2	7.2	25
RB141	DT	527372, 150595	2	2.7	24

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration ($\mu\text{g}/\text{m}^3$)
RB145	DT	527850, 150159	2	2.2	34
RB146	DT	528760, 156277	2	3.2	41
RB147	DT	528732, 156407	2	51	16
RB148	DT	528855, 156674	2.5	2.1	63
RB149	DT	527736, 142710	2.5	1.6	46
RB150	DT	525397, 150867	2	3.4	38
RB151	DT	528502, 142952	2.5	1.8	33
RB152	DT	528599, 152439	2.5	1.6	33
RB153	DT	527837, 148046	2.5	2.9	29
RB167	DT	527829, 150643	3	3.1	25
RB174	DT	527851, 142842	2	3	31
RB175	DT	527952, 142999	2.5	2.8	31
RB176	DT	527770, 142777	2	10.2	25
RB177	DT	527757, 142759	2	8.6	25
RB178	DT				26
RB179	DT	528591, 141830	2.5	N/A	25
RB180	DT				26

Table 4-6: Monitored annual average PM_{10} concentrations at Reigate and Banstead continuous monitoring stations, 2017

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration ($\mu\text{g}/\text{m}^3$)
RG1	Continuous (TEOM)	528208, 142337	3.5	19.1	16
RG5	Continuous (FDMS)				15

4.6 Runnymede Borough Council

Figure 4.7 presents the locations of monitoring sites throughout Runnymede, comprising 25 diffusion tubes and two AQMAs. The AQMAs are:

- M25 AQMA, declared for annual mean NO₂, annual mean PM₁₀ and 24-hour mean PM₁₀ concentrations. The AQMA combines 2 area: Area 1 extends 70m east and west of the centre line of the M25 between Junction 11 [and] Junction 13, plus an area where the M25 crosses over Vicarage Road/ High Street Egham; and Area 2 extends 55m east and west of the centre line of the M25 between Junction 11 [and] the southerly boundary of the borough.
- Addlestone AQMA, declared for annual mean NO₂ concentrations.

Table 4-7 presents the monitored annual average NO₂ concentrations for Runnymede in 2017. Exceedences of the air quality objective of 40µg/m³ for annual average NO₂ concentrations are shown in **bold**.

Table 4-7: Monitored annual average NO₂ concentrations at Runnymede diffusion tubes and continuous monitoring stations, 2017

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration (µg/m ³)
RYMV	DT	505797, 162303	2.3	2	32
RY4	DT	505726, 164626	2	6	17
RY14	DT	504993, 164602	2.3	2	48
RY19	DT	505227, 162701	2	2	34
RY21	DT	504260, 166943	2	1	34
RY23	DT	504888, 166786	2.2	1	51
RY25	DT	501749, 171325	2.3	13	30
RY26	DT	501715, 171381	2.2	2	42
RY33	DT	501679, 171677	2.1	15	31
RY34	DT	499335, 170688	2.3	1	22
RY39	DT	498829, 166213	1.8	10	23
RY40	DT	502037, 165370	2.5	68	16
RY43	DT	504996, 165339	2.3	2	37
RY44	DT	504621, 164433	2.4	2	27
RY45	DT	504844, 166647	2.3	2	37
RY53	DT	504967, 164922	2.4	2	34
RY54	DT	505032, 164552	2.3	2	30
RY55	DT	505592, 164840	2.3	0.2	33
RY59	DT	503012, 171332	2.3	1	32
RY60	DT	504960, 164801	2.4	2	33
RY61	DT	504906, 164558	2.4	2	31
RY62	DT	505081, 164431	2.3	2	34
RY64	DT	505253, 164400	2.3	1	26
RY65	DT	505801, 165041	2.3	2	27
RY66	DT	505705, 164951	2.3	2	25

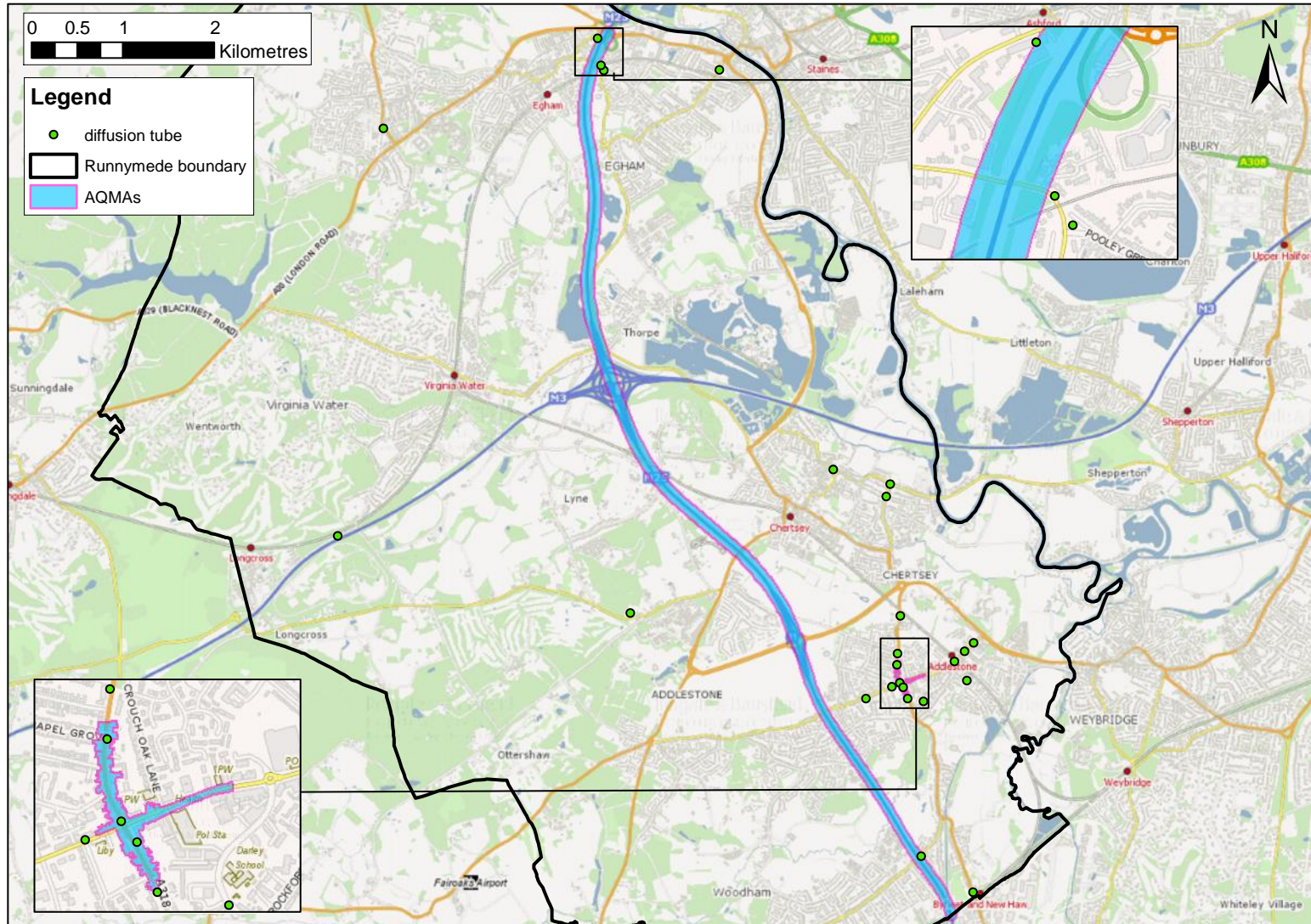


Figure 4.7: Diffusion tubes, continuous monitoring stations and AQMA location, Runnymede

4.7 Spelthorne Borough Council

Figure 4.8 presents the locations of monitoring sites in Spelthorne, comprising 44 diffusion tubes, three continuous monitors and one AQMA encompassing the entire borough of Spelthorne. The AQMA was declared for annual mean NO₂ concentrations.

Table 4-8 presents the monitored annual average NO₂ concentrations for Spelthorne in 2017. The table includes annual average NO_x concentrations for continuous monitors. Exceedences of the UK Air Quality Objective of 40µg/m³ for annual average NO₂ concentrations are highlighted in **bold**.

Table 4-9 presents the monitored annual average PM₁₀ and PM_{2.5} concentrations at three continuous monitors in Spelthorne in 2017.

Three sites include triplicate diffusion tubes collocated with continuous monitors:

- SP16/17/18 are collocated with BAA_Oaks; and
- SP43/44/45 are collocated with SUN_01.

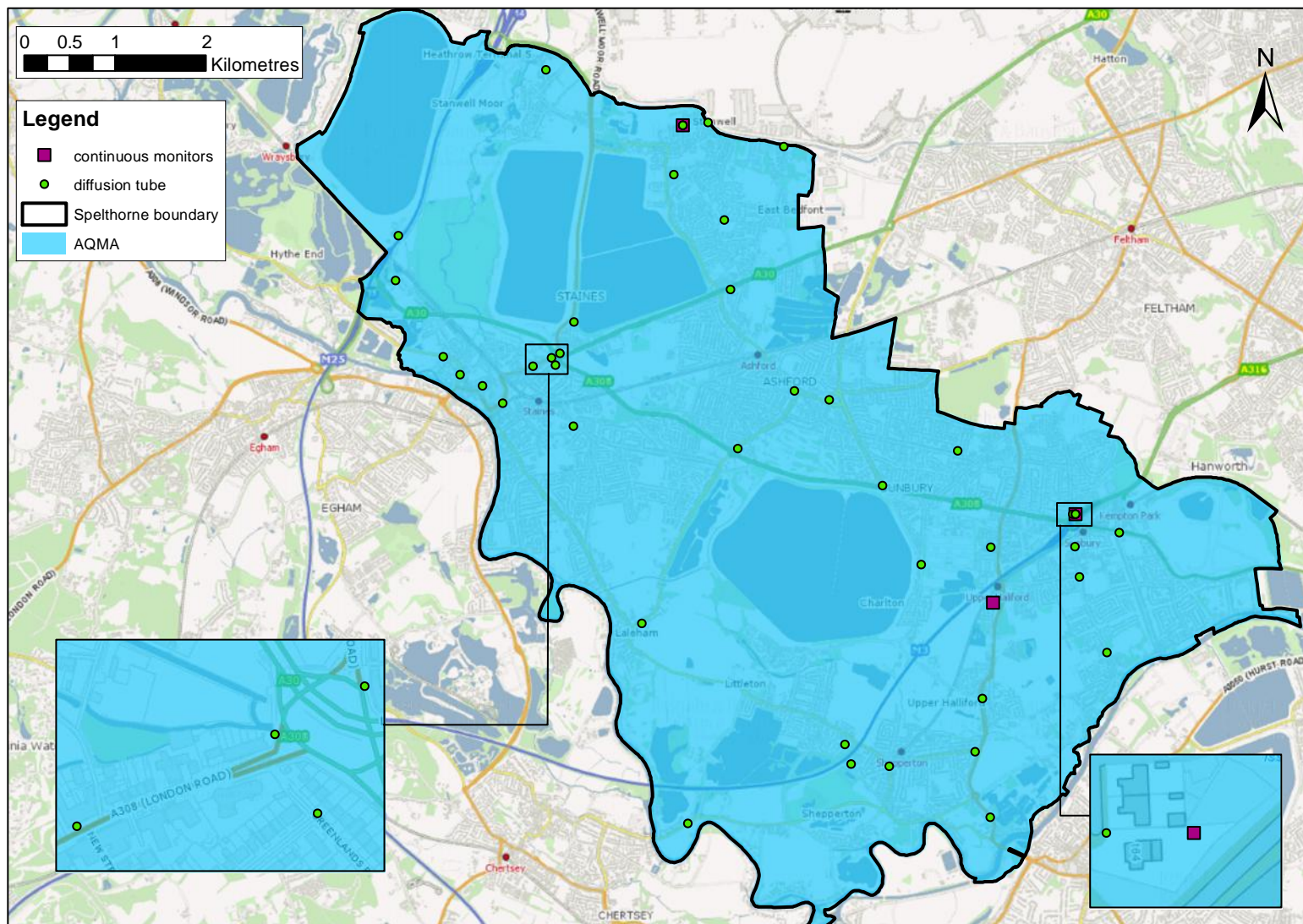


Figure 4.8: Diffusion tubes, continuous monitoring stations and AQMA, Spelthorne

Table 4-8: Monitored annual average NO₂ and NO_x concentrations at Spelthorne continuous monitoring stations and diffusion tubes, 2017

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration (µg/m ³)
BAA_Oaks	Continuous	505735, 174489	3.5	1	26 [NO _x 47]
SCC_ECO	Continuous	509155, 169228	2.16	5.5	24 [NO _x 44]
SUN_01	Continuous	510063, 170200	2.06	19	33 [NO _x 59]
SP1	DT	503529, 171619	2.5	N/A	28
SP3	DT	503098, 171935	2.5	0.5	31
SP4	DT	510054, 169843	2.5	2	27
SP5	DT	506967, 171563	2.3	1.5	37
SP6	DT	508763, 170900	2.5	0.5	24
SP10	DT	509124, 166861	2.4	1.5	35
SP11	DT	509034, 168169	2.2	1.8	35
SP12	DT	504538, 172318	2.5	1	31
SP14	DT	504228, 175098	2.8	N/A	25
SP16	DT				26
SP17	DT	505735, 174489	1.7	N/A	26
SP18	DT				27
SP19	DT	506851, 174252	2.5	1.5	32
SP20	DT	504334, 171845	1.7	1	32
SP21	DT	509131, 169840	2.5	N/A	26
SP23	DT	507525, 167662	2.7	1	23
SP24	DT	502577, 172777	2.8	N/A	27
SP26	DT	505635, 173948	2.7	N/A	28
SP27	DT	503286, 171743	2.8	2	31
SP28	DT	504291, 171926	2.4	1.5	35
SP29	DT	504383, 171975	2.4	1	44
SP31	DT	506265, 172682	2.4	2	36
SP32	DT	507347, 171462	2.2	1	29
SP33	DT	506339, 170927	2.3	3	34
SP34	DT	507936, 170518	2.2	2	38
SP35	DT	510028, 170200	2.5	10	37
SP36	DT	510104, 169508	2.5	2.2	40
SP38	DT	505289, 168996	2.1	2	24
SP39	DT	504532, 171172	2.4	N/A	25
SP41	DT	510407, 168677	2.2	0.5	30
SP43	DT				33
SP44	DT	510063, 170200	2	29	33
SP45	DT				33
SP46	DT	503754, 171428	2.5	1	31
SP47	DT	506193, 173447	2.5	1.5	25
SP48	DT	506012, 174518	2.5	1	30
SP49	DT	502605, 173274	2.15	7.5	29
SP50	DT	508364, 169648	2.6	1.8	33
SP51	DT	504087, 171832	2.1	3.3	37
SP52	DT	510542, 169996	2.1	2.1	32
SP53	DT	505792, 166789	2.44	1.6	29
SP55	DT	508954, 167584	2.3	1	33
SP56	DT	507587, 167445	2	1.6	21
SP57	DT	508008, 167422	2.5	1.7	33

Table 4-9: Monitored annual average PM_{10} and $PM_{2.5}$ concentrations at Spelthorne continuous monitoring stations, 2017

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	PM_{10} Concentration ($\mu\text{g}/\text{m}^3$)	$PM_{2.5}$ Concentration ($\mu\text{g}/\text{m}^3$)
BAA_Oaks	Continuous	505735, 174489	3.5	1	14	9
SCC_ECO	Continuous	509155, 169228	2.16	5.5	21	15
SUN_01	Continuous	510063, 170200	2.06	19	13	8

4.8 Surrey Heath Borough Council

Figure 4.9 presents the locations of monitoring sites in Surrey Heath, comprising 36 diffusion tubes, one continuous monitor and one AQMA, extending along the M3 bounded by Frimley Road, Camberley and Ravenswood Roundabout, Camberley. The AQMA was for NO₂ annual mean and PM₁₀ 24-hour mean concentrations.

Table 4-10 presents the monitored annual average NO₂ concentrations for Surrey Heath in 2017. The table includes annual average NO_x concentrations for continuous monitors. Exceedences of the UK Air Quality Objective of 40µg/m³ for annual average NO₂ concentrations are highlighted in **bold**. PM₁₀ is also monitored at the continuous monitor CM1, in accordance with monitoring the 24-hour mean for PM₁₀ within the AQMA.

Table 4-11 presents the monitored annual average for PM₁₀ concentrations at the continuous monitor in Surrey Heath in 2017. SH15/22/25, are triplicate diffusion tubes collocated with the continuous monitor CM1.

Table 4-10: Monitored annual average NO₂ concentrations at Surrey Heath continuous monitoring station and diffusion tubes, 2017

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration (µg/m ³)
CM1	Continuous	488649, 159805	1.5	17	36 [NO _x 66]
SH1	DT	491010, 163344	2.5	1	14
SH2	DT	491063, 163333	1.75	2.5	19
SH3	DT	492810, 164408	1.75	N/A	13
SH4	DT	494764, 159623	1.75	N/A	21
SH5	DT	489463, 160583	1.75	17	19
SH6	DT	494973, 159612	1.75	2.3	19
SH7	DT	496221, 164430	1.75	10	28
SH8	DT	496169, 164464	1.75	62	16
SH9	DT	489617, 161874	1.75	4.8	16
SH10	DT	485860, 160109	1.75	3	21
SH11	DT	486933, 159006	1.75	6	21
SH12	DT	487490, 160788	1.75	2	22
SH13	DT	488740, 159579	1.75	1	20
SH14	DT	488619, 159658	1.75	1	21
SH15	DT				24
SH22	DT	488649, 159805	1.75	17	25
SH25	DT				23
SH16	DT	486834, 158336	1.75	35	24
SH17	DT	495487, 158960	1.75	2	15
SH20	DT	490353, 157214	1.75	2	17
SH21	DT	495134, 161087	1.75	N/A	14
SH23	DT	490781, 160269	1.75	1	17
SH24	DT	497344, 161734	1.75	2	22
SH26	DT	487762, 161392	1.75	N/A	21
SH27	DT	495546, 158848	1.75	3	23

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration ($\mu\text{g}/\text{m}^3$)
SH28	DT	495325, 159055	1.75	5	19
SH29	DT	494222, 163476	1.75	0	14
SH30	DT	487181, 158432	1.75	20	24
SH31	DT	487024, 158415	1.75	20	19
SH32	DT	486982, 158389	1.75	20	21
SH33	DT	486848, 158311	1.75	20	25
SH34	DT	487934, 159132	1.75	50	19
SH35	DT	489189, 160209	1.75	5	19
SH36	DT	489347, 160392	1.75	15	20
SH37	DT	489081, 160271	1.75	5	21
SH38	DT	491706, 163145	1.75	15	24

Table 4-11: Monitored annual average PM_{10} concentration at Surrey Heath continuous monitoring station, 2017

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	PM_{10} Concentration ($\mu\text{g}/\text{m}^3$)
CM1	Continuous	488649, 159805	1.5	1.7	17

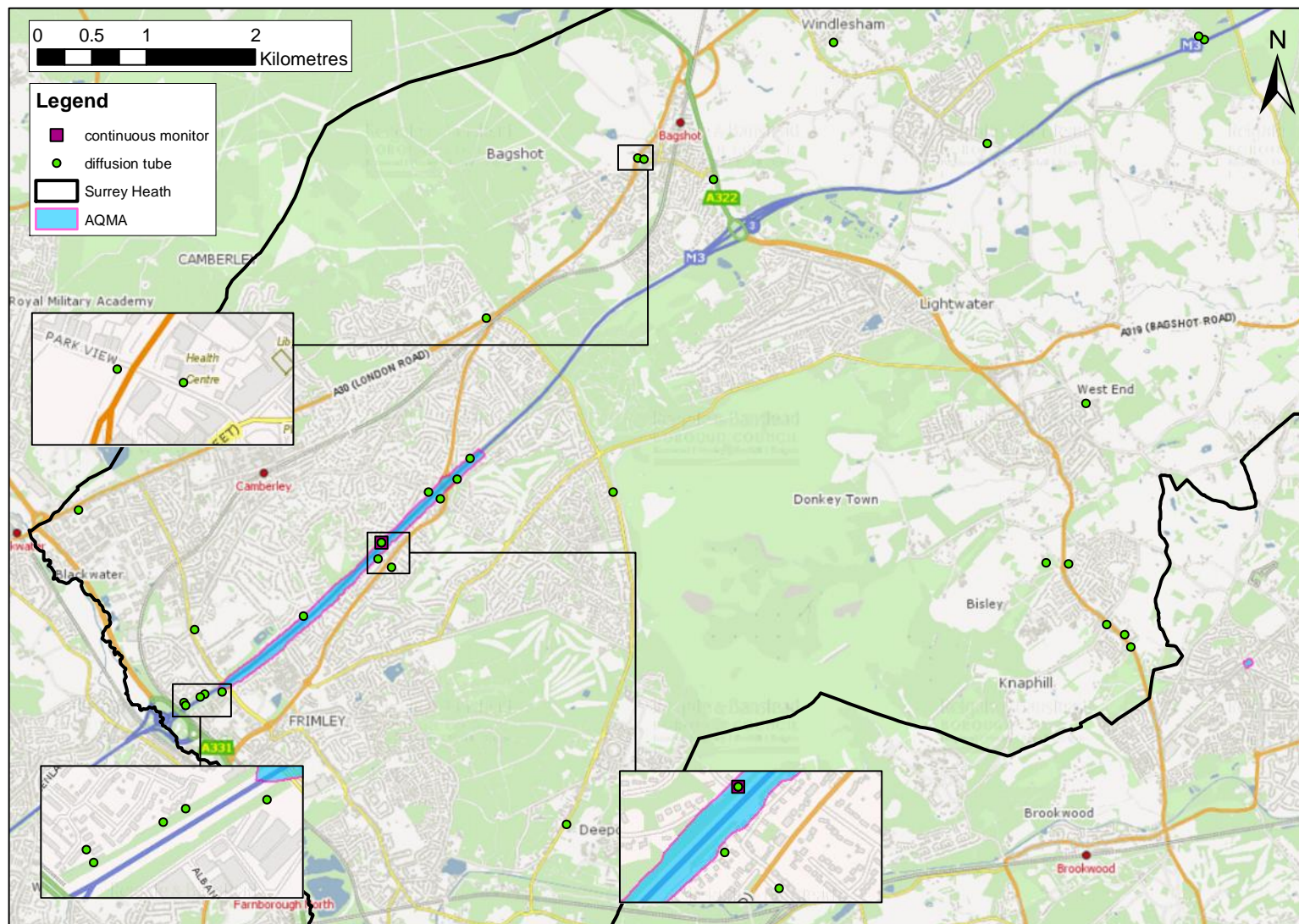


Figure 4.9: Diffusion tubes, continuous monitoring station and AQMA across Surrey Heath

4.9 Tandridge District Council

Figure 4.10 presents the locations of monitoring sites throughout Tandridge, comprising 28 diffusion tubes. Tandridge District Council has not declared any AQMAs.

Table 4-12 presents the monitored annual average NO₂ concentrations in Tandridge in 2017. Exceedences of the air quality objective of 40µg/m³ for annual average NO₂ concentrations are shown in **bold**. Note, there is one diffusion tube in Tandridge managed by Reigate and Banstead Borough Council. Details for this diffusion tube, RB102, are provided in Table 4-5

Table 4-12: Monitored annual average NO₂ concentrations at Tandridge diffusion tubes, 2017

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration (µg/m ³)
TANWI_001	DT	534825, 151633	2.5	N/A	23
TANWI_002	DT	534949, 151684	2.5	N/A	31
TANWI_003	DT	535012, 151821	2.5	N/A	42
TANWI_004	DT	535002, 151856	2.5	N/A	26
TANWI_005	DT	534993, 152052	2.5	N/A	41
TANWI_006	DT	535020, 152269	2.5	N/A	25
TD5	DT	535071, 152659	2.5	2.2	29
TD7	DT	535167, 152200	2.5	152	19
TD8	DT	534883, 152316	2.5	132	19
TD9	DT	539111, 153656	2.5	1.5	17
TD14	DT	534364, 157506	2.5	0.5	27
TD19	DT	531134, 143585	2.5	130	21
TD23	DT	535840, 158430	2.5	1.5	23
TD25	DT	533839, 158847	2.5	1.7	19
TD26	DT	531105, 142939	2.5	133	23
TD27	DT	530719, 150539	2.5	1.3	29
TD28	DT	539881, 152746	2.5	1.5	28
TD30	DT	540258, 153783	2.5	1.5	22
TD31	DT	535186, 159127	2.5	0.5	20
TD32	DT	539684, 152744	2.5	1.5	22
TD33	DT	532790, 155873	2.5	1	25
TD34	DT	539464, 152936	2.5	0.4	20
TD35	DT	531952, 150789	2.5	2.5	27
TD36	DT	534050, 155838	2.5	1	25
TD37	DT	530385, 150477	2.5	1	19
TD38	DT	531840, 150826	2.5	1	25
TD39	DT	536909, 139713	2.5	0.5	26
TD40	DT	530592, 150508	2.5	1.5	33

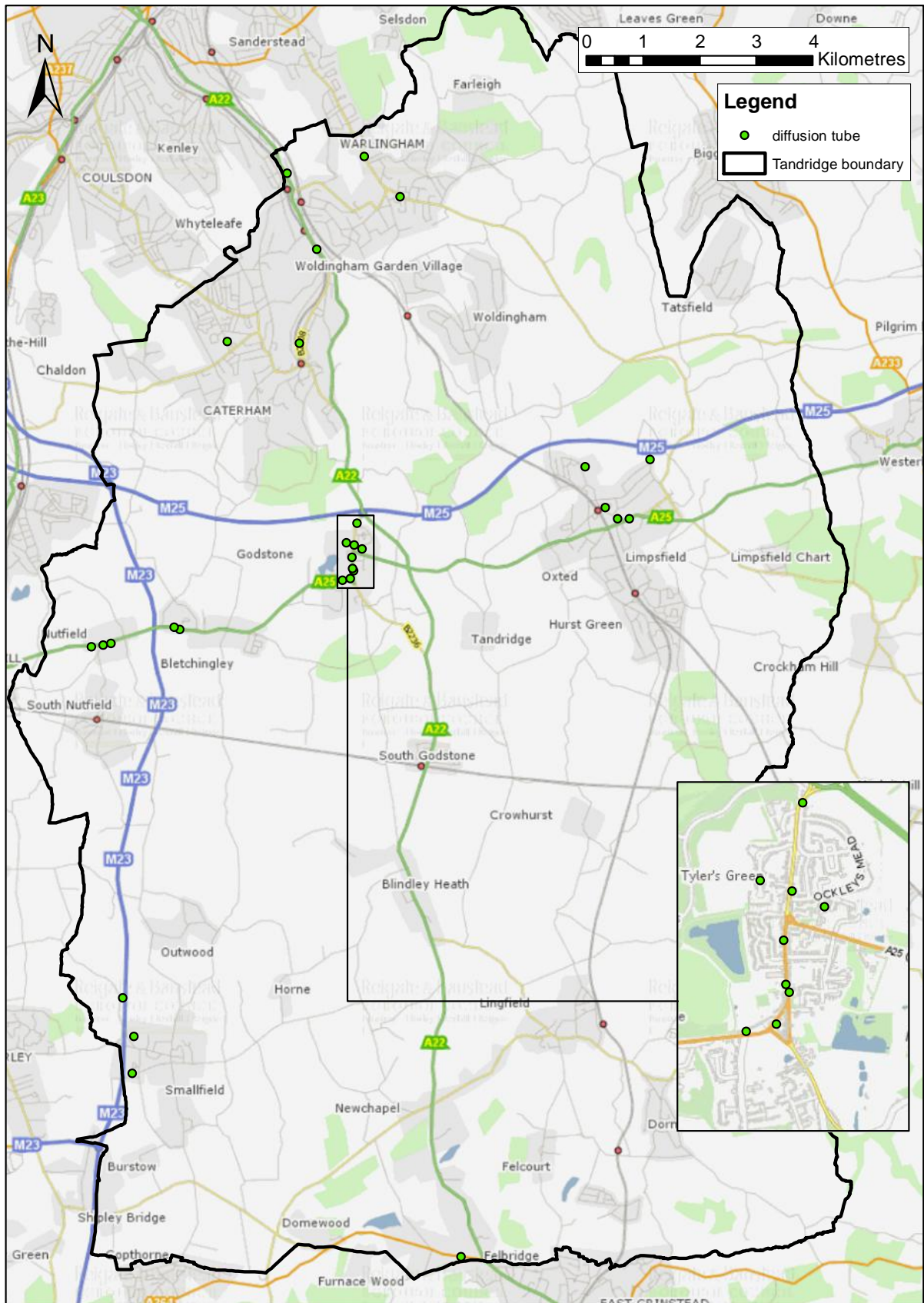


Figure 4.10: Diffusion tube locations, Tandridge

4.10 Waverley Borough Council

Figure 4.11 presents the locations of the two active AQMAs in Waverley. The AQMAs are:

- AQMA No. 1 Farnham
- AQMA No. 2 Godalming

Both AQMAs were declared for annual mean NO₂ concentrations.

Monitoring data for Waverley were not provided.

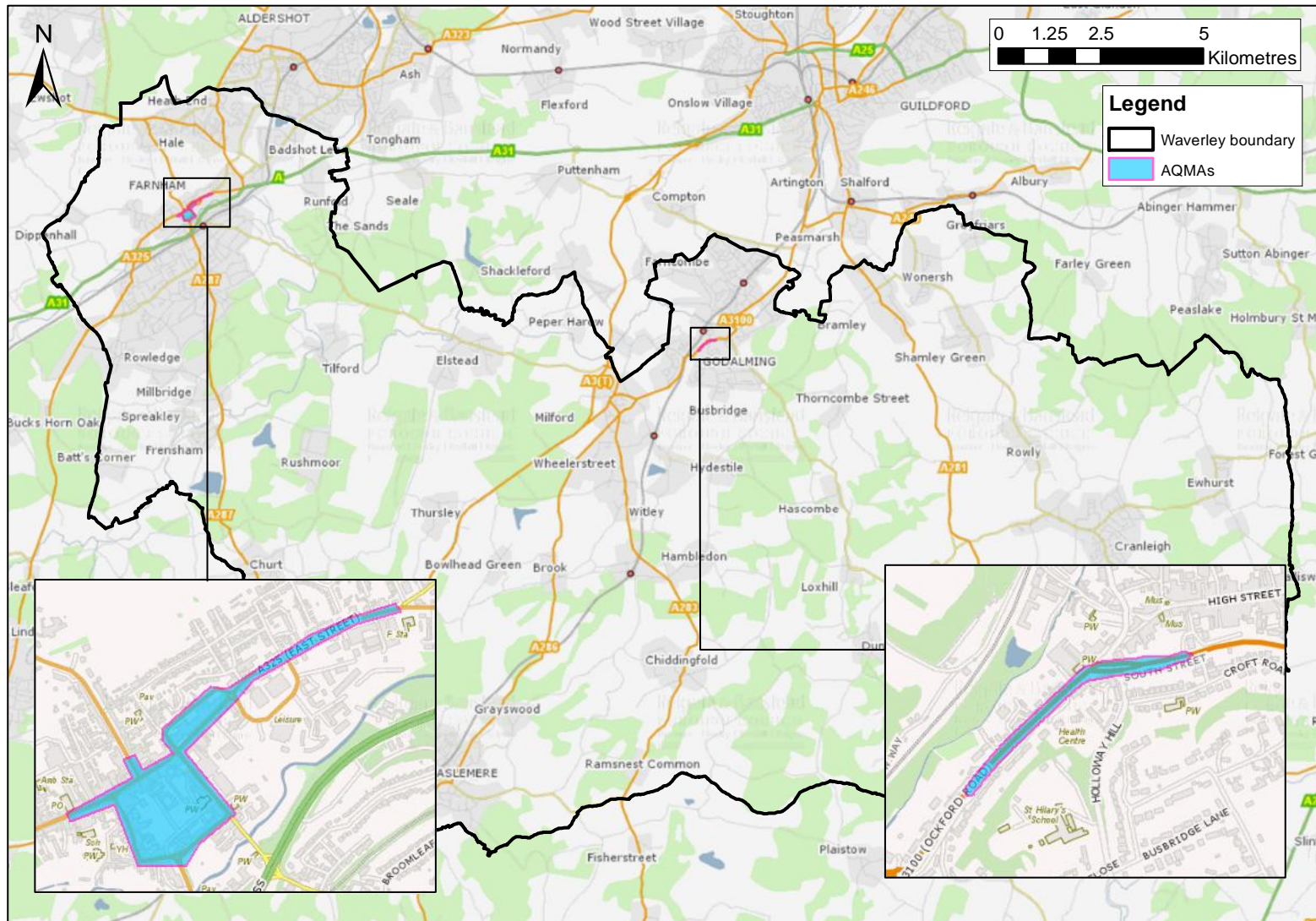


Figure 4.11: AQMA locations: Waverley

4.11 Woking Borough Council

Figure 4.12 presents the locations of monitoring sites throughout Woking, comprising 32 diffusion tubes and two AQMAs. The AQMAs are:

- Anchor Hill
- A small section of Guildford Road

Both AQMA were declared for annual mean NO₂ concentrations.

Table 4-13 presents the monitored annual average NO₂ concentrations for Woking in 2017. Exceedences of the UK Air Quality Objective of 40µg/m³ for annual average NO₂ concentrations are highlighted in **bold**.

Table 4-13: Monitored annual average NO₂ concentrations at Woking diffusion tubes, 2017

Site ID	Monitor type	Location	Height (m)	Distance to kerb (m)	Concentration (µg/m ³)
WOK_AH1	DT	496618, 158700	2.5	1	35
WOK_AH2	DT	496615, 158695	2.5	5	32
WOK_AH3	DT	496646, 158750	2.5	5	23
WOK_AH4	DT	496679, 158767	2.5	2	27
WOK_AH5	DT	496594, 158698	2.5	5	26
WOK_AH6	DT	496585, 158688	2.5	2	29
WOK_BD	DT	498025, 158949	2.5	2	15
WOK_BR	DT	495822, 157793	2.5	1	25
WOK_BR1	DT	495850, 157187	2.5	1.5	23
WOK_BW	DT	495875, 157972	2.5	1	22
WOK_CH	DT	500417, 158102	2.5	1.5	37
WOK_CH2	DT	500368, 158072	2.5	1	42
WOK_CH3	DT	500332, 158012	2.5	1.5	42
WOK_CH4	DT	500332, 157983	2.5	1	38
WOK_CR	DT	506401, 160505	2.5	1	21
WOK_CW	DT	496215, 157991	2.5	2	22
WOK_GR	DT	499950, 158540	2.5	1	26
WOK_LD	DT	503243, 159658	2.5	1	17
WOK_LGR	DT	496601, 158668	2.5	3	24
WOK_LT1	DT	500453, 158100	2.5	1	35
WOK_LTK	DT	500442, 158121	2.5	1	25
WOK_M25	DT	505611, 161179	2.5	0	43
WOK_MR	DT	501613, 159646	2.5	2	32
WOK_MR2	DT	501613, 159646	2.5	2	28
WOK_OR	DT	501665, 159161	2.5	3	25
WOK_PR	DT	504925, 161063	2.5	1	23
WOK_RC	DT	500946, 157110	2.5	1	18
WOK_TC	DT	506731, 161230	2.5	4	26
WOK_TW	DT	498435, 159451	2.5	1.5	14
WOK_VW	DT	500515, 159020	2.5	1	32
WOK_YR	DT	500450, 158278	2.5	1	25
WOK_YR1	DT	500451, 158256	2.5	1	25

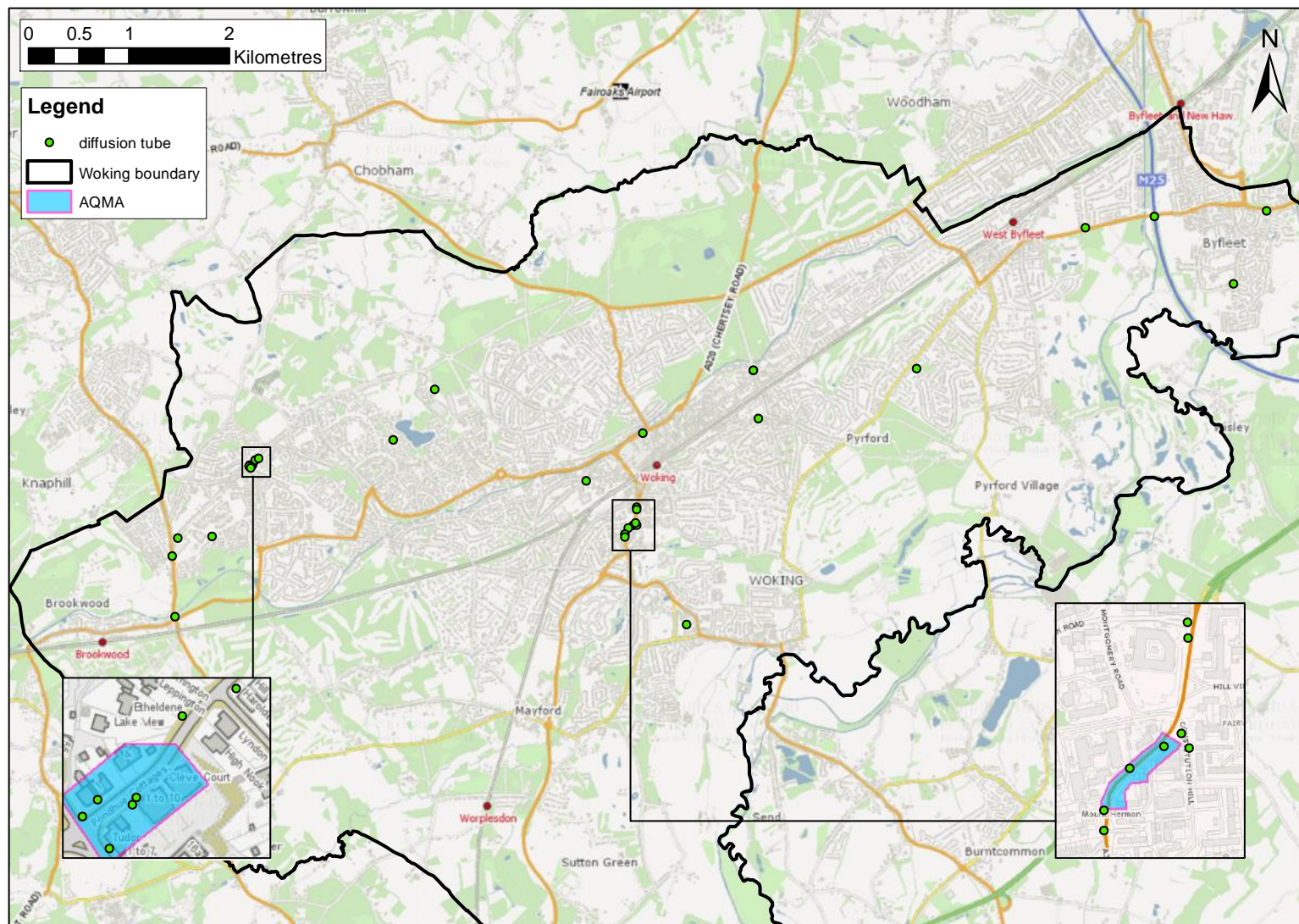


Figure 4.12: Diffusion tubes and AQMAs, Woking

5 Air quality modelling

5.1 Modelling software

All modelling was carried out using ADMS-Urban² version 4.2, developed by CERC. This model allows the effects of wider urban areas on local air quality to be taken into account.

5.2 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 roughness length of 0.5m was used for the dispersion site throughout the modelling, representing open suburbia.

The difference in land use at the meteorological station compared to the study area was taken into account by entering a different surface roughness for the meteorological station. See Section 5.4 for further details.

5.3 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 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. 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 minimum Monin-Obukhov length of 30 m was used in the modelling.

² <http://cerc.co.uk/environmental-software/ADMS-Urban-model.html>

5.4 Meteorological data

A year of hourly sequential meteorological data measured at Heathrow Airport in 2017 was used for model verification and subsequent modelling.

Table 5-1 summarises the meteorological data from Heathrow Airport. To take account of the different surface characteristics at Heathrow Airport, compared to the modelled area, a surface roughness of 0.2 m was assumed for the meteorological station.

Table 5-1: Summary of Heathrow meteorological data

Year	% of hours used	Parameter	Minimum	Maximum	Mean
2017	99.7	Temperature (°C)	-4	34	12.0
		Wind speed (m/s)	0	17	4.1
		Cloud cover (oktas)	0	8	5

The ADMS meteorological pre-processor, written by the UK Met Office, uses the data provided to calculate the parameters required by the program. Figure 5.1 presents a wind rose showing the frequency of occurrence of wind from different directions for a number of wind speed ranges for Heathrow Airport.

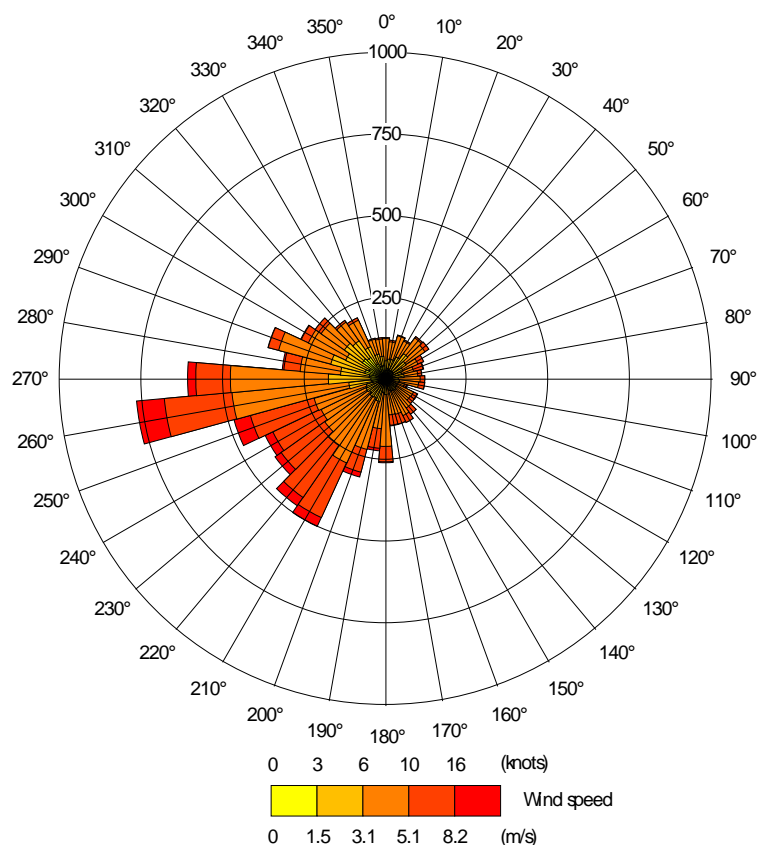


Figure 5.1: Wind rose for Heathrow 2017

5.5 Chemistry

The ADMS-Urban explicit chemistry scheme was used to model the interconversion between NO and NO₂, using wind dependent background concentrations derived from AURN rural monitoring sites. This approach allows for direct model verification against monitored concentrations for NO_x and NO₂, with simultaneous consideration of source dependent primary NO₂.

5.6 Background data

Hourly background data for the modelled pollutants and sulphur dioxide and ozone were input to the model to represent the concentrations in the air being blown into the area. NO_x, NO₂, SO₂, PM₁₀, PM_{2.5} and O₃ concentrations from Rochester Stoke, Chilbolton, Lullington Heath and Haringey Priory Park South for 2017 were input to the model, the monitored concentration used for each hour depending upon the wind direction for that hour, as shown in Figure 5.2.

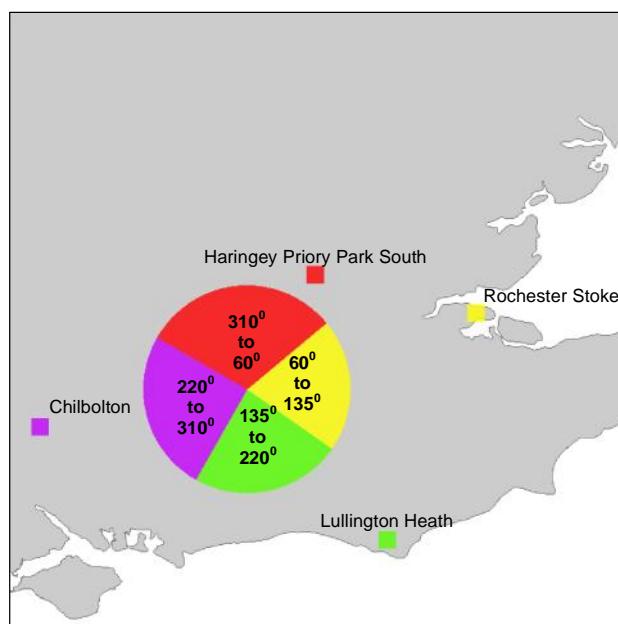


Figure 5.2: Wind direction segments used to calculate background concentrations for NO_x, NO₂, O₃, PM₁₀, PM_{2.5} and SO₂

Table 5-2 summarises the annual statistics for background data used for the modelling, calculated using wind data from Heathrow Airport.

Table 5-2: Summary of 2017 background data used in the modelling (µg/m³)

Statistic	NO _x	NO ₂	O ₃	PM ₁₀	PM _{2.5}	SO ₂
Annual average	17.5	12.0	51.3	14.8	8.8	0.9
99.79 th percentile of hourly average	392.4	80.0	111.8	-	-	-
90.41 st percentile of 24-hour average	-	-	-	26.0	19.0	1.4

5.7 Street canyons

The advanced street canyon module option in ADMS-Urban was used to modify the dispersion of pollutants from a road source according to the presence and properties of canyon walls on one or both sides of the road. Building footprint and height information was taken from OS Mastermap data, provided by Reigate and Banstead Borough Council. At some locations, the properties of canyons were altered due to inconsistencies between the width of the modelled road and the related canyon. Along the M3, street canyon parameters were altered to account for noise barriers on either side of the road, such as fences and hedges. These affect the dispersion of road emissions.

6 Emissions

Emission inventories were compiled for each of the scenarios modelled, using CERC's EMIT³ emissions inventory tool, version 3.6.

6.1 Road transport

Emissions from road transport were calculated using an activity data approach, whereby Annual Average Daily Traffic flows (AADTs) for each road link were combined with emission factors and speed data to calculate emissions for each road link on a vehicle-by-vehicle basis. This methodology is described below.

6.1.1 Emission factors

Traffic emissions of NO_x, NO₂, PM₁₀ and PM_{2.5} were calculated from traffic flows using EFT v8.0.1 emission factors based on Euro vehicle emissions categories. This dataset includes speed-emissions data that are based COPERT 5⁴ emission factors. EFT v8.0.1 include exhaust, brake, tyre and road wear for PM₁₀ and PM_{2.5}; resuspension emission factors were taken from a report produced by TRL Limited on behalf of Defra⁵.

Note that there is large uncertainty surrounding the current emissions estimates of NO_x from all vehicle types, in particular diesel vehicles; refer to, for example, an AQEG report from 2007⁶ and a Defra report from 2011⁷. In order to address this discrepancy, the NO_x emission factors were modified based on published Remote Sensing Data (RSD)⁸ for vehicle NO_x emissions in London. Scaling factors were applied to each vehicle category and speed.

6.1.2 Activity data

Traffic activity data were derived the Surrey Traffic Model, supplemented by Department for Transport (DfT) count data and local data from borough council detailed and further assessments. The split between these traffic data sources is illustrated by Figure 6.1.

³ <http://cerc.co.uk/environmental-software/EMIT-tool.html>

⁴ <http://www.emisia.com/copert/General.html>

⁵ Road vehicle non-exhaust particulate matter: final report on emission modelling, TRL Limited Project Report PPR110 http://uk-air.defra.gov.uk/reports/cat15/0706061624_Report2_Emission_modelling.PDF

⁶ [Trends in primary nitrogen dioxide in the UK](#)

⁷ [Trends in NO_x and NO₂ emissions and ambient measurements in the UK](#)

⁸ Carslaw, D and Rhys-Tyler, G 2013: New insights from comprehensive on-road measurements of NO_x, NO₂ and NH₃ from vehicle emission remote sensing in London, UK. *Atmos. Env.* **81** pp 339–347.

Surrey County Council provided AM peak, PM peak and inter-peak traffic flows and speeds, by vehicle type, from the Surrey Traffic Model for major roads across Surrey. The AM and PM peak flows were used to derive AADTs using conversion factors provided by Surrey County Council.

For each road, one of six conversion factors were applied depending on the type of road. Speeds used for the emission calculations for each road were derived by calculating a weighted average speeds, based on the flow of each vehicle throughout the day.

DfT provides traffic count data for the primary and strategic road network for the whole of the UK. Checking of traffic inputs during the model verification stage showed poor agreement between measured daily flows and the values derived from the Surrey Traffic Model on some motorways and major A roads. Therefore for the final emission calculations where DfT traffic counts were available, they were used in preference to values derived from the Surrey Traffic Model outputs.

Traffic inputs were refined, to use traffic flows and / or speeds from previous local assessments, where the values were significantly different to values calculated from the Surrey Traffic Model values. Local adjustments were based on traffic data reported in:

- Guildford Borough Council's Detailed Assessment for Compton Village⁹;
- Woking Borough Council's Further Assessment for Anchor Hill¹⁰; and
- Woking Borough Council's Detailed Assessment for Guildford Road¹¹.

⁹ http://www2.guildford.gov.uk/councilmeetings/documents/s9029/Item%2013%206-%20AQMA%20Compton%20-%20App%206%20-%20Compton%20AQAP%20Guildford_Draft1.pdf

¹⁰ <https://www.woking.gov.uk/sites/default/files/documents/environmentalservices/detailedassessmentforguildfordroad.pdf>

¹¹ https://www.woking.gov.uk/sites/default/files/documents/environmentalservices/WBC_Guildford%20Rd_AQAP%20final%20report.pdf

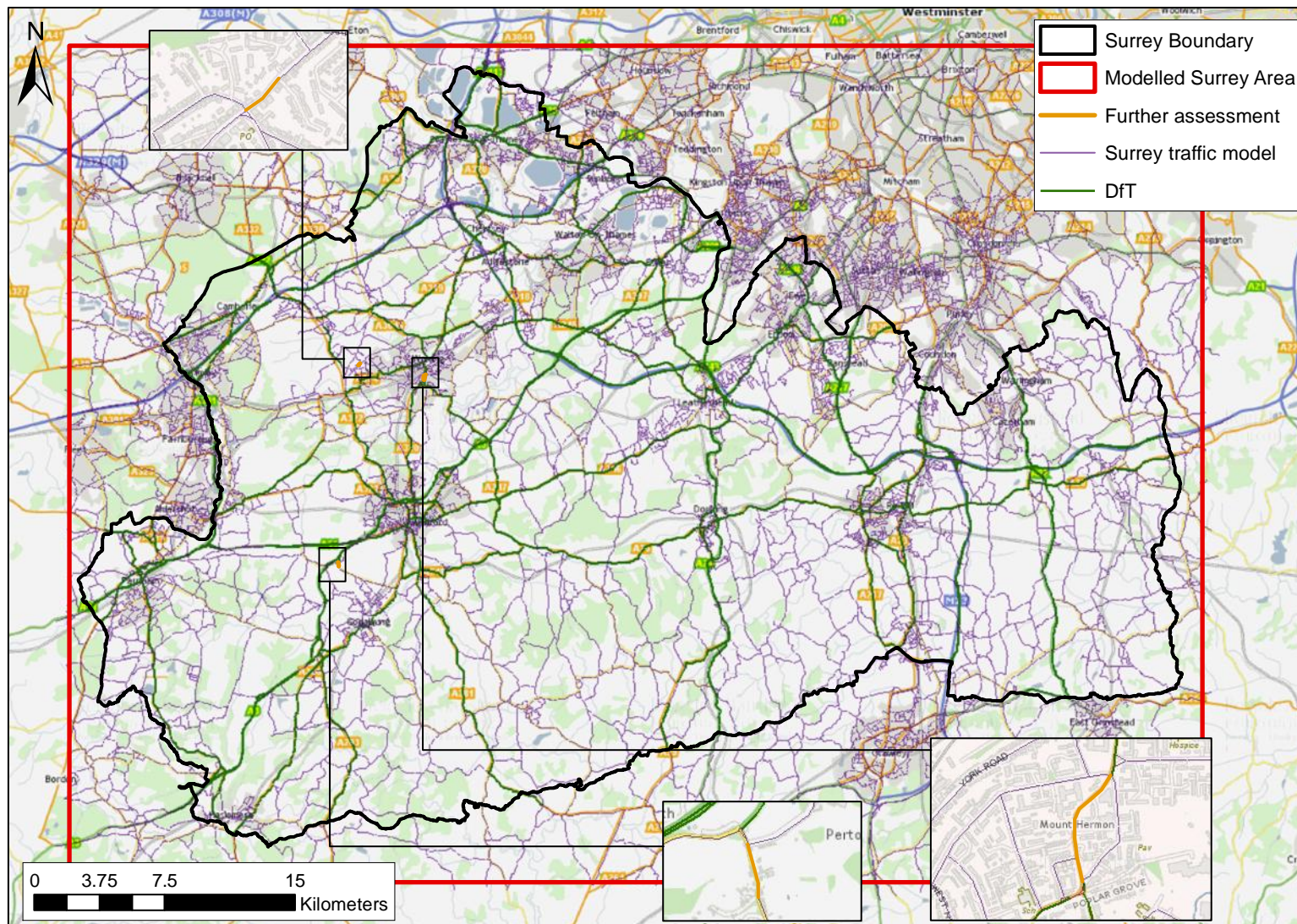


Figure 6.1: Traffic activity data split between Surrey traffic model output and DfT count statistics

6.1.3 Time-varying emissions

The variations of traffic flows during the day were taken into account by applying a diurnal profile to the road emissions. The profile was constructed by combining profiles derived from automatic traffic count (ATC) data for A25 Nutfield Road, provided by Surrey County Council, and average traffic distribution on all roads in Great Britain, as published by the DfT.¹² Averaging these two sets of profiles, generated a profile that was more consistent with the traffic flow conversion factors provided by Surrey County Council for all A & B roads in the county, leading to a greater confidence in the time-varying emissions profile used in the modelling. A comparison between the derived conversion factors for these profiles is shown in Table 6-1.

The calculated profile, shown in Figure 6.2, was applied to all modelled roads and grid sources, representing emissions aggregated on 1-km square basis, as described in Section 6.3.

Table 6-1: Comparison of traffic flow conversion factors for variation of traffic flows during the day

	Weekday to daily		Weekday				AM & PM peak to AADT	
	12hr to 24hr	24hr to 24hr	12hr to 24hr	AM peak to 24 hr	PM peak to 24 hr	AM peak spread		PM peak spread
DfT: UK roads	1.20	0.94	1.28	14.00	12.89	0.35	0.35	6.31
ATC – A25 Nutfield Road	1.13	0.94	1.20	10.84	10.87	0.40	0.39	5.12
Diurnal profile used in model	1.16	0.94	1.24	12.22	12.69	0.38	0.36	5.66
Surrey CC: All A & B roads	1.16	0.92	1.26	12.83	12.07	0.36	0.36	5.73

¹² <https://www.gov.uk/government/statistical-data-sets/road-traffic-statistics-tra>

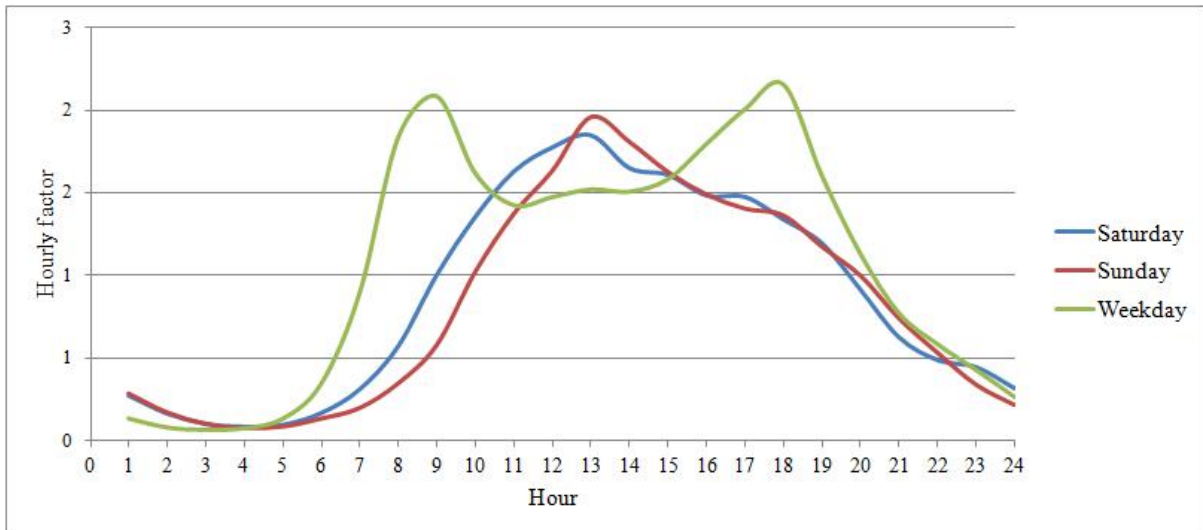


Figure 6.2: Diurnal emission factor profile used for road and grid sources

6.2 Industrial sources

The individual boroughs provided locations and parameters of 47 large industrial sources; including stack height, stack diameter, velocity, temperature and NO_x, PM₁₀ and PM_{2.5} emissions. These large industrial sources were modelled as point sources.

6.3 Other emissions

Emissions from other sources across the modelling domain were taken from the National Atmospheric Emissions Inventory (NAEI) 2015. Emissions from all other source types were modelled as an aggregated grid source with a resolution of 1 km. The NAEI data include emissions from Heathrow Airport and Gatwick Airport, located on the border of Surrey. The Surrey modelled area extends from (48000, 12900) to (54500, 17700), this extent is shown in Figure 6.1

7 Model verification

The first stage of a modelling assessment is to model a current case in order to verify that the input data and model set-up are appropriate for the area, by comparing measured and modelled concentrations for local monitoring locations. The monitor locations used for this purpose are described in Section 4. Concentrations were calculated at these monitoring locations for 2017.

The model verification involves an iterative process to improve the model set-up, for better agreement between measured and modelled concentrations. Table 7-1 summarises the main changes made to the model during the model verification process.

Table 7-1: Main changes to the model setup during the verification process

Verification version	Model changes
V1	<p>AA DT for all 61,294 road links derived from Surrey Traffic model data.</p> <p>Automated calculation of street canyon parameters on a Surrey-wide basis.</p> <p>Detailed checking and adjustment, where necessary, of the modelled distances between road sources and monitoring locations.</p> <p>Further manual changes to street canyons to ensure that monitoring locations were correctly located inside or outside of them.</p>
V2	<p>AA DT changed for 6,633 road links within the Surrey boundary, using DfT 2017 traffic counts.</p>
V3	<p>Street canyon parameters altered to account for the impact of noise barriers (fence and hedges) on the dispersion of emissions from the M3.</p>
V4	<p>AA DT changed of 10 road links where local traffic flows have been reported in detailed and further assessments.</p>

Model verification was conducted using meteorological data from both Heathrow Airport and Gatwick Airport. Due to generally better agreement between modelled and monitored concentrations, in particular at continuous monitoring sites, the set-up using Heathrow Airport data was used for the main modelling.

A comparison of model verification results using Heathrow and Gatwick data is included in Appendix A. Full details of the model verification using Gatwick Airport data is provided in Appendix B, including a summary of the meteorological data and the background data calculated using Gatwick wind data.

Figure 7.1 presents a scatter plot of monitored and modelled annual average NO₂ concentrations at the locations of 367 diffusion tubes and nine continuous monitors across the Surrey boroughs using Heathrow Airport meteorological data. Table 7-2 summarises model verification statistics at these locations. These data are also presented as box plots in Figure 7.2, to show the spread of measured and modelled annual average NO₂ concentrations by borough.

A summary of all continuous monitoring data is provided in Table 7-3. Further analysis of monitored and modelled concentrations at continuous monitoring locations are provided in the box plots in Figure 7.3 to Figure 7.6, comparing range of hourly mean concentrations NO_x, NO₂, PM₁₀ and PM_{2.5}. Note, only hours where there is valid model and monitor output are compared for continuous monitors.

Modelled annual average NO₂ concentrations are within 25% of the monitored value at 277 of 376 locations (74%), showing generally good performance of the model set-up across Surrey.

Some of the highest monitored concentrations, typically representing busy junctions or congested roads, are underpredicted by the model. These underpredictions may be due to complex traffic characteristics, e.g. slow moving stop-start traffic, not being fully represented in the model inputs. Locations where this is likely to be the case include RB136, located on the junction between Brighton Road and Star Lane, and RY23, located on the junction between Weir Road and Bridge Road. In addition, CH2, CH3 and LT1 along Guildford Road, Woking will be affected by congestion originating from diversions associated with development in the town centre¹³.

Concentrations are overpredicted by the model at three types of locations: background locations where the lowest concentrations in Surrey are measured; some locations close to the M3 and M25 motorways; and close to Gatwick Airport. The model overpredictions at some background locations are due to the background inputs to the model being higher than measured values. Along motorways, the model set-up may not fully capture the shielding impact of noise barriers and other noise abatement features along these roads. Gatwick Airport emissions are included as part of aggregated 1 km grid emissions; this generalised treatment will lead to some overprediction of concentrations close to the airport, affecting modelled concentrations at the RG3 continuous monitor, collocated diffusion tubes RB99, RB100 and RB101, along with MV9.

Discrepancies between modelled and monitored concentrations also represent uncertainty in the monitored values. Diffusion tube measurements are less accurate than measurements from continuous monitors; therefore good model agreement at continuous monitor sites is typically a better indicator of performance than comparisons against diffusion tube measurements.

Overall the model set-up provides a level of agreement that gives confidence for Surrey-wide model outputs.

¹³ https://www.woking.gov.uk/sites/default/files/documents/licencing/ASR_WBC_2018_Issued.pdf

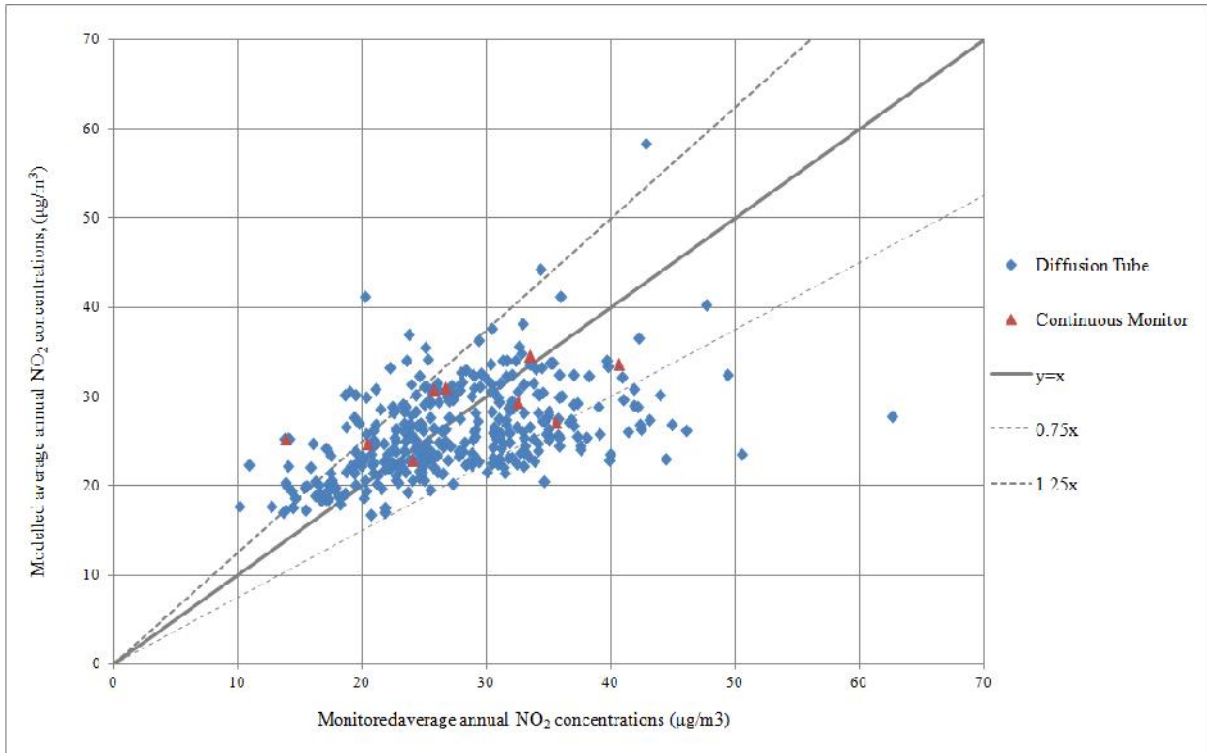


Figure 7.1: Scatter plot of measured and modelled annual average NO₂ concentrations

Table 7-2: Model verification statistics for annual average NO₂ concentrations

Heathrow	Min	Max	Mean	Count	Modelled / Monitored	<0.75	>0.75<1.25	>1.25	% >0.75<1.25
Diffusion tubes	16.7	58.3	26.1	367	1.00	56	269	42	73
Continuous monitors	22.8	34.5	28.8	9	1.09	0	8	1	89
All monitors	16.7	58.3	26.1	376	1.00	56	277	43	74

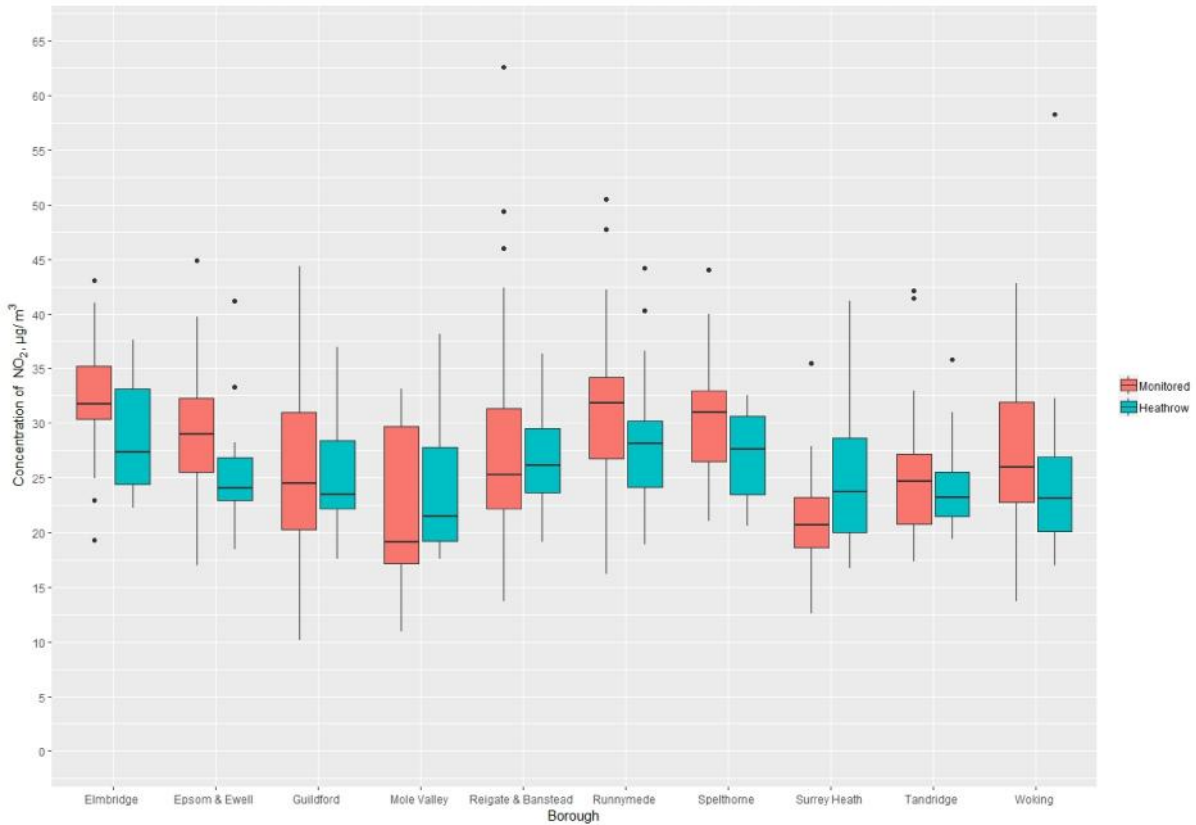


Figure 7.2: Box plots showing the spread of measured and modelled annual average NO_2 concentrations by Surrey borough. In this plot ‘outliers’, outside the range of $\pm 1.5 \times$ (inter-quartile range), are presented as points

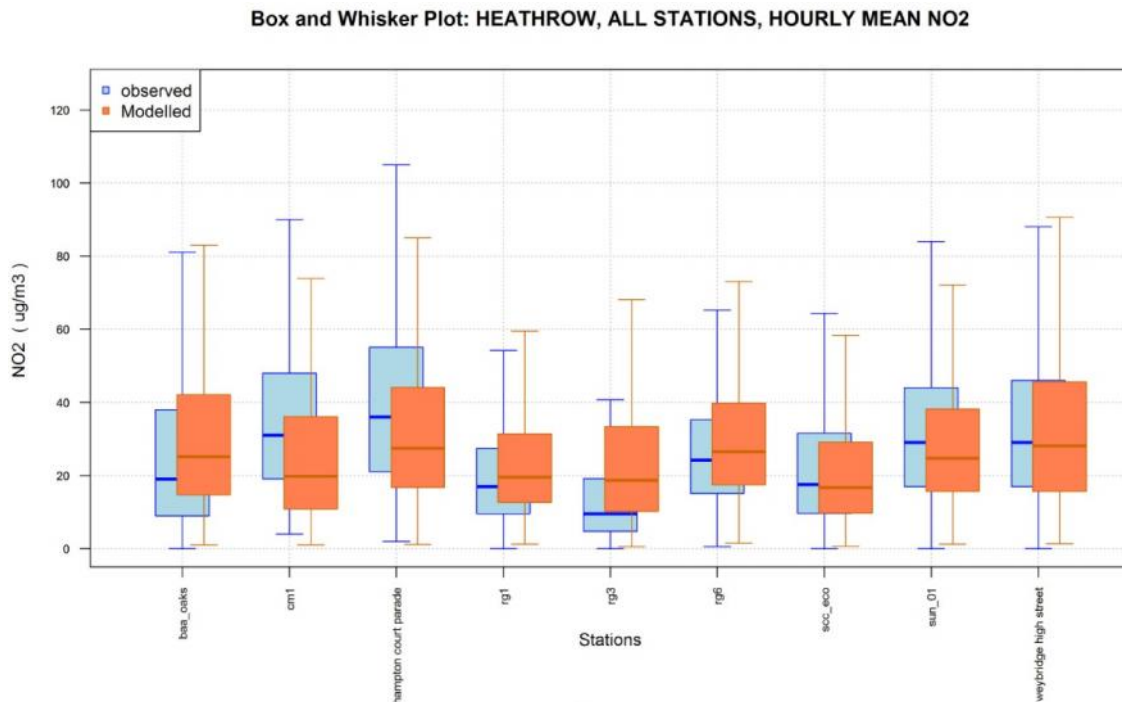


Figure 7.3: Box plots of measured and modelled hourly mean NO_2 concentrations at continuous monitoring sites

Box and Whisker Plot: HEATHROW, ALL STATIONS, HOURLY MEAN NO_x

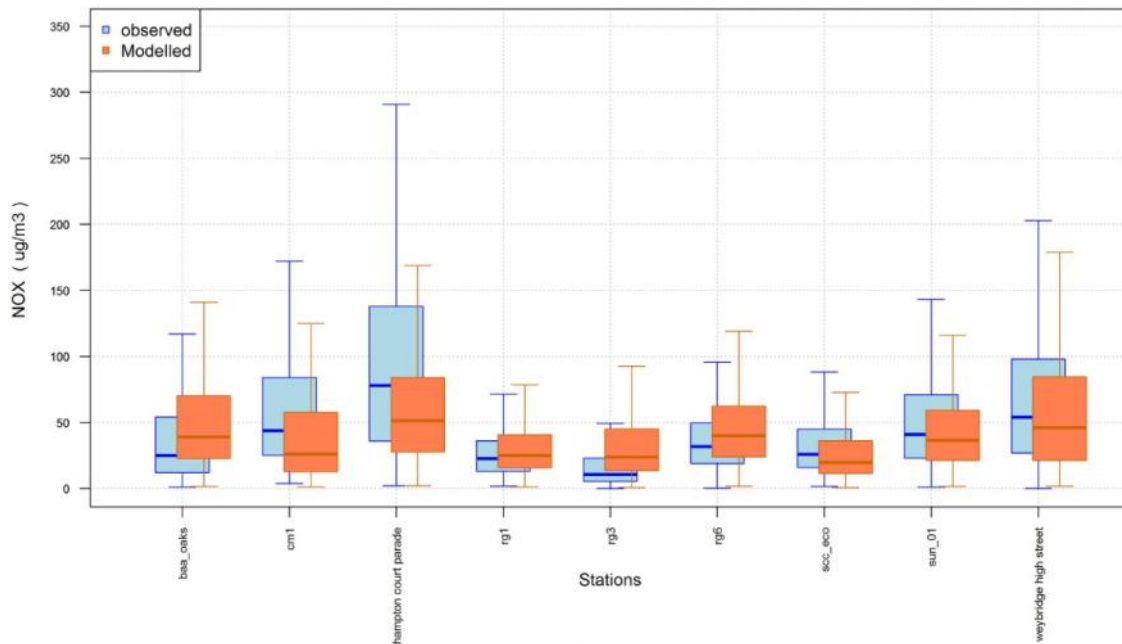


Figure 7.4: Box plots of measured and modelled hourly mean NO_x concentrations at continuous monitoring sites

Box and Whisker Plot: HEATHROW, ALL STATIONS, HOURLY MEAN PM₁₀

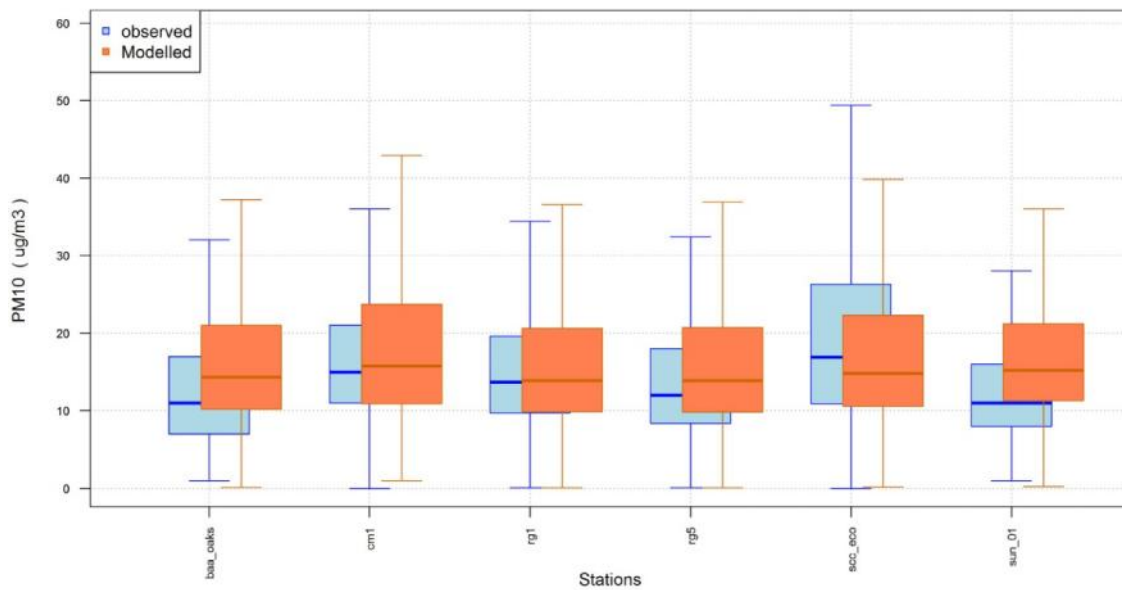


Figure 7.5: Box plots of measured and modelled hourly mean PM₁₀ concentrations at continuous monitoring sites

Box and Whisker Plot: HEATHROW, ALL STATIONS, HOURLY MEAN PM_{2.5}

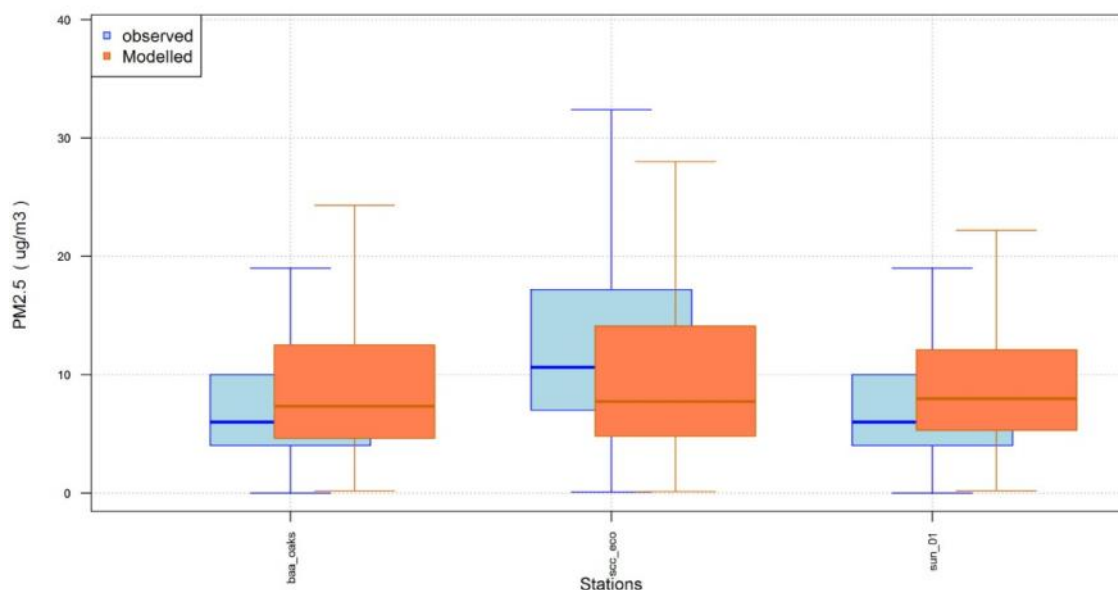


Figure 7.6: Box plots of measured and modelled hourly mean PM_{2.5} concentrations at continuous monitoring sites

Table 7-3: Measured and modelled annual average NO_x, NO₂, PM₁₀ and PM_{2.5} concentrations at continuous monitoring sites

Site ID	Monitored concentration, µg/m ³				Modelled concentration, µg/m ³				Modelled / Monitored (%)			
	NO _x	NO ₂	PM ₁₀	PM _{2.5}	NO _x	NO ₂	PM ₁₀	PM _{2.5}	NO _x	NO ₂	PM ₁₀	PM _{2.5}
BAA_OAKS	47.1	25.8	14.1	9.2	62.0	30.6	17.8	11.0	132	119	126	119
CM1	65.8	35.6	17.0	-	46.7	27.0	19.6	-	71	76	115	-
Hampton Court Parade	108.4	40.6	-	-	69.9	33.7	-	-	65	83	-	-
RG1	34.1	20.4	16.2	-	38.5	24.7	17.5	-	113	121	108	-
RG3	19.3	13.9	-	-	43.0	25.2	-	-	222	182	-	-
RG5	-	-	15.2	-	-	-	17.5	-	-	-	115	-
RG6	46.1	26.7	-	-	55.2	30.9	-	-	120	116	-	-
SCC_ECO	44.2	24.1	20.7	14.5	35.3	22.8	18.6	12.1	80	95	90	83
SUN_01	58.6	32.5	13.1	8.0	48.4	29.4	17.8	10.2	83	90	135	127
Weybridge High Street	77.5	33.5	-	-	66.8	34.5	-	-	86	103	-	-

8 Air quality maps

This section comprises county-wide air quality maps, for comparison against air quality objectives for NO₂, PM₁₀ and PM_{2.5}, outlined in Section 3. Annual mean NO₂, PM₁₀ and PM_{2.5} maps for individual boroughs are presented in separate reports.

Contour plots of pollutant concentrations were generated using a model output on a 100 m regular grid across the region, along with additional output points along modelled roads to capture the steep concentration gradients at roadside. These model-calculated concentrations are used to generate 10 m resolution air quality maps in GIS software, using the Natural Neighbour interpolation method.

In the air quality maps, exceedences of the air quality objective are shown in orange and red, and pollutant concentrations below objectives are shown in blue, green and yellow.

Figure 8.1 presents a contour plot of the modelled annual mean NO₂ concentrations across Surrey for 2017. Modelled concentrations show exceedences of the 40 µg/m³ annual mean NO₂ objective along motorways and other busy roads.

Figure 8.2 presents a contour plot of the modelled 99.79th percentile of hourly mean NO₂ concentrations across Surrey for 2017. Modelled concentrations show exceedences of the 200 µg/m³ objective concentration are along the motorways, as well as stretches of other busy roads.

Figure 8.3 presents a contour plot of the modelled annual mean PM₁₀ concentrations across Surrey for 2017. There are no exceedences of the 40 µg/m³ annual mean PM₁₀ objective outside the footprint of modelled roads.

Figure 8.4 presents a contour plot of the modelled 90.41st 24-hourly mean PM₁₀ concentrations across Surrey for 2017. Modelled concentrations show exceedences of the 50 µg/m³ objective along motorways and busy A roads.

Figure 8.5 presents a contour plot of the modelled annual mean PM_{2.5} concentrations across Surrey for 2017. Modelled concentrations show no exceedences of the 25 µg/m³ objective.

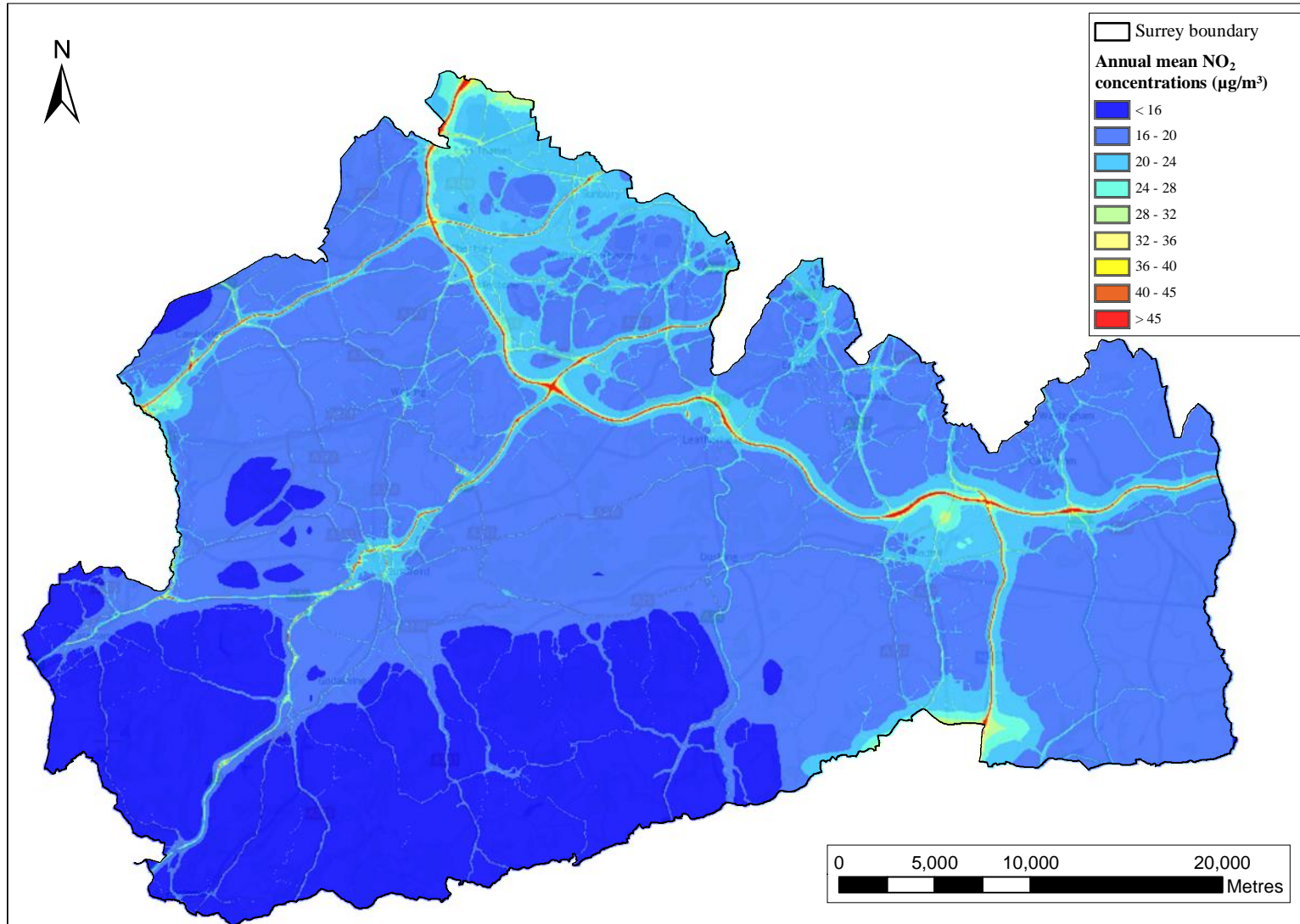


Figure 8.1: Annual mean NO_2 concentrations, 2017 ($\mu\text{g}/\text{m}^3$)

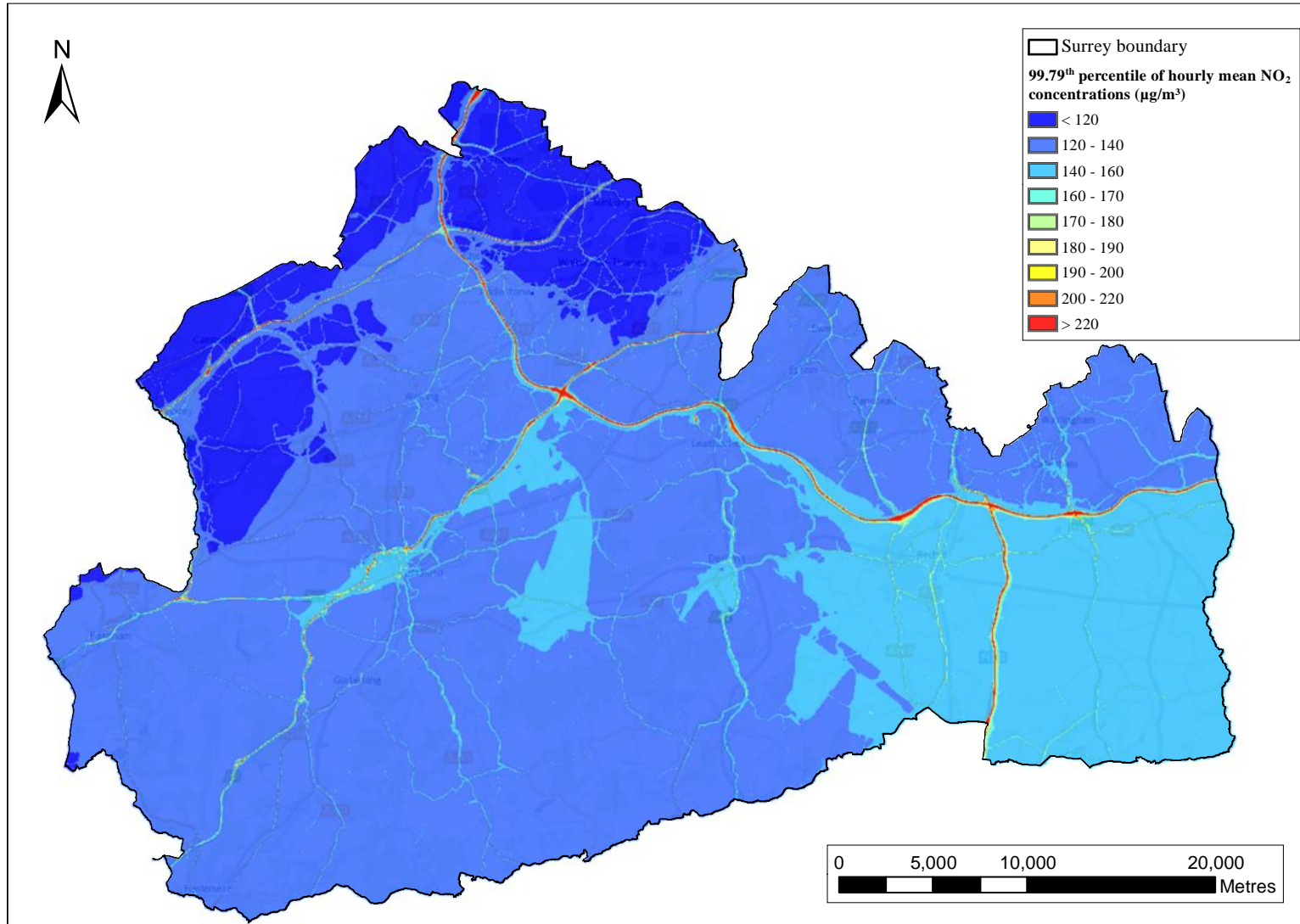


Figure 8.2: 99.79th percentile of hourly mean NO₂ concentrations, 2017 (µg/m³)

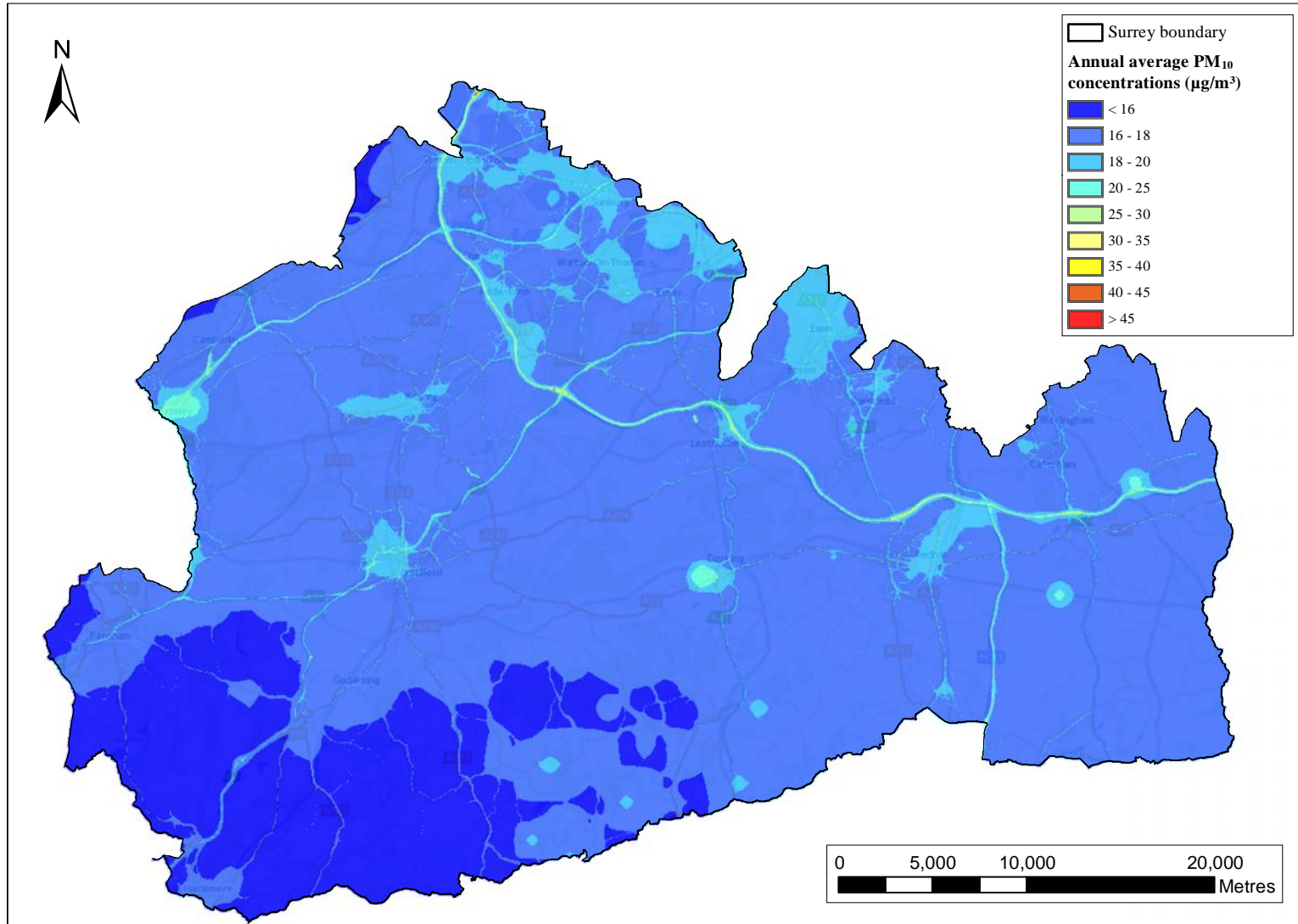


Figure 8.3: Annual mean PM₁₀ concentrations, 2017 ($\mu\text{g}/\text{m}^3$)

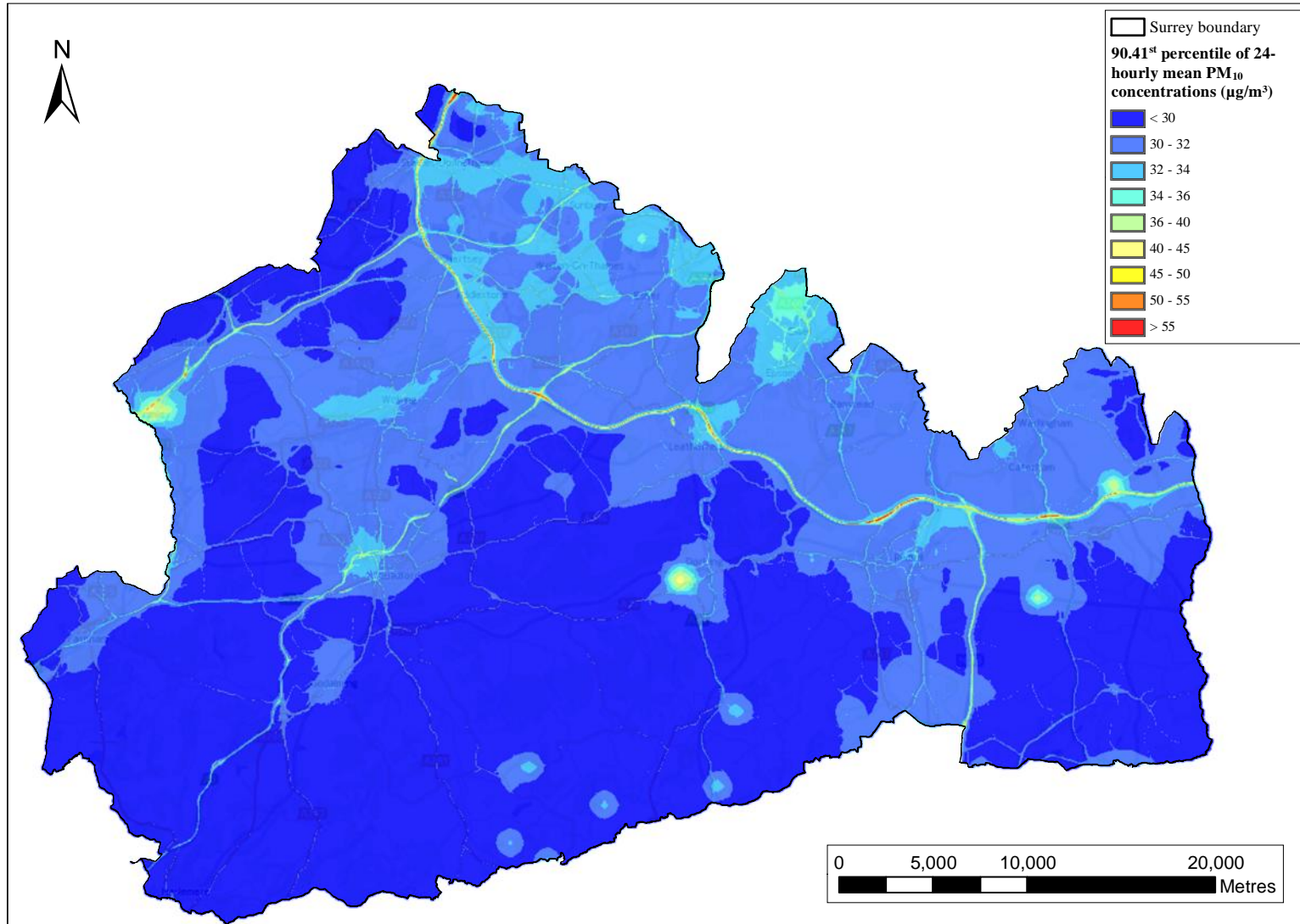


Figure 8.4: 90.41st percentile of 24-hourly mean PM_{10} concentrations, 2017 ($\mu\text{g}/\text{m}^3$)

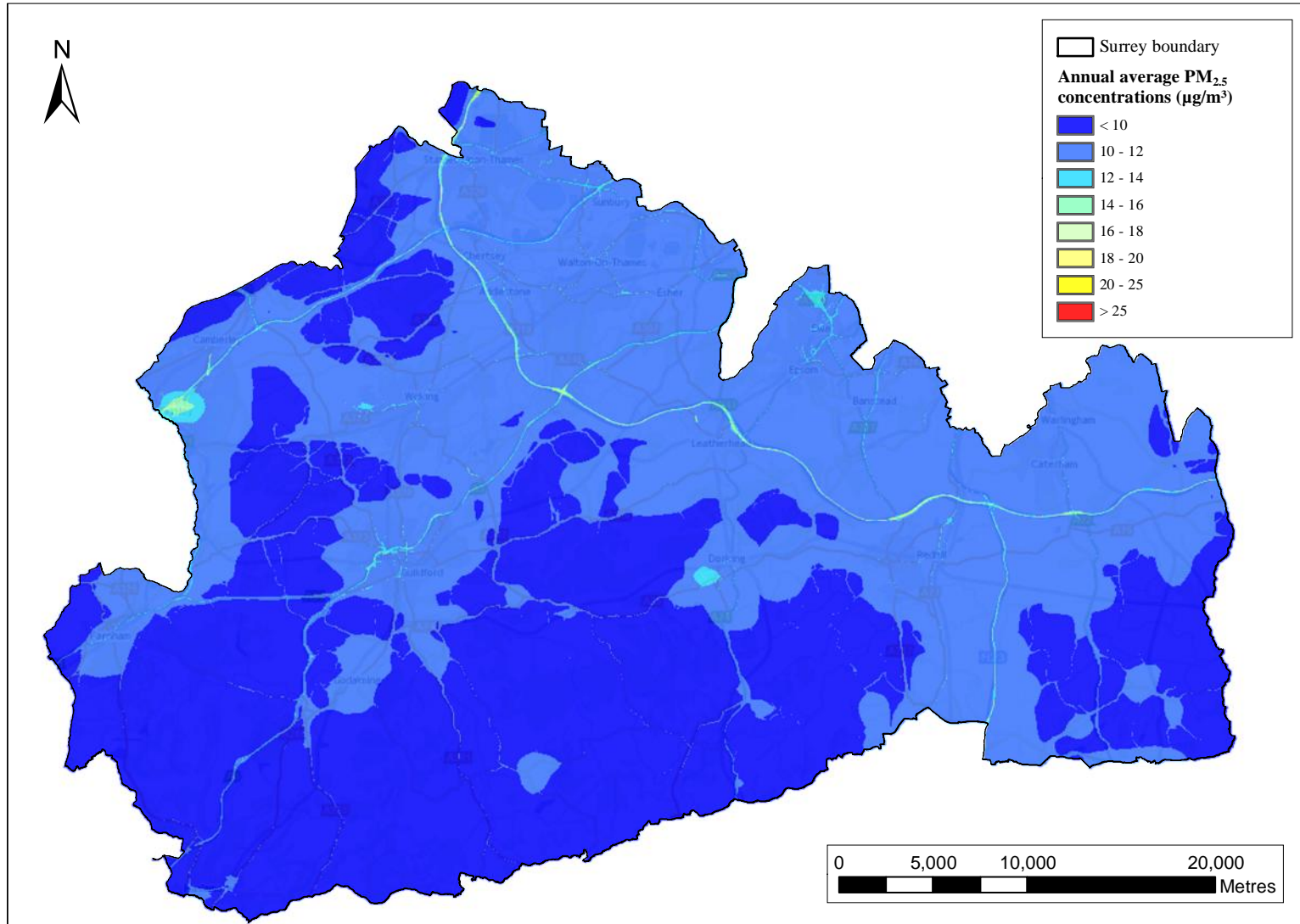


Figure 8.5: Annual mean PM_{2.5} concentrations, 2017 (µg/m³)

9 Mortality burden calculations

This section summarises local mortality burden of air pollution calculations. It includes the calculation of the number of deaths attributable to air pollution, the associated life-years lost and economic cost.

The mortality burden is 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)*¹⁴. 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 NO₂ and PM_{2.5}. The 2018 COMEAP report *Associations of long-term average concentrations of nitrogen dioxide with mortality*¹⁵ recommends revised CRFs for anthropogenic PM_{2.5} and NO₂ 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 NO₂ taken from four studies, as shown in Table 9-1, with the results from the two pollutants added for each study.

Table 9-1: Coefficients for use in burden calculations

Pollutant	Unadjusted coefficient	Jerrett et al (2013)	Fischer et al (2015)	Beelen et al (2014)	Crouse et al (2015)
NO ₂	1.023	1.019	1.016	1.011	1.020
PM _{2.5}	1.060	1.029	1.033	1.053	1.019

Mortality burdens calculations were carried out for Lower Layer Super Output Areas (LSOAs), each representing an area with a population of approximately 1,500. The Office for National Statistics (ONS) publishes population¹⁶ and death¹⁷ data split by age for each LSOA.

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 9-1, and c is the average pollutant concentration for that LSOA calculated from the concentration contour maps, presented in Section 8.

¹⁴ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/332854/PHE_CRCE_010.pdf

¹⁵ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734799/COMEAP_NO2_Report.pdf

¹⁶ <https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/lowersuperoutputareamidyearpopulationestimates>

¹⁷ <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/009235numberofdeathsregisteredineachlowersuperoutputareabysexandagedeathsregisteredin2017>

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 each local authority 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 life expectancy data are taken from the Public Health England Life Expectancy Calculator¹⁸, which uses ONS population and deaths data as input.

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 guidance¹⁹ of £42,780 at 2017 prices was used.

The mortality burdens by borough, provided in this report, were then calculated by aggregating the results for all LSOAs within each borough. All reported values are rounded to whole numbers. Ward level results are reported separately, for which the LSOAs results were aggregated by ward using ONS best fit lookup²⁰.

Table 9-2 summarises attributable deaths, life years lost and economic cost through NO₂ and PM_{2.5} concentrations by borough, using unadjusted coefficients for each of the single pollutants. A further calculation relating to the economic cost of life years lost is also included for each of the separate pollutants.

Table 9-3 summarises attributable deaths, life years lost and economic cost through NO₂ and PM_{2.5} concentrations by borough, using Fischer et al (2015) coefficients. A further calculation relating to the economic cost of life years lost is also included.

Table 9-4 summarises attributable deaths, life years lost and economic cost through NO₂ and PM_{2.5} concentrations by borough, using Beelen et al (2014) coefficients. A further calculation relating to the economic cost of life years lost is also included.

Table 9-5 summarises attributable deaths, life years lost and economic cost through NO₂ and PM_{2.5} concentrations by borough, using Crouse et al (2015) coefficients. A further calculation relating to the economic cost of life years lost is also included.

Table 9-6 summarises attributable deaths, life years lost and economic cost through NO₂ and PM_{2.5} concentrations by borough, using Jerrett et al (2013) coefficients. A further calculation relating to the economic cost of life years lost is also included.

¹⁸ <https://fingertips.phe.org.uk/.../PHE%20Life%20Expectancy%20Calculator.xlsm>

¹⁹ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/770649/imp-act-pathway-approach-guidance.pdf

²⁰ <http://geoportal.statistics.gov.uk/datasets/lower-layer-super-output-area-2011-to-ward-2018-lookup-in-england-and-wales-v3>

The calculated total life years lost in Surrey due to NO₂ and PM_{2.5} concentrations range from 6,610 years to 8,059 years. The calculated total economic cost ranges from £283 million to £345 million.

Using the unadjusted coefficients for the separate pollutants, the life years lost resulting from NO₂ and PM_{2.5} concentrations across Surrey are 5233 and 6200, respectively. The equivalent economic costs for NO₂ and PM_{2.5} are £224 million and £265 million, respectively.

Table 9-2: Summary of attributable deaths, life years lost and economic cost for NO₂ and PM_{2.5} concentrations by borough using unadjusted coefficients

Borough	NO ₂					PM _{2.5}					Total life years lost	Total economic cost (£)
	Concentrations (µg/m ³)	Attributable fraction	Attributable deaths	Life years lost	Economic cost (£)	Concentrations (µg/m ³)	Attributable fraction	Attributable deaths	Life years lost	Economic cost (£)		
Elmbridge	20.5	0.045	49	593	25,357,526	11.1	0.053	58	698	29,869,955	1,291	55,227,481
Epsom and Ewell	20.1	0.045	27	320	13,700,751	11.5	0.056	33	398	17,034,551	718	30,735,302
Guildford	19.0	0.042	45	558	23,858,735	10.7	0.051	55	678	28,998,352	1,236	52,857,086
Mole Valley	19.0	0.042	36	435	18,591,686	10.7	0.051	44	524	22,396,999	958	40,988,686
Reigate and Banstead	20.6	0.046	64	711	30,421,065	10.9	0.052	72	805	34,454,788	1,516	64,875,853
Runnymede	21.5	0.048	36	394	16,865,480	10.9	0.052	39	426	18,244,557	821	35,110,037
Spelthorne	22.4	0.050	44	525	22,469,203	11.2	0.054	48	570	24,389,831	1,095	46,859,034
Surrey Heath	20.1	0.045	34	394	16,858,630	11.0	0.053	40	469	20,056,469	863	36,915,098
Tandridge	19.5	0.043	35	418	17,882,645	10.5	0.050	41	482	20,602,534	900	38,485,179
Waverley	16.0	0.036	43	495	21,175,301	10.0	0.047	56	655	28,040,798	1,150	49,216,099
Woking	18.8	0.042	33	390	16,680,170	11.1	0.053	41	494	21,149,863	884	37,830,033
Total	-	-	445	5233	223,861,191	-	-	527	6200	265,238,697	11,433	489,099,888

*The pollutant concentrations presented are based on LSOA averaged concentrations and the attributable fractions and life years lost are calculated accordingly

Table 9-3: Summary of attributable deaths, life years lost and economic cost for NO₂ and PM_{2.5} concentrations by borough using Fischer et al (2015) coefficients

Borough	NO ₂					PM _{2.5}					Total life years lost	Total economic cost (£)
	Concentrations (µg/m ³)	Attributable fraction	Attributable deaths	Life years lost	Economic cost (£)	Concentrations (µg/m ³)	Attributable fraction	Attributable deaths	Life years lost	Economic cost (£)		
Elmbridge	20.5	0.032	35	417	17,824,921	11.1	0.030	33	394	16,846,034	810	34,670,955
Epsom & Ewell	20.1	0.031	19	225	9,630,009	11.5	0.031	19	225	9,612,179	450	19,242,188
Guildford	19.0	0.030	32	392	16,763,900	10.7	0.029	31	382	16,345,903	774	33,109,804
Mole Valley	19.0	0.030	26	305	13,064,606	10.7	0.029	25	295	12,624,867	601	25,689,473
Reigate and Banstead	20.6	0.032	45	500	21,389,258	10.9	0.030	41	454	19,427,194	954	40,816,452
Runnymede	21.5	0.034	25	277	11,862,444	10.9	0.029	22	240	10,287,053	518	22,149,497
Spelthorne	22.4	0.035	31	369	15,806,811	11.2	0.031	27	322	13,757,475	691	29,564,286
Surrey Heath	20.1	0.031	24	277	11,850,254	11.0	0.030	23	264	11,310,743	541	23,160,997
Tandridge	19.5	0.031	25	294	12,567,679	10.5	0.028	23	271	11,610,548	565	24,178,227
Waverley	16.0	0.025	30	347	14,862,852	10.0	0.027	32	369	15,792,233	717	30,655,084
Woking	18.8	0.029	23	274	11,720,132	11.1	0.030	23	279	11,927,804	553	23,647,936
Total	-	-	313	3,678	157,342,867	-	-	297	3,496	149,542,033	7,174	306,884,900

*The pollutant concentrations presented are based on LSOA averaged concentrations and the attributable fractions and life years lost are calculated accordingly

Table 9-4: Summary of attributable deaths, life years lost and economic cost for NO₂ and PM_{2.5} concentrations by borough using Beelen et al (2014) coefficients

Borough	NO ₂					PM _{2.5}					Total life years lost	Total economic cost (£)
	Concentrations (µg/m ³)	Attributable fraction	Attributable deaths	Life years lost	Economic cost (£)	Concentrations (µg/m ³)	Attributable fraction	Attributable Deaths	Life years lost	Economic cost (£)		
Elmbridge	20.5	0.022	24	289	12,346,890	11.1	0.0475	51	621	26,555,749	909	38,902,639
Epsom & Ewell	20.1	0.022	13	156	6,670,048	11.5	0.0494	30	354	15,146,527	510	21,816,575
Guildford	19.0	0.021	22	271	11,608,229	10.7	0.0455	49	603	25,777,396	874	37,385,625
Mole Valley	19.0	0.021	18	211	9,047,391	10.7	0.0455	39	465	19,909,296	677	28,956,687
Reigate and Banstead	20.6	0.022	31	346	14,818,304	10.9	0.0466	64	716	30,630,022	1,062	45,448,326
Runnymede	21.5	0.023	17	192	8,220,312	10.9	0.0463	34	379	16,219,233	571	24,439,545
Spelthorne	22.4	0.024	21	256	10,955,112	11.2	0.0481	42	507	21,684,524	763	32,639,636
Surrey Heath	20.1	0.022	16	192	8,208,181	11.0	0.0470	36	417	17,830,832	609	26,039,013
Tandridge	19.5	0.021	17	203	8,703,922	10.5	0.0446	36	428	18,313,016	632	27,016,937
Waverley	16.0	0.017	21	240	10,284,062	10.0	0.0422	50	583	24,920,582	823	35,204,644
Woking	18.8	0.020	16	190	8,115,712	11.1	0.0473	37	440	18,803,078	629	26,918,790
Total	-	-	217	2547	108,978,162	-	-	468	5512	235,790,256	8,059	344,768,418

*The pollutant concentrations presented are based on LSOA averaged concentrations and the attributable fractions and life years lost are calculated accordingly

Table 9-5: Summary of attributable deaths, life years lost and economic cost for NO₂ and PM_{2.5} concentrations by borough using Crouse et al (2015) coefficients

Borough	NO ₂					PM _{2.5}					Total life years lost	Total economic cost (£)
	Concentrations (µg/m ³)	Attributable fraction	Attributable deaths	Life years lost	Economic cost (£)	Concentrations (µg/m ³)	Attributable fraction	Attributable Deaths	Life years lost	Economic cost (£)		
Elmbridge	20.5	0.040	43	518	22,148,554	11.1	0.018	19	230	9,828,813	747	31,977,368
Epsom & Ewell	20.1	0.039	23	280	11,966,481	11.5	0.018	11	131	5,609,791	411	17,576,272
Guildford	19.0	0.037	39	487	20,835,475	10.7	0.017	18	223	9,534,357	710	30,369,831
Mole Valley	19.0	0.037	32	380	16,236,635	10.7	0.017	14	172	7,363,936	552	23,600,571
Reigate and Banstead	20.6	0.040	56	621	26,573,932	10.9	0.017	24	265	11,333,366	886	37,907,298
Runnymede	21.5	0.042	31	344	14,734,858	10.9	0.017	13	140	6,001,204	485	20,736,061
Spelthorne	22.4	0.043	38	459	19,632,227	11.2	0.018	16	188	8,027,452	647	27,659,680
Surrey Heath	20.1	0.039	30	344	14,724,961	11.0	0.017	13	154	6,599,042	498	21,324,003
Tandridge	19.5	0.038	31	365	15,618,115	10.5	0.016	13	158	6,771,424	523	22,389,539
Waverley	16.0	0.031	37	432	18,483,797	10.0	0.016	19	215	9,207,092	647	27,690,889
Woking	18.8	0.037	29	341	14,566,604	11.1	0.018	14	163	6,959,188	503	21,525,792
Total	-	-	389	4570	195,521,638	-	-	173	2039	87,235,665	6,610	282,757,304

*The pollutant concentrations presented are based on LSOA averaged concentrations and the attributable fractions and life years lost are calculated accordingly

Table 9-6: Summary of attributable deaths, life years lost and economic cost for NO₂ and PM_{2.5} concentrations by borough using Jerrett et al (2013) coefficients

Borough	NO ₂					PM _{2.5}					Total life years lost	Total economic cost (£)
	Concentrations (µg/m ³)	Attributable fraction	Attributable Deaths	Life years lost	Economic cost (£)	Concentrations (µg/m ³)	Attributable fraction	Attributable Deaths	Life years lost	Economic cost (£)		
Elmbridge	20.5	0.038	41	493	21,072,493	11.1	0.027	29	347	14,860,060	840	35,932,554
Epsom & Ewell	20.1	0.037	22	266	11,384,960	11.5	0.028	17	198	8,479,675	464	19,864,636
Guildford	19.0	0.035	37	463	19,821,949	10.7	0.025	27	337	14,417,750	800	34,239,699
Mole Valley	19.0	0.035	30	361	15,447,070	10.7	0.025	22	260	11,135,650	621	26,582,720
Reigate and Banstead	20.6	0.038	53	591	25,283,706	10.9	0.026	36	401	17,136,317	992	42,420,023
Runnymede	21.5	0.040	30	328	14,020,157	10.9	0.026	19	212	9,073,983	540	23,094,140
Spelthorne	22.4	0.041	36	437	18,680,483	11.2	0.027	24	284	12,135,893	720	30,816,376
Surrey Heath	20.1	0.037	28	327	14,009,495	11.0	0.026	20	233	9,977,234	561	23,986,729
Tandridge	19.5	0.036	29	347	14,858,852	10.5	0.025	20	239	10,240,605	587	25,099,457
Waverley	16.0	0.030	35	411	17,582,034	10.0	0.024	28	326	13,927,537	737	31,509,571
Woking	18.8	0.035	27	324	13,858,042	11.1	0.026	21	246	10,521,603	570	24,379,645
Total	-	-	370	4348	186,019,243	-	-	262	3083	131,906,307	7,432	317,925,550

*The pollutant concentrations presented are based on LSOA averaged concentrations and the attributable fractions and life years lost are calculated accordingly

10 Source apportionment

Apportionment of emissions and concentrations by source group is presented in this section. The first section presents apportionment of emissions from sources within the Surrey modelled area and the second section presents source apportionment of concentrations summarised by borough.

More detailed source apportionment of concentrations is reported separately, to show the concentration breakdown at each of the 222 receptor locations provided by the borough councils.

10.1 Emissions

Figure 10.1 shows the breakdown of Surrey NO_x emissions by each major source group. The majority of NO_x emissions (53%) are from road sources. Other sources, from NAEI data, represent 44% of NO_x emissions in Surrey; this group includes the emissions from sources such as other transport and machinery (65%), combustion in commercial, residential and agricultural sectors (27%) and combustion in industry (7%).

Road transport NO_x emissions by vehicle type is shown in Figure 10.2. The largest contributions to road transport NO_x emissions are from light diesel vehicles (73%), corresponding to the Diesel Cars (34%) and LGV (39%) source apportionment groups; note the LGV group contains both petrol and diesel light goods vehicles, of which 97% are assumed to be diesel in the EFT fleet projections used in the emission calculations.

The proportion NO_x emitted as NO₂, known as primary NO₂, will vary by vehicle type. Primary NO₂ percentages by vehicle type for 2017 are shown in Table 10-1. Highest NO₂ percentages are for the NO_x emissions from light diesel vehicles, which along with Figure 10.2; indicate that these vehicles will have the largest direct contribution to NO₂ concentrations.

Table 10-1: Primary NO₂ percentage for Surrey road transport NO_x emissions by vehicle type

Petrol Cars and Motorcycles	Diesel Cars	LGVs	Buses and Coaches	Rigid HGVs	Articulated HGVs	All vehicles
5%	35%	34%	10%	10%	9%	27%

Figure 10.3 shows the contribution to PM₁₀ emissions within Surrey by each major source group. Compared to the NO_x emissions breakdown the proportion of PM₁₀ emissions attributed to road emissions is significantly smaller (24%). The largest emissions come from other sources (75%) such as commercial, residential and agricultural sectors (67%), production processes (12%) and other transport and machinery (6%).

A breakdown of road transport exhaust PM_{10} emissions by vehicle type is shown in Figure 10.4; similar to the breakdown of NO_x emissions by vehicle type, exhaust PM_{10} emissions are dominated by light diesel vehicle emissions. However, as shown by Figure 10.5 road transport PM_{10} emissions are dominated by non-exhaust emissions such as brake wear (32%) and tyre wear (23%); only 12% of road transport PM_{10} emissions in Surrey are attributed to exhaust emissions.

The apportionment of $PM_{2.5}$ emissions are shown in Figure 10.6 to Figure 10.8. The breakdown of $PM_{2.5}$ is similar to the breakdown of PM_{10} emissions: 82% of emissions stem from other sources such as commercial, residential and agricultural sectors (79%), other transport and machinery (7%) and other sources and sinks (4%). 17% of Surrey emissions are attributed to road transport, these road transport emissions are dominated by non-exhaust emissions (78%). Road transport exhaust emissions are dominated by light diesel vehicles (74%). Note that resuspension does not contribute to $PM_{2.5}$ emissions.

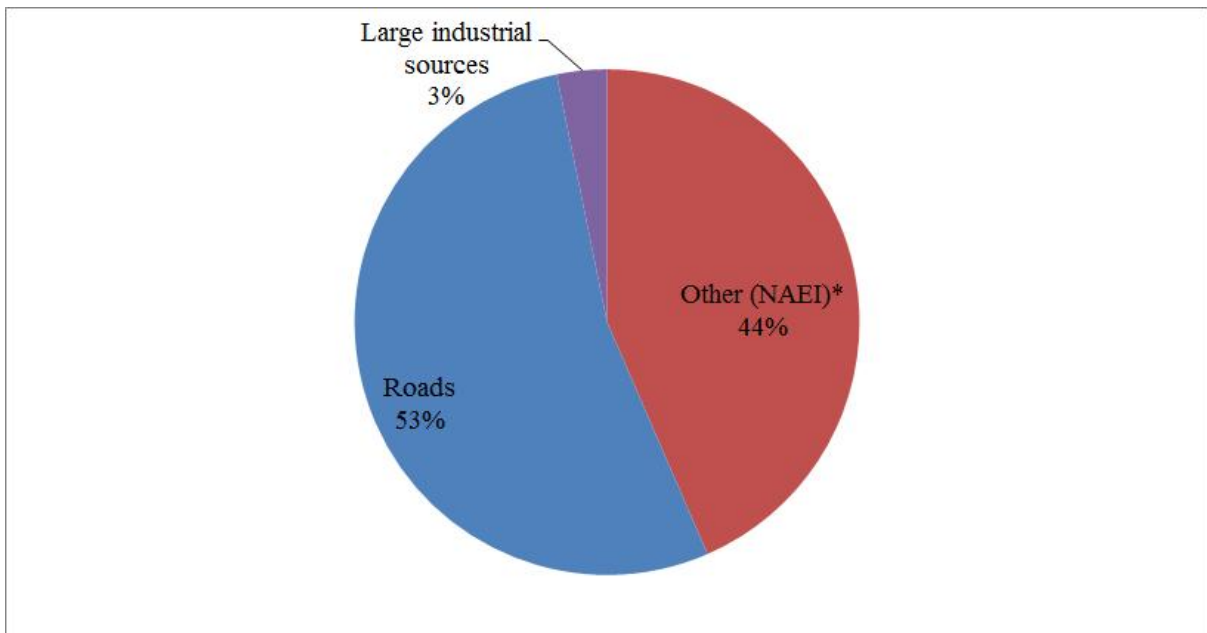


Figure 10.1: Surrey NO_x emissions by major source group. *See Section 10.1 for details of Other (NAEI) group

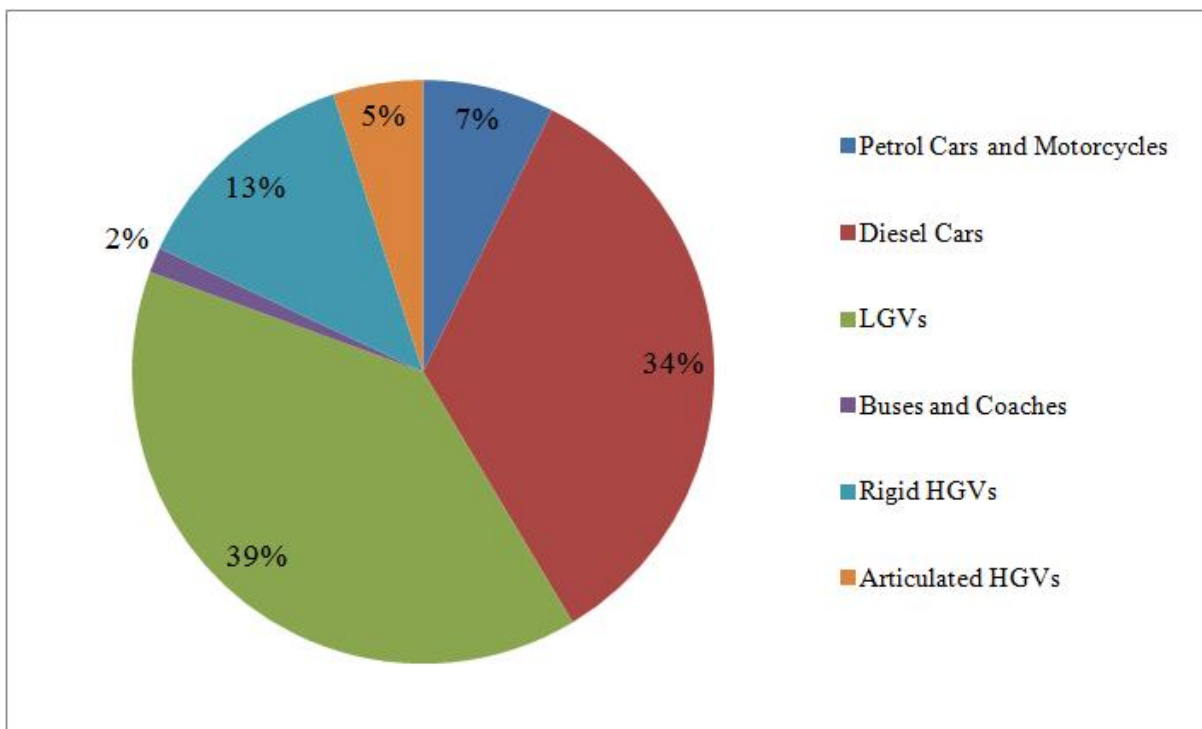


Figure 10.2: Surrey road transport NO_x emissions by vehicle category

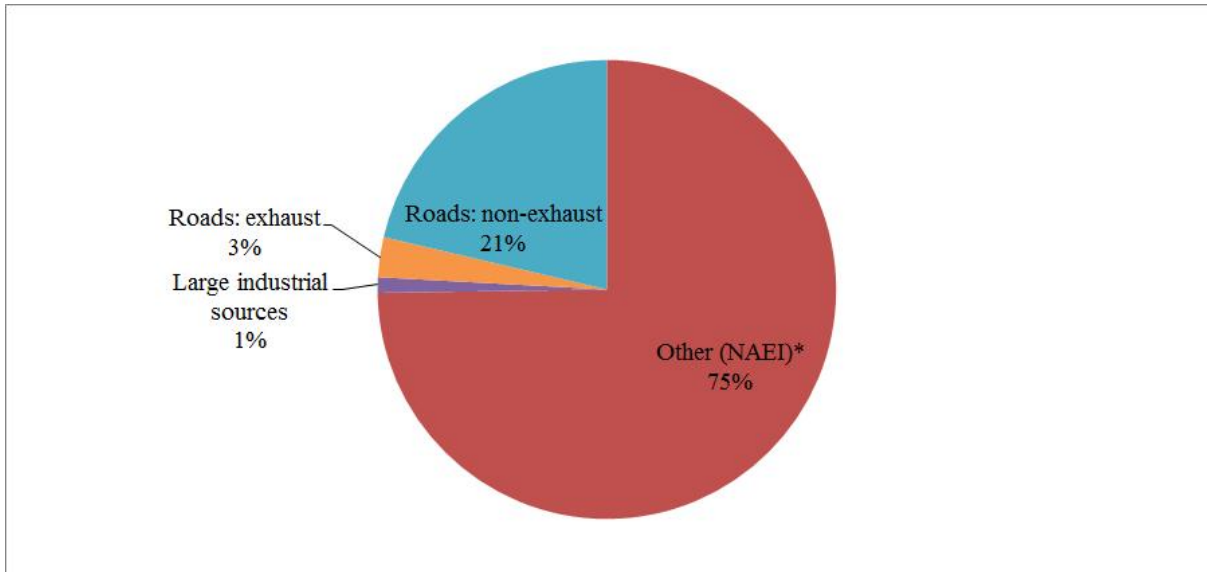


Figure 10.3: Surrey PM_{10} emissions by major source group. *See Section 10.1 for details of Other (NAEI) group

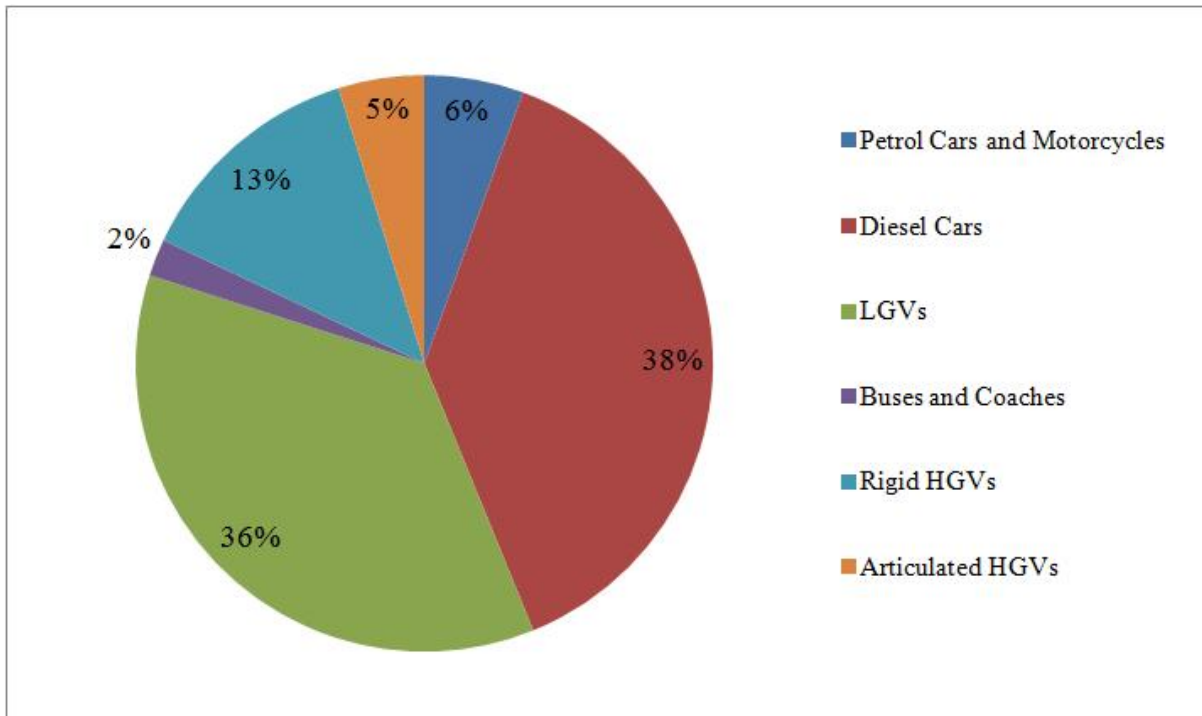


Figure 10.4: Surrey road transport exhaust PM_{10} emissions by vehicle category

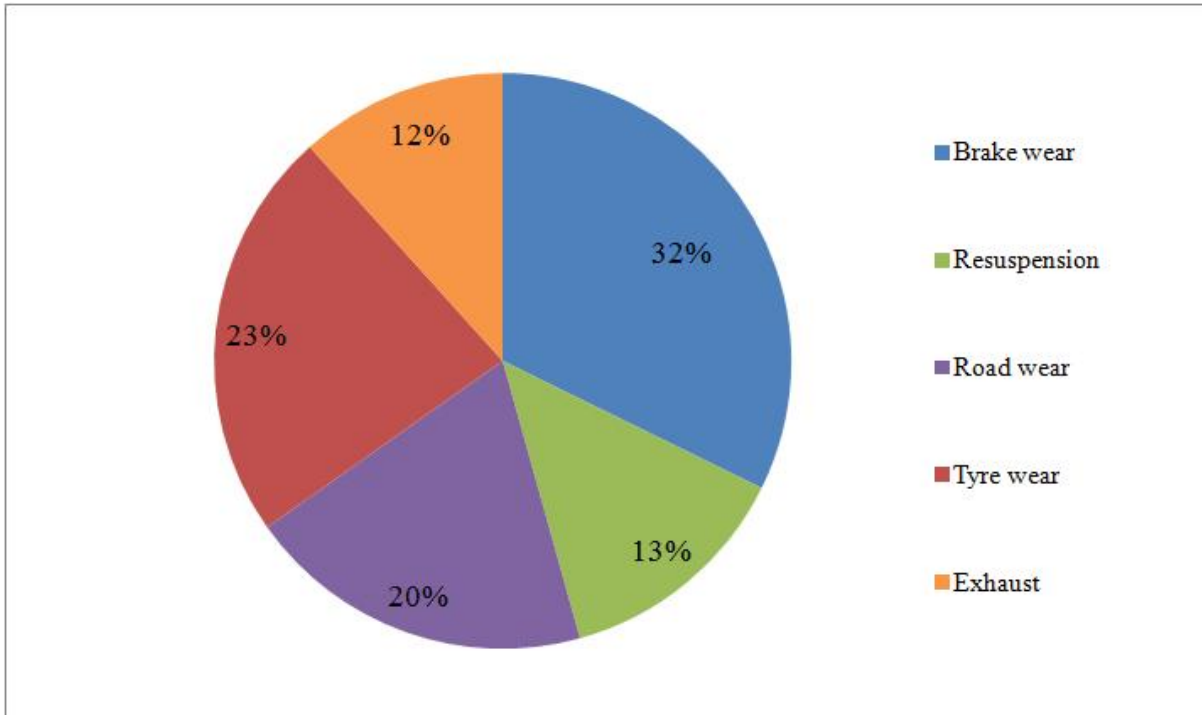


Figure 10.5: Surrey Road transport PM_{10} emissions by exhaust and non-exhaust components

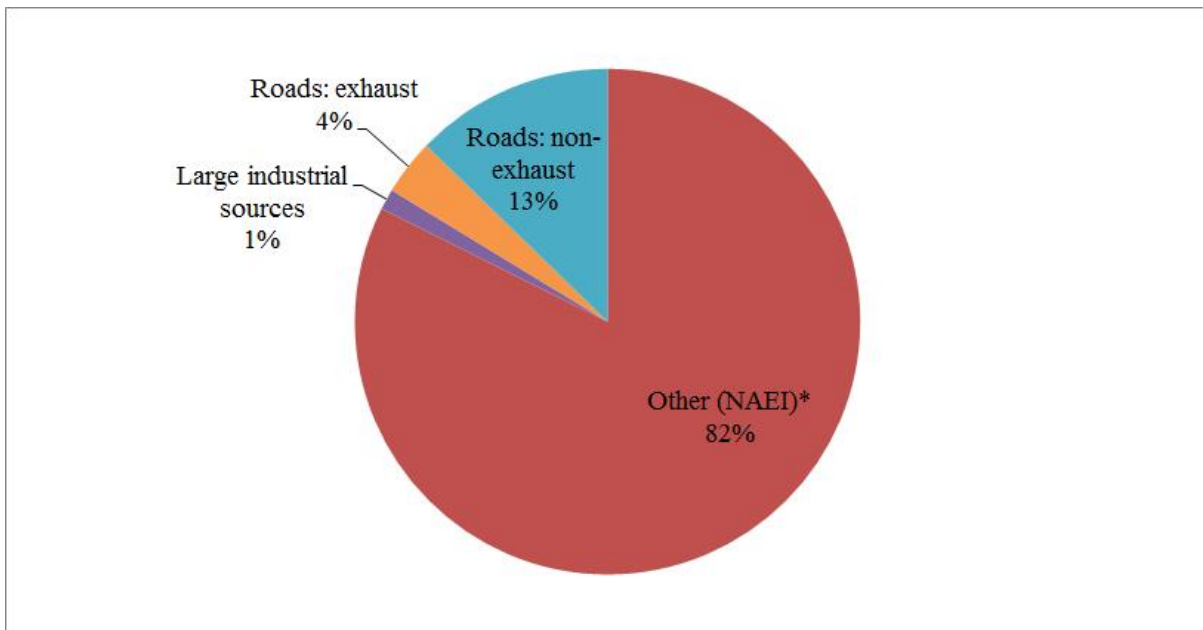


Figure 10.6: Surrey $PM_{2.5}$ emissions by major source group. *See Section 10.1 for details of Other (NAEI) group

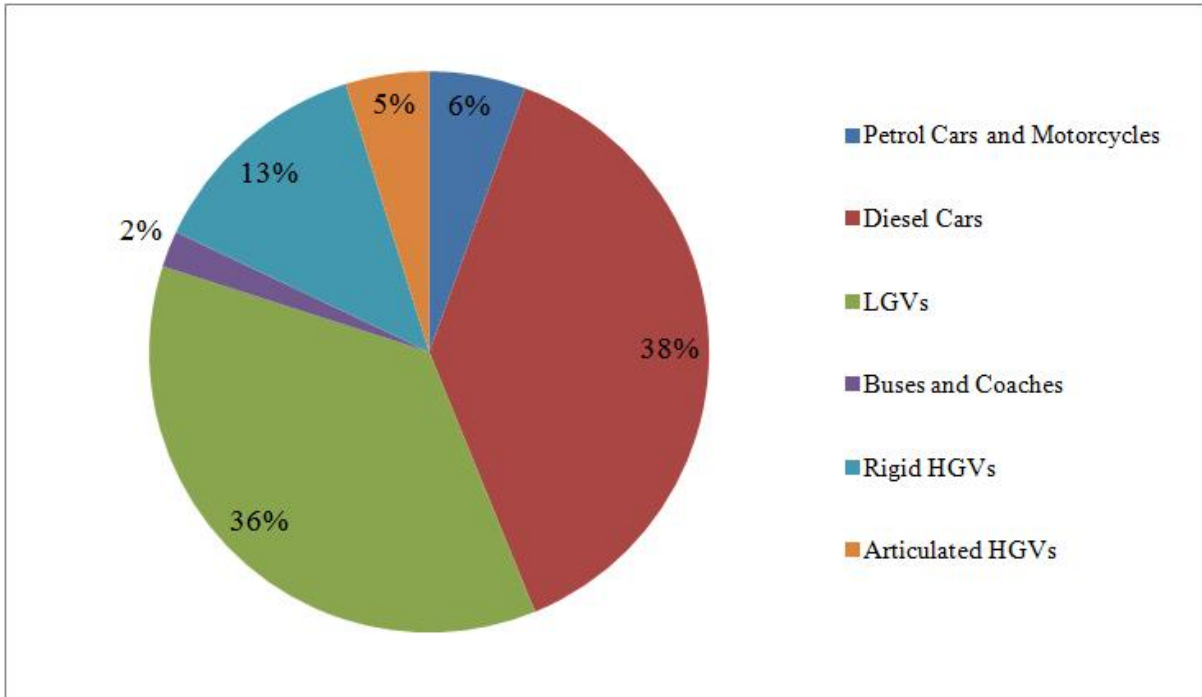


Figure 10.7: Surrey road transport exhaust $PM_{2.5}$ emissions by vehicle category

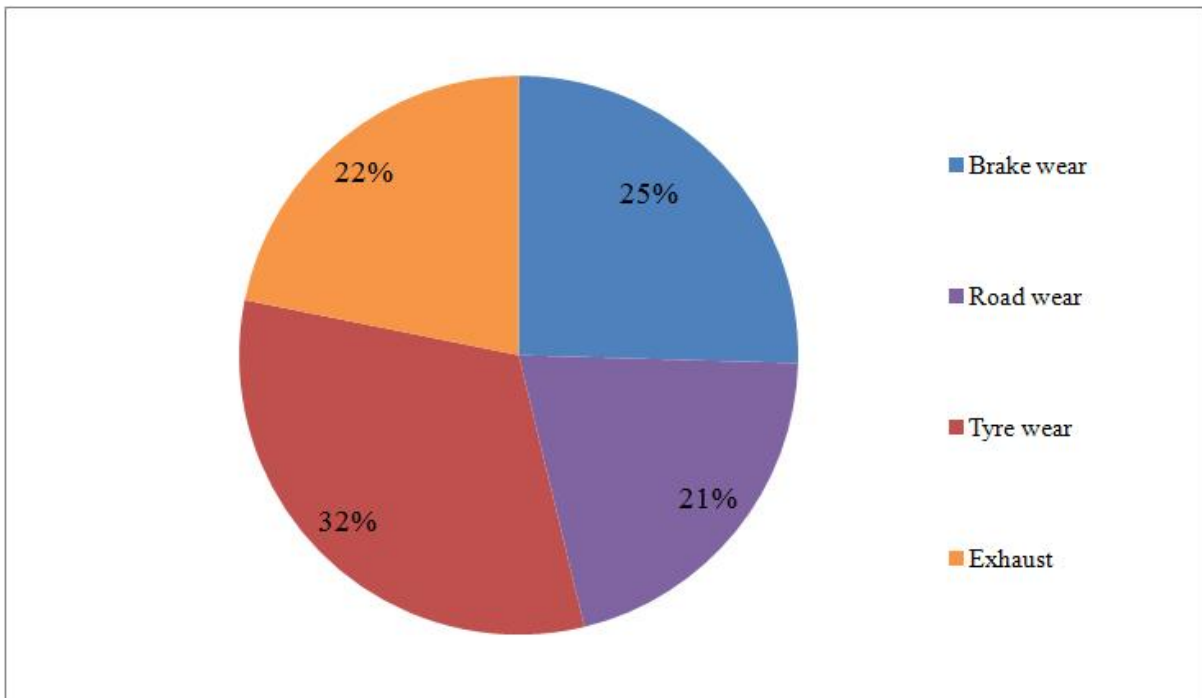


Figure 10.8: Surrey road transport $PM_{2.5}$ emissions by exhaust and non-exhaust components

10.2 Concentrations

The apportionment of modelled concentrations was carried out for 222 receptor locations provided by the borough councils, representing a mixture of roadside and urban background locations. Note that none of these receptor locations are located in Runnymede. It should be further noted that the proportion of site types for each borough is not comparable, for example, some boroughs focused on source apportionment sites by roadsides.

In this report, source apportionment concentrations averaged by borough are presented. Concentrations for individual source apportionment locations are reported in a separate report for each borough.

Figure 10.9 presents total NO_x concentrations by major source group, including background concentrations from outside of Surrey. Of sources within Surrey, road transport is the largest contributor to NO_x concentrations across all boroughs, contributing an average of 49% of total NO_x concentrations.

The average contribution of other sources to NO_x concentrations is higher in Spelthorne (23%) compared to the average of all other boroughs (11%). This is due to the proximity of some of the source apportionment locations to Heathrow Airport.

Road transport NO_x concentrations split by vehicle category are presented in Figure 10.10. The borough average breakdowns of concentrations are largely in line with the Surrey-wide breakdown of emissions by vehicle type shown in Figure 10.2.

A summary of NO_x source apportionment is provided in Table 10-2.

Note that the contribution of different source groups to the total NO₂ concentration cannot be quantified because of the non-linearity nature of the chemical reactions which take place in the atmosphere. The contribution of different source groups to total NO₂ concentrations will be related to the contribution of each group to the total NO_x concentrations and the proportion of NO_x emissions emitted as NO₂ (primary NO₂).

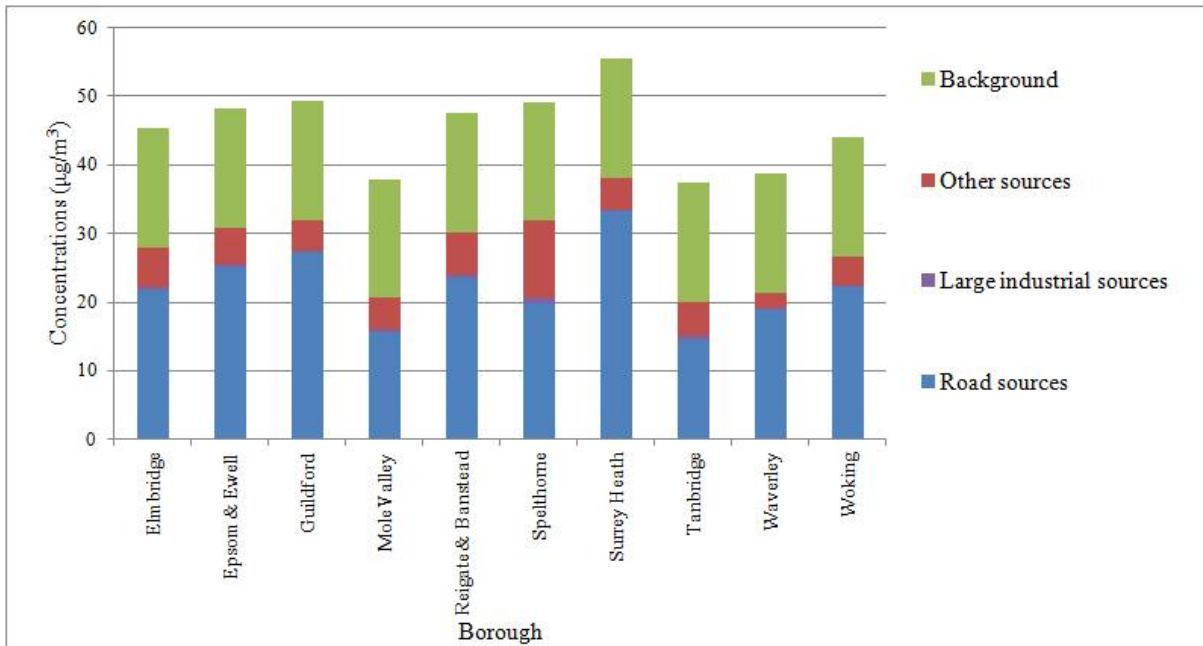


Figure 10.9: NO_x concentrations by major source group, averaged by borough

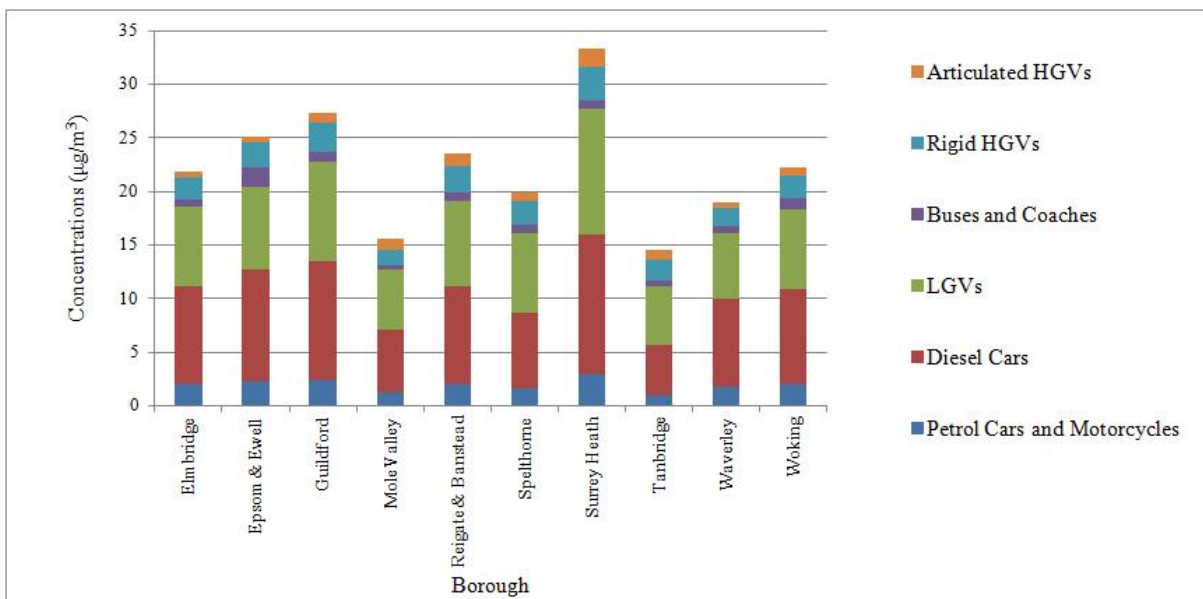


Figure 10.10: Road transport NO_x concentrations by vehicle category, averaged by borough

Table 10-2: Summary of NO_x concentration source apportionment, averaged by borough

NO _x (µg/m ³)	Type of source apportionment									
	Source type				Vehicle type					
Borough	Road sources	Other sources	Background	Large industrial sources	Petrol Cars & Motorcycles	Diesel Cars	LGVs	Buses & Coaches	Rigid HGVs	Articulated HGVs
Elmbridge	21.9	5.6	17.4	0.4	2.0	9.1	7.4	0.7	2.1	0.5
Epsom & Ewell	25.1	5.4	17.4	0.3	2.3	10.4	7.7	1.8	2.3	0.6
Guildford	27.3	4.4	17.4	0.2	2.4	11.1	9.3	0.9	2.7	0.9
Mole Valley	15.6	4.7	17.4	0.3	1.2	5.8	5.7	0.4	1.4	1.1
Reigate & Banstead	23.6	6.2	17.4	0.5	2.0	9.2	7.9	0.8	2.5	1.2
Spelthorne	19.9	11.1	17.4	0.8	1.5	7.2	7.4	0.8	2.2	0.9
Surrey Heath	33.3	4.6	17.4	0.2	2.9	13.2	11.7	0.8	3.0	1.7
Tandridge	14.6	4.9	17.4	0.5	1.0	4.7	5.4	0.6	2.0	0.9
Waverley	19.0	2.3	17.4	0.1	1.8	8.2	6.2	0.6	1.7	0.5
Woking	22.2	4.2	17.4	0.2	2.0	9.0	7.4	1.0	2.1	0.8

Figure 10.11 presents total PM₁₀ concentrations by major source group. For all boroughs, background concentrations from outside the modelled Surrey area are the largest contributor to total PM₁₀ concentrations; across the source apportionment locations, sources within Surrey represent an average of 21% of total PM₁₀ concentrations.

Exhaust road transport PM₁₀ concentrations split by vehicle category are shown in Figure 10.12. Non-exhaust sources are the major contributor (88%) to road transport PM₁₀ concentrations, as illustrated by Figure 10.13.

A summary of PM₁₀ source apportionment is provided in Table 10-3.

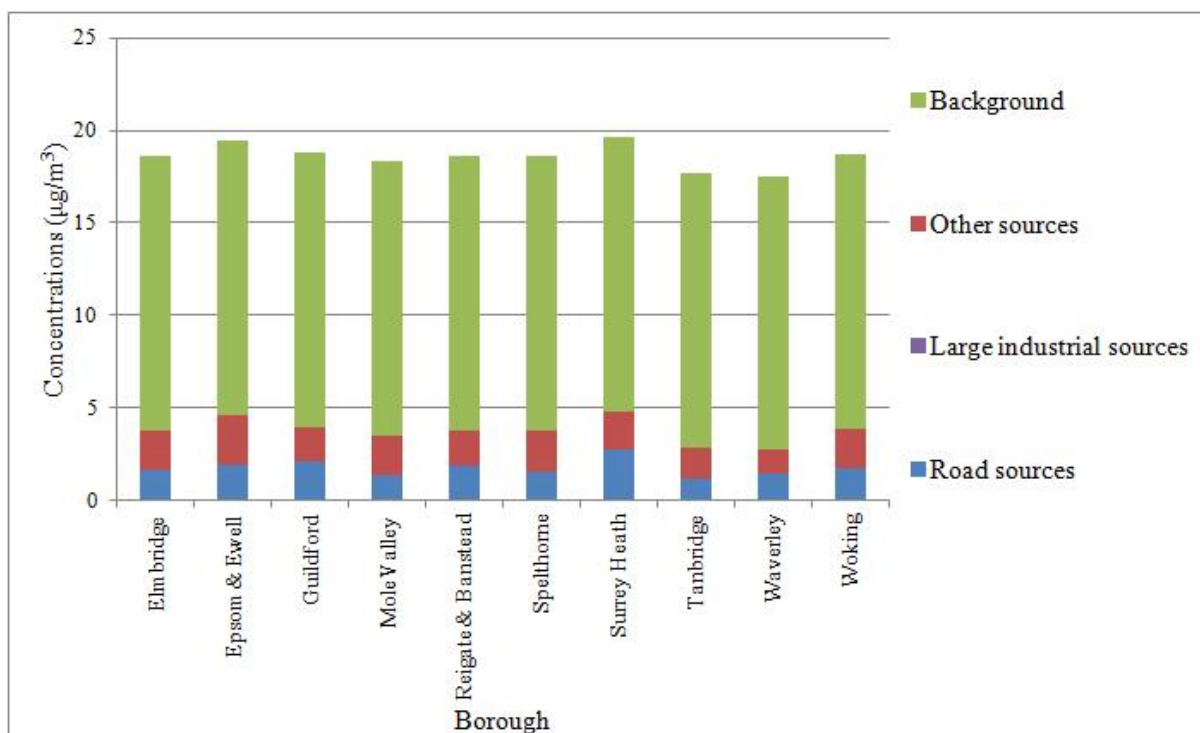


Figure 10.11: PM₁₀ concentrations by major source group, averaged by borough

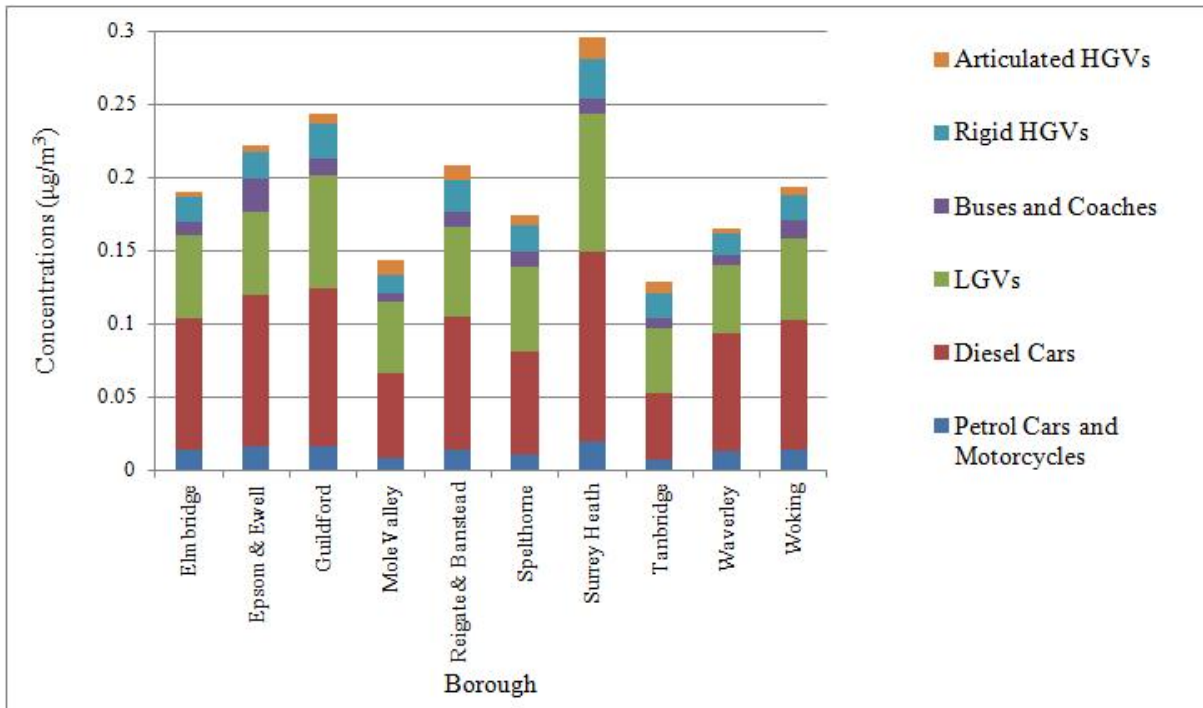


Figure 10.12: Road transport exhaust PM₁₀ concentrations by vehicle category, averaged by borough

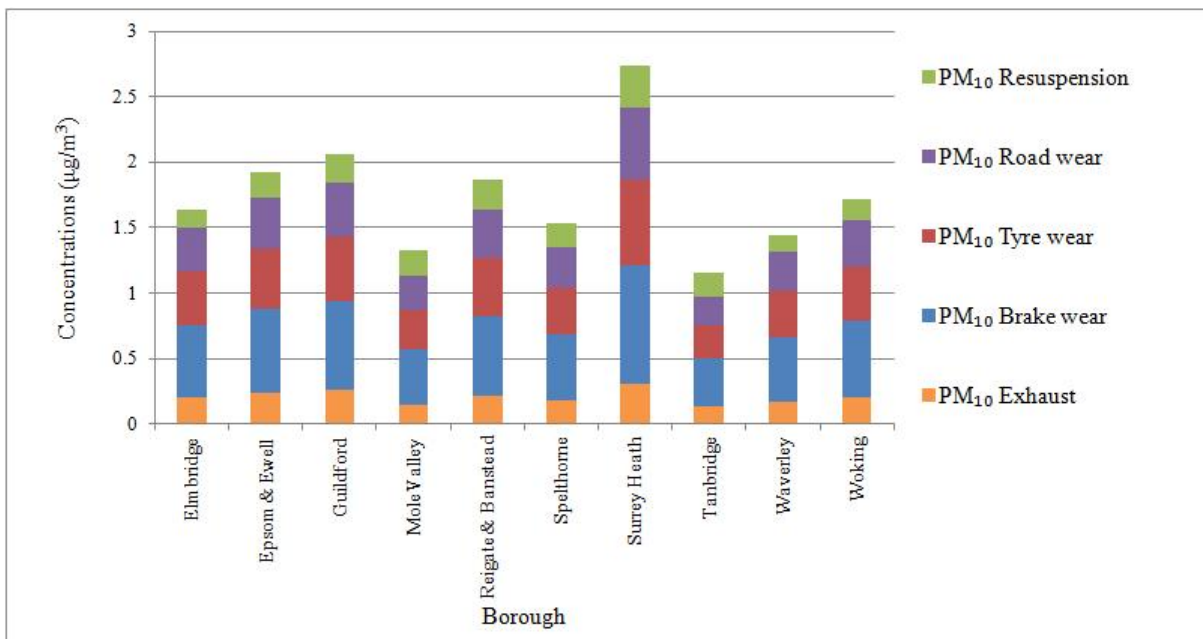


Figure 10.13: Road transport PM₁₀ concentrations by exhaust and non-exhaust components, averaged by borough

Table 10-3: Summary of PM₁₀ concentration source apportionment, averaged by borough

PM ₁₀ (µg/m ³)	Type of source apportionment													
	Source type				Road transport - exhaust by vehicle type						Road transport - non-exhaust			
Receptor	Road sources	Other sources	Background	Large industrial sources	Petrol Cars & Motorcycles	Diesel Cars	LGVs	Buses & Coaches	Rigid HGVs	Articulated HGVs	PM ₁₀ Brake wear	PM ₁₀ Tyre wear	PM ₁₀ Resuspension	PM ₁₀ Road wear
Elmbridge	1.6	2.1	14.8	<0.1	0.02	0.09	0.06	<0.01	0.02	<0.01	0.6	0.4	0.1	0.3
Epsom & Ewell	1.9	2.7	14.8	<0.1	0.02	0.11	0.06	0.02	0.02	<0.01	0.6	0.5	0.2	0.4
Guildford	2.1	1.9	14.8	<0.1	0.02	0.11	0.08	0.01	0.02	<0.01	0.7	0.5	0.2	0.4
Mole Valley	1.3	2.1	14.8	<0.1	<0.01	0.06	0.05	<0.01	0.01	0.01	0.4	0.3	0.2	0.3
Reigate & Banstead	1.9	1.9	14.8	<0.1	0.02	0.09	0.07	0.01	0.02	0.01	0.6	0.4	0.2	0.4
Spelthorne	1.5	2.2	14.8	<0.1	0.01	0.07	0.06	0.01	0.02	<0.01	0.5	0.4	0.2	0.3
Surrey Heath	2.7	2.1	14.8	<0.1	0.02	0.14	0.10	0.01	0.03	0.02	0.9	0.7	0.3	0.5
Tandridge	1.2	1.7	14.8	<0.1	<0.01	0.05	0.05	<0.01	0.02	<0.01	0.4	0.3	0.2	0.2
Waverley	1.4	1.3	14.8	<0.1	0.01	0.08	0.05	<0.01	0.01	<0.01	0.5	0.4	0.1	0.3
Woking	1.7	2.1	14.8	<0.1	0.01	0.09	0.06	0.01	0.02	<0.01	0.6	0.4	0.2	0.4

Figure 10.14 presents total PM_{2.5} concentrations by major source group. In line with the breakdown of PM₁₀ concentrations, background concentrations from outside Surrey are the largest contributor to total PM_{2.5} concentrations.

Exhaust road transport PM₁₀ concentrations split by vehicle category are shown in Figure 10.15. Non-exhaust sources are the major contributor to road transport PM_{2.5} concentrations, as illustrated in Figure 10.16.

A summary of PM_{2.5} source apportionment is provided in Table 10-4.

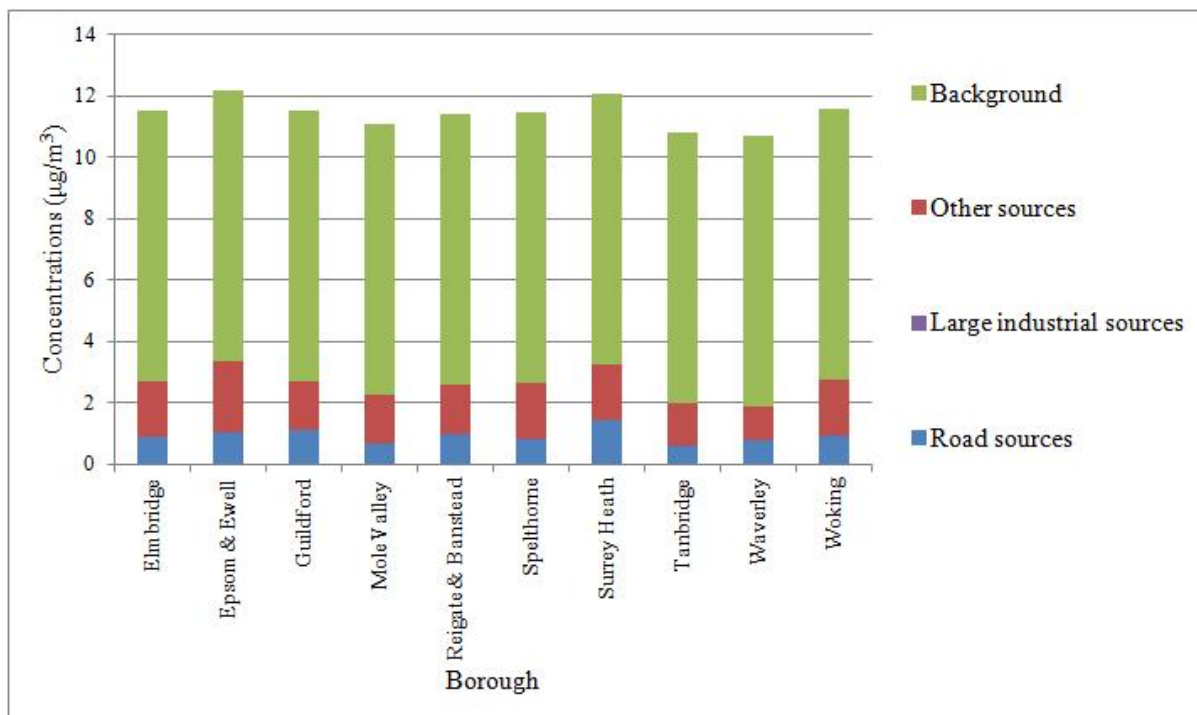


Figure 10.14: PM_{2.5} concentrations by major source group, averaged by borough

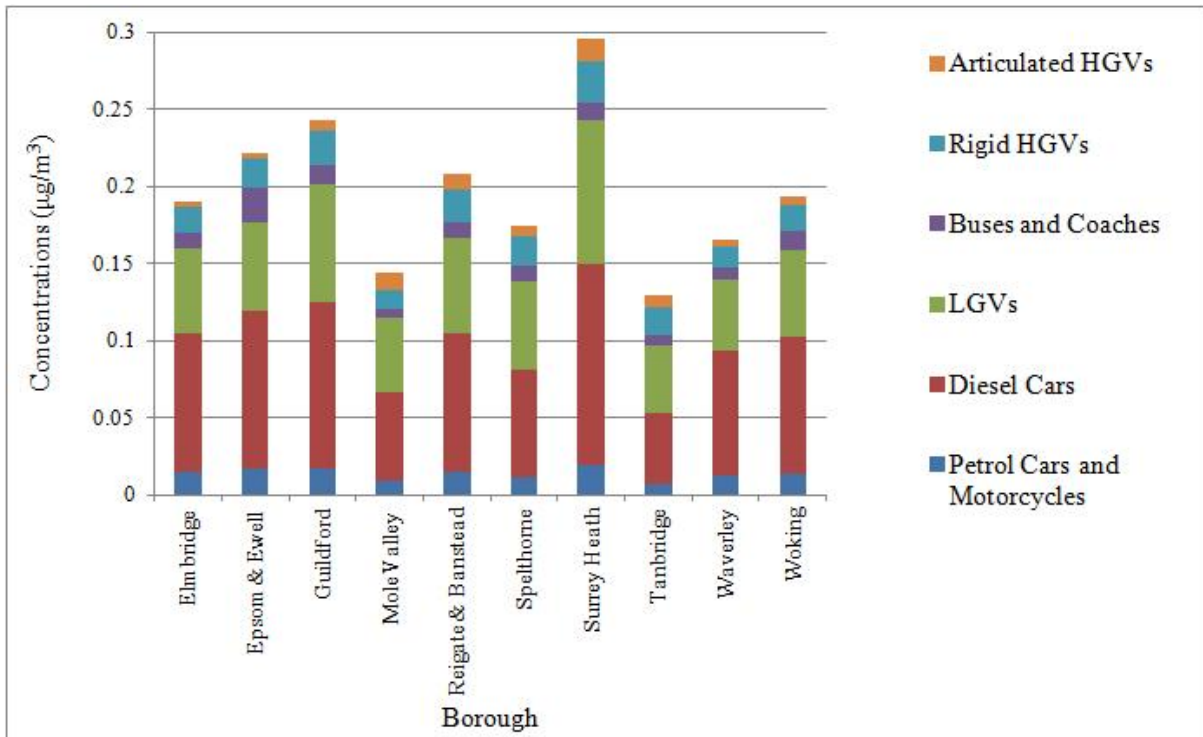


Figure 10.15: Road transport exhaust PM_{2.5} concentrations by vehicle category, averaged by borough

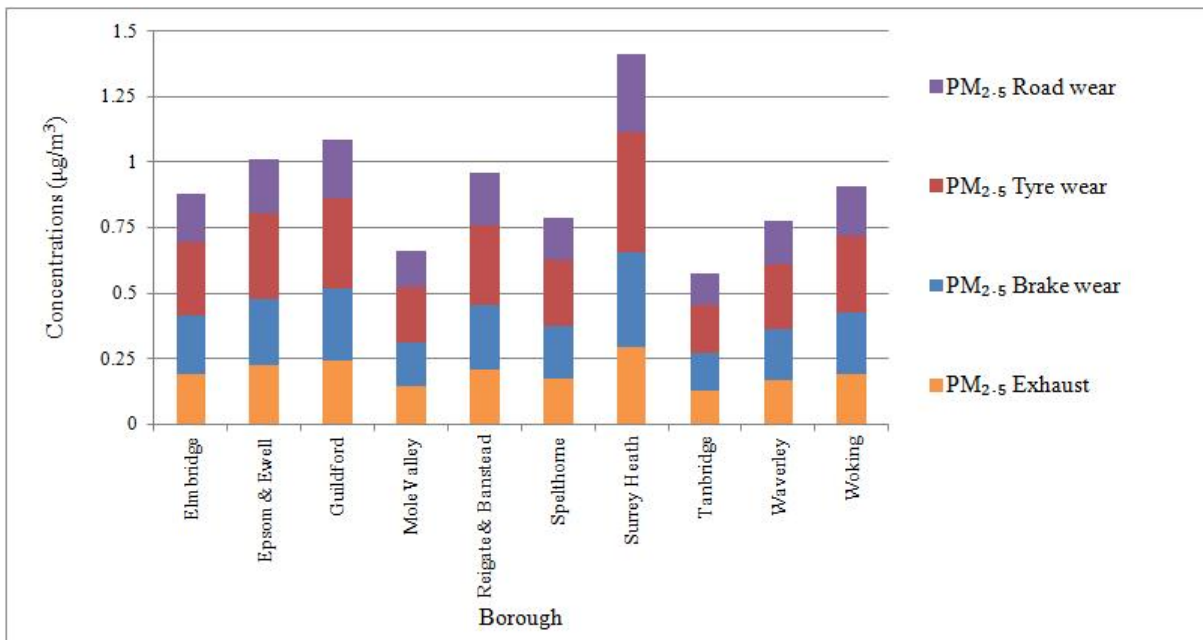


Figure 10.16: Road transport PM_{2.5} concentrations by exhaust and non-exhaust components, averaged by borough

Table 10-4: Summary of PM_{2.5} concentration source apportionment, averaged by borough

PM _{2.5} (µg/m ³)	Type of source apportionment												
	Source type				Road transport - exhaust by vehicle type						Road transport - non-exhaust		
Receptor	Road sources	Other sources	Background	Large industrial sources	Petrol Cars & Motorcycles	Diesel Cars	LGVs	Buses & Coaches	Rigid HGVs	Articulated HGVs	PM _{2.5} Brake wear	PM _{2.5} Tyre wear	PM _{2.5} Road wear
Elmbridge	0.9	1.8	8.8	<0.1	0.01	0.09	0.06	<0.01	0.02	<0.01	0.2	0.3	0.2
Epsom & Ewell	1.0	2.3	8.8	<0.1	0.02	0.10	0.06	0.02	0.02	<0.01	0.3	0.3	0.2
Guildford	1.1	1.6	8.8	<0.1	0.02	0.11	0.08	0.01	0.02	<0.01	0.3	0.3	0.2
Mole Valley	0.7	1.6	8.8	<0.1	<0.01	0.06	0.05	<0.01	0.01	0.01	0.2	0.2	0.1
Reigate & Banstead	1.0	1.6	8.8	<0.1	0.01	0.09	0.06	<0.01	0.02	0.01	0.2	0.3	0.2
Spelthorne	0.8	1.8	8.8	<0.1	0.01	0.07	0.06	<0.01	0.02	<0.01	0.2	0.3	0.2
Surrey Heath	1.4	1.8	8.8	<0.1	0.02	0.13	0.09	0.01	0.03	0.01	0.4	0.5	0.3
Tandridge	0.6	1.4	8.8	<0.1	<0.01	0.05	0.04	<0.01	0.02	<0.01	0.1	0.2	0.1
Waverley	0.8	1.1	8.8	<0.1	0.01	0.08	0.05	<0.01	0.01	<0.01	0.2	0.3	0.2
Woking	0.9	1.8	8.8	<0.1	0.01	0.09	0.06	0.01	0.02	<0.01	0.2	0.3	0.2

11 Discussion

Air quality modelling has been carried out for NO₂, PM₁₀ and PM_{2.5} using ADMS-Urban (version 4.2). This has been carried out to assess relevant pollutant concentrations throughout Surrey in 2017 against the air quality objectives. The detailed modelling is supplemented by mortality burden calculations and source apportionment.

Model verification was carried out to ensure a suitable model set-up for detailed modelling; this was done by comparing modelled concentrations with measured data from diffusion tubes and continuous monitors at a variety of site types throughout Surrey. The model verification shows a generally good performance of the model set-up across Surrey, with modelled annual average NO₂ concentrations falling within 25% of the monitored values at 74% of the locations.

The model was run to produce contour plots of annual mean NO₂, 99.79th percentile of hourly mean NO₂, annual mean PM₁₀, 90.41st percentile of 24-hourly mean PM₁₀ and annual mean PM_{2.5} concentrations.

This modelling predicts exceedences for three of the five air quality objectives, along motorways and stretches of busy roads. The exceptions are annual mean PM₁₀ concentrations, which has no exceedences outside the footprint of modelled roads and PM_{2.5} which has no exceedences across Surrey.

The health impacts associated with air quality across Surrey and the contributions from each borough and ward have been assessed by calculating the number of attributable deaths and corresponding life-years lost due to NO₂ and PM_{2.5} concentrations. The methodology used for these calculations is outlined in Appendix A of the Public Health England guidance *Estimating local mortality burdens associated with particulate air pollution (April 2014)*. Using this approach along with four studies suggesting a range of CRF pairs, the combined health impacts of NO₂ and PM_{2.5} were calculated to be in a range of 6,610 and 8,059 life-years lost which equates to an economic cost between £283 million and £345 million in 2017. Using the unadjusted value, the lowest life years lost were calculated to be 5233, resulting from NO₂ concentrations. This equates to an economic cost of £224 million.

Source apportionment has been carried out across Surrey, calculating the contributions of each major source group to NO_x, PM₁₀ and PM_{2.5} pollutant emissions and resulting concentrations.

NO_x emissions within Surrey are dominated by road transport, specifically light diesel vehicles; in addition the primary NO₂ proportion for these vehicle types is higher than for other vehicles. NO_x concentrations within Surrey are greatest from road transport. The distribution of vehicle type concentrations is in line with breakdown of vehicle type emissions.

PM₁₀ and PM_{2.5} emissions within Surrey are largely dominated by other emissions from NAEI data. The largest contributor to both PM₁₀ and PM_{2.5} concentrations is background concentrations, from outside Surrey.

APPENDIX A: Model verification data

Appendix A presents a comparison of model verification results using Heathrow Airport and Gatwick Airport meteorological data. Table A.1 is a summary table of monitored and modelled concentrations using the two sets of meteorological data for all monitoring sites.

Table A.1: Monitored and modelled NO₂ concentrations at monitoring locations

Site ID	Concentration, $\mu\text{g}/\text{m}^3$			Gatwick Modelled / Monitored ratio	Heathrow Modelled / Monitored ratio	Borough
	Monitored	Gatwick	Heathrow			
Hampton Court Parade	40.6	36.8	33.7	91%	83%	Elmbridge
Weybridge High St	33.5	38.6	34.5	115%	103%	Elmbridge
Esher 1	37.5	26.6	24.4	71%	65%	Elmbridge
Esher 4	33.7	29.0	25.2	86%	75%	Elmbridge
Esher 5	43.1	32.9	27.4	76%	64%	Elmbridge
Esher 7	39.6	40.8	34.0	103%	86%	Elmbridge
Esher 8	39.1	28.2	25.8	72%	66%	Elmbridge
Esher 9	29.0	28.6	26.3	99%	91%	Elmbridge
Esher 10	28.8	26.0	23.7	90%	82%	Elmbridge
Esher 11	33.1	26.8	24.5	81%	74%	Elmbridge
Esher 13	31.9	32.4	28.9	102%	91%	Elmbridge
Hampton court 1	35.8	32.9	29.9	92%	84%	Elmbridge
Hinchley wood 1	35.8	26.7	24.4	75%	68%	Elmbridge
Hinchley wood 2	31.2	26.4	24.2	85%	78%	Elmbridge
Molesey 1	28.5	24.3	22.6	85%	79%	Elmbridge
Hampton court 5	25.6	26.7	23.8	104%	93%	Elmbridge
Molesey 8	31.5	29.9	27.3	95%	87%	Elmbridge
Molesey 9	32.7	26.0	23.7	80%	72%	Elmbridge
Molesey 10	27.8	26.2	23.9	94%	86%	Elmbridge
Hampton court 2	35.2	36.9	33.8	105%	96%	Elmbridge
Hampton court 3	35.3	36.9	33.8	105%	96%	Elmbridge
Hampton court 4	35.1	36.9	33.8	105%	96%	Elmbridge
Walton 3	30.4	24.3	22.5	80%	74%	Elmbridge
Walton 5	27.8	30.0	27.5	108%	99%	Elmbridge
Walton 8	30.9	24.6	22.5	80%	73%	Elmbridge
Walton 9	30.5	25.1	23.2	82%	76%	Elmbridge
Walton 10	33.5	30.9	26.6	92%	79%	Elmbridge
Walton 11	30.9	32.6	29.8	106%	96%	Elmbridge
Weybridge 1	30.4	42.4	37.6	139%	124%	Elmbridge

Site ID	Concentration, µg/m ³			Gatwick Modelled / Monitored ratio	Heathrow Modelled / Monitored ratio	Borough
	Monitored	Gatwick	Heathrow			
Weybridge 4	30.6	28.3	25.9	92%	85%	Elmbridge
Weybridge 5	34.4	37.7	33.2	110%	97%	Elmbridge
Weybridge 6	28.4	39.8	32.9	140%	116%	Elmbridge
Weybridge 7	41.0	32.6	29.6	80%	72%	Elmbridge
Weybridge 8	35.9	27.6	25.4	77%	71%	Elmbridge
Weybridge 9	22.9	24.6	22.2	107%	97%	Elmbridge
Weybridge 10	31.6	38.1	34.0	121%	108%	Elmbridge
Weybridge 11	31.2	38.1	34.0	122%	109%	Elmbridge
Weybridge 12	32.3	38.1	34.0	118%	105%	Elmbridge
Cobham 1	30.4	33.2	31.3	109%	103%	Elmbridge
Cobham 6	24.9	27.6	26.1	111%	105%	Elmbridge
Cobham 7	32.5	32.7	30.5	101%	94%	Elmbridge
Downside 3	19.3	31.6	27.7	164%	144%	Elmbridge
EE1	34.2	26.5	24.7	77%	72%	Epsom & Ewell
EE3	17.0	19.3	18.4	114%	108%	Epsom & Ewell
EE6	31.6	27.9	26.8	88%	85%	Epsom & Ewell
EE7	35.9	43.9	41.2	122%	115%	Epsom & Ewell
EE9	23.4	22.4	21.6	96%	92%	Epsom & Ewell
EE10	44.9	28.5	26.8	63%	60%	Epsom & Ewell
EE14	25.6	24.3	22.9	95%	89%	Epsom & Ewell
EE16	31.0	25.5	23.0	82%	74%	Epsom & Ewell
EE17	30.6	26.0	24.3	85%	79%	Epsom & Ewell
EE22	39.7	34.8	33.3	88%	84%	Epsom & Ewell
EE36	26.5	25.7	24.3	97%	92%	Epsom & Ewell
EE38	25.4	25.9	23.7	102%	93%	Epsom & Ewell
EE39	27.9	25.2	23.7	90%	85%	Epsom & Ewell
EE42	29.1	30.6	28.2	105%	97%	Epsom & Ewell
EE43	28.8	24.4	22.3	85%	77%	Epsom & Ewell
EE45	22.8	25.6	23.8	112%	104%	Epsom & Ewell
EE47	24.8	24.3	23.2	98%	94%	Epsom & Ewell
EE48	29.3	24.7	22.8	84%	78%	Epsom & Ewell
EE49	28.9	26.9	25.2	93%	87%	Epsom & Ewell
EE50	36.8	28.9	27.4	79%	74%	Epsom & Ewell
GUL_GD1	28.9	34.5	32.4	119%	112%	Guildford
GUL_GD2	30.6	27.0	26.1	88%	85%	Guildford

Site ID	Concentration, µg/m ³			Gatwick Modelled / Monitored ratio	Heathrow Modelled / Monitored ratio	Borough
	Monitored	Gatwick	Heathrow			
GUL_GD3	17.5	24.0	23.4	137%	134%	Guildford
GUL_GD6	10.1	17.5	17.6	173%	174%	Guildford
GUL_GD9	17.1	25.2	24.2	147%	142%	Guildford
GUL_GD10	15.4	20.7	19.8	134%	129%	Guildford
GUL_GD11	24.3	29.7	25.1	122%	103%	Guildford
GUL_GD13	31.1	34.2	31.4	110%	101%	Guildford
GUL_GD14	32.0	30.8	29.0	96%	91%	Guildford
GUL_GD15	27.8	32.5	30.7	117%	110%	Guildford
GUL_C4	39.9	23.1	22.9	58%	57%	Guildford
GUL_C9	44.4	23.3	23.0	52%	52%	Guildford
GUL_C10	31.8	23.4	23.1	74%	73%	Guildford
GUL_SH1	35.8	26.6	25.7	74%	72%	Guildford
GUL_RP1	27.6	35.0	30.3	127%	110%	Guildford
GUL_RP2	23.8	37.8	36.9	159%	155%	Guildford
GUL_WS1	13.8	20.5	20.3	149%	147%	Guildford
GUL_WP1	25.4	24.3	23.0	96%	91%	Guildford
GUL_ASH1	17.6	21.6	20.6	123%	117%	Guildford
GUL_ASH2	22.4	32.7	28.8	146%	129%	Guildford
GUL_send1	22.2	23.1	22.0	104%	99%	Guildford
GUL_send2	20.7	24.9	23.5	120%	114%	Guildford
GUL_WCL	20.1	19.5	18.7	97%	93%	Guildford
GUL_T1	22.9	21.5	20.4	94%	89%	Guildford
GUL_STN	24.7	24.9	22.5	101%	91%	Guildford
GUL_FRH1	34.5	28.7	27.2	83%	79%	Guildford
MV1	24.4	26.8	26.7	110%	109%	Mole Valley
MV2	20.2	20.6	20.5	102%	101%	Mole Valley
MV3	16.9	19.5	19.0	115%	112%	Mole Valley
MV4	14.4	17.7	17.6	123%	122%	Mole Valley
MV6	30.3	34.0	33.6	112%	111%	Mole Valley
MV7	17.2	20.6	19.3	120%	112%	Mole Valley
MV8	18.1	21.0	18.8	116%	104%	Mole Valley
MV9	10.9	25.9	22.4	238%	206%	Mole Valley
MV10	32.9	42.3	38.1	129%	116%	Mole Valley
MV12	29.5	33.9	31.1	115%	105%	Mole Valley
MV13	33.1	24.1	23.7	73%	72%	Mole Valley

Site ID	Concentration, $\mu\text{g}/\text{m}^3$			Gatwick Modelled / Monitored ratio	Heathrow Modelled / Monitored ratio	Borough
	Monitored	Gatwick	Heathrow			
MV14	17.7	20.5	19.5	116%	110%	Mole Valley
RG1	20.4	28.7	24.7	141%	121%	Reigate & Banstead
RG3	13.9	24.9	25.2	179%	181%	Reigate & Banstead
RG6	26.7	34.8	30.9	130%	116%	Reigate & Banstead
RB1	32.4	26.1	26.6	81%	82%	Reigate & Banstead
RB3	17.6	21.2	20.3	120%	115%	Reigate & Banstead
RB8	17.8	20.3	19.8	114%	111%	Reigate & Banstead
RB9	16.6	19.6	19.1	118%	115%	Reigate & Banstead
RB11	22.8	30.2	26.2	132%	115%	Reigate & Banstead
RB12	28.3	26.2	22.4	93%	79%	Reigate & Banstead
RB13	19.9	25.7	22.2	129%	112%	Reigate & Banstead
RB17	14.0	20.1	19.9	144%	142%	Reigate & Banstead
RB18	22.6	26.9	25.4	119%	112%	Reigate & Banstead
RB19	23.5	30.3	28.8	129%	123%	Reigate & Banstead
RB20	32.8	39.3	34.8	120%	106%	Reigate & Banstead
RB21	34.1	25.2	23.9	74%	70%	Reigate & Banstead
RB22	19.7	28.9	27.0	147%	137%	Reigate & Banstead
RB23	16.2	21.1	20.5	130%	127%	Reigate & Banstead
RB24	21.1	28.7	24.7	136%	117%	Reigate & Banstead
RB25	21.8	28.7	24.7	132%	113%	Reigate & Banstead
RB26	20.9	28.7	24.7	137%	118%	Reigate & Banstead
RB27	25.3	37.2	34.2	147%	135%	Reigate & Banstead
RB29	24.8	29.0	26.7	117%	108%	Reigate & Banstead
RB30	24.3	32.5	30.1	134%	124%	Reigate & Banstead
RB31	16.0	23.2	24.8	145%	155%	Reigate & Banstead
RB33	21.1	29.2	26.8	138%	127%	Reigate & Banstead
RB34	24.1	22.8	23.0	95%	95%	Reigate & Banstead
RB36	20.3	33.4	30.0	165%	148%	Reigate & Banstead
RB37	24.0	35.4	31.4	148%	131%	Reigate & Banstead
RB39	25.1	40.3	35.5	161%	141%	Reigate & Banstead
RB40	20.3	29.3	25.8	144%	127%	Reigate & Banstead
RB43	23.3	29.3	29.0	126%	124%	Reigate & Banstead
RB44	30.8	26.2	25.3	85%	82%	Reigate & Banstead
RB45	28.0	24.6	23.8	88%	85%	Reigate & Banstead
RB46	35.9	34.8	32.4	97%	90%	Reigate & Banstead

Site ID	Concentration, $\mu\text{g}/\text{m}^3$			Gatwick Modelled / Monitored ratio	Heathrow Modelled / Monitored ratio	Borough
	Monitored	Gatwick	Heathrow			
RB47	35.0	26.4	26.4	75%	75%	Reigate & Banstead
RB49	42.4	29.7	26.3	70%	62%	Reigate & Banstead
RB50	26.1	28.0	24.8	107%	95%	Reigate & Banstead
RB51	20.8	26.2	22.4	126%	108%	Reigate & Banstead
RB52	24.7	27.1	23.2	110%	94%	Reigate & Banstead
RB53	25.3	29.2	25.0	115%	99%	Reigate & Banstead
RB54	23.4	29.0	25.0	124%	107%	Reigate & Banstead
RB55	22.8	30.5	26.4	134%	116%	Reigate & Banstead
RB56	24.0	31.8	27.8	133%	116%	Reigate & Banstead
RB57	26.2	33.3	29.4	127%	112%	Reigate & Banstead
RB58	26.8	33.9	30.0	126%	112%	Reigate & Banstead
RB59	27.8	35.3	31.4	127%	113%	Reigate & Banstead
RB60	27.3	33.4	29.6	122%	108%	Reigate & Banstead
RB61	22.6	32.3	28.5	143%	126%	Reigate & Banstead
RB64	22.1	27.5	23.5	124%	106%	Reigate & Banstead
RB65	22.4	26.5	22.6	118%	101%	Reigate & Banstead
RB66	21.8	26.7	22.7	122%	104%	Reigate & Banstead
RB68	24.0	29.7	25.8	124%	108%	Reigate & Banstead
RB69	26.5	30.1	26.0	114%	98%	Reigate & Banstead
RB70	24.3	28.1	24.1	116%	99%	Reigate & Banstead
RB72	22.2	26.5	22.5	119%	101%	Reigate & Banstead
RB73	22.0	26.1	22.3	119%	101%	Reigate & Banstead
RB74	22.5	31.8	28.2	141%	125%	Reigate & Banstead
RB75	23.9	30.4	26.6	127%	111%	Reigate & Banstead
RB76	20.1	26.9	22.9	134%	114%	Reigate & Banstead
RB77	20.9	26.5	22.5	127%	108%	Reigate & Banstead
RB78	27.0	34.4	30.5	127%	113%	Reigate & Banstead
RB81	30.9	23.1	22.4	75%	72%	Reigate & Banstead
RB82	33.8	24.7	22.7	73%	67%	Reigate & Banstead
RB95	25.2	24.4	23.1	97%	92%	Reigate & Banstead
RB98	25.8	30.6	26.5	119%	103%	Reigate & Banstead
RB99	14.1	24.9	25.2	177%	179%	Reigate & Banstead
RB100	13.7	24.9	25.2	182%	184%	Reigate & Banstead
RB101	14.0	24.9	25.2	178%	180%	Reigate & Banstead
RB102	20.9	27.9	24.5	133%	117%	Reigate & Banstead

Site ID	Concentration, µg/m ³			Gatwick Modelled / Monitored ratio	Heathrow Modelled / Monitored ratio	Borough
	Monitored	Gatwick	Heathrow			
RB104	34.7	26.8	27.3	77%	79%	Reigate & Banstead
RB105	39.0	29.9	28.8	77%	74%	Reigate & Banstead
RB106	29.3	29.2	27.2	100%	93%	Reigate & Banstead
RB107	26.1	23.6	23.4	90%	90%	Reigate & Banstead
RB109	32.5	23.0	22.4	71%	69%	Reigate & Banstead
RB110	29.3	39.5	36.3	135%	124%	Reigate & Banstead
RB111	30.3	32.5	30.6	107%	101%	Reigate & Banstead
RB113	27.1	32.7	31.2	121%	115%	Reigate & Banstead
RB115	30.5	29.5	30.6	97%	100%	Reigate & Banstead
RB116	31.9	29.0	28.8	91%	90%	Reigate & Banstead
RB117	35.1	27.9	25.5	79%	73%	Reigate & Banstead
RB118	31.5	22.5	21.4	71%	68%	Reigate & Banstead
RB120	32.9	27.0	26.1	82%	79%	Reigate & Banstead
RB122	31.5	34.4	32.3	109%	103%	Reigate & Banstead
RB123	35.8	29.0	27.5	81%	77%	Reigate & Banstead
RB124	34.5	32.6	30.4	94%	88%	Reigate & Banstead
RB125	34.9	27.1	25.8	78%	74%	Reigate & Banstead
RB136	49.4	36.0	32.4	73%	66%	Reigate & Banstead
RB137	42.3	29.4	26.8	70%	63%	Reigate & Banstead
RB140	25.5	29.8	27.6	117%	108%	Reigate & Banstead
RB141	23.7	24.4	22.8	103%	96%	Reigate & Banstead
RB145	33.7	33.1	31.5	98%	93%	Reigate & Banstead
RB146	40.9	34.8	32.2	85%	79%	Reigate & Banstead
RB147	16.5	21.2	20.1	128%	122%	Reigate & Banstead
RB148	62.6	30.5	27.8	49%	44%	Reigate & Banstead
RB149	46.0	31.2	26.1	68%	57%	Reigate & Banstead
RB150	37.5	25.3	24.1	67%	64%	Reigate & Banstead
RB151	33.3	27.0	23.3	81%	70%	Reigate & Banstead
RB152	33.4	37.0	33.6	111%	101%	Reigate & Banstead
RB153	29.0	26.7	26.0	92%	90%	Reigate & Banstead
RB167	24.9	24.9	23.1	100%	93%	Reigate & Banstead
RB174	31.1	30.8	25.9	99%	83%	Reigate & Banstead
RB175	30.6	31.1	26.6	102%	87%	Reigate & Banstead
RB176	25.4	33.7	29.6	133%	117%	Reigate & Banstead
RB177	24.9	35.6	31.1	143%	125%	Reigate & Banstead

Site ID	Concentration, µg/m ³			Gatwick Modelled / Monitored ratio	Heathrow Modelled / Monitored ratio	Borough
	Monitored	Gatwick	Heathrow			
RB178	25.6	34.7	30.9	136%	121%	Reigate & Banstead
RB179	25.3	34.7	30.9	137%	122%	Reigate & Banstead
RB180	25.9	34.7	30.9	134%	119%	Reigate & Banstead
RY4	17.5	23.5	21.5	134%	123%	Runnymede
RY14	47.7	43.7	40.3	92%	84%	Runnymede
RY19	34.3	50.1	44.2	146%	129%	Runnymede
RY21	34.1	30.1	28.1	88%	82%	Runnymede
RY23	50.5	26.3	23.5	52%	47%	Runnymede
RY25	29.6	36.3	32.5	123%	110%	Runnymede
RY26	42.2	40.6	36.6	96%	87%	Runnymede
RY33	31.0	34.5	29.4	111%	95%	Runnymede
RY34	22.5	26.9	24.1	120%	107%	Runnymede
RY39	23.4	34.2	28.3	146%	121%	Runnymede
RY40	16.2	20.5	18.9	127%	117%	Runnymede
RY43	36.6	29.6	27.1	81%	74%	Runnymede
RY44	27.1	27.2	24.4	100%	90%	Runnymede
RY45	37.3	28.5	25.5	76%	68%	Runnymede
RY53	34.2	33.0	30.2	96%	88%	Runnymede
RY54	30.4	30.3	28.2	100%	93%	Runnymede
RY55	33.1	26.1	23.7	79%	72%	Runnymede
RY59	31.8	31.3	28.7	98%	90%	Runnymede
RY60	32.6	38.5	35.6	118%	109%	Runnymede
RY61	31.4	27.2	24.7	87%	79%	Runnymede
RY62	33.9	36.2	33.1	107%	98%	Runnymede
RY64	25.8	24.4	22.1	95%	86%	Runnymede
RY65	26.7	28.7	25.0	107%	94%	Runnymede
RY66	24.8	25.8	23.6	104%	95%	Runnymede
RYMV	32.1	31.9	28.7	99%	89%	Runnymede
BAA_Oaks	25.8	34.6	30.6	134%	119%	Spelthorne
SUN_01	32.5	36.7	29.4	113%	91%	Spelthorne
SCC_ECO	24.1	24.8	22.8	103%	95%	Spelthorne
SP1	28.0	26.8	24.0	96%	86%	Spelthorne
SP3	31.0	30.7	27.6	99%	89%	Spelthorne
SP4	27.0	30.1	27.6	111%	102%	Spelthorne
SP5	37.0	29.6	26.8	80%	72%	Spelthorne

Site ID	Concentration, µg/m ³			Gatwick Modelled / Monitored ratio	Heathrow Modelled / Monitored ratio	Borough
	Monitored	Gatwick	Heathrow			
SP6	24.0	23.0	20.6	96%	86%	Spelthorne
SP10	35.0	30.2	27.9	86%	80%	Spelthorne
SP11	35.0	27.8	25.1	79%	72%	Spelthorne
SP12	31.0	25.9	23.0	84%	74%	Spelthorne
SP14	25.0	31.7	29.1	127%	116%	Spelthorne
SP16	26.0	34.7	30.7	133%	118%	Spelthorne
SP17	26.0	34.7	30.7	133%	118%	Spelthorne
SP18	27.0	34.7	30.7	129%	114%	Spelthorne
SP19	32.0	35.9	32.5	112%	102%	Spelthorne
SP20	32.0	25.2	23.1	79%	72%	Spelthorne
SP21	26.0	24.5	21.5	94%	83%	Spelthorne
SP23	23.0	25.5	21.9	111%	95%	Spelthorne
SP24	27.0	33.2	29.5	123%	109%	Spelthorne
SP26	28.0	34.4	31.6	123%	113%	Spelthorne
SP27	31.0	29.0	25.6	94%	83%	Spelthorne
SP28	35.0	31.7	28.3	91%	81%	Spelthorne
SP29	44.0	34.1	30.1	78%	68%	Spelthorne
SP31	36.0	33.4	30.1	93%	84%	Spelthorne
SP32	29.0	29.0	25.4	100%	88%	Spelthorne
SP33	34.0	36.4	30.3	107%	89%	Spelthorne
SP34	38.0	28.5	25.4	75%	67%	Spelthorne
SP35	37.0	35.8	29.1	97%	79%	Spelthorne
SP36	40.0	25.3	23.5	63%	59%	Spelthorne
SP38	24.0	25.8	22.9	108%	95%	Spelthorne
SP39	25.0	25.0	22.3	100%	89%	Spelthorne
SP41	30.0	23.9	21.6	80%	72%	Spelthorne
SP43	33.0	38.4	31.4	116%	95%	Spelthorne
SP44	33.0	38.4	31.4	116%	95%	Spelthorne
SP45	33.0	38.4	31.4	116%	95%	Spelthorne
SP46	31.0	28.0	25.4	90%	82%	Spelthorne
SP47	25.0	24.6	22.4	98%	90%	Spelthorne
SP48	30.0	35.9	31.9	120%	106%	Spelthorne
SP49	29.0	42.1	32.3	145%	111%	Spelthorne
SP50	33.0	31.2	28.2	95%	85%	Spelthorne
SP51	37.0	36.4	32.4	98%	88%	Spelthorne

Site ID	Concentration, µg/m ³			Gatwick Modelled / Monitored ratio	Heathrow Modelled / Monitored ratio	Borough
	Monitored	Gatwick	Heathrow			
SP52	32.0	32.1	29.5	100%	92%	Spelthorne
SP53	29.0	25.9	23.4	89%	81%	Spelthorne
SP55	33.0	26.4	23.8	80%	72%	Spelthorne
SP56	21.0	25.5	24.7	121%	118%	Spelthorne
SP57	33.0	23.9	22.2	72%	67%	Spelthorne
CM1	35.6	35.3	27.0	99%	76%	Surrey Heath
SH1	14.3	23.2	19.4	162%	136%	Surrey Heath
SH2	18.6	22.2	19.2	119%	103%	Surrey Heath
SH3	12.6	20.3	17.7	161%	140%	Surrey Heath
SH4	20.7	17.6	16.7	85%	81%	Surrey Heath
SH5	18.6	38.6	30.2	208%	162%	Surrey Heath
SH6	19.5	21.6	20.0	111%	103%	Surrey Heath
SH7	27.9	37.3	32.7	134%	117%	Surrey Heath
SH8	15.8	27.4	22.0	173%	139%	Surrey Heath
SH9	15.6	24.3	20.0	156%	128%	Surrey Heath
SH10	21.2	22.2	20.2	105%	95%	Surrey Heath
SH11	21.3	24.0	21.1	113%	99%	Surrey Heath
SH12	21.6	22.0	19.6	102%	91%	Surrey Heath
SH13	20.0	25.4	23.2	127%	116%	Surrey Heath
SH14	21.5	31.3	28.6	146%	133%	Surrey Heath
SH15	23.8	35.3	27.0	148%	113%	Surrey Heath
SH16	24.3	35.2	28.3	145%	116%	Surrey Heath
SH17	14.6	19.8	18.7	136%	128%	Surrey Heath
SH20	16.7	19.7	18.4	118%	110%	Surrey Heath
SH21	13.8	18.3	17.3	133%	125%	Surrey Heath
SH22	24.7	35.3	27.0	143%	109%	Surrey Heath
SH23	17.3	20.8	19.5	120%	113%	Surrey Heath
SH24	22.2	35.6	33.2	160%	150%	Surrey Heath
SH25	23.4	35.3	27.0	151%	115%	Surrey Heath
SH26	21.3	23.3	20.1	109%	94%	Surrey Heath
SH27	23.2	24.7	22.7	106%	98%	Surrey Heath
SH28	19.5	25.8	23.7	132%	122%	Surrey Heath
SH29	14.0	26.7	22.2	191%	159%	Surrey Heath
SH30	23.6	35.1	34.0	149%	144%	Surrey Heath
SH31	19.0	39.3	30.5	207%	161%	Surrey Heath

Site ID	Concentration, µg/m ³			Gatwick Modelled / Monitored ratio	Heathrow Modelled / Monitored ratio	Borough
	Monitored	Gatwick	Heathrow			
SH32	21.1	39.6	30.8	188%	146%	Surrey Heath
SH33	24.6	41.1	32.3	167%	131%	Surrey Heath
SH34	18.7	33.3	26.6	178%	142%	Surrey Heath
SH35	19.5	32.5	30.1	167%	154%	Surrey Heath
SH36	20.2	44.9	41.2	222%	204%	Surrey Heath
SH37	20.9	32.6	26.1	156%	125%	Surrey Heath
SH38	23.8	28.8	25.3	121%	106%	Surrey Heath
TD5	29.0	31.0	31.0	107%	107%	Tandridge
TD7	19.4	21.6	21.4	111%	110%	Tandridge
TD8	19.3	21.7	21.7	112%	112%	Tandridge
TD9	17.3	20.0	20.3	116%	117%	Tandridge
TD14	26.9	24.8	22.8	92%	85%	Tandridge
TD19	20.9	28.4	25.1	136%	120%	Tandridge
TD23	23.4	25.0	23.9	107%	102%	Tandridge
TD25	18.7	23.0	21.5	123%	115%	Tandridge
TD26	23.4	29.6	26.0	126%	111%	Tandridge
TD27	28.8	30.2	30.0	105%	104%	Tandridge
TD28	27.8	23.9	23.2	86%	84%	Tandridge
TD30	21.8	21.2	21.7	97%	100%	Tandridge
TD31	19.6	24.0	22.5	123%	115%	Tandridge
TD32	22.0	22.2	22.1	101%	101%	Tandridge
TD33	25.0	22.5	20.6	90%	82%	Tandridge
TD34	20.3	19.5	19.4	96%	96%	Tandridge
TD35	26.7	26.8	26.2	100%	98%	Tandridge
TD36	24.8	23.3	21.6	94%	87%	Tandridge
TD37	19.1	22.9	22.1	120%	116%	Tandridge
TD38	25.1	25.2	24.5	100%	98%	Tandridge
TD39	26.5	21.4	21.4	81%	81%	Tandridge
TD40	33.0	25.7	25.4	78%	77%	Tandridge
TANWI_001	23.2	22.6	22.1	97%	95%	Tandridge
TANWI_002	31.4	22.6	22.1	72%	70%	Tandridge
TANWI_003	42.1	30.2	28.9	72%	69%	Tandridge
TANWI_004	26.0	33.2	31.6	128%	121%	Tandridge
TANWI_005	41.4	27.0	26.1	65%	63%	Tandridge
TANWI_006	24.6	24.6	24.0	100%	98%	Tandridge

Site ID	Concentration, µg/m ³			Gatwick Modelled / Monitored ratio	Heathrow Modelled / Monitored ratio	Borough
	Monitored	Gatwick	Heathrow			
WOK_LTK	24.6	23.1	21.6	94%	88%	Woking
WOK_LT1	34.6	21.8	20.5	63%	59%	Woking
WOK_M25	42.8	65.7	58.3	154%	136%	Woking
WOK_CR	20.9	23.1	21.4	111%	102%	Woking
WOK_RC	18.2	18.8	17.9	103%	98%	Woking
WOK_AH1	34.6	31.0	27.2	90%	79%	Woking
WOK_AH2	31.9	29.5	25.9	92%	81%	Woking
WOK_AH3	22.8	28.4	25.0	125%	110%	Woking
WOK_AH4	27.3	22.8	20.2	84%	74%	Woking
WOK_AH5	26.4	27.2	24.6	103%	93%	Woking
WOK_AH6	29.1	27.9	25.5	96%	88%	Woking
WOK_LGR	23.7	20.1	19.2	85%	81%	Woking
WOK_LD	17.3	19.6	18.5	113%	107%	Woking
WOK_VW	31.9	30.7	28.4	96%	89%	Woking
WOK_BD	15.5	18.4	17.3	119%	112%	Woking
WOK_BR	24.6	22.2	20.9	90%	85%	Woking
WOK_BR1	22.8	22.2	20.5	97%	90%	Woking
WOK_PR	22.8	23.4	21.2	103%	93%	Woking
WOK_GR	26.4	22.3	21.3	84%	81%	Woking
WOK_MR	31.9	27.2	24.9	85%	78%	Woking
WOK_MR2	28.2	27.2	24.9	96%	88%	Woking
WOK_CH	37.3	33.2	29.2	89%	78%	Woking
WOK_CH2	41.9	31.4	29.0	75%	69%	Woking
WOK_CH3	41.9	33.0	30.8	79%	74%	Woking
WOK_CH4	38.2	34.9	32.3	91%	85%	Woking
WOK_TC	26.4	27.1	26.3	103%	100%	Woking
WOK_OR	25.5	21.0	19.6	82%	77%	Woking
WOK_YR	24.6	28.5	26.8	116%	109%	Woking
WOK_YR1	25.5	31.4	29.2	123%	115%	Woking
WOK_TW	13.7	18.1	17.0	132%	124%	Woking
WOK_CW	21.8	18.0	17.0	83%	78%	Woking
WOK_BW	21.8	18.7	17.6	86%	81%	Woking

Appendix B: Model verification using Gatwick Airport meteorological data

Appendix B presents figures and tables for model verification data using Gatwick Airport meteorological data. Appendix B consists of:

1. Figure B.1: Presents a wind rose showing the frequency of occurrence of wind from different directions for a number of wind speed ranges for Gatwick Airport
2. Table B.1: Summarises the meteorological data from Gatwick Airport. To take account of the different surface characteristics at Gatwick, compared to the modelled area, a surface roughness of 0.2m was assumed for the meteorological station
3. Table B.2: Summarises background data calculated using Gatwick wind data
4. Figure B.2: A scatter plot modelled against monitored NO₂ concentrations at all monitoring sites
5. Table B.3: A summary of statistics by type of monitor
6. Figure B.3: A box plots comparing the spread of modelled against monitored hourly mean NO₂ concentrations at continuous monitoring sites.
7. Figure B.4: A box plots comparing the spread of modelled against monitored hourly mean NO_x concentrations at continuous monitoring sites.
8. Figure B.5: A box plots comparing the spread of modelled against monitored hourly mean PM₁₀ concentrations at continuous monitoring sites.
9. Figure B.6: A box plots comparing the spread of modelled against monitored hourly mean PM_{2.5} concentrations at continuous monitoring sites
10. Table B.4: A table summarising monitored and modelled NO_x, NO₂, PM₁₀ and PM_{2.5} for all continuous monitoring sites. Using Gatwick meteorological data.

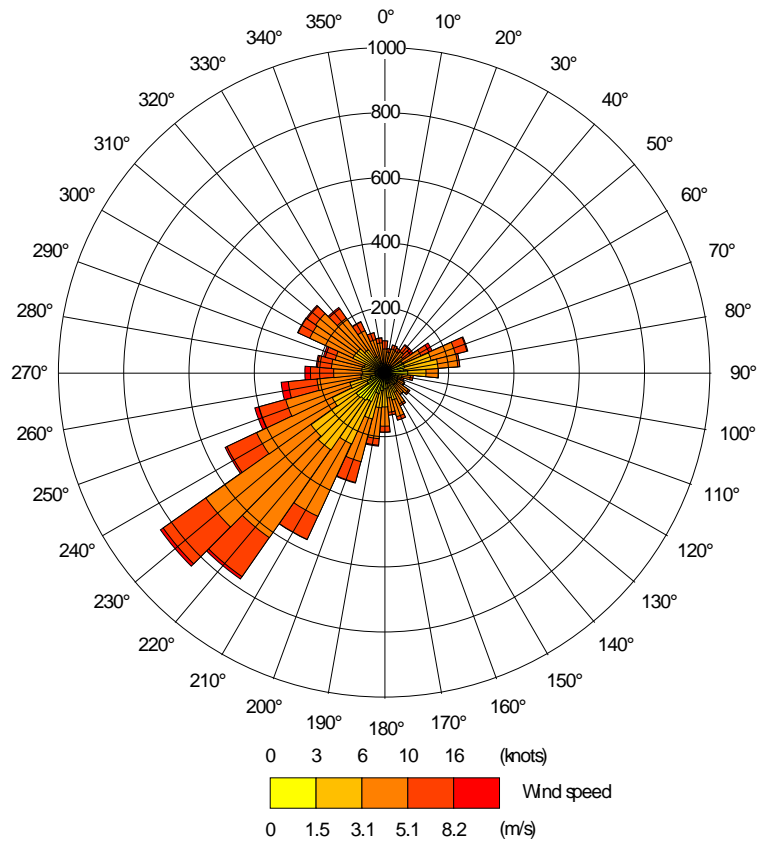


Figure B.1: Wind rose for Gatwick 2017

Table B.1: Summary of Gatwick Airport meteorological data

Year	% of hours used	Parameter	Minimum	Maximum	Mean
2017	99.7	Temperature (°C)	-6	32	11.3
		Wind speed (m/s)	0	16.5	3.5
		Cloud cover (oktas)	0	8	3

Table B.2: Summary of 2017 background data ($\mu\text{g}/\text{m}^3$), calculated using wind data from Gatwick Airport

Statistic	NO _x	NO ₂	O ₃	PM ₁₀	PM _{2.5}	SO ₂
Annual average	15.5	11.7	52.0	14.7	8.7	0.9
99.79 th percentile of hourly average	255.2	74.6	112.4	-	-	-
90.41 st percentile of 24-hour average	-	-	-	26.5	18.8	1.4

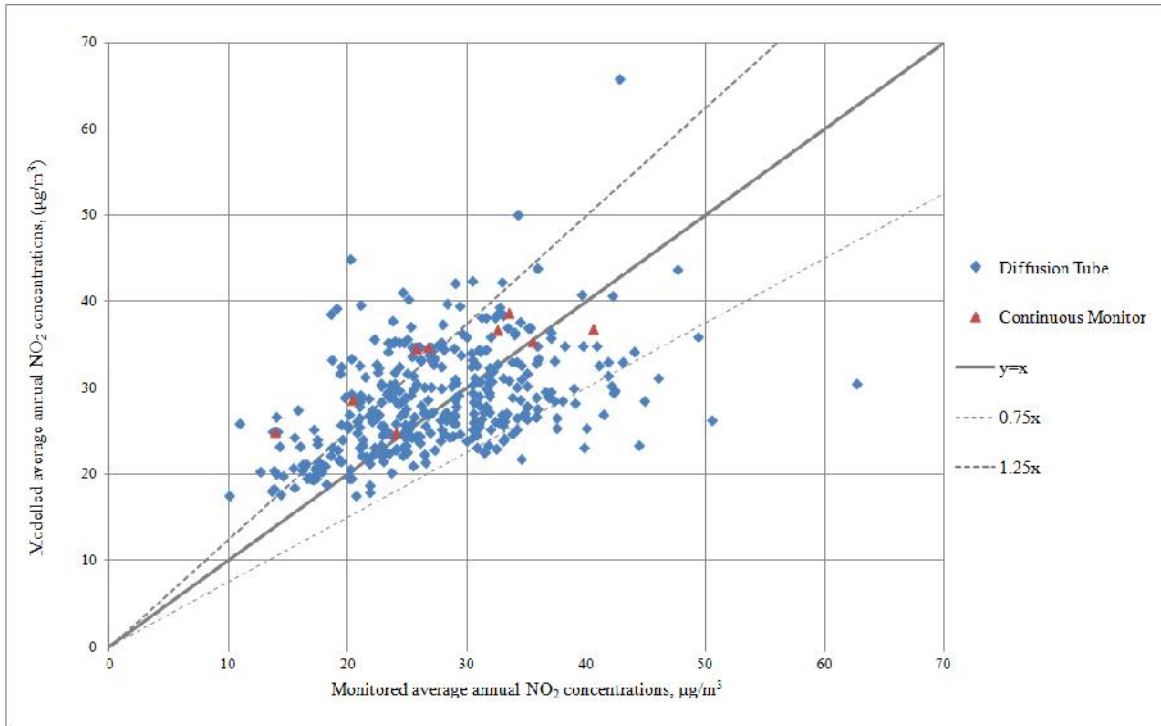


Figure B.2: Surrey measured and modelled annual average NO₂ concentrations using Gatwick meteorological data

Table B.3: Model verification statistics for NO₂ concentrations using Gatwick Airport meteorological data

Gatwick	Min	Max	Mean	Count	Modelled / Monitored	<0.75	>0.75 <1.25	>1.25	% >0.75<1.25
Diffusion tubes	17.5	65.7	28.7	367	1.10	29	245	93	67
Continuous monitors	24.8	38.6	32.8	9	1.23	0	5	4	56
All monitors	17.5	65.7	28.8	376	1.10	29	250	97	67

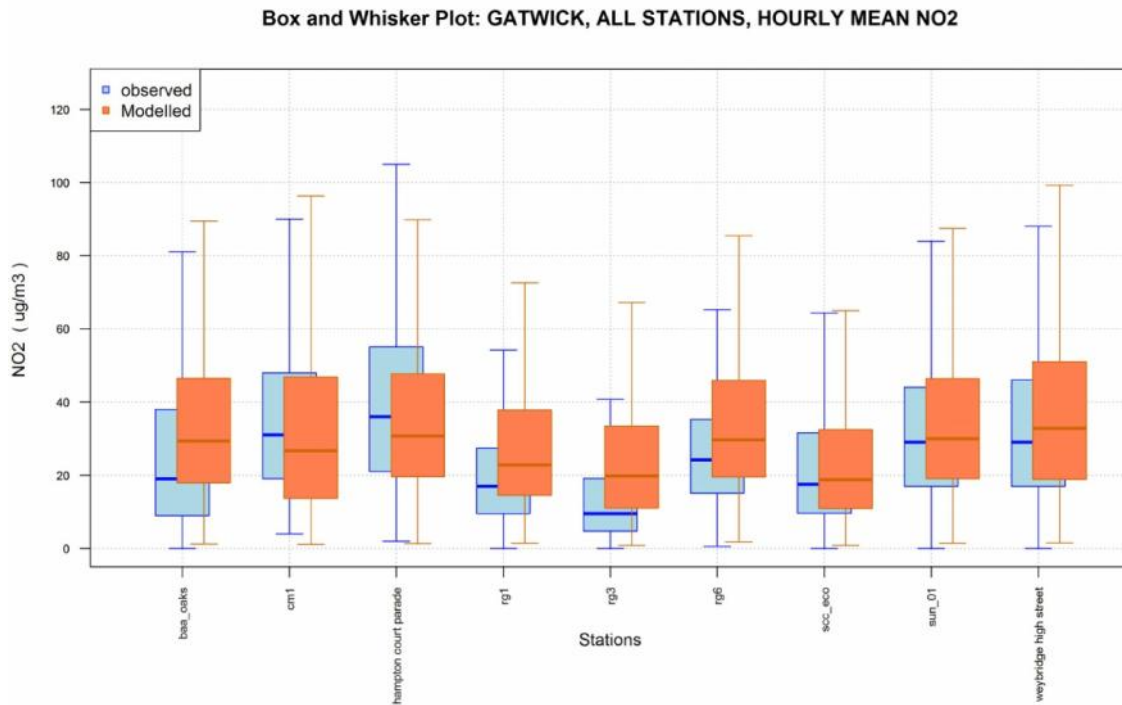


Figure B.3: Surrey measured and modelled annual average NO₂ concentrations at continuous monitoring sites using Gatwick meteorological data

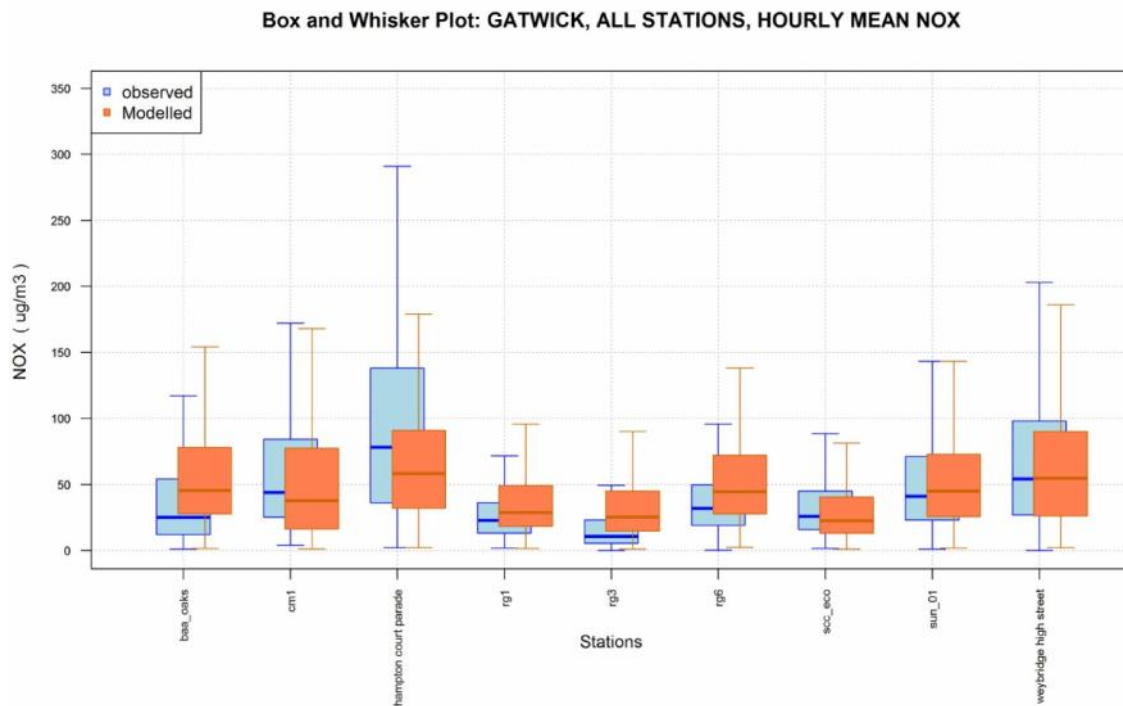


Figure B.4: Surrey measured and modelled annual average NO_x concentrations at continuous monitoring sites using Gatwick meteorological data

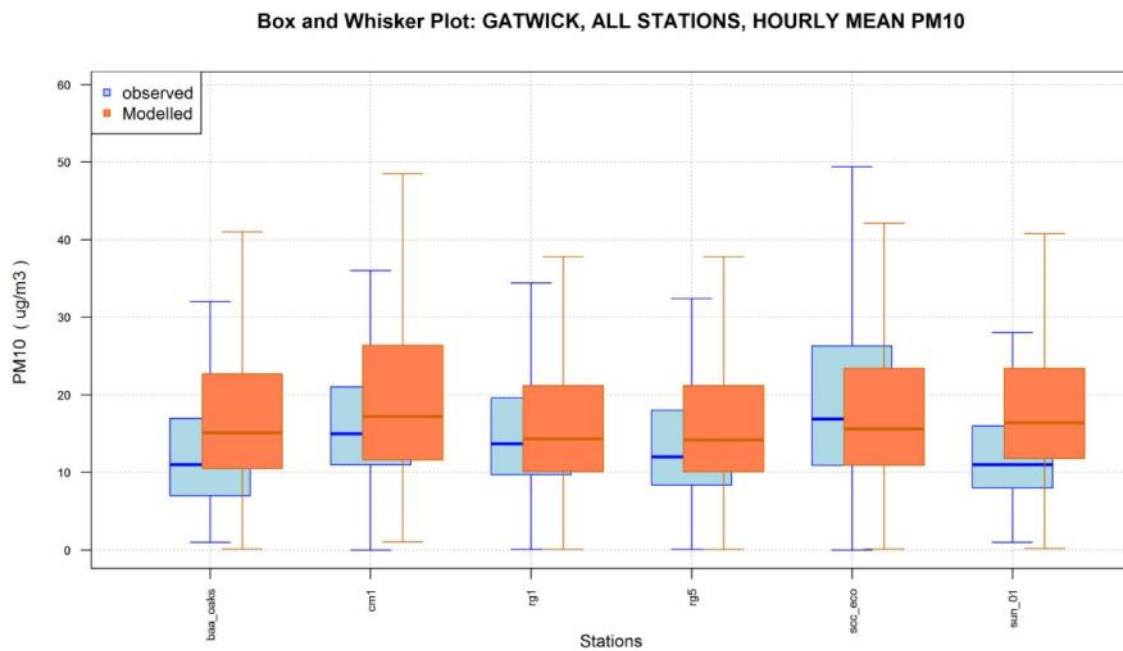


Figure B.5: Surrey measured and modelled annual average PM₁₀ concentrations at continuous monitoring sites using Gatwick meteorological data

Box and Whisker Plot: GATWICK, ALL STATIONS, HOURLY MEAN PM2.5

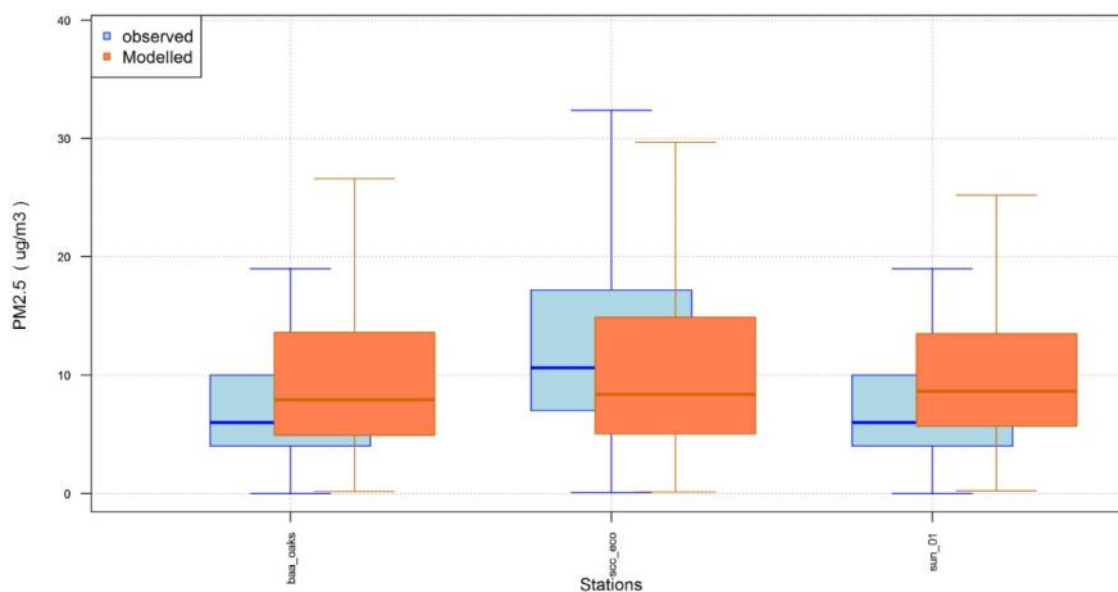


Figure B.6: Surrey measured and modelled annual average PM_{2.5} concentrations at continuous monitoring sites using Gatwick meteorological data

Table B.4: Surrey measured and modelled annual average NO_x, NO₂, PM₁₀ and PM_{2.5} concentrations at continuous monitoring sites using Gatwick meteorological data

Site ID	Monitored concentration, $\mu\text{g}/\text{m}^3$				Modelled concentration, $\mu\text{g}/\text{m}^3$				Modelled / Monitored (%)			
	NO _x	NO ₂	PM ₁₀	PM _{2.5}	NO _x	NO ₂	PM ₁₀	PM _{2.5}	NO _x	NO ₂	PM ₁₀	PM _{2.5}
BAA_Oaks	47.1	25.8	14.1	9.2	67.3	34.6	19.2	12.0	143	134	136	131
CM1	65.8	35.6	17.0	-	61.5	35.3	22.0	-	93	99	129	-
Hampton Court Parade	108.4	40.6	-	-	73.6	36.8	-	-	68	91	-	-
RG1	34.1	20.4	16.2	-	43.8	28.7	17.7	-	128	141	109	-
RG3	19.3	13.9	-	-	39.0	24.9	-	-	202	180	-	-
RG5	-	-	15.2	-	-	-	17.7	-	-	-	116	-
RG6	46.1	26.7	-	-	62.0	34.8	-	-	135	130	-	-
SCC_ECO	44.2	24.1	20.7	14.5	35.8	24.8	19.8	12.9	81	103	95	89
SUN_01	58.6	32.5	13.1	8.0	60.9	36.7	19.6	11.3	104	113	149	141
Weybridge High Street	77.5	33.5	-	-	70.3	38.6	-	-	91	115	-	-

APPENDIX C: 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 has been extensively used for the Review and Assessment of Air Quality carried out by Local Authorities in the UK and for a wide range of planning and policy studies across the world. The following is a summary of the capabilities and validation of ADMS-Urban. More details can be found on the CERC web site at www.cerc.co.uk.

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; 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, Windows 8, Windows 7 and Windows Vista environments. The manipulation of data is further facilitated by the possible integration of ADMS-Urban with a Geographical Information System (GIS) (MapInfo, ArcGIS, or the ADMS-Mapper) and the CERC Emissions Inventory Toolkit, EMIT.

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, 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 pre-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 industrial emissions from chimneys as well as emissions from road traffic and domestic heating systems. 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 can be integrated with the ArcGIS or MapInfo to facilitate 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.

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)*²¹, 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 model²² 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)*²³ atmospheric chemistry scheme. The original scheme has seven reactions, including those occurring between nitrogen oxides and ozone. The remaining reactions are 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 the situation when high concentrations of nitric oxide (NO) can convert to nitrogen dioxide (NO₂) using molecular oxygen.

In addition to the basic GRS scheme, ADMS-Urban also includes a trajectory model²⁴ 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.

²¹ 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.

²² 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.harmonisation.org/Conferences/Proceedings/_Varna/publishedSections/H16-067-Hood-EA.pdf

²³ 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.

²⁴ 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.

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 FLOWSTAR²⁵ model developed by CERC.

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, during projects supported by local governments and research organisations. A summary of published model validation studies is available at www.cerc.co.uk/Validation, with other publications available at www.cerc.co.uk/publications.

²⁵ 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.