Epping Forest NO_2 and NH_3 Diffusion Tube Monitoring

Air Quality Monitoring Technical Note

Epping Forest District Council

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Quality information

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Distribution List

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1. Introduction

1.1 Overview

In 2018, AECOM was commissioned to set up a diffusion tube network monitoring nitrogen dioxide (NO_2) and ammonia (NH_3) concentrations at 13 transects in the vicinity of the Epping Forest Special Area of Conservation (SAC) / Site of Special Scientific Interest (SSSI). The study also included one background NO_2 and NH_3 monitoring location in the Forest well away from roads, an additional NO_2 background location within the Forest, and a co-located NO_2 monitoring site alongside the automatic monitoring station at the Prince of Wales school in Enfield. The nine months of monitoring commenced on 24th May 2018, and was decommissioned on 15th February 2019. More recently, a three month co-location of NH_3 tubes was set up with an ALPHA sampler at the UKEAP Cromwell Road site in central London.

The locations for 13 transects perpendicular to major roads in the Forest were agreed with Epping Forest District Council (EFDC) and the City of London (CoL) Conservators. Measurement locations along the transects were spaced at approximate distances of 0 metres (m), 5m, 10m, 20m, 40m, 70m, 100m, 150m and 200m back from the kerb. Five transects (T1, T3, T4, T6, T8) included NO_2 and NH_3 monitoring sites along the transect[1], with triplicate tubes set up at 0m and 20m or 40m. For the remaining transects (T2, T5, T7, T10, T11, T12, T13, T14), NO_2 monitoring sites were chosen using the same approximate spacing up to 40m from the kerb (0m, 5m, 10m, 20m, 40m), with one triplicate site at the roadside. The monitoring locations are shown in Appendix A.

The transect monitoring provides information regarding the drop-off of pollutant concentrations from road traffic sources. The 200m transect extent was selected as it is well documented that the contribution to NO_x and NO_2 from road traffic is unlikely to extend discernibly beyond this distance from the road. Similarly, the contribution to NH_3 concentrations from road traffic is unlikely to extend significantly beyond 40m from the road.

The NO_2 diffusion tubes were prepared and analysed by Gradko International Ltd using a 50% triethanolamine (TEA) in water solution. The NH_3 diffusion tubes were also prepared and analysed by Gradko International Ltd in accordance with in-house method GLM 8.

The triplicate tubes for each location were assessed for their precision as part of the QA/QC process when processing the results. The coefficient of variance (CV) was used to assess the precision of the triplicate tubes. CV values of less than 20% indicate good precision in the results presented. Any triplicate results with CV values greater than 20% were omitted from the final dataset.

Over the monitoring period, any unreliable data were discarded. Reasons for data rejection include tube contamination by water droplets, insects or spiders and their nests, and also when results were found to be spuriously low or high, relative to other similar sites.

1.2 Scope of the Survey

The purpose of the survey was to provide:

- monthly mean concentrations of oxides of nitrogen (NOx), as µg/m^3 of nitrogen dioxide (NO_2) at locations ranging from zero to 200 metres from the roadside within the SAC/SSSI, and at locations representative of background conditions within the SAC/SSSI; and
- monthly mean concentrations of reductant of nitrogen, as µg/m^3 of ammonia (NH_3) at locations ranging from zero to 200 metres from the roadside within the SAC/SSSI, and at locations representative of background conditions within the SAC/SSSI.

The monthly mean values can be used to calculate long term mean concentration values, such as annual mean concentration values, that can be compared against relevant air quality standards for the protection of ecosystems. These standards are listed in Appendix B.

[1] NH_3 monitoring at T4 was up to 40m from the kerb.

2. Monitoring Methodology

2.1 Staff and Materials

The survey was undertaken by suitably qualified and trained staff. The results of the survey have been analysed and reviewed appropriately by air quality professionals.

There is no internationally recognised standard for the use of passive diffusion tubes (Palmes tubes) to sample nitrogen dioxide and ammonia. However, the method is widely used, especially in UK and European countries, as a method for informing decision making for the development control process.

The NO_2 diffusion tubes were prepared and analysed by Gradko International Ltd using a 50% triethanolamine (TEA) in water solution. Gradko is a UKAS accredited laboratory (ISO: 17025).

The NH_3 diffusion tubes were also prepared and analysed by Gradko International Ltd in accordance with in-house method GLM 8[2]. Gradko proposed changing the sampling rate used to calculate concentrations of ammonia in air (µg/m^3) in January 2019, following a study that found that the Gradko DIF400 diffusion tubes have a positive bias compared to the controlled atmosphere[3]. However, procedure GLM 8 was maintained for the Epping Forest and London Cromwell Road tubes so as to maintain consistency throughout the study, and a bias adjustment factor was calculated specifically for the study, as presented in Appendix E.

2.2 Survey Permissions

Epping Forest is a registered charity managed by the City of London. The survey used passive methods to measure the concentrations of gases within the SAC/SSSI, and as such there was no need to carry out any works which could potentially affect the environment within the site. As a statutory site of ecological importance, permission was sought and granted by the City of London Conservators to undertake works within the site each month.

2.3 Monitoring Locations

Much of the SAC/SSSI is densely wooded. The monitoring locations chosen at the time of the commencement of the baseline survey therefore reflected the practicalities of gaining safe access to those parts of the site at all times of the year. Care was taken to select monitoring locations which were safely accessible.

Details of each sampling location were recorded. Due to the nature of the study area, it was not possible to mount the diffusion tubes on stakes driven into the ground and so appropriate tree trunks or large branches were chosen to mount the tubes, subject to sufficient clearance around the tubes from smaller branches and/or summer leaves. Where possible, at roadside locations street furniture was used to mount the tubes. The height of the samplers was recorded, and a photograph of the sampling site saved to file.

The survey included two sampling positions representative of background air pollutant concentrations within the SAC/SSSI. The background locations were remote from any potentially significant local sources of the pollutants being sampled. Details of all locations used in the survey are presented in Appendix A.

2.4 Sampling Methodology

Baseline sampling for NO_2 and NH_3 was undertaken within the SAC/SSSI, during the period May 2018 to February 2019.

Pollutant specific passive diffusion tubes suitable for the measurement of NO_2 and NH_3 are commercially available from a wide range of organisations. The concentration of NO_x can be calculated from NO_2 monitoring results by using the NO_x:NO_2 converter tool provided by Defra[4].

The diffusion tubes were stored in a refrigerator when not in use and care was taken during transfer to and from the sampling site to avoid exposure of the tubes to intense UV light or extreme temperatures.

[2] https://www.gradko.com/environmental/products/ammonia.shtml
[3] https://www.sciencedirect.com/science/article/pii/S1352231018308185
[4] Current version of the tool is version 6.1, https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html#NOxNO2calc

The tubes were exposed on site for a period of approximately 4 weeks, consistent with the sampling advice provided by the Gradko. Following exposure, the tubes were collected and re-sealed before being returned to the laboratory for analysis.

Additional tubes were used as controls (travel blanks) during the survey. These tubes were not exposed to the air but were analysed. The controls serve to identify any potential issues with handling and use of the diffusion tubes.

The tubes were positioned at a height above local ground level of around 2m. Appropriate fixings were used to hold the tubes at a suitable distance away from obstructions and at the correct angle. Examples of the diffusion tube setup are shown in Figure 1.

Figure 1: Examples of diffusion tube mounting in Epping Forest

3. NO_2 Monitoring Results

Appendix C presents the raw NO_2 monitoring data for each period of the monitoring survey. Those data that are considered to be suspicious are flagged for exclusion in the following analysis.

A local bias adjustment factor was calculated using data from the triplicate diffusion tubes co-located with the Enfield Prince of Wales School continuous monitoring station and a spreadsheet tool provided by Defra to calculate precision and accuracy of diffusion tubes. The local bias adjustment factor was calculated to be 1.04 and applied to the raw diffusion tube monitoring results. Further details of the bias adjustment factor calculation can be found in Appendix D.

For monitoring surveys of less than one year, or where there are gaps in the data, it is best practice to calculate annualisation factors, which are used to estimate annual mean concentrations from the monitored period mean concentrations. The annualisation calculation is described in Box 7.10 of Defra's technical guidance LAQM.TG16[5]. Location-specific annualisation factors were calculated for each tube location based on the differing periods of missing or excluded data. Further details of the calculation of annualisation factors can be found in Appendix D.

Table 1 shows the period mean NO_2 concentrations, 2018-equivalent annualised and bias-adjusted annual mean NO_2 concentrations, the background NO_2 and NO_x concentrations, and derived annual mean NO_x concentration. The annual mean NO_x concentration can be compared against the annual mean objective for the protection of ecosystems, 30 µg/m^3.

The 2018 annual mean equivalent NO_2 concentrations range from 16.0 µg/m^3 at T9_B3, over 200m from the road (background location), to 59.5 µg/m^3 at the T3_N0 triplicate roadside site. Good agreement was found between the monitored NO_2 background concentration at T9_B3 (16.0 µg/m^3) and Defra's 1 km x 1 km background maps for the grid squares across Epping Forest. Consequently, the measured NO_2 concentration at T9_B3 has been used as the background NO_2 concentration in Defra's NO_x to NO_2 calculator[6] to derive the annual mean NO_x concentrations for each monitoring location. The corresponding background NO_x concentration was calculated by multiplying the monitored T9_B3 NO_2 concentration by the ratio of the Defra mapped background NO_x:NO_2 concentrations for the 1 km x 1 km grid square within which T9_B3 is located (542500,197500); this gave a background NO_x concentration of 22.0 µg/m^3 for Epping Forest.

Figure 2 presents the monitoring results from the transect locations, with measured concentrations plotted against increasing distance from the nearest road. The same trend was seen for all transects; peaks in concentrations are recorded at the roadside locations, with concentrations decreasing with distance away from the road, tending towards background levels at 70-100m from the road edge.

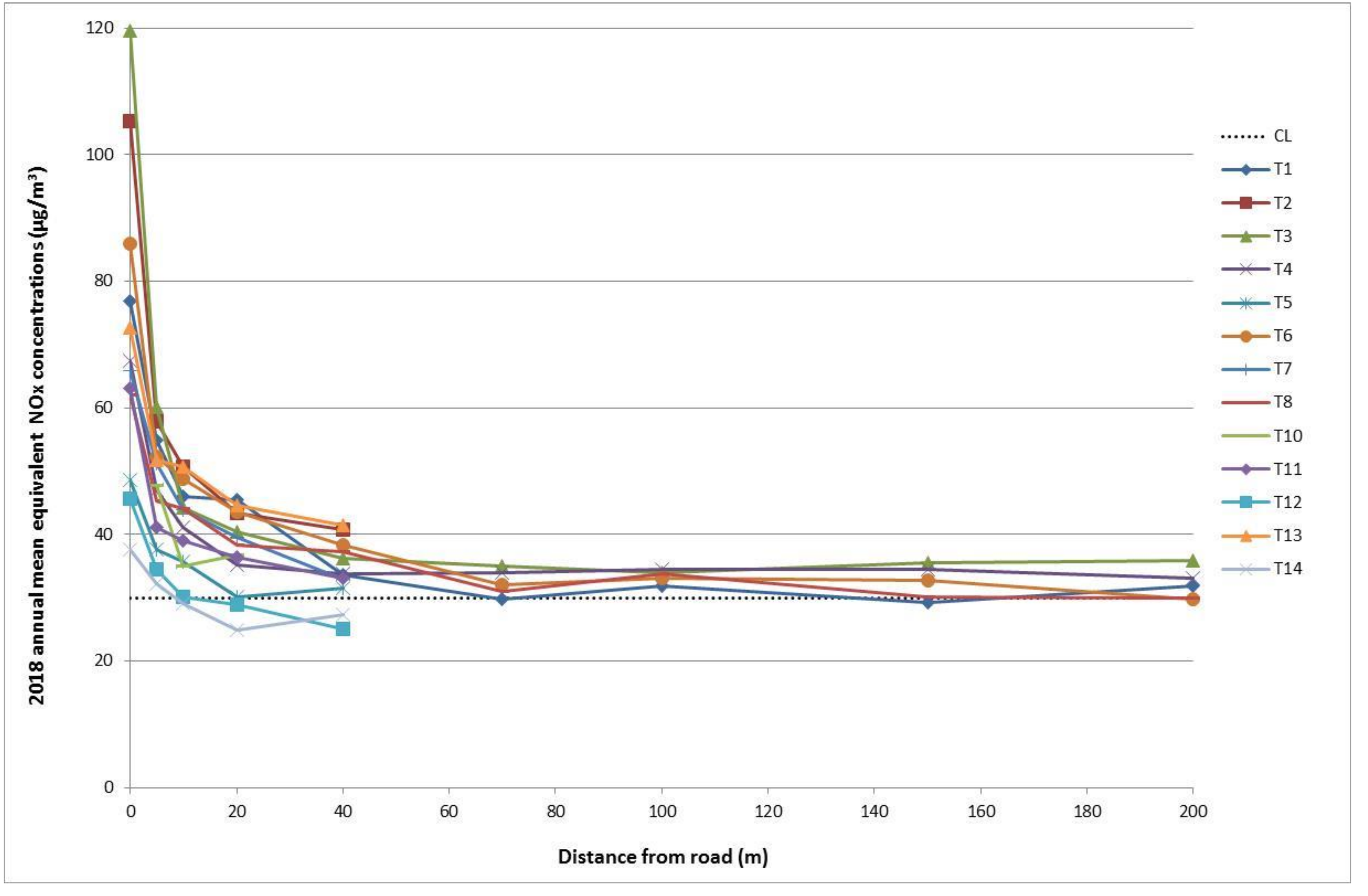
The critical level of 30 µg/m^3 of NO_x as an annual mean is set in the EU Ambient Air Quality Directive, and transposed into UK law by the Air Quality Standards Regulations 2010 for the protection of vegetation. The results of the monitoring survey indicate that concentrations of NO_x exceed this critical level at most of the monitoring sites.

Concentrations lie just below the critical level at a small number of sites beyond 150m from the roadside, and closer to the road at transects located adjacent to less trafficked roads:

- Transect 1, south of A121 Honey Lane – 70m, 150m;
- Transect 6, east of Wake Arms roundabout, between A121 Golding's Hill and B172 – 200m;
- Transect 8, east of A104 Epping New Road – 200m;
- T9_B3; background location >200m from trafficked roads;
- Transect 12, north of A1069 Ranger's Road – 20m, 40m;
- Transect 14, Theydon Road, opposite Theydon Bois Golf Club – 10m, 20m, 40m.

[5] Defra, Local Air Quality Management Technical Guidance LAQM.TG(16), 2018.
[6] Defra's NOx to NO_2 calculator v6.1 https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html#NOxNO2calc

Figure 2: 2018 Annual Mean Equivalent NO_x Concentrations with Distance from the Road



Note: ‘CL’ denotes the NOx critical level, or annual mean air quality objective of 30 µg/m^3 for the protection of vegetation.

Table 1: Epping Forest NO_2 Diffusion Tube Results

Diffusion Tube Location	Distance from Road (m)	NO_2 Period Mean[a] (µg/m^3)	Local Bias Adjustment Factor[b]	Annualisation Factor[c]	Bias Adjusted NO_2 2018 Annual Mean Equivalent (µg/m^3)	Background NO_2[d] (µg/m^3)	Background NO_X[e] (µg/m^3)	Derived Road NO_X[f] (µg/m^3)	Derived Total NO_X[g] (µg/m^3)
T1_N0 (Tri)	0	40.3	1.04	1.01	42.5	16.0	22.0	54.9	**76.8**
T1_N5	5	30.9	1.04	1.01	32.6	16.0	22.0	32.9	**54.8**
T1_N10	10	26.9	1.04	1.01	28.3	16.0	22.0	23.9	**45.9**
T1_N20	20	26.6	1.04	1.01	28.1	16.0	22.0	23.5	**45.4**
T1_N40 (Tri)	40	21.0	1.04	1.01	22.2	16.0	22.0	11.7	**33.6**
T1_N70	70	19.9	1.04	0.97	20.2	16.0	22.0	7.9	29.8
T1_N100	100	19.8	1.04	1.03	21.3	16.0	22.0	10.0	**31.9**
T1_N150	150	18.8	1.04	1.01	19.9	16.0	22.0	7.3	29.2
T1_N200	200	20.1	1.04	1.01	21.2	16.0	22.0	9.8	**31.8**
T2_N0 (Tri)	0	51.2	1.04	1.01	54.1	16.0	22.0	83.3	**105.3**
T2_N5	5	32.3	1.04	1.01	34.0	16.0	22.0	35.9	**57.9**
T2_N10	10	29.1	1.04	1.01	30.7	16.0	22.0	28.8	**50.7**
T2_N20	20	25.7	1.04	1.01	27.1	16.0	22.0	21.4	**43.3**
T2_N40	40	24.4	1.04	1.01	25.7	16.0	22.0	18.7	**40.7**
T3_N0 (Tri)	0	56.4	1.04	1.01	59.5	16.0	22.0	97.7	**119.6**
T3_N5	5	33.2	1.04	1.01	35.0	16.0	22.0	38.1	**60.1**
T3_N10	10	26.1	1.04	1.01	27.5	16.0	22.0	22.4	**44.3**
T3_N20 (Tri)	20	24.3	1.04	1.01	25.6	16.0	22.0	18.5	**40.4**
T3_N40	40	22.3	1.04	1.01	23.5	16.0	22.0	14.3	**36.2**
T3_N70	70	21.7	1.04	1.01	22.9	16.0	22.0	13.0	**35.0**
T3_N100	100	21.2	1.04	1.01	22.3	16.0	22.0	12.0	**34.0**
T3_N150	150	20.7	1.04	1.07	23.1	16.0	22.0	13.5	**35.4**
T3_N200	200	22.1	1.04	1.01	23.3	16.0	22.0	13.8	**35.8**
T4_N0 (Tri)	0	36.4	1.04	1.01	38.4	16.0	22.0	45.5	**67.5**

Diffusion Tube Location	Distance from Road (m)	NO_2 Period Mean[a] (µg/m^3)	Local Bias Adjustment Factor[b]	Annualisation Factor[c]	Bias Adjusted NO_2 2018 Annual Mean Equivalent (µg/m^3)	Background NO_2[d] (µg/m^3)	Background NO_X[e] (µg/m^3)	Derived Road NO_X[f] (µg/m^3)	Derived Total NO_X[g] (µg/m^3)
T4_N5	5	26.7	1.04	1.04	28.8	16.0	22.0	25.0	**46.9**
T4_N10	10	24.6	1.04	1.01	26.0	16.0	22.0	19.2	**41.1**
T4_N20 (Tri)	20	21.8	1.04	1.01	23.0	16.0	22.0	13.2	**35.2**
T4_N40	40	21.0	1.04	1.01	22.2	16.0	22.0	11.7	**33.7**
T4_N70	70	21.2	1.04	1.01	22.3	16.0	22.0	12.0	**33.9**
T4_N100	100	21.4	1.04	1.01	22.6	16.0	22.0	12.6	**34.5**
T4_N150	150	21.4	1.04	1.01	22.6	16.0	22.0	12.6	**34.5**
T4_N200	200	20.8	1.04	1.01	21.9	16.0	22.0	11.2	**33.1**
T5_N0 (Tri)	0	28.1	1.04	1.01	29.6	16.0	22.0	26.7	**48.6**
T5_N5	5	22.9	1.04	1.01	24.2	16.0	22.0	15.6	**37.5**
T5_N10	10	22.0	1.04	1.01	23.2	16.0	22.0	13.7	**35.7**
T5_N20	20	19.2	1.04	1.01	20.3	16.0	22.0	8.1	**30.0**
T5_N40	40	20.0	1.04	1.01	21.1	16.0	22.0	9.5	**31.5**
T6_N0 (Tri)	0	43.9	1.04	1.01	46.3	16.0	22.0	63.9	**85.9**
T6_N5	5	29.7	1.04	1.01	31.4	16.0	22.0	30.3	**52.2**
T6_N10	10	28.2	1.04	1.01	29.7	16.0	22.0	26.8	**48.7**
T6_N20 (Tri)	20	25.8	1.04	1.01	27.2	16.0	22.0	21.6	**43.6**
T6_N40	40	23.3	1.04	1.01	24.6	16.0	22.0	16.4	**38.4**
T6_N70	70	21.0	1.04	0.97	21.3	16.0	22.0	10.0	**32.0**
T6_N100	100	20.2	1.04	1.04	21.9	16.0	22.0	11.1	**33.1**
T6_N150	150	20.6	1.04	1.01	21.7	16.0	22.0	10.8	**32.7**
T6_N200	200	18.8	1.04	1.03	20.1	16.0	22.0	7.8	29.7
T7_N0 (Tri)	0	35.7	1.04	1.01	37.7	16.0	22.0	43.9	**65.8**
T7_N5	5	29.3	1.04	1.01	30.9	16.0	22.0	29.3	**51.2**
T7_N10	10	25.9	1.04	1.01	27.4	16.0	22.0	22.0	**43.9**

Diffusion Tube Location	Distance from Road (m)	NO_2 Period Mean[a] (µg/m³)	Local Bias Adjustment Factor[b]	Annualisation Factor[c]	Bias Adjusted NO_2 2018 Annual Mean Equivalent (µg/m³)	Background NO_2[d] (µg/m³)	Background NO_X[e] (µg/m³)	Derived Road NO_X[f] (µg/m³)	Derived Total NO_X[g] (µg/m³)
T7_N20	20	23.9	1.04	1.01	25.2	16.0	22.0	17.6	**39.6**
T7_N40	40	20.4	1.04	1.03	21.8	16.0	22.0	11.0	**33.0**
T8_N0 (Tri)	0	34.0	1.04	1.01	35.9	16.0	22.0	40.0	**62.0**
T8_N5	5	26.5	1.04	1.01	28.0	16.0	22.0	23.3	**45.2**
T8_N10	10	26.0	1.04	1.01	27.5	16.0	22.0	22.2	**44.1**
T8_N20 (Tri)	20	23.2	1.04	1.01	24.5	16.0	22.0	16.3	**38.2**
T8_N40	40	22.8	1.04	1.01	24.0	16.0	22.0	15.3	**37.2**
T8_N70	70	19.7	1.04	1.01	20.7	16.0	22.0	9.0	**30.9**
T8_N100	100	21.1	1.04	1.01	22.2	16.0	22.0	11.8	**33.7**
T8_N150	150	19.3	1.04	1.01	20.3	16.0	22.0	8.1	**30.1**
T8_N200	200	19.1	1.04	1.01	20.2	16.0	22.0	7.9	29.8
T9_B3 (Tri)	>200	13.9	1.04	1.10	16.0 [d]	16.0	22.0	0.0 [g]	22.0 [d]
T10_N5 (Tri)	5	27.7	1.04	1.01	29.2	16.0	22.0	25.8	**47.8**
T10_N10	10	21.1	1.04	1.04	22.8	16.0	22.0	13.0	**34.9**
T10_N20	20	22.5	1.04	1.01	23.8	16.0	22.0	14.8	**36.8**
T10_N40	40	[h]	1.04	1.01	[h]	16.0	22.0	[h]	[h]
T11_N0 (Tri)	0	34.5	1.04	1.01	36.4	16.0	22.0	41.2	**63.1**
T11_N5	5	24.6	1.04	1.01	25.9	16.0	22.0	19.1	**41.0**
T11_N10	10	23.6	1.04	1.01	24.9	16.0	22.0	17.0	**39.0**
T11_N20	20	22.4	1.04	1.01	23.6	16.0	22.0	14.4	**36.4**
T11_N40	40	20.4	1.04	1.03	21.8	16.0	22.0	11.1	**33.0**
T12_N0 (Tri)	0	26.7	1.04	1.01	28.2	16.0	22.0	23.6	**45.6**
T12_N5	5	21.4	1.04	1.01	22.6	16.0	22.0	12.5	**34.4**
T12_N10	10	19.2	1.04	1.01	20.3	16.0	22.0	8.1	**30.1**
T12_N20	20	18.7	1.04	1.01	19.7	16.0	22.0	6.9	28.9

Diffusion Tube Location	Distance from Road (m)	NO_2 Period Mean[a] (µg/m^3)	Local Bias Adjustment Factor[b]	Annualisation Factor[c]	Bias Adjusted NO_2 2018 Annual Mean Equivalent (µg/m^3)	Background NO_2[d] (µg/m^3)	Background NO_X[e] (µg/m^3)	Derived Road NO_X[f] (µg/m^3)	Derived Total NO_X[g] (µg/m^3)
T12_N40	40	16.7	1.04	1.01	17.6	16.0	22.0	3.1	25.0
T13_N0 (Tri)	0	38.6	1.04	1.01	40.7	16.0	22.0	50.8	**72.7**
T13_N5	5	29.5	1.04	1.01	31.1	16.0	22.0	29.7	**51.7**
T13_N10	10	29.1	1.04	1.01	30.6	16.0	22.0	28.7	**50.7**
T13_N20	20	26.1	1.04	1.02	27.7	16.0	22.0	22.6	**44.6**
T13_N40	40	24.8	1.04	1.01	26.2	16.0	22.0	19.6	**41.5**
T14_N0 (Tri)	0	22.9	1.04	1.01	24.2	16.0	22.0	15.7	**37.6**
T14_N5	5	20.3	1.04	1.01	21.4	16.0	22.0	10.2	**32.1**
T14_N10	10	18.8	1.04	1.01	19.8	16.0	22.0	7.2	29.1
T14_N20	20	16.6	1.04	1.01	17.5	16.0	22.0	2.9	24.8
T14_N40	40	18.4	1.04	0.99	18.8	16.0	22.0	5.3	27.2
Co-Lo (Tri)	>200	22.9	1.04	1.01	24.1	16.0	22.0	15.5	**37.4**
BG_N	>200	20.4	1.04	0.97	20.7	16.0	22.0	8.8	**30.7**

Notes:
[a] Excludes data flagged for exclusion (see Appendix C);
[b] Derived from co-location of tubes at Enfield Prince of Wales School (Appendix D);
[c] 2018 annual mean equivalent is calculated using data from three background continuous monitoring sites (London Haringey Priory Park South, Enfield Prince of Wales School and Redbridge Ley Street);
[d] Monitored concentration from T9_B3 (Tri) taken as background NO_2 concentration for Epping Forest;
[e] Background NO_X concentration calculated by multiplying the monitored T9_B3 (Tri) NO_2 concentration by the ratio of the Defra mapped background NO_X:NO_2 concentrations for the 1 km x 1 km grid square within which T9_B3 (Tri) is located (542500,197500);
[f] Derived using Defra's NO_X to NO_2 calculator;
[g] Background NO_X plus derived road NO_X
[h] Insufficient data collected (1 month) to derive annual mean.

4. NH_3 Monitoring Results

A three-month co-location study was undertaken by AECOM from December 2018 to February 2019 at the London Cromwell Road UK Eutrophying and Acidifying Pollutant (UKEAP) network site in order to derive a bias adjustment factor for the Epping Forest diffusion tube survey. The Cromwell Road monitoring station is equipped with the Adapted Low-cost Passive High-Absorption (ALPHA) passive sampler that measures gaseous ammonia on a monthly basis. The raw diffusion tube data from the co-location study are presented in Appendix E, along with details of the bias adjustment factor calculation. A bias adjustment factor of 0.59 was calculated, indicating that the diffusion tubes overestimate NH_3 concentrations by approximately 40% in comparison to the ALPHA sampler.

Location-specific annualisation factors were calculated for each tube location to estimate annual mean concentrations from the monitored period mean concentrations. Further details of the calculation of annualisation factors can be found in Appendix E.

Table 2 shows the period mean NH_3 concentrations and 2018-equivalent annualised and bias-adjusted annual mean NH_3 concentrations. The annual mean NH_3 concentrations can be compared against the critical levels for ammonia; 1 µg/m^3 for lichens and bryophytes, and 3 µg/m^3 for other vegetation (see Appendix B). The raw monthly NH_3 concentrations from the NH_3 monitoring survey in Epping Forest are presented in Appendix F.

The 2018 annual mean equivalent NH_3 concentrations range from 1.6 µg/m^3 at 100m from the roadside, to 4.3 µg/m^3 at the T6_A0 triplicate roadside site. The concentration recorded at the T9 B3 background site for 2018 is 1.7 µg/m^3, which is in reasonable agreement with the APIS background concentration of 1.1 µg/m^3 (1.09 µg/m^3) for Epping Forest that was used in the 2019 HRA modelling.

Figure 3 presents the monitoring results from the transect locations, with measured concentrations plotted against increasing distance from the nearest road. The same trend was broadly seen for all transects; peaks in concentrations are recorded at the roadside locations, with concentrations decreasing with distance away from the road, tending towards background levels at 70-100m from the road edge.

The critical level of 1 µg/m^3 of NH_3 as an annual mean is set by the Convention on Long-Range Transboundary Air Pollution (CLRTAP) for the protection of lichen and bryophytes. The results of the monitoring survey indicate that concentrations of NH_3 exceed this critical level at all the monitoring sites, including at the T9 B3 background site, greater than 200m from trafficked roads.

The critical level of 3 µg/m^3 of NH_3 as an annual mean is set by CLRTAP for the protection of other vegetation. The results of the monitoring survey indicate that concentrations of NH_3 exceed this critical level at locations within approximately 5 m of heavily trafficked roads and fall off sharply to levels below the critical level within 20 m of the kerb. At distances of 50m from the roadside and above, there is little evidence of any influence of road traffic sources on monitored NH_3 concentrations.

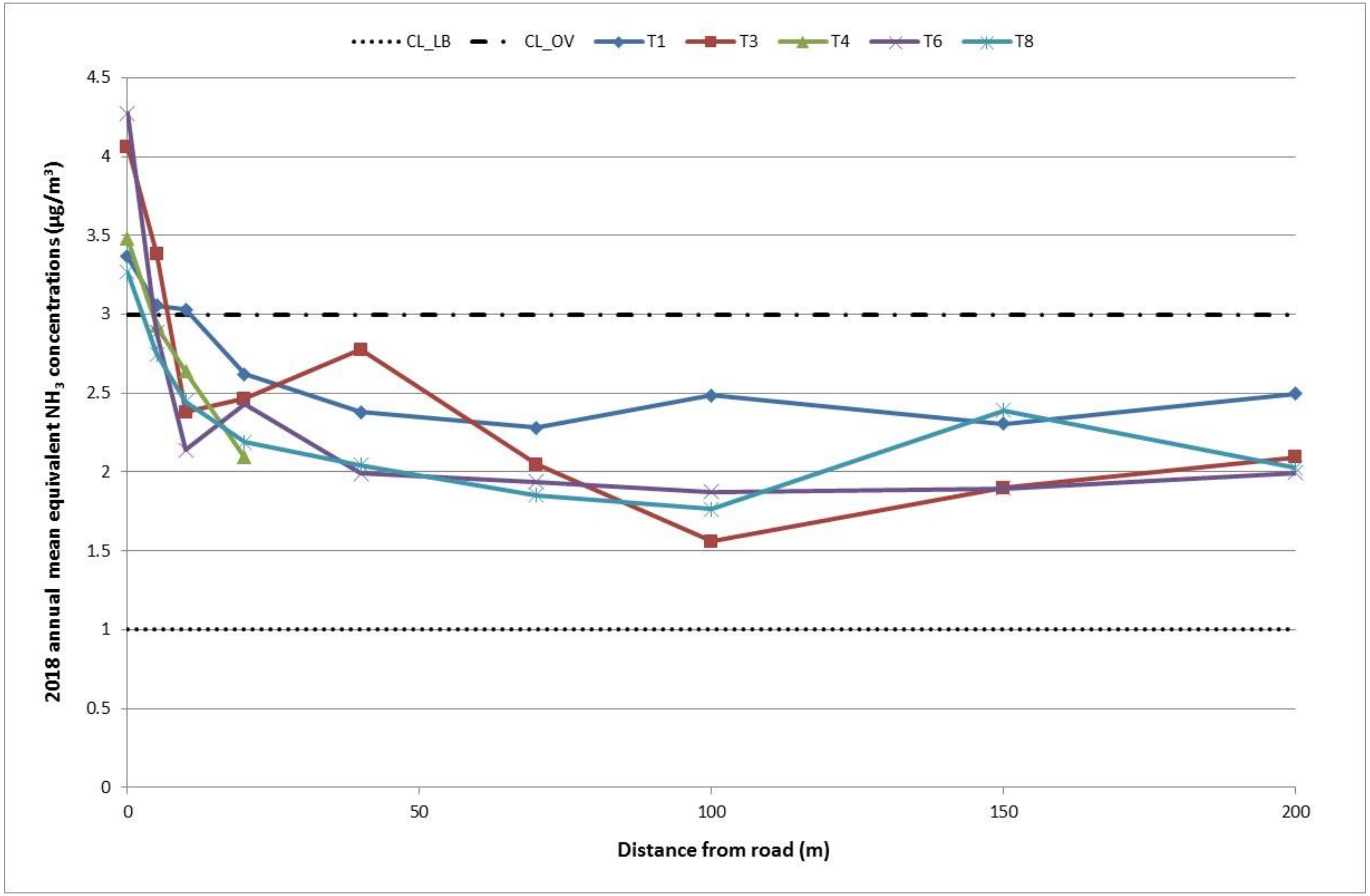
Table 2: Epping Forest NH_3 Diffusion Tube Results

Diffusion Tube Location	Distance from Road (m)	NH_3 Period Mean[a] (µg/m^3)	Bias Adjustment Factor[b]	Annualisation Factor[c]	Bias Adjusted NH_3 2018 Annual Mean Equivalent (µg/m^3)
T1_A0 (Tri)	0	5.2	0.59	1.09	3.4
T1_A5	5	5.4	0.59	0.97	3.1
T1_A10	10	5.3	0.59	0.97	3.0
T1_A20	20	4.6	0.59	0.97	2.6
T1_A40 (Tri)	40	3.6	0.59	1.11	2.4
T1_A70	70	3.5	0.59	1.09	2.3
T1_A100	100	4.2	0.59	1.01	2.5
T1_A150	150	3.6	0.59	1.09	2.3
T1_A200	200	3.9	0.59	1.09	2.5
T3_A0 (Tri)	0	7.1	0.59	0.97	4.1
T3_A5	5	5.3	0.59	1.07	3.4

Diffusion Tube Location	Distance from Road (m)	NH_3 Period Mean[a] ($\mu g/m^3$)	Bias Adjustment Factor[b]	Annualisation Factor[c]	Bias Adjusted NH_3 2018 Annual Mean Equivalent ($\mu g/m^3$)
T3_A10	10	4.0	0.59	1.01	2.4
T3_A20 (Tri)	20	3.8	0.59	1.09	2.5
T3_A40	40	4.3	0.59	1.09	2.8
T3_A70	70	3.2	0.59	1.09	2.0
T3_A100	100	3.3	0.59	0.79	1.6
T3_A150	150	3.5	0.59	0.92	1.9
T3_A200	200	3.3	0.59	1.07	2.1
T4_A0 (Tri)	0	5.4	0.59	1.09	3.5
T4_A5	5	4.5	0.59	1.09	2.9
T4_A10	10	4.1	0.59	1.09	2.6
T4_A20	20	3.5	0.59	1.01	2.1
T4_A40	40	3.1	0.59	[d]	[d]
T6_A0 (Tri)	0	6.6	0.59	1.09	4.3
T6_A5	5	4.5	0.59	1.09	2.9
T6_A10	10	3.3	0.59	1.11	2.1
T6_A20 (Tri)	20	3.8	0.59	1.09	2.4
T6_A40	40	3.1	0.59	1.07	2.0
T6_A70	70	3.0	0.59	1.09	1.9
T6_A100	100	3.3	0.59	0.98	1.9
T6_A150	150	2.9	0.59	1.09	1.9
T6_A200	200	3.1	0.59	1.09	2.0
T8_A0 (Tri)	0	5.1	0.59	1.09	3.3
T8_A5	5	4.3	0.59	1.09	2.7
T8_A10	10	3.8	0.59	1.09	2.4
T8_A20 (Tri)	20	3.4	0.59	1.09	2.2
T8_A40	40	3.2	0.59	1.09	2.0
T8_A70	70	3.2	0.59	0.98	1.9
T8_A100	100	2.7	0.59	1.09	1.8
T8_A150	150	3.7	0.59	1.10	2.4
T8_A200	200	3.1	0.59	1.09	2.0
T9_B3 (Tri)	>200	2.9	0.59	0.98	1.7

Notes:
[a] Excludes data flagged for exclusion (see Appendix F);
[b] Derived from co-location of tubes at UKEAP London Cromwell Road (see Appendix E);
[c] 2018 annual mean equivalent is calculated using data from four UKEAP background monitoring sites (see Appendix E);
[d] Insufficient data collected (1 month) to derive annual mean.

Figure 3: 2018 Annual Mean Equivalent NH_3 Concentrations with Distance from the Road



Note: 'CL_LB' denotes the NH_3 critical level for lichen and bryophytes (1 µg/m^3); 'CL_OV' denotes the critical level for other vegetation (3 µg/m^3)

Data from the Defra UKEAP Network[7] for 2015 to 2018, inclusive, are shown in Table 3 to compare against NH_3 concentrations measured in Epping Forest. All the UKEAP network sites are equipped with ALPHA passive samplers that measure gaseous ammonia on a monthly basis. The London Cromwell Road and Rothamsted sites also have Denuder for Long Term Atmospheric sampling (DELTA) active samplers, although the results from the DELTA samplers have not been used for comparison in this report.

Table 3: UKEAP Site Information and Annual Mean NH_3 Concentrations

UKEAP Site Name	Site Type	Analyser Type	Gaseous NH_3 Monitoring Method	Annual Mean NH_3 Concentration			
				2015	2016	2017	2018
London - Cromwell Road	Urban Traffic	DELTA sampler ALPHA sampler	Active Passive	3.97 -	2.79 -	- 2.93	- 3.27
Rothamsted	Rural Background	ALPHA sampler	Passive	1.17	1.14	1.42	1.56
Burnham Beeches	Rural Background	ALPHA sampler	Passive	-	-	0.82	0.96
Alice Holt 2	Rural Background	ALPHA sampler	Passive	0.59	0.57	0.72	0.87
Thursley Common 2	Rural Background	ALPHA sampler	Passive	0.94	1.16	0.68	1.13

Compared to the 2015 to 2018 annual mean NH_3 concentrations monitored at the UKEAP locations in Table 3, the NH_3 concentrations monitored in Epping Forest along the five transects were similar to those recorded at Cromwell Road at locations close to the roadside, falling towards concentrations similar to those recorded at Rothamstead beyond approximately 50m from the roadside. Concentrations in the 2015 to 2018 period ranged between 2.9 µg/m^3 and 4.0 µg/m^3 at the London Cromwell Road urban traffic site, whilst at the rural background sites the monitored concentrations were much lower, ranging between 0.6 µg/m^3 and 1.6 µg/m^3.

[7] https://uk-air.defra.gov.uk/networks/network-info?view=ukeap

5. Limitations and Further Work

Due to the nature of the study, it was not possible to mount the diffusion tubes on stakes driven into the ground and so appropriate tree trunks or large branches were chosen to mount the tubes, subject to sufficient clearance around the tubes from smaller branches and/or summer leaves. As such, the diffusion tubes are subject to frequent contamination from the ecology present in the Forest (especially spiders, nests and webs), which can reduce the robustness and accuracy of the results. Where values are unusual and/or where the laboratory has marked a tube as contaminated on receipt, the tube results have been excluded from the calculation of the period mean NO_2 and NH_3 concentrations.

It is recommended that trends in NO_2/NO_x and NH_3 concentrations are tracked going forward by a repetition of this monitoring survey every two years for a period of nine months. A period of nine months will allow for monitoring across the different seasons, and will provide a robust dataset from which to derive annual mean concentrations. Whilst ongoing monitoring is not considered to be necessary, periodic monitoring of pollutant concentrations will allow Epping Forest District Council to track any trends over the course of the Local Plan.

6. Summary

AECOM was commissioned to set up a diffusion tube network monitoring ambient nitrogen dioxide (NO_2) and ammonia (NH_3) concentrations in the Epping Forest SAC/SSSI. The survey was active for 9 months between May 2018 and February 2019. Monitoring locations were set up along thirteen transects extending away from roads and junctions within Epping Forest. The locations included a background site well away from roads, a co-location with an automatic monitor measuring NO_2, and an additional 3-month co-location with a passive NH_3 ALPHA sampler in London.

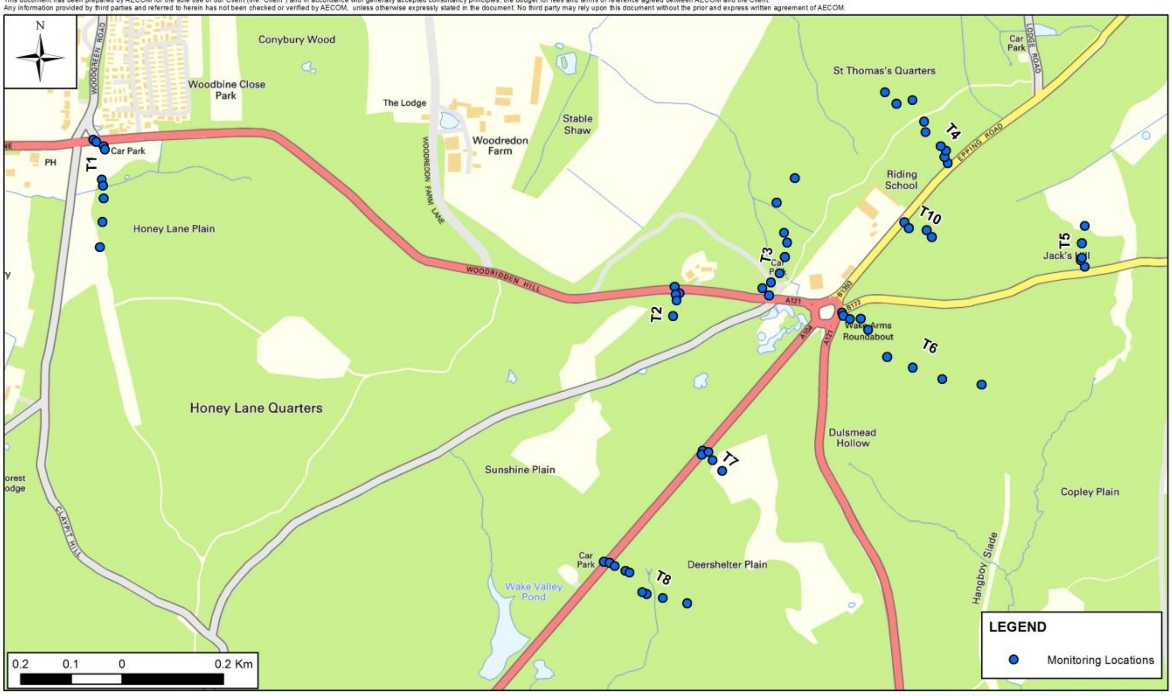
Annualised and bias-adjusted NO_2 diffusion tube results from the study showed that concentrations varied from 16.0 µg/m^3 at the background location to 59.5 µg/m^3 at the T3_N0 roadside location on the T3 transect near the Wake Arms Roundabout. The trend of highest concentrations being found at the roadside locations, and a corresponding fall-off in concentration with distance from the road, was consistent across all transects. Despite the fall-off in NO_2 concentrations away from roads, the majority of monitoring locations were shown to exceed the critical level of NOx on an annual mean basis (30 µg/m^3) for vegetation protection, with the exception of the background location, locations mainly >150m from roads, and nearer to less heavily-trafficked roads.

Annualised and bias-adjusted NH_3 diffusion tube results from the study showed that concentrations varied from 1.6 µg/m^3 at 100m from the roadside, to 4.3 µg/m^3 at the T6_A0 triplicate roadside site (immediately east of the Wake Arms roundabout), with a measured concentration of 4.1 µg/m^3 recorded at T3 A0 roadside location on the T3 transect near the Wake Arms Roundabout. The trend of highest concentrations being found at the roadside locations, and a corresponding fall-off in concentration with distance from the road, was consistent across all transects. Despite the fall-off in concentrations away from roads, all the monitoring locations were shown to exceed the critical level of 1 µg/m^3 on an annual mean basis for the protection of lichen and bryophytes. Monitoring sites up to 5m from the roadside were observed to exceed the critical level of 3 µg/m^3, set for the protection of other vegetation. Background concentrations of NH3 recorded in Epping Forest were found to be similar to those concentrations recorded at the UKEAP Rothamsted site, whilst roadside concentrations were similar to those concentrations recorded at the London Cromwell Road urban traffic UKEAP site.

This report recommends that further 9-month periods of NO_2 and NH_3 monitoring are conducted every two years in order to cost-effectively obtain good seasonal coverage of conditions and to track any trends in NO_2 and NH_3 concentrations across the project over the course of the Local Plan.

Appendix A Epping Forest NO_2 and NH_3 Monitoring Locations

Monitoring	Location	NO_2 monitoring	NH_3 monitoring
Transect 1	South of A121 Honey Lane	0-200m	0-200m
Transect 2	South of A121, west of Wake Arms roundabout	0-40m	-
Transect 3	North of A121, west of Wake Arms roundabout	0-200m	0-200m
Transect 4	West of B1393 Epping Road, north of Wake Arms roundabout	0-200m	0-40m
Transect 5	North of B172, east of Wake Arms roundabout	0-40m	-
Transect 6	East of Wake Arms roundabout, between A121 Golding's Hill and B172	0-200m	0-200m
Transect 7	East of A104 Epping New Road, south of Wake Arms roundabout	0-40m	-
Transect 8	East of A104 Epping New Road, south of Wake Arms roundabout	0-200m	0-200m
Transect 10	East of B1393 Epping Road, north of Wake Arms roundabout	0-40m	-
Transect 11	East of A104 Epping New Road, north of Robin Hood roundabout	0-40m	-
Transect 12	north of A1069 Ranger's Road	0-40m	-
Transect 13	South of B1393 High Road	0-40m	-
Transect 14	West of Theydon Road, opposite Theydon Bois Golf Club	0-40m	-
T9 / B3	Rural background location >200m from trafficked roads	Triplicate	Triplicate
The Warren	Background location; within 200m of carpark and access roads	Single	-
Prince of Wales School, Enfield	Co-located with continuous monitor	Triplicate	-
London – Cromwell Road	Co-located with UKEAP ALPHA sampler	-	Triplicate



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Client: Epping Forest District Council	Title: Monitoring Locations and Transects near Wake Arms Roundabout	AECOM 10th Floor, Sunley House, 4 Bedford Park, Croydon CR0 2AP Tel: +44 (0) 20 8639 3500 Fax: +44 (0) 20 8663 6723 www.aecom.com	Design: JM	Drawn: JM
Project: Epping Forest Monitoring			Chk'd: HV	App'd: HV
			Date: 26/04/2019	Scale at A3: 1:8,000
			Drawing Number:	

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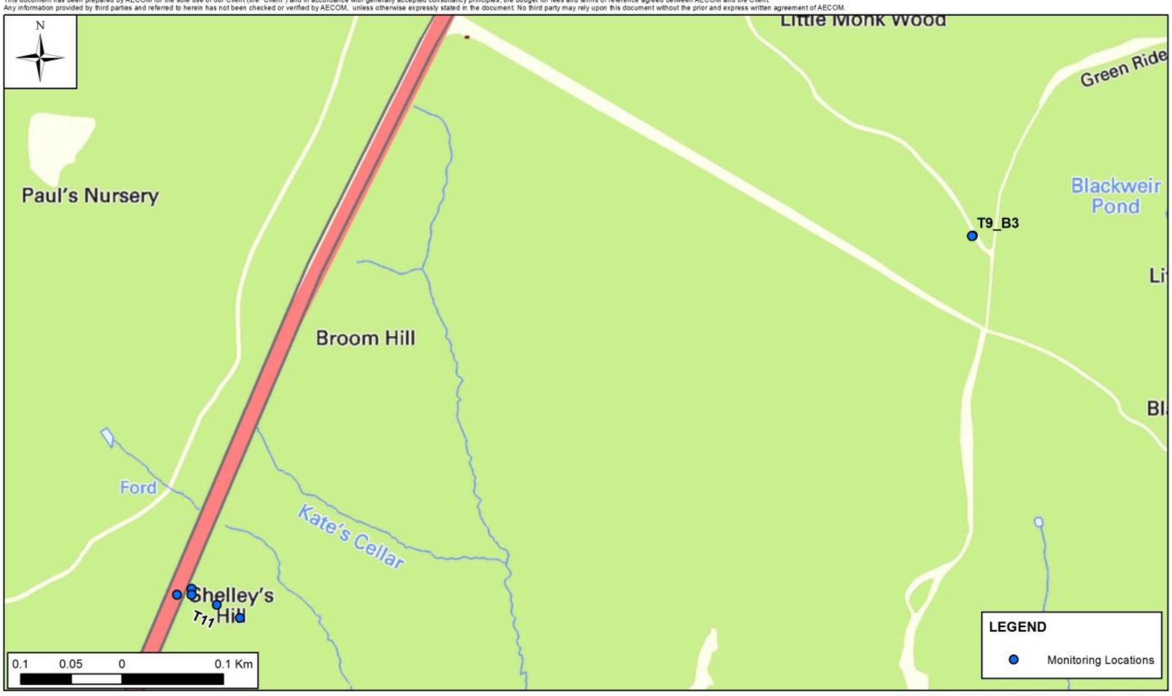

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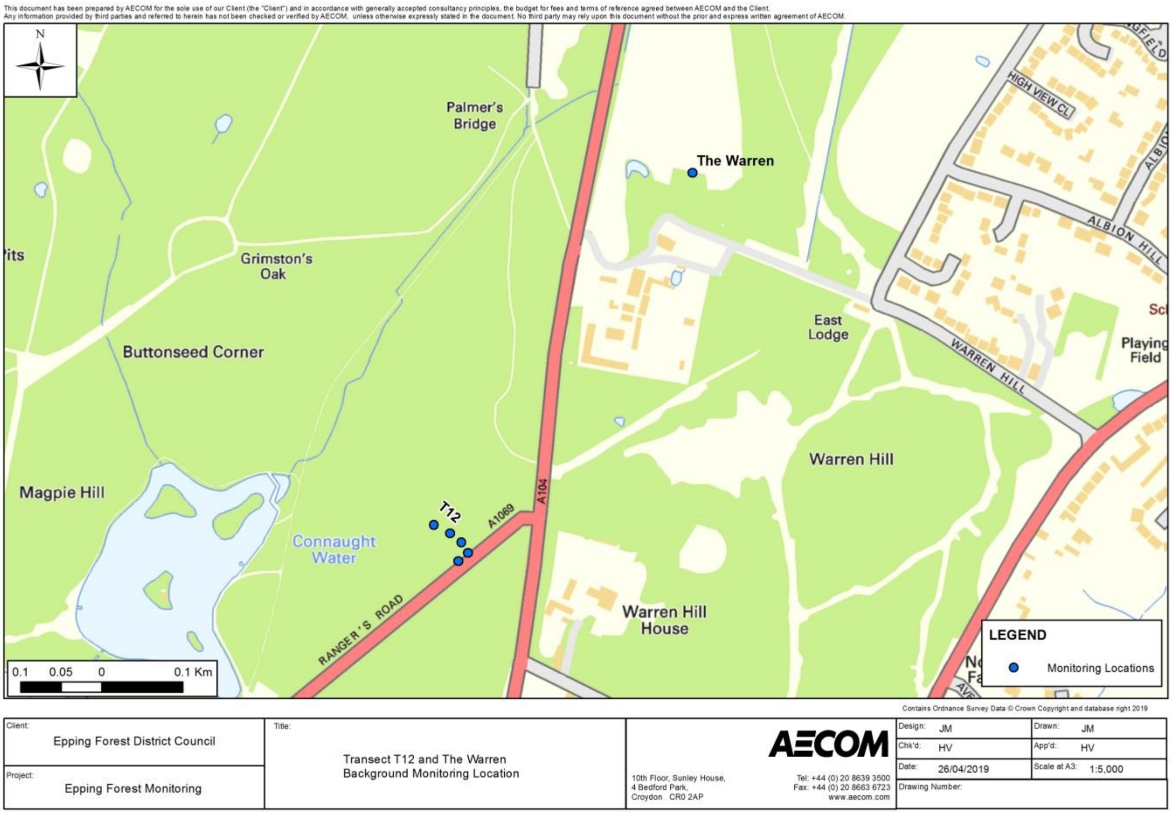
Client: Epping Forest District Council	Title: Transect T11 and Background Monitoring Location (T9_B3)	AECOM 10th Floor, Sunley House, 4 Bedford Park, Croydon CR0 2AP Tel: +44 (0) 20 8639 3500 Fax: +44 (0) 20 8663 6723 www.aecom.com	Design: JM	Drawn: JM
Project: Epping Forest Monitoring			Chk'd: HV	App'd: HV
			Date: 26/04/2019	Scale at A3: 1:4,000
			Drawing Number:	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N
Palmer's Bridge
The Warren
Grimston's Oak
Buttonseed Corner
East Lodge
Warren Hill
Magpie Hill
T12
A1069
A104
Connaught Water
RANGER'S ROAD
Warren Hill House
HIGH VIEW CL
ALBION HILL
WARREN HILL
Playing Field
0.1 0.05 0 0.1 Km
LEGEND
Monitoring Locations
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Project: Epping Forest Monitoring
Title: Transect T12 and The Warren Background Monitoring Location
AECOM
10th Floor, Sunley House, 4 Bedford Park, Croydon CR0 2AP
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Fax: +44 (0) 20 8663 6723
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N
Bell Common Tunnel
M25
Bell Common
Bell Common Tunnel
THEYDON ROAD
HIGH ROAD
T13
FOREST SIDE
Bowlands Meadow
Great Gregories Farm
Epping Thicks
Epping Forest
Green Ride
T14
THEYDON ROAD
CH
0.1 0.05 0 0.1 Km
LEGEND
Monitoring Locations
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Client: Epping Forest District Council
Project: Epping Forest Monitoring
Title: Transects T13 and T14 Monitoring Locations
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Scale at A3: 1:5,000
Drawing Number:

Appendix B Air Quality Standards for the Protection of Ecosystems

Critical Levels for Air Pollutants for the Protection of Designated Habitat Sites

Pollutant	Reference	Concentration ($\mu g/m^3$)	Measured as	Notes
Oxides of Nitrogen (as nitrogen dioxide)	WHO, CLRTAP, UK AQ Directive	30	Annual mean	-
	WHO, CLRTAP	75	Daily mean	-
Ammonia	CLRTAP	1	Annual mean	For Lichens and bryophytes
		3	Annual mean	Other vegetation

Appendix C Raw NO_2 Monitoring Data

Location ID	Distance from Road (m)	Monthly Mean NO_2 Concentration (µg/m^3)								
		May (24/05–19/06)	June (19/06–17/07)	July (17/07–23/08)	Aug (23/08–20/09)	Sep (20/09–17/10)	Oct (17/10–21/11)	Nov (21/11–19/12)	Dec (19/12–17/01)	Jan (17/01–15/02)
T1_N0 (Tri)	0	36.2	37.3	32.1	34.7	38.5	40.7	42.6	47.4	45.4
		46.1	13.4*	32.1	35.4	40.5	43.5	39.6	41.5	50.3
		44.4	38.0	No data	36.1	41.0	37.2	42.1	43.3	51.7
T1_N5	5	19.7	28.2	26.1	28.1	33.4	34.0	32.6	36.7	39.4
T1_N10	10	25.2	22.9	19.4	23.8	28.8	25.1	29.6	32.3	34.7
T1_N20	20	20.4	21.2	21.5	21.3	29.3	29.1	31.0	32.5	33.4
T1_N40 (Tri)	40	16.7	16.2	18.1	16.1	23.4	24.4	22.9	25.6	27.2
		18.3	15.6	1.9*	16.9	23.6	23.7	22.6	24.5	26.4
		18.6	16.7	17.5	17.5	23.4	22.2	21.5	23.2	26.2
T1_N70	70	14.0	15.3	8.4*	16.6	22.1	19.4	24.2	20.3	27.6
T1_N100	100	16.0	14.7	16.7	18.8	23.5	22.5	22.5	No data	23.9
T1_N150	150	13.1	12.9	17.6	15.6	18.3	21.6	20.5	24.0	25.9
T1_N200	200	14.0	12.9	17.6	14.5	22.0	22.3	24.0	26.4	27.3
T2_N0 (Tri)	0	49.3	51.0	54.0	50.5	57.3	51.1	48.0	47.7	58.7
		48.2	50.9	54.8	49.6	57.6	51.9	44.1	46.1	59.8
		47.4	50.5	53.4	48.4	57.1	44.7	44.8	32.4*	59.7
T2_N5	5	34.7	34.1	29.3	23.8	37.4	36.4	29.8	34.8	30.0
T2_N10	10	29.5	27.0	26.0	24.7	35.3	25.9	29.7	29.7	33.7
T2_N20	20	20.5	20.6	22.1	23.4	29.4	28.4	25.5	27.7	33.2
T2_N40	40	18.6	18.2	18.9	22.3	27.2	28.3	26.3	29.0	30.8
T5_N0 (Tri)	0	18.3	17.1	32.1	29.4	32.4	28.0	31.1	28.8	33.3
		21.8	19.6	31.8	32.1	17.9*	26.3	27.2	27.8	35.4
		19.6	19.2	30.8	29.4	32.7	26.9	29.8	29.5	35.9
T5_N5	5	15.5	14.3	24.1	21.1	25.1	22.9	24.7	25.0	33.2
T5_N10	10	14.2	12.5	22.4	19.3	23.4	23.8	26.2	26.1	30.2
T5_N20	20	12.6	12.5	18.3	18.8	23.5	12.5	24.5	20.8	29.8
T5_N40	40	11.9	8.2	17.2	15.9	22.3	21.9	27.7	25.6	28.9
T3_N0 (Tri)	0	55.8	56.6	59.8	57.6	62.8	53.1	65.8	46.5	59.5
		51.8	56.0	61.3	50.2	56.7	63.8	56.5	46.2	37.6*
		56.9	53.7	60.8	51.0	62.7	56.4	47.7	54.1	59.8
T3_N5	5	23.3	29.9	36.7	35.2	38.3	32.9	35.2	30.0	37.5
T3_N10	10	11.9	21.3	31.6	26.7	32.1	24.0	24.0	28.2	35.1
T3_N20 (Tri)	20	15.5	16.9	24.8	19.4	28.4	26.9	30.1	26.8	30.9
		15.0	16.3	24.8	17.1	27.4	28.3	28.2	25.4	30.8
		15.6	17.0	24.9	21.6	28.9	29.7	27.8	26.1	8.4*
T3_N40	40	11.6	14.7	21.0	19.8	25.0	21.9	29.6	27.3	29.7
T3_N70	70	12.6	14.8	20.2	18.9	26.4	23.2	25.3	25.4	28.2
T3_N100	100	10.8	14.1	21.0	18.5	20.7	27.0	28.0	23.3	27.2

Location ID	Distance from Road (m)	Monthly Mean NO_2 Concentration (µg/m^3)								
		May (24/05–19/06)	June (19/06–17/07)	July (17/07–23/08)	Aug (23/08–20/09)	Sep (20/09–17/10)	Oct (17/10–21/11)	Nov (21/11–19/12)	Dec (19/12–17/01)	Jan (17/01–15/02)
T3_N150	150	13.3	12.2	20.1	18.1	25.7	27.2	3.6*	No data	28.4
T3_N200	200	12.7	12.6	20.3	19.0	25.6	26.2	25.9	24.4	31.9
T4_N0 (Tri)	0	30.6	31.5	36.5	37.5	42.3	35.5	41.6	36.5	40.5
		33.2	30.5	36.6	35.7	40.7	31.0	39.6	37.6	43.4
		31.9	30.8	37.7	34.4	41.4	39.8	33.4	35.6	36.9
T4_N5	5	21.6	22.4	25.1	25.2	31.7	28.5	No data	27.9	31.2
T4_N10	10	17.1	16.8	23.8	23.2	27.4	27.1	27.8	25.7	32.6
T4_N20 (Tri)	20	15.8	15.0	21.1	20.0	26.4	26.1	26.1	21.5	26.4
		13.4	15.1	17.6	20.7	26.5	25.5	23.6	25.2	25.0
		14.8	15.1	19.6	20.9	26.9	19.5	27.3	16.4*	29.2
T4_N40	40	12.2	13.1	16.8	18.5	25.7	24.3	27.1	23.5	28.1
T4_N70	70	12.4	13.6	20.5	16.5	24.1	22.8	26.5	25.3	28.7
T4_N100	100	11.4	13.6	19.7	18.4	24.4	24.7	27.5	25.5	27.8
T4_N150	150	12.9	13.4	19.2	18.0	24.3	24.8	24.9	27.3	28.2
T4_N200	200	13.1	11.6	19.5	17.1	23.9	23.8	25.2	24.2	28.4
T6_N0 (Tri)	0	44.7	40.9	44.6	44.4	46.3	43.8	36.8	49.7	44.8
		41.9	35.5	47.4	43.0	46.5	39.7	39.0	53.4	46.9
		41.6	32.7	50.1	43.1	48.7	41.0	38.9	52.6	47.4
T6_N5	5	24.3	26.0	30.3	28.3	33.8	28.9	26.3	36.1	33.6
T6_N10	10	24.2	22.2	24.6	30.0	32.1	23.3	27.7	35.5	33.9
T6_N20 (Tri)	20	18.0	19.8	26.7	22.1	30.5	25.7	20.4	33.7	31.1
		19.5	20.5	22.9	23.2	27.1	25.9	27.4	35.0	34.5
		18.8	20.1	25.8	24.3	28.7	26.2	24.9	30.6	32.4
T6_N40	40	12.3	17.6	23.8	22.9	27.1	25.4	22.9	26.3	31.6
T6_N70	70	13.5	14.0	7.6*	16.3	21.8	19.8	26.1	28.6	28.3
T6_N100	100	13.0	12.9	17.1	17.2	22.2	20.5	No data	28.1	31.1
T6_N150	150	12.6	13.0	18.2	16.8	21.7	24.2	22.7	27.7	28.2
T6_N200	200	10.9	12.4	17.5	15.7	20.6	4.9*	22.2	24.2	27.2
T7_N0 (Tri)	0	35.5	36.8	29.7	29.8	38.3	38.8	33.2	34.2	36.7
		33.8	37.3	32.7	27.7	38.0	34.2	38.2	37.2	42.3
		40.2	34.1	33.8	32.9	37.6	38.5	39.8	41.4	31.7
T7_N5	5	26.5	26.5	23.6	25.1	32.9	30.5	31.6	36.2	30.8
T7_N10	10	17.5	21.8	18.4	22.5	29.2	29.0	27.9	33.3	33.8
T7_N20	20	18.2	18.3	18.8	20.6	27.1	26.3	23.8	29.3	32.6
T7_N40	40	14.5	14.7	17.6	17.0	24.4	No data	22.2	28.2	24.5
T10_N5 (Tri)	5	18.4	18.1	26.4	23.6	30.7	30.1	29.8	36.5	35.7
		21.0	18.7	25.3	25.7	28.9	26.8	34.1	35.3	36.7
		18.8	18.7	25.2	24.9	29.9	28.4	20.8*	33.6	35.2
T10_N10	10	9.4	14.4	20.5	13.1	25.9	24.1	No data	30.2	31.3
T10_N20	20	14.1	13.2	20.9	20.1	21.4	26.2	28.9	30.9	27.1

Location ID	Distance from Road (m)	Monthly Mean NO_2 Concentration (µg/m^3)								
		May (24/05–19/06)	June (19/06–17/07)	July (17/07–23/08)	Aug (23/08–20/09)	Sep (20/09–17/10)	Oct (17/10–21/11)	Nov (21/11–19/12)	Dec (19/12–17/01)	Jan (17/01–15/02)
T10_N40	40	15.2*	No data	No data	No data	No data	No data	No data	No data	No data
T8_N0 (Tri)	0	28.6	33.4	33.5	33.7	40.3	35.2	28.1	37.8	43.4
		28.3	25.2	35.5	31.7	39.4	33.4	33.1	37.0	43.8
		29.2	27.4	33.4	36.1	37.4	32.1	31.6	27.0	43.4
T8_N5	5	23.7	21.5	26.9	28.9	33.5	20.5	22.7	28.6	32.7
T8_N10	10	25.9	17.6	26.0	22.9	30.2	22.9	26.6	29.1	33.1
T8_N20 (Tri)	20	17.1	15.4	22.1	20.8	26.0	27.8	24.8	29.1	25.4
		15.5	14.5	22.7	21.2	27.7	25.3	24.8	27.3	31.9
		15.6	16.1	21.4	20.8	27.5	22.0	25.2	27.8	31.9
T8_N40	40	15.1	14.6	21.2	19.8	26.0	23.7	27.3	25.4	31.6
T8_N70	70	13.6	11.8	18.7	15.5	23.3	22.1	19.6	21.9	30.3
T8_N100	100	10.8	12.8	19.5	16.6	23.2	23.6	25.5	25.6	31.9
T8_N150	150	10.3	11.3	17.2	15.5	21.2	21.6	23.7	24.0	28.7
T8_N200	200	11.5	11.4	17.4	15.9	19.4	22.7	24.1	20.9	28.9
T11_N0 (Tri)	0	30.5	25.7	34.1	32.8	40.9	28.8	14.6*	34.9	48.8
		28.0	25.3	32.5	35.6	41.7	19.7*	30.1	40.6	48.2
		25.7	26.6	29.3	32.6	37.7	34.5	35.2	27.4*	50.6
T11_N5		18.7	19.1	24.8	24.0	27.5	26.3	24.4	24.0	32.2
T11_N10	10	16.1	15.9	21.2	21.9	28.2	22.9	23.6	28.1	34.4
T11_N20	20	13.6	14.1	19.9	18.8	25.8	21.6	27.0	26.5	33.9
T11_N40	40	11.4	13.4	17.8	17.4	24.6	22.8	26.0	9.9*	29.5
T12_N0 (Tri)	0	21.3	19.8	23.6	21.6	29.0	12.7*	25.3	17.4*	36.8
		22.7	20.2	24.9	23.3	30.4	29.4	33.5	27.9	35.7
		20.2	20.6	24.6	23.4	31.3	29.4	33.0	23.5	34.3
T12_N5	5	14.6	13.8	18.8	18.9	23.8	24.2	26.8	22.2	29.5
T12_N10	10	9.6	12.4	19.9	13.2	21.3	23.5	25.2	20.9	27.3
T12_N20	20	11.9	11.5	17.7	15.5	21.1	19.1	22.0	21.2	27.7
T12_N40	40	10.6	10.6	16.8	15.5	19.4	20.3	10.4	19.9	27.0
T13_N0 (Tri)	0	40.1	38.1	33.6	36.8	40.6	37.5	14.7*	44.2	45.6
		37.1	39.5	37.2	33.8	45.0	36.0	34.2	40.7	43.2
		38.7	36.3	37.4	35.4	45.8	34.3	35.8	39.9	40.0
T13_N5	5	31.1	26.1	25.7	27.2	35.6	29.6	25.5	36.5	28.2
T13_N10	10	24.8	25.9	24.7	26.3	31.5	29.7	28.4	31.5	38.6
T13_N20	20	22.7	23.3	23.0	25.8	No data	27.1	23.9	27.9	35.2
T13_N40	40	19.4	22.4	20.6	22.6	31.1	19.5	26.6	27.0	34.0
T14_N0 (Tri)	0	19.1	20.0	22.5	19.4	26.0	20.7	26.7	20.9	27.3
		19.8	22.5	22.8	20.9	25.7	19.2	25.0	22.4	30.5
		18.8	18.7	22.3	20.3	26.0	24.8	26.1	24.6	26.4
T14_N5	5	16.5	16.3	19.2	16.0	23.1	23.8	20.9	20.1	26.5
T14_N10	10	16.8	14.3	18.6	17.0	22.2	19.8	18.5	19.1	22.5
T14_N20	20	12.7	13.7	17.1	14.6	20.9	19.6	12.9	17.5	20.4

Location ID	Distance from Road (m)	Monthly Mean NO_2 Concentration (µg/m^3)								
		May (24/05–19/06)	June (19/06–17/07)	July (17/07–23/08)	Aug (23/08–20/09)	Sep (20/09–17/10)	Oct (17/10–21/11)	Nov (21/11–19/12)	Dec (19/12–17/01)	Jan (17/01–15/02)
T14_N40	40	13.5	14.1	17.6	No data	No data	20.8	20.2	18.4	24.1
T9_B3 (Tri)	>200m	9.4	9.1	6.8	13.1	18.9	19.9	19.6	0.5*	42.5*
		9.3	9.4	6.5	13.1	18.4	18.2	22.0	0.5*	41.8*
		9.9	10.1	No data	12.6	18.4	18.8	22.5	0.5*	44.2*
Co-Lo (Tri)	>200m	16.4	10.4*	19.1	19.9	29.3	No data	28.4	27.2	32.0
		12.1	17.3	18.4	17.9	28.3	24.3	27.2	26.3	27.6
		16.9	16.8	19.7	19.8	28.5	26.2	21.3	26.2	27.7
BG_N	>200m	No data	18.3	16.7	15.4	20.8	20.7	22.3	21.8	27.3

Note: *Data marked with an asterisk are flagged for exclusion from analysis.

Appendix D NO_2 bias adjustment and annualisation

A local bias adjustment factor was calculated using data from the triplicate diffusion tubes co-located with the Enfield Prince of Wales School continuous monitoring station and a spreadsheet tool provided by Defra to calculate precision and accuracy of diffusion tubes[8]. The local bias adjustment factor was calculated to be 1.04 and applied to the raw diffusion tube monitoring results.

Calculation of Local Bias Adjustment Factor for NO_2

Checking Precision and Accuracy of Triplicate Tubes

AEA Energy & Environment
From the AEA group

Period	Start Date dd/mm/yyyy	End Date dd/mm/yyyy	Tube 1 µgm⁻³	Tube 2 µgm⁻³	Tube 3 µgm⁻³	Triplicate Mean	Standard Deviation	Coefficient of Variation (CV)	95% CI of mean	Automatic Method: Period Mean	Automatic Method: Data Capture (% DC)	Data Quality Check: Tubes Precision Check	Data Quality Check: Automatic Monitor Data
1	24/05/2018	19/06/2018	16.4	12.1	16.9	15	2.7	18	6.6	15.19	99.85	Good	Good
2	19/06/2018	17/07/2018		17.3	16.8	17	0.3	2	3.1	17.52	99.70	Good	Good
3	17/07/2018	23/08/2018	19.1	18.4	19.7	19	0.7	4	1.7	18.39	99.89	Good	Good
4	23/08/2018	20/09/2018	19.9	17.9	19.8	19	1.1	6	2.8	16.96	99.85	Good	Good
5	20/09/2018	17/10/2018	29.3	28.3	28.5	29	0.5	2	1.2	26.56	72.99	Good	Poor Data Captu
6	17/10/2018	21/11/2018		24.3	26.2	25	1.3	5	12.1	26.08	99.88	Good	Good
7	21/11/2018	19/12/2018	28.4	27.2	21.3	26	3.8	15	9.5	28.03	99.71	Good	Good
8	19/12/2018	17/01/2019	27.2	26.3	26.2	27	0.5	2	1.3	27.51	99.86	Good	Good
9	17/01/2019	14/02/2019	32.0	27.6	27.7	29	2.5	9	6.3	33.91	100.00	Good	Good
10													
11													
12													
13													
											Overall survey -->	Good precision	Good Overall DC

It is necessary to have results for at least two tubes in order to calculate the precision of the measurements

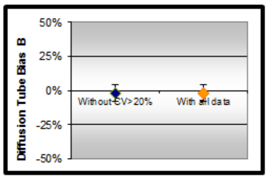
Site Name/ ID: EN7

Precision: 9 out of 9 periods have a CV smaller than 20%

(Check average CV & DC from Accuracy calculations)

Accuracy (with 95% confidence interval)
without periods with CV larger than 20%
Bias calculated using 8 periods of data
Bias factor A: 1.04 (0.97 - 1.11)
Bias B: -4% (-10% - 3%)
Diffusion Tubes Mean: 22 µgm⁻³
Mean CV (Precision): 8
Automatic Mean: 23 µgm⁻³
Data Capture for periods used: 100%
Adjusted Tubes Mean: 23 (21 - 25) µgm⁻³

Accuracy (with 95% confidence interval)
WITH ALL DATA
Bias calculated using 8 periods of data
Bias factor A: 1.04 (0.97 - 1.11)
Bias B: -4% (-10% - 3%)
Diffusion Tubes Mean: 22 µgm⁻³
Mean CV (Precision): 8
Automatic Mean: 23 µgm⁻³
Data Capture for periods used: 100%
Adjusted Tubes Mean: 23 (21 - 25) µgm⁻³



Jaume Targa, for AEA
Version 04 - February 2011

An example of the annualisation calculation for the NO_2 diffusion tubes for the 24/05/2018 to 15/02/2019 period is presented below. An average factor of 1.01 was calculated using data from three background continuous monitoring locations. The time period used to calculate the period mean for the continuous monitoring locations was the same as for the diffusion tubes (24/05/2018 to 15/02/2019), and the annual mean period used was the 2018 calendar year in order to calculate a 2018 annual mean equivalent. Additional annualisation factors were calculated for each tube location where there were missing or excluded data from the monitoring period. These location-specific factors are presented in Section 3.

Annualisation Calculation for NO_2 Tubes for May 2018 to February 2019 Period

Site Name	2018 Annual Mean (Am) NO_2 Concentration (µg/m³)	Period Mean (Pm) NO_2 Concentration (µg/m³)	Am/Pm Ratio
London Haringey Priory Park South	22.5	22.0	1.03
Enfield Prince of Wales School	23.4	23.2	1.01
Redbridge Ley Street	30.5	30.3	1.01
Average Am/Pm Ratio			1.01

[8] AEA_DifTPAB_v04 Spreadsheet to assist Diffusion Tube users in calculating precision and accuracy of their co-location studies. https://laqm.defra.gov.uk/bias-adjustment-factors/local-bias.html

Appendix E NH_3 co-location, bias adjustment and annualisation

A three-month co-location study was undertaken by AECOM from December 2018 to February 2019 at the London Cromwell Road UK Eutrophying and Acidifying Pollutant (UKEAP) network site in order to derive a bias adjustment factor for the Epping Forest diffusion tube survey. The Cromwell Road monitoring station is equipped with the Adapted Low-cost Passive High-Absorption (ALPHA) passive sampler that measures gaseous ammonia on a monthly basis. The raw diffusion tube data from the co-location study are presented below.

Cromwell Road NH_3 co-location data

Location ID	Diffusion Tube Monthly Mean NH_3 Concentration ($\mu g/m^3$)		
	December 2018 (04/12/2018 – 09/01/2019)	January 2019 (09/01/2019 – 06/02/2019)	February 2019 (06/02/2019 – 05/03/2019)
Cromwell Road A	4.76	5.90	5.73
Cromwell Road B	4.61	10.35*	5.57
Cromwell Road C	4.91	5.92	5.47

Note: * Data marked with an asterisk are flagged for exclusion from analysis.

The monthly mean UKEAP ALPHA NH_3 concentrations are compared with the co-located monthly average diffusion tube data below. A bias adjustment factor of 0.59 is calculated.

Calculation of Cromwell Road NH_3 Bias Adjustment Factor

Location	Monthly Mean NH_3 Concentration ($\mu g/m^3$)			Period Mean ($\mu g/m^3$)
	December 2018	January 2019	February 2019	
UKEAP London -Cromwell Road	2.81	2.72*	4.07*	3.20
Diffusion Tube Monthly Mean	4.76	5.91	5.59	5.42
Bias Adjustment Factor				0.59

Note: * Data marked with an asterisk are provisional UKEAP data.

An example of the annualisation calculation for the NH_3 diffusion tubes for the 24/05/2018 to 15/02/2019 period is presented below. An average factor of 1.09 is calculated using data from four UKEAP background monitoring locations. The time period used to calculate the period mean for the UKEAP monitoring locations was broadly the same as for the diffusion tubes (May 2018 to February 2019), and the annual mean period used was the 2018 calendar year in order to calculate a 2018 annual mean equivalent. Additional annualisation factors were calculated for each tube location where there were missing or excluded data from the monitoring period. These location-specific factors are presented in Section 4.

Annualisation Calculation for NH_3 Tubes for May 2018 to February 2019 Period

Site Name	2018 Annual Mean (Am) NH_3 Concentration ($\mu g/m^3$)	Period Mean (Pm) NH_3 Concentration ($\mu g/m^3$)	Am/Pm Ratio
Rothamsted	1.56	1.54	1.01
Burnham Beeches	0.96	0.90	1.06
Alice Holt 2	0.87	0.82	1.06
Thursley Common 2	1.13	0.91	1.24
Average Am/Pm Ratio			1.09

Appendix F Raw NH_3 monitoring data

Location ID	Distance from Road (m)	Monthly Mean NH_3 Concentration (µg/m³)								
		May (24/05 – 19/06)	Jun (19/06 – 17/07)	Jul (17/07 – 23/08)	Aug (23/08 – 20/09)	Sep (20/09 – 17/10)	Oct (17/10 – 21/11)	Nov (21/11 – 19/12)	Dec (19/12 – 17/01)	Jan (17/01 – 15/02)
T1_A0 (Tri)	0	6.5	7.1	5.6	5.3	7.2	4.7	3.5	4.7	2.9
		6.5	6.9	5.6	5.4	5.9	3.2*	4.0	4.7	2.8
		6.7	7.3	5.9	5.1	5.8	5.4	3.3	4.5	2.7
T1_A5	5	5.5	6.3	5.5	4.5	6.7	7.6	40.0*	4.8	2.1
T1_A10	10	4.9	6.2	5.8	4.5	7.6	6.9	2.7*	4.6	2.1
T1_A20	20	4.4	5.7	5.0	3.9	4.6	7.6	12.1*	3.7	1.9
T1_A40 (Tri)	40	3.7	4.6	15.3*	20.9*	9.7*	5.5	3.9	2.6	1.4
		3.7	8.5*	2.4*	3.6	14.5*	10.6*	3.5	2.6	1.5
		3.7	4.5	13.0*	3.5	4.6*	6.3	5.1*	2.8	1.5
T1_A70	70	3.5	4.3	4.0	3.6	3.2	3.7	4.6	3.5	1.4
T1_A100	100	3.6	4.2	4.7	3.5	3.5	11.2*	8.2	No data	1.3
T1_A150	150	3.5	3.9	3.6	3.4	2.8	3.2	7.0	3.3	1.4
T1_A200	200	2.9	5.2	3.8	3.2	6.6	2.0	6.6	3.0	1.5
T3_A0 (Tri)	0	6.3	8.1	8.1	6.5	7.3	9.8	18.9*	5.5	4.2
		6.9	7.7	9.1	7.3	7.1	16.9*	16.0*	5.1	4.2
		6.7	8.0	8.4	7.9	7.0	10.2	11.0*	5.3	4.4
T3_A5	5	4.2	5.7	7.2	5.2	15.5*	7.0	7.6	3.4	2.4
T3_A10	10	4.0	5.8	4.5	4.8	3.7	10.3*	4.3	2.7	2.0
T3_A20 (Tri)	20	3.5	4.4	4.4	3.5	3.2	4.4	3.1*	2.6	1.8
		3.7	4.7	3.9	3.6	82.8*	5.1	5.6	2.9	1.8
		3.5	4.4	4.2	4.1	3.9	2.7*	5.3	2.9	1.9
T3_A40	40	3.2	4.2	5.1	4.0	5.3	5.9	6.6	2.8	1.7
T3_A70	70	2.9	2.9	4.1	3.0	3.2	5.7	3.0	2.5	1.3
T3_A100	100	2.7	4.7	4.1	3.7	11.9*	15.8*	19.3*	9.7*	1.5
T3_A150	150	3.5	4.3	3.8	3.3	5.2	No data	No data	3.0	1.3
T3_A200	200	3.0	4.5	4.1	3.7	14.1*	10.9*	3.9	2.4	1.6
T4_A0 (Tri)	0	4.9	5.5	6.2	4.8	10.0*	8.1	9.2*	3.8	2.7
		4.8	5.4	5.8	5.3	5.0	5.9*	6.0	3.5	2.7
		4.9	5.9	6.0	5.2	5.4	9.4	7.2	3.5	2.8
T4_A5	5	3.8	4.4	4.8	4.0	4.0	5.2	10.0	2.7	1.9
T4_A10	10	2.9	4.2	3.9	3.7	3.1	3.2	11.6	2.6	1.6
T4_A20	20	3.3	3.6	6.1	3.4	4.3	21.2*	3.2	2.4	1.7
T4_A40	40	3.1	No data	No data	No data	No data	No data	No data	No data	No data
T6_A0 (Tri)	0	6.2	7.5	8.1	6.3	6.3	4.4	11.4	5.4	3.7
		6.0	7.5	7.7	6.4	17.0*	4.3	12.5	5.4	3.9

Location ID	Distance from Road (m)	Monthly Mean NH_3 Concentration (µg/m³)								
		May (24/05 – 19/06)	Jun (19/06 – 17/07)	Jul (17/07 – 23/08)	Aug (23/08 – 20/09)	Sep (20/09 – 17/10)	Oct (17/10 – 21/11)	Nov (21/11 – 19/12)	Dec (19/12 – 17/01)	Jan (17/01 – 15/02)
		6.2	6.9	7.4	6.5	6.5	4.4	17.6*	5.6	3.8
T6_A5	5	3.8	5.0	6.5	4.0	8.2	3.5	3.5	3.8	2.1
T6_A10	10	3.5	4.8	28.9*	4.2	14.5*	2.3	2.7	3.5	2.0
T6_A20 (Tri)	20	4.1	5.0	5.3	4.0	15.0*	2.6	3.7*	3.4	1.8
		3.7	4.4	6.6	4.0	6.0	2.6	2.2	3.2	1.8
		3.8	4.6	4.7	3.7	5.7	2.4	2.8	3.3	1.8
T6_A40	40	3.5	3.9	4.2	3.8	8.6*	2.1	2.6	3.7	1.4
T6_A70	70	2.7	3.8	4.1	3.2	3.5	2.8	2.9	2.5	1.5
T6_A100	100	3.1	3.9	3.9	3.3	9.7*	3.9	No data	3.0	1.8
T6_A150	150	3.1	4.0	4.0	3.0	3.1	2.3	2.3	3.3	1.5
T6_A200	200	2.8	4.4	4.7	3.1	3.3	2.6	2.7	2.4	1.8
T8_A0 (Tri)	0	4.0	5.0	5.1	5.1	7.4	9.1	4.6	3.9	2.3
		4.4	4.8	5.3	4.0	6.8	10.0	3.9	4.1	2.4
		4.8	4.7	4.6	4.2	4.2*	3.4*	4.0	3.5	2.3
T8_A5	5	4.1	4.5	4.8	5.2	4.4	6.3	4.0	3.2	1.8
T8_A10	10	3.4	4.0	4.6	3.8	7.2	4.1	2.5	2.9	1.7
T8_A20 (Tri)	20	3.1	3.9	3.4	3.6	5.9	3.1	2.1	2.7	1.7
		3.0	3.8	3.6	3.2	6.6	4.5	2.1	2.9	16.2*
		3.2	4.1	3.6	3.2	3.7	3.6	2.2	2.7	1.8
T8_A40	40	2.9	3.9	3.8	3.1	3.1	2.7	4.5	2.7	1.7
T8_A70	70	2.8	4.2	4.5	2.9	11.1*	7.8*	3.7	2.6	1.7
T8_A100	100	2.7	3.0	3.7	2.8	3.4	2.7	2.3	2.7	1.4
T8_A150	150	2.9	3.4	4.6	3.0	14.1*	4.7	4.4	2.8	No data
T8_A200	200	2.8	3.6	3.7	3.3	3.0	5.3	2.9	2.3	1.4
T9_B3 (Tri)	>200m	8.5*	4.1	4.3	2.7	7.7*	4.0*	2.7	21.8*	1.4
		3.0	3.8	3.7	3.1	4.9*	12.7*	1.5*	No data	1.3
		3.0	4.0	3.6	3.0	14.7*	12.3*	2.3	4.9	1.5

Note: *Data marked with an asterisk are flagged for exclusion from analysis.