London City Airport Air Quality Measurement Programme:

Annual Report 2011

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Experts in air quality management & assessment

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Executive Summary

This document represents the 2011 Annual Report for the Air Quality Measurement Programme (AQMP) that is operated by Air Quality Consultants Ltd. on behalf of London City Airport. This programme measures concentrations of nitrogen dioxide (NO_2) and fine particles (the so called PM_{10} fraction, i.e. particles that are less than 10 micrometres in diameter).

Monitoring is carried out at two automatic monitoring stations. One is situated on the roof of City Aviation House (LCA-CAH) whilst the other is to the north of Royal Albert Dock, adjacent to the Newham Dockside building (LCA-ND). These automatic sites are supplemented by a network of passive monitoring devices (nitrogen dioxide diffusion tubes) located at a further 19 sites in and around the Airport boundary.

The Government has set a number of air quality objectives to protect human health. These are equivalent to, or are more stringent than the limit values set by the European Union. Both the objectives and the limit values are based on monitoring carried out over the period of a calendar year.

In some cases, these objectives and limit values refer to average concentrations of pollutants measured over the calendar year (the "annual mean"); in other cases they refer to the number of hours or days on which a specified pollutant concentration should not be exceeded (for example, no more than 35 days in each calendar year on which PM_{10} concentrations exceed 50 µg/m^3, and no more than 18 hours in each calendar year on which nitrogen dioxide concentrations exceed 200 µg/m^3).

In addition to the objectives and limit values, the Government has established a set of descriptors for the 1-hour mean concentrations of nitrogen dioxide and 24-hour mean concentrations of PM_{10}. Air quality is defined by these descriptors as being Low, Moderate, High and Very High (these descriptors have recently been modified and therefore differ from those reported previously).

Pollution concentrations measured in and around the Airport are associated with a wide range of sources at the local, regional, national and international scales. On occasions when pollution levels rise, these higher levels are often observed across the whole of London as a "regional pollution episode". To assist with the interpretation of the results, pollution levels measured at other London monitoring sites are included in this report.

Nitrogen Dioxide

The 2011 annual mean nitrogen dioxide concentration measured at the automatic station on the roof of City Aviation House was 33.1 µg/m^3 (microgrammes per cubic metre); a slightly lower concentration (29.5 µg/m^3 annual mean equivalent) was measured at the Newham Dockside site. The annual mean objective (40 µg/m^3) was not exceeded at either site in 2011. There were no recorded exceedences of the 1-hour mean objective, and all 1-hour mean concentrations were classified as "Low".

Annual mean concentrations of nitrogen dioxide at other background sites in London over this period ranged from 23.1 to 48.4 µg/m^3, with similar patterns in levels as seen at the two London City Airport sites. There was a good correlation between observed peaks at the Airport sites and other London sites, suggesting that these occurrences were principally due to regional sources and changing weather conditions that affect the dispersion and dilution of pollutant emissions.

The annual mean nitrogen dioxide concentrations measured at the diffusion tube sites ranged from 28.7 to 41.1 µg/m^3 compared with the objective value of 40 µg/m^3. There were no measured exceedences of the annual mean objective where there is relevant exposure. As measured concentrations are well below 60 µg/m^3, it is highly unlikely that the 1-hour mean objective will be exceeded.

Fine Particles (PM_{10})

The annual mean PM_{10} concentration measured at the automatic station on the roof of City Aviation House was 24 µg/m^3 (microgrammes per cubic metre). This compares with the objective value of 40 µg/m^3. There were 16 recorded exceedences of the 24-hour mean objective (compared with the 35 exceedences allowed in a calendar year). The majority of the running 24-hour mean concentrations were classified as "Low" (95.4%); running 24-hour mean concentrations were classified as "Moderate" and "High" for 4.2% and 0.4% of the time respectively. There were no running 24-hour mean concentrations within the 'Very High' pollution band.

Concentrations of PM_{10} at other background sites in London over this period showed similar patterns as seen at the Airport site. There was a good correlation between observed peaks at the Airport site and other London sites, suggesting that these occurrences were principally due to regional sources and changing weather conditions that affect the dispersion and dilution of pollutant emissions.

1 Introduction

1.1 This document represents the 2011 Annual Report for the Air Quality Measurement Programme, operated on behalf of London City Airport (LCA).

1.2 Approval to expand Airport operations to 120,000 aircraft movements per annum was granted in July 2009. A legal agreement between London City Airport and the London Borough of Newham associated with this planning approval sets out a number of obligations, one of which relates to an Air Quality Measurement Programme (AQMP).

1.3 The AQMP, as defined within the legal agreement, comprises an automatic air quality monitoring station situated on the roof of City Aviation House, and a network of nitrogen dioxide diffusion tubes, situated in and around the Airport site. In addition, London City Airport commissioned a second automatic air quality monitoring station at a site adjacent to the Newham Dockside building in September 2008. The operation of this additional site falls outside the AQMP, but the data are included in this Annual Report for the sake of completeness.

1.4 The monitoring programme is managed by Air Quality Consultants Ltd. (AQC) on behalf of London City Airport. Service support for the automatic monitoring stations is provided by Enviro Technology Services plc, with AEA providing independent audit checks.

1.5 Chapter 3 of this Report sets out the various standards and guidelines against which air pollution concentrations should be compared. Chapter 4 describes the monitoring methodology and provides a summary of the measured concentrations in 2011 with respect to these criteria, and compares the measured concentrations with other local monitoring sites. Chapter 5 then provides some analysis of the monitoring data with respect to trends and source contributions.

2 Assessment Criteria

2.1 The Government has established a set of air quality standards and objectives to protect human health. The 'standards' are set as concentrations below which effects are unlikely even in sensitive population groups, or below which risks to public health would be exceedingly small. They are based purely upon the scientific and medical evidence of the effects of an individual pollutant. The 'objectives' set out the extent to which the Government expects the standards to be achieved by a certain date. They take account of economic efficiency, practicability, technical feasibility and timescale. The objectives for use by local authorities are prescribed within the Air Quality Regulations, 2000 (Stationery Office, 2000) and the Air Quality (England) (Amendment) Regulations 2002 (Stationery Office, 2002). The relevant objectives for this report are provided in Table 1.

Table 1: Relevant Air Quality Objectives

Pollutant	Time Period	Objective / Value
Nitrogen Dioxide	1-hour mean	200 μg/m^3 not to be exceeded more than 18 times a year
	Annual mean	40 μg/m^3
Fine Particles (PM_{10})[a]	24-hour mean	50 μg/m^3 not to be exceeded more than 35 times a year [b]
	Annual mean	40 μg/m^3

[a] Measured by the gravimetric method.

[b] Equivalent to a 90th percentile of 24-hour mean concentrations of 50 μg/m^3.

2.2 The objectives for nitrogen dioxide and PM_{10} were to have been achieved by 2005 and 2004 respectively, and continue to apply in all future years thereafter.

2.3 The European Union has also set limit values for both nitrogen dioxide and PM_{10}. Achievement of these values is a national obligation rather than a local one. The limit values for nitrogen dioxide are the same levels as the UK objectives, and are to be achieved by 2010 (Stationery Office, 2007). The limit values for PM_{10} are also the same level as the UK statutory objectives, and were to be achieved by 2005. The objectives are the same as, or more stringent than, the limit values, thus it is appropriate to focus the assessment on the objectives.

2.4 In addition to the objectives and limit values, Defra (2011a) has established a set of descriptors, for the 1-hour mean concentrations of nitrogen dioxide and 24-hour mean concentrations of PM_{10}, classifying the levels as Low, Moderate, High and Very High. This air quality banding has recently been revised by Defra to be more stringent, in response to a request by the Committee on the Medical Effects of Air Pollutants (COMEAP), and takes into account the latest research into the health effects of air pollution. The banding is referred to as the Daily Air Quality Index (DAQI). The new DAQI criteria are set out in Table 2 and are referred to in this report.

Table 2: DAQI Bandings (µg/m^3)

Band	Index	Nitrogen Dioxide 1-Hour Mean	PM_{10} Running 24-Hour Mean [a]
Low	1	0 – 66	0 – 16
	2	67 – 133	17 – 33
	3	134 – 199	34 – 49
Moderate	4	200 – 267	50 – 58
	5	268 – 334	59 – 66
	6	335 – 399	67 – 74
High	7	400 – 467	75 – 83
	8	468 – 534	84 – 91
	9	535 – 599	92 – 99
Very High	10	600 or more	100 or more

a Reference Equivalent

3 Monitoring Methodology and Results

Automatic Monitoring Stations

3.1 Monitoring was carried out at two automatic stations as follows:

- City Aviation House (LCA-CAH): Nitrogen dioxide and PM_{10}
- Newham Dockside (LCA-ND): Nitrogen dioxide

3.2 The location of the two automatic sites is shown in Figure 1.

3.3 The LCA-CAH automatic monitoring station measures PM_{10} using a Rupprecht and Patashnick TEOM 1400 Particulate Monitor, whilst both automatic stations measure nitrogen dioxide using M200E TAPI chemiluminescence analysers. The data are stored as 15-minute mean concentrations. Before further processing and ratification the raw PM_{10} concentrations have been adjusted to a "reference-equivalent" concentration using the Volatile Correction Model (VCM) as recommended by Defra (2009). This adjusts the TEOM data using the "purge" concentration measured by an FDMS analyser, assuming this represents the volatile component that has been lost. A "VCM web portal" has been established that allows this correction to be derived from the mean of up to three nearby FDMS analysers in the national network.

3.4 Independent site audits, conducted by AEA, confirmed that both automatic monitoring stations were operating above the minimum standards set for the national networks operated by Government. Audits were carried out 20th October 2010, 9th March 2011, 15th September 2011 and 5th March 2012 and have been taken into account in producing the fully ratified dataset.

3.5 Ratification of the data has been based on calibration factors determined from the calibration reports, along with visual examination of the data and comparison with monitoring data from nearby national network background sites (Bexley, Bloomsbury and Eltham) (Defra, 2011a). Any erroneous data have been flagged and removed from subsequent analysis. One-hour, daily, and annual means have then been calculated.

3.6 Pollution concentrations measured at both automatic Airport monitoring stations are associated with a wide range of sources at the local, regional, national and international scales. On occasions when pollution levels rise, these higher levels are often observed across the whole of London as a "regional pollution episode". To assist with the interpretation of the results, comparable data have been obtained from the national Air Quality Archive (Defra, 2011a) for three background sites, Bexley, Bloomsbury and Eltham, and from the London Air Quality Network (KCL, 2011) for two sites within the London Borough of Newham at Wren Close, Canning Town (background) and Cam Road, Stratford (roadside).

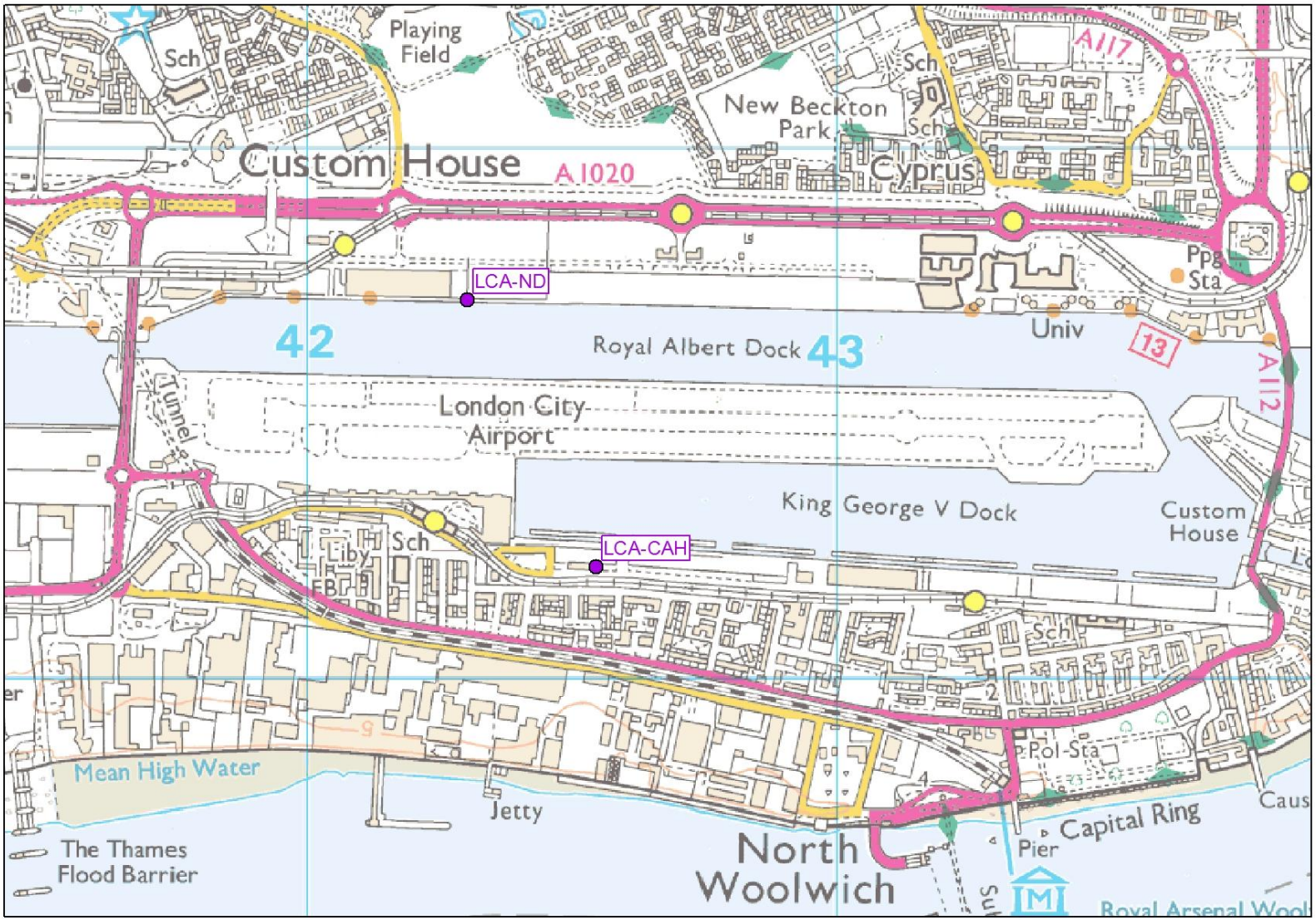

Figure 1: Automatic Monitoring Locations (red dots).

Nitrogen Dioxide

3.7 The 2011 nitrogen dioxide results for the LCA-CAH and LCA-ND automatic monitoring stations are summarised in Table 3. Data capture at for the LCA-CAH site was high (96%[1]); at LCA-ND, data capture was lower (66%) due to analyser problems between April and June 2011[2]. The annual mean concentrations did not exceed the objective of 40 µg/m^3 at either site. The 1-hour mean objective was also not exceeded, with no 1-hour mean concentrations above 200 µg/m^3, compared with the 18 exceedences allowed.

Table 3: Nitrogen Dioxide (NO_2) Data Summary for LCA-CAH and LCA-ND, 2011[a]

Pollutant	LCA-CAH	LCA-ND	Objectives
	NO_2	NO_2	
Maximum 1-Hour Mean	150 µg/m^3	148 µg/m^3	
No. 1-Hour Mean > 200 µg/m^3	0	0	200 µg/m^3; no more than 18 exceedences
Annual Mean	33.1 µg/m^3	31.2 µg/m^3 [b]	40 µg/m^3
Data Capture	96.3%	66.1%	-

[a] Nitrogen oxides concentrations are provided in Appendix 1.
[b] The value presented is the measured value. Due to the low data capture at this site, a 2011 "annualised mean" of 29.5 µg/m^3 has been calculated, based on an approach recommended by Defra. This calculation is shown in Appendix 2.

3.8 Table 4 includes the distribution of the 1-hour mean values into the different pollution bands (DAQI).

Table 4: DAQI Bandings, 2011

	Index	LCA-CAH	LCA-ND
Number Very High [a]	10	0	0
Number High [a]	9	0	0
	8	0	0
	7	0	0
Number Moderate [a]	6	0	0
	5	0	0
	4	0	0
Number Low [a]	3	1	1
	2	763	425
	1	7202	2834

a Number of 1-hour values

1 It is inevitable that a small amount of data will be "lost" in each year due to routine downtime for calibrations and site servicing.

2 There was a problem with the LCA-ND monitor between April to June 2011, which required the removal of these data from the final ratified dataset.

3.9 All measured 1-hour mean nitrogen dioxide concentrations fell into the 'Low' pollution band during 2011, at both monitoring sites.

3.10 Nitrogen dioxide concentrations for five monitoring sites across London in 2011 are summarised in Table 5. These sites range from central London (Bloomsbury) to outer London (Bexley). The measured annual mean concentrations at London City Airport (33.1 µg/m^3 at LCA-CAH and 31.5 µg/m^3 at LCA-ND) were similar to that measured at Canning Town (37.2 µg/m^3), lower than those at Bloomsbury and Stratford (48.4 µg/m^3 and 46.8 µg/m^3 respectively), and higher than those measured at Eltham and Bexley (24.5 µg/m^3 and 23.1 µg/m^3, respectively). This is broadly consistent with the location of London City Airport between the areas of high concentrations in central London and lower concentrations towards the outskirts. The maximum 1-hour mean concentrations recorded at LCA-CAH and LCA-ND were lower than those at Bloomsbury, Canning Town and Stratford, and higher than those at Eltham and Bexley.

Table 5: Nitrogen Dioxide (NO_2) Data Summary for London Monitoring Sites, 2011[a]

	Background Site				Roadside Site
	Bexley	**Bloomsbury**	**Eltham**	**Canning Town**	**Stratford**
Max. 1-hr Mean (µg/m^3)	139	164	124	167	186
No. 1-hr >200 µg/m^3	0	0	0	0	0
Annual Mean (µg/m^3)	23.1	48.4	24.5	37.2	46.8
Data Capture (%)	97.6	97.1	97.3	84.4	95.0

[a] Includes provisional data. Nitrogen oxides concentrations are provided in Appendix 1.

Particulate Matter PM_{10}

3.11 The 2011 PM_{10} results for the LCA-CAH automatic monitoring station are summarised in Table 6. Data capture was 98% for the full year. The recorded annual mean concentration (24 µg/m^3) was well below the objective of 40 µg/m^3. There were 16 measured exceedences of the 24-hour mean objective level of 50 µg/m^3, compared with the 35 exceedences allowed. In addition, the 90th percentile of daily mean concentrations (39 µg/m^3)[3] was below 50 µg/m^3.

[3] When data capture is below 90%, Defra Technical Guidance (LAQM.TG(09)) recommends that a comparison should be made with the relevant percentile value of the objective.

Table 6: PM_{10} Data Summary for LCA-CAH, 2011

Pollutant	TEOM, VCM-corrected	PM_{10} Objectives
	PM_{10}	
Maximum 24-hour Mean	82.8 µg/m^3	-
No. 24-Hour Means >50 µg/m^3	16	50 µg/m^3; no more than 35 exceedences
90th Percentile	39.3 µg/m^3	50 µg/m^3
Annual Mean	23.9 µg/m^3	40 µg/m^3
Data Capture	98 %	-

3.12 Table 7 includes the distribution of the running 24-hour mean values into the different pollution bands (DAQI).

Table 7: DAQI Bandings for PM_{10}, 2011

	Index	PM_{10}
Number Very High [a]	10	0
Number High [a]	9	0
	8	22
	7	14
Number Moderate [a]	6	25
	5	106
	4	218
Number Low [a]	3	880
	2	5218
	1	1863

[a] Number of running 24-hour mean values, updated every hour.

3.13 The majority of running 24-hour measured PM_{10} concentrations fell into the 'Low' pollution band (95.4%) during 2011; there were 349 running 24-hour concentrations within the 'Moderate' pollution band (4.2%) and 36 running 24-hour concentrations within the 'High' pollution band (0.4%). There were no 'Very High' events.

3.14 PM_{10} concentrations for five sites across London in 2011 are summarised in Table 8. These sites range from central London (Bloomsbury and Eltham) to outer London (Bexley), with two in east London (Canning Town and Stratford). The measured annual mean concentration at London City Airport (24 µg/m^3) was lower than that at Stratford (28 µg/m^3) and Canning Town (26 µg/m^3), and higher than that measured at Bexley (22 µg/m^3 using VCM-corrected TEOM, 19 µg/m^3 using FDMS), Bloomsbury (22 µg/m^3) and Eltham (22 µg/m^3). The number of 24-hour mean exceedences of 50 µg/m^3 were the same as at Stratford, lower than at Bloomsbury and Eltham and higher than at Bexley and Canning Town, whilst the 90th percentile at LCA-CAH was higher than those at Bexley and Bloomsbury, the same as at Eltham and lower than that at Canning Town and Stratford.

Table 8: PM_{10} Data Summary of Background London Monitoring Sites, 2011[a]

	Background Site					Roadside Site
	Bexley (TEOM)	Bexley (FDMS)	Bloomsbury	Eltham	Canning Town	Stratford
Maximum 24-hr mean (µg/m^3)	79	98	89	109	77	76
Annual Mean (µg/m^3)	22	19	22	22	26	28
No. 24-hr mean >50 µg/m^3	13	12	19	18	15	16
90th Percentile	36	34	37	39	42	44
Data Capture (%)	98	92	97	93	68	71

[a] All values are reference equivalent. All data are derived from an FDMS analyser, with the exception of the Bexley TEOM, which has been adjusted using the VCM.

Nitrogen Dioxide Diffusion Tube Network

3.15 London City Airport also operates a network of passive diffusion tube samplers for nitrogen dioxide. The intent of this network is to establish the wider spatial pattern of nitrogen dioxide concentrations in the area surrounding the Airport. The locations of the monitoring sites are shown in Figure 2, and are described in Table 9; grid references and the monthly mean data are provided in Appendix 3. The diffusion tubes are exposed for approximately 4-week intervals. They are supplied and analysed by Gradko International Ltd., and are prepared using the 20% TEA in water method.

3.16 The diffusion tubes record monthly mean concentrations, which have been averaged to give the annual mean. The results cannot therefore be directly compared with the 1-hour mean objective. However, measurements across the UK have shown that the 1-hour mean nitrogen dioxide objective is unlikely to be exceeded where the annual mean concentration is below 60 µg/m^3 (Defra, 2009).

Table 9: Description of Diffusion Tube Monitoring Sites

Location	Site ID
Lamp post at top of Parker Street, adjacent to housing	LCA 01
Lamp post on Camel Road, adjacent to nearest property on Hartmann Street	LCA 02
Lamp post on access road in Silvertown Quay. Approx. 36 metres from kerbside of main road	LCA 03
Lamp post at waterfront to east end of Newham Dockside	LCA 04
Lamp post on Straight Road, at kerbside	LCA 05
Lamp post on pedestrian walkway adjacent to nearest housing at Gallions Way	LCA 06
Landing Lights	LCA 07
Lamp post on Brixham Street	LCA 08
City Aviation House (triplicate tubes)	LCA 09
Jet Centre – airside	LCA 10
Lamp post at waterfront, eastern end of the University of East London	LCA 11
ILS, to north of runway and south of Royal Albert Dock	LCA 12
Lamp post at north west corner of Newham Dockside	LCA 13
Lamp post on waterfront at western end of Newham Dockside	LCA 14
Lamp post at kerbside (approx 1 m) of Royal Albert Way	LCA 15
Waterfront, approx 180 m east of Newham Dockside	LCA 16
North west of site 16, approx 85 m back from Waterfront	LCA 17
Newham Dockside analyser	LCA 18
Waterfront, approximately 460m east of Newham Dockside	LCA 19

3.17 It is important to note that not all of these monitoring sites represent relevant public exposure for annual mean concentrations of nitrogen dioxide; thus the objectives are not strictly applicable at all of these sites. For instance, the sites at Landing Lights (LCA 07), the Jet Centre (LCA 10) and the ILS (LCA 12) are located on land that is not generally accessible by the public, or is owned by the Airport. The sites at LCA 04 (at the waterfront of Newham Dockside), LCA 11 (at the waterfront of the University of East London) and LCA 13, 14, 15 and 16 (in the vicinity of Newham Dockside and Royal Albert Way) would also not represent relevant exposure for annual mean concentrations according to the criteria defined in LAQM.TG(09)[4], but are relevant for 1-hour concentrations. Site LCA 03 is located within an area of land allocated for redevelopment at Silvertown Quay, but public access is currently prohibited. These sites have been included in the study to better understand the spatial pattern of nitrogen dioxide concentrations around the Airport.

3.18 Diffusion tubes are known to show systematic bias in relation to automatic (reference) monitors. For this reason, a co-location study has been carried out, with triplicate tubes exposed alongside

[4] Defra Technical Guidance Note LAQM.TG(09) suggests that in the case of the annual mean objective, a relevant location might be where a member of the public would be exposed for a cumulative period of 6 months in a year.

the inlet to the automatic monitor at LCA-CAH, and a single tube exposed in close proximity to the inlet of the LCA-ND automatic monitor. Comparison of the matched period results shows that the diffusion tubes were over-reading by an average of 40%. An adjustment factor of 0.738 has therefore been applied to all diffusion tube results to ensure that they give the best representation of true concentrations (see Appendix 4). The results from the triplicate tubes indicate "good" precision (±6.1%) for the study in 2011, see Appendix 5 (Defra, 2009).

3.19 The bias-adjusted results are summarised in Table 10, and also shown in Figure 3. The results show that the annual mean objective of 40 µg/m^3 was exceeded at one location (LCA 04) during 2011. All measured annual mean nitrogen dioxide concentrations were well below 60 µg/m^3, and it is thus unlikely that the 1-hour mean objective will have been exceeded at any location.

3.20 It is important to note that there is no relevant exposure to the annual mean objective at LCA04. The site is close to the edge of Royal Albert Dock, with no local pollution sources within 100 m. This site has been identified in previous years as the location with the highest concentration. It is also of note that monitoring site LCA 12, which lies just to the north of the main runway, recorded a much lower concentration (32.3 µg/m^3) in 2011, suggesting that the Airport is not significantly contributing to the elevated levels at LCA 04.

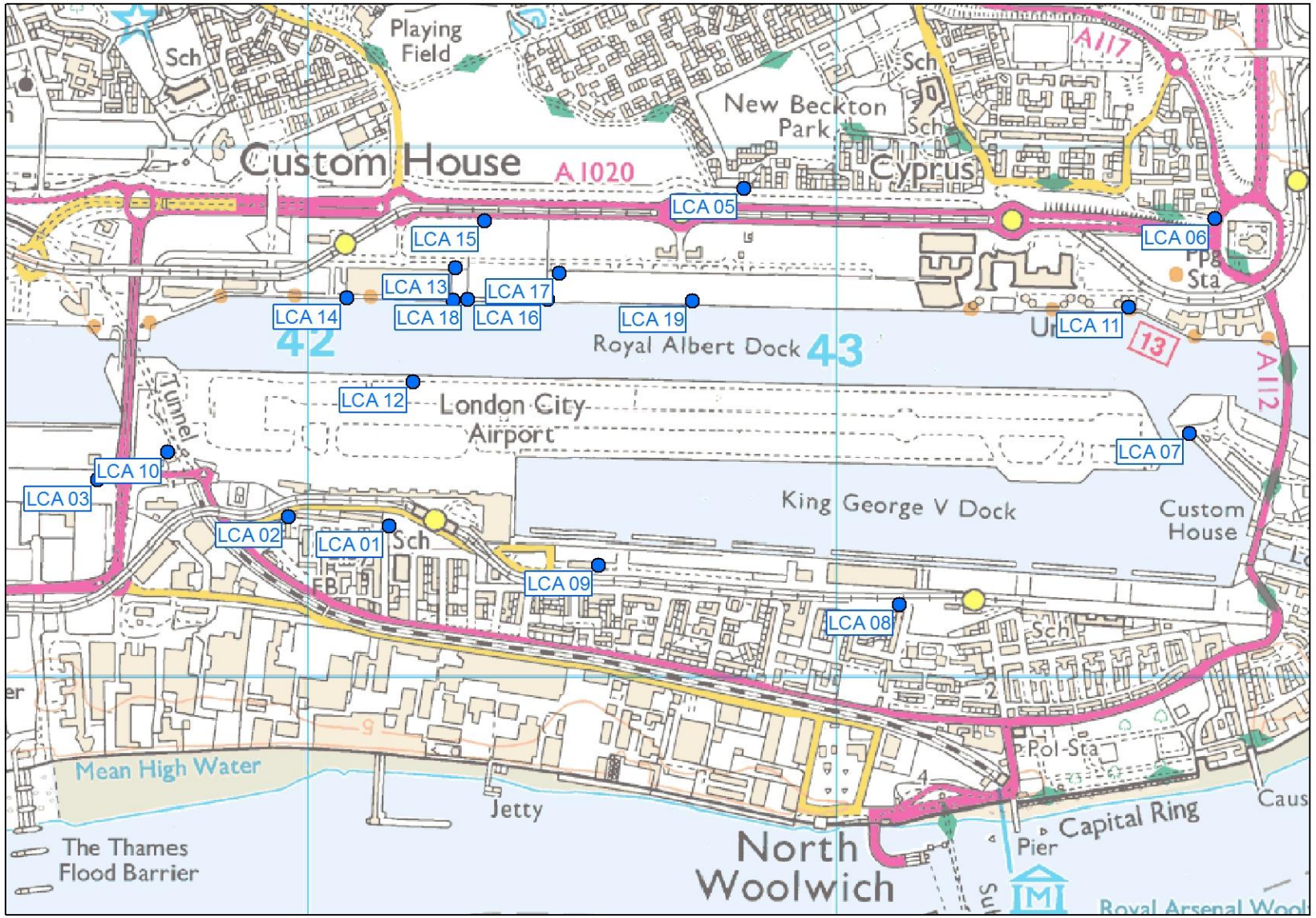

Figure 2: Diffusion Tube Monitoring Locations (green dots).

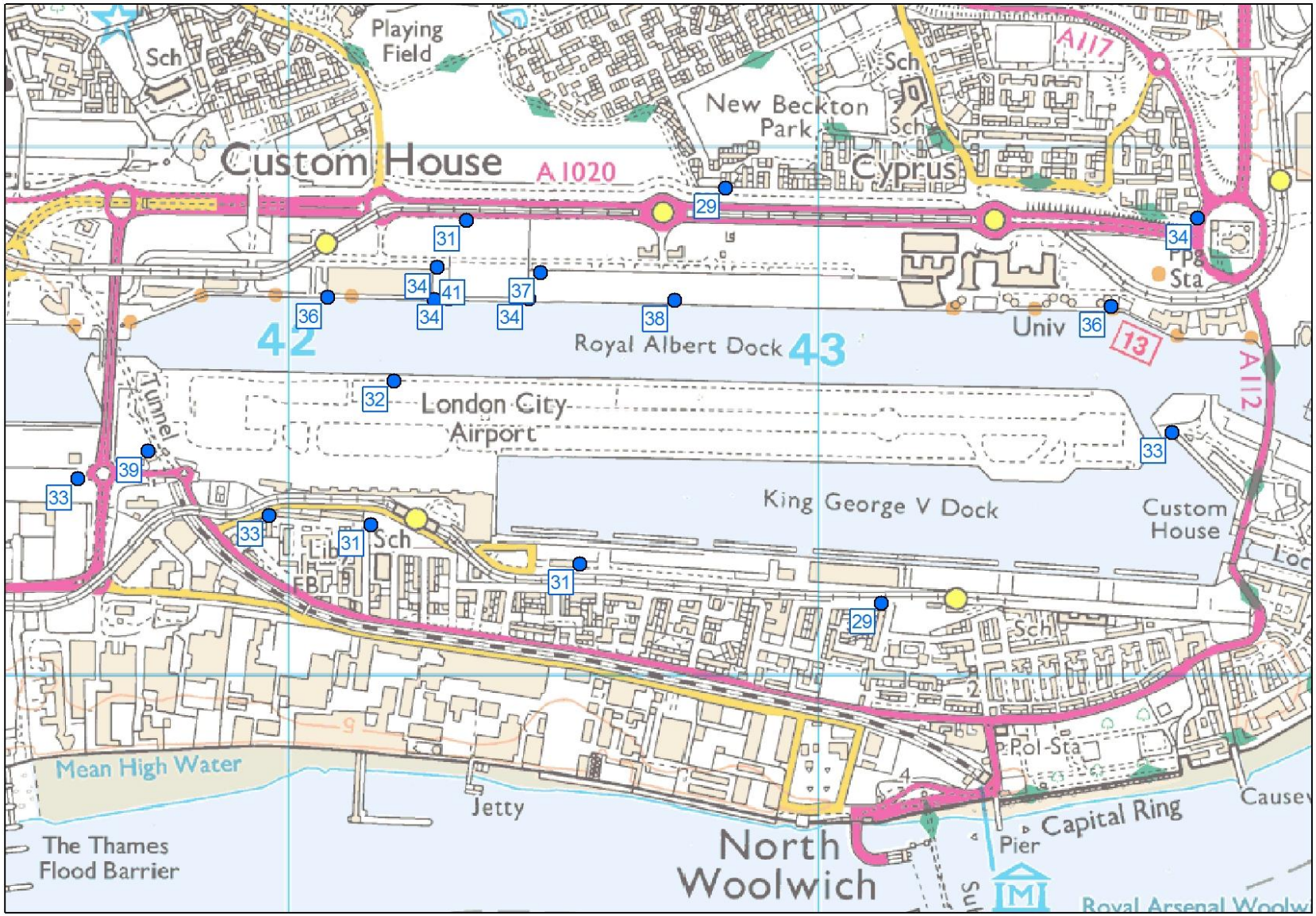

Figure 3: Nitrogen Dioxide Diffusion Tube Results, 2011 (µg/m^3).

Table 10: Diffusion Tube Data Summary for London City Airport, 2011 (Adjusted for Bias)

Site ID	Adjusted Value (µg/m^3)[a]
LCA 01	31.5
LCA 02	33.3
LCA 03	32.6
LCA 04	41.1
LCA 05	28.9
LCA 06	33.5
LCA 07	32.8
LCA 08	28.7
LCA 09	31.1
LCA 10	39.4
LCA 11	36.4
LCA 12	32.3
LCA 13	33.7
LCA 14	36.1
LCA 15	31.3
LCA 16	33.6
LCA 17	36.6
LCA 18	34.0
LCA 19	37.7

[a] Data have been adjusted using a local bias adjustment factor for 2011 of 0.738. The co-location studies are carried out at LCA-CAH using triplicate tubes and at LCA-ND with a single tube located at the automatic monitors. Diffusion tubes were exposed for the period between 8th January 2011 and 6th January 2012.

4 Data Analyses

4.1 This chapter provides analyses of the data covering time series, trends and source contributions.

Time Series

4.2 The measured 1-hour mean nitrogen dioxide concentrations at LCA-CAH and LCA-ND, and at Bexley, Bloomsbury, Eltham, Canning Town and Stratford, are shown as a time series in Figures 4 and 5 respectively.

4.3 The concentrations over the monitoring period show similar patterns at all seven monitoring sites. The concurrence of periods with elevated concentrations at all sites suggests that these episodes were due to regional changes in concentrations.

4.4 The measured daily mean PM_{10} concentrations at LCA-CAH and LCA-ND, and at the two Bexley monitors, Bloomsbury, Eltham, Canning Town and Stratford, are shown in Figures 6 and 7 respectively. Once again, the analysis suggests that periods of high pollution were principally due to regional changes in concentrations.

Trends in Pollutant Concentrations

4.5 The automatic station at the LCA-CAH site has been in operation since September 2006, and it useful to identify whether there are any trends in the measured pollutant concentrations over time.

4.6 Figure 8 shows the trends in measured annual mean nitrogen dioxide concentrations at LCA-CAH and five other monitoring locations. Between 2007 and 2011, there appears to have been a slight downward trend in annual mean nitrogen dioxide concentrations measured at all sites.

4.7 The trends in annual mean PM_{10} concentrations are shown in Figure 9, for the LCA-CAH site and three other monitoring locations, for which five years data were available. The pattern is similar at all sites, with a decrease from 2007 to 2008 then an increase from 2010 to 2011, but no real trend over the five years.

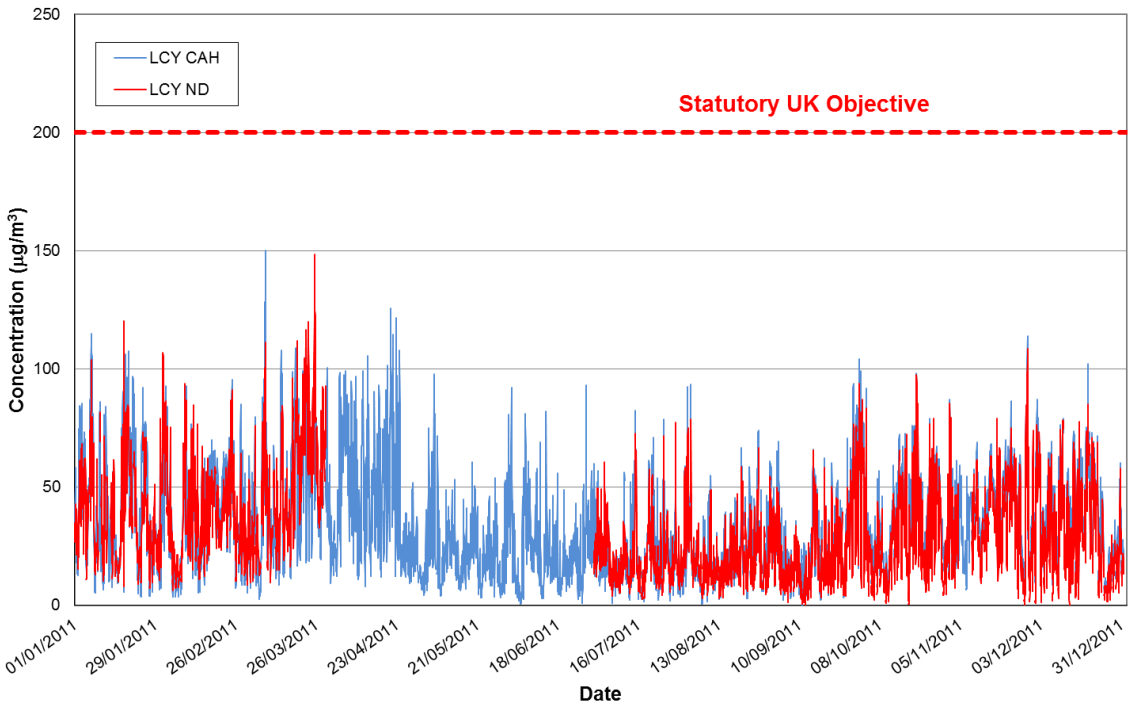

Figure 4: 1-Hour Mean Nitrogen Dioxide Concentrations at London City Airport, 2011

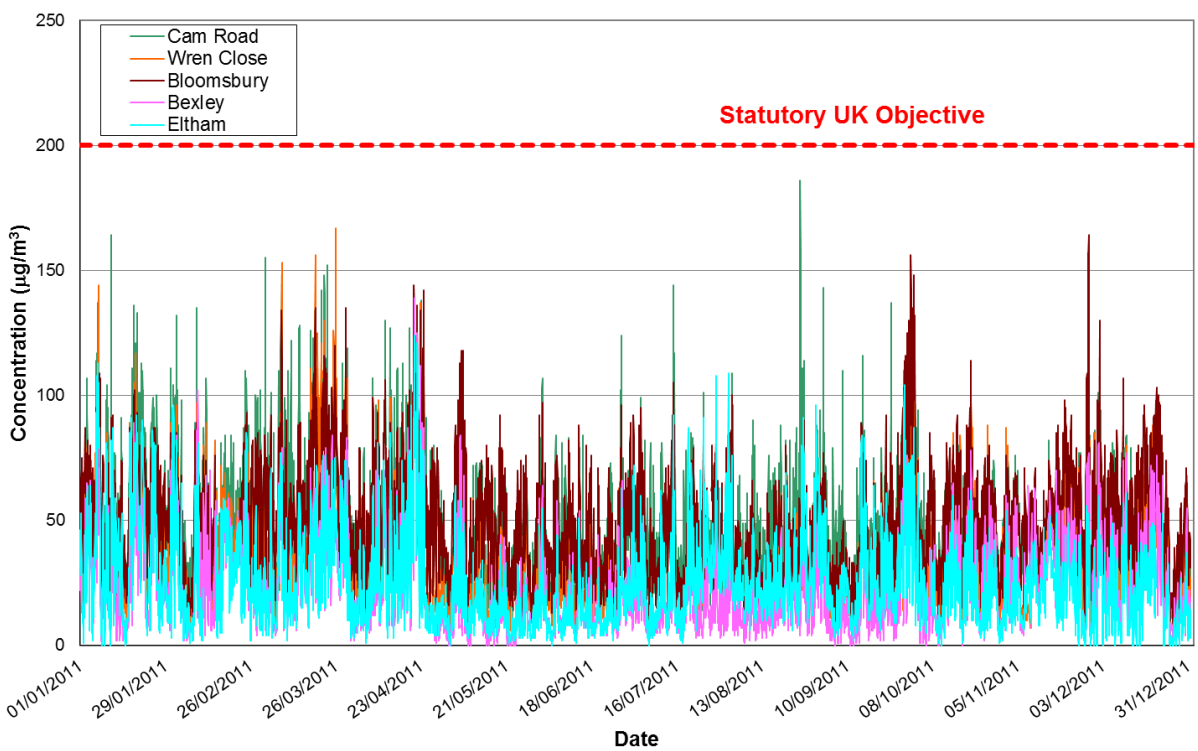

Figure 5: 1-Hour Mean Nitrogen Dioxide Concentrations at London Monitoring Sites, 2011

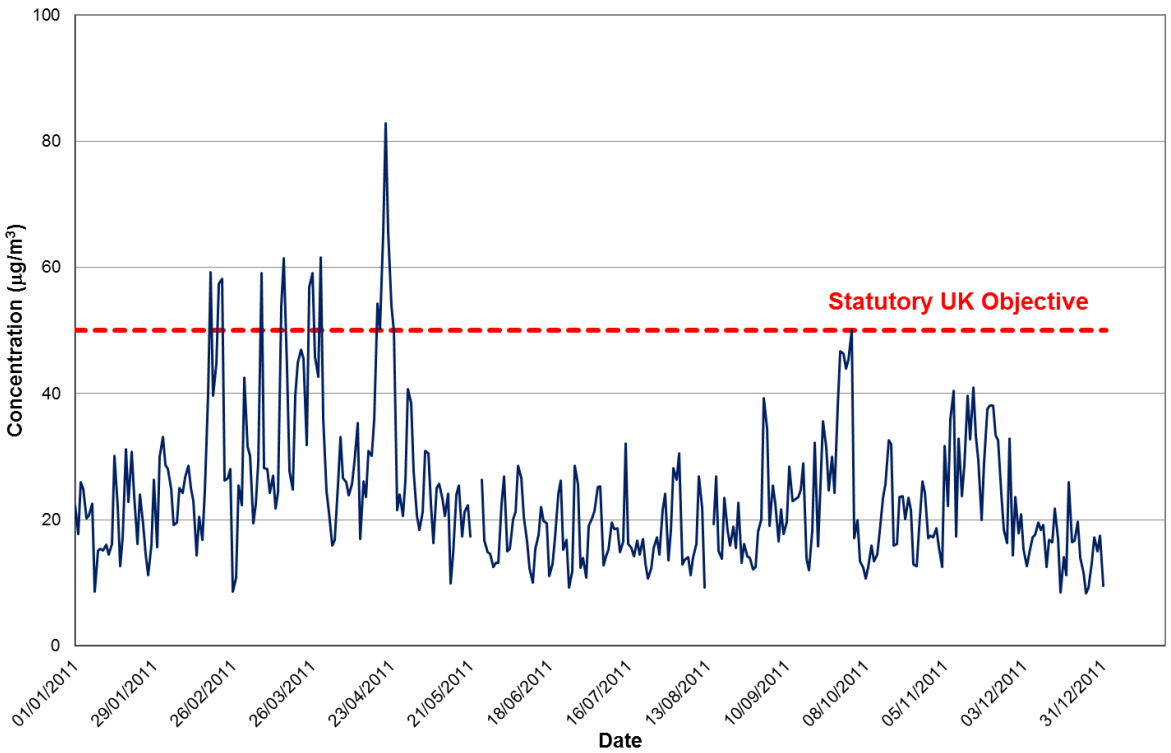

Figure 6: Daily Mean PM_{10} Concentrations at London City Airport (LCA-CAH), 2011

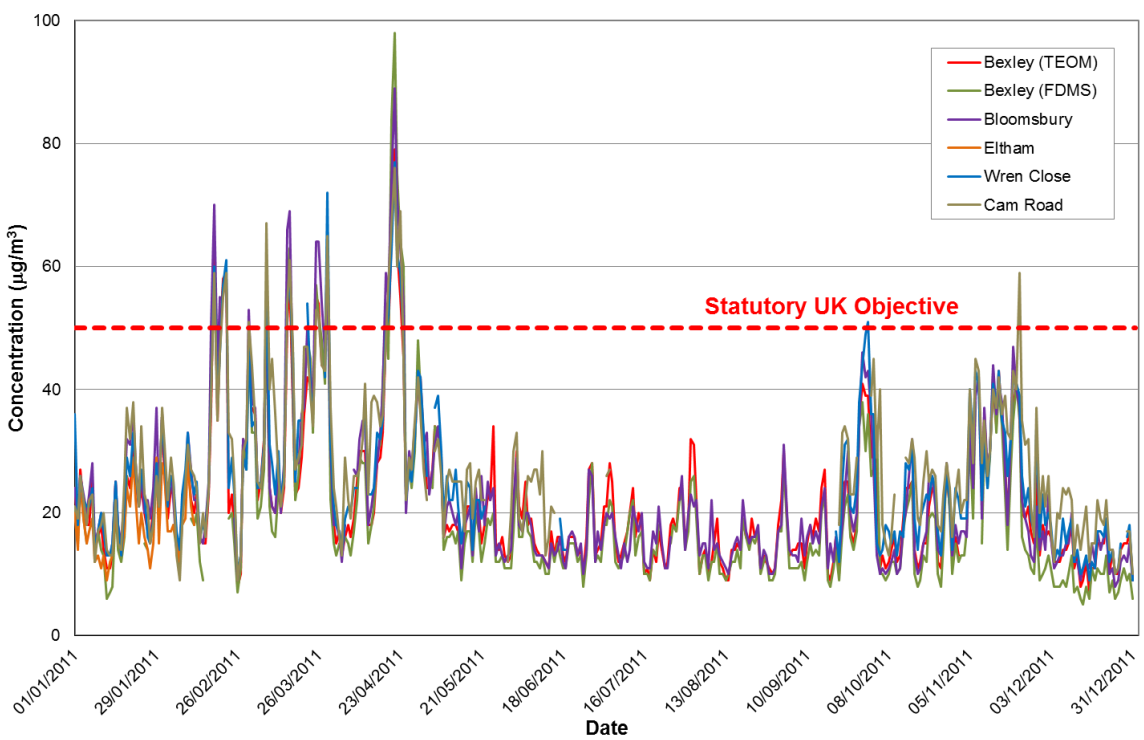

Figure 7: Daily Mean PM_{10} Concentrations at London Monitoring Sites, 2011

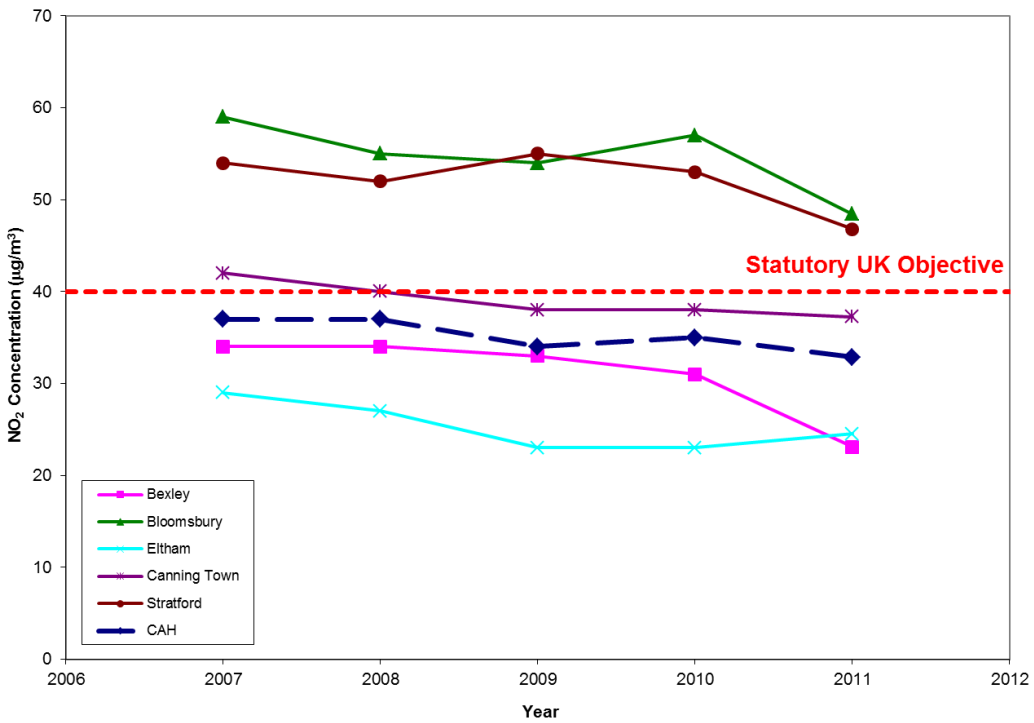

Figure 8: Annual Mean Nitrogen Dioxide Concentrations, 2007 – 2011 (µg/m^3)

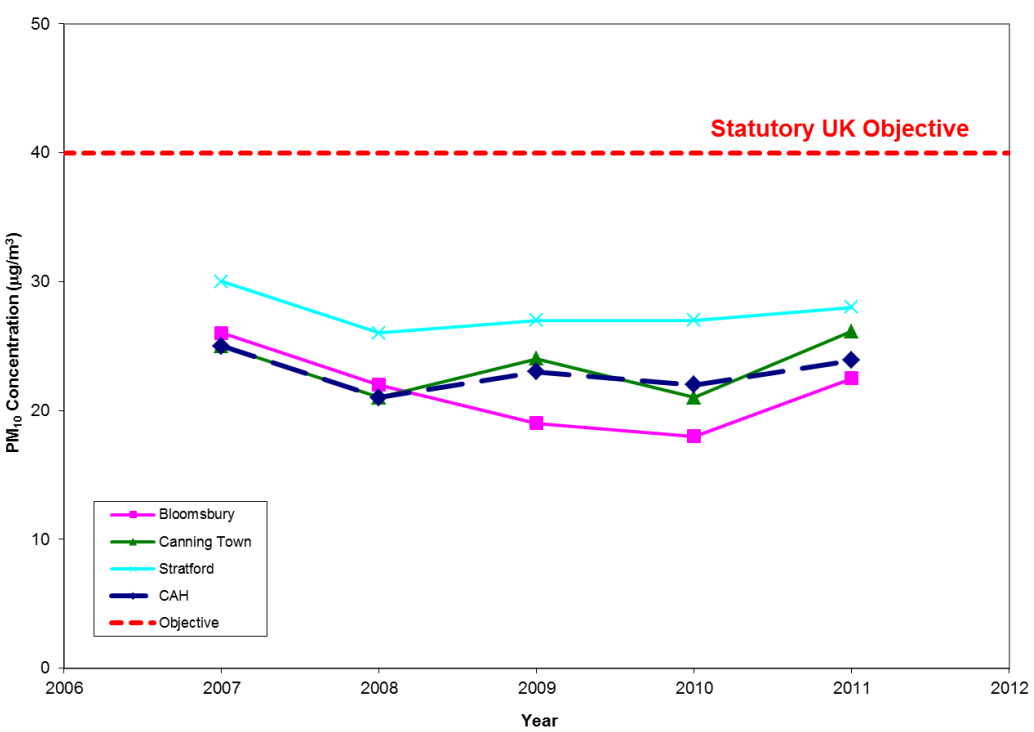

Figure 9: Annual Mean PM_{10} Concentrations, 2007 – 2011 (µg/m^3)

Bivariate Pollution Roses

4.8 Pollution roses are a useful technique for exploring the influence of different sources of air pollution at a monitoring site. Usually, the data are processed into average concentrations by wind direction, such that it is possible to identify whether elevated pollution concentrations are associated with different wind directions.

4.9 Data analysis tools available via the "Openair" website[5] include the preparation of "bivariate pollution roses". These bivariate roses process average pollution concentration data by both wind direction and wind speed. They provide a powerful tool in identifying source contributions to measured concentrations at monitoring sites. The concentrations are shown by colour shading, with the distance from the centre point representing increasing wind speed.

4.10 It is known from both modelling studies and the analysis of empirical data that emissions from different source types behave differently in low and high wind speed conditions. For emissions from ground-level sources (such as road traffic), concentrations are highest during low wind speeds, and decrease rapidly with increasing wind speed (due to greater dilution and dispersion). In contrast, emissions released from elevated (e.g. chimney) sources, give rise to higher concentrations at higher wind speeds, as the plume is more likely to come down to ground close to the source. Emissions from the buoyant plumes of jet aircraft engines tend to behave in a similar manner to elevated sources. Carslaw *et al* (2006) showed how these bivariate plots could be used to identify the contribution of aircraft emissions to measured concentrations at Heathrow Airport.

4.11 Figure 10 shows bivariate pollution roses for NO_x concentrations in 2011 at the LCA-CAH and LCA-ND sites. It can be seen for both bivariate pollution roses that the highest NO_x concentrations occur during low wind speeds (i.e. towards the centre of the rose) indicating that the highest concentrations are associated with ground-level source releases (the wind speed scale runs from 0 m/s to 20 m/s, with the concentration scale running from 0 to just over 100 $\mu g/m^3$). There is some indication of a contribution to NO_x concentrations at LCA-ND with winds from the east at moderate wind speeds; this may be associated with boiler emissions from the University. There is no evidence of a significant contribution from Airport operations to measured NO_x concentrations at either monitoring site.

[5] www.openair-project.org/about_us.php

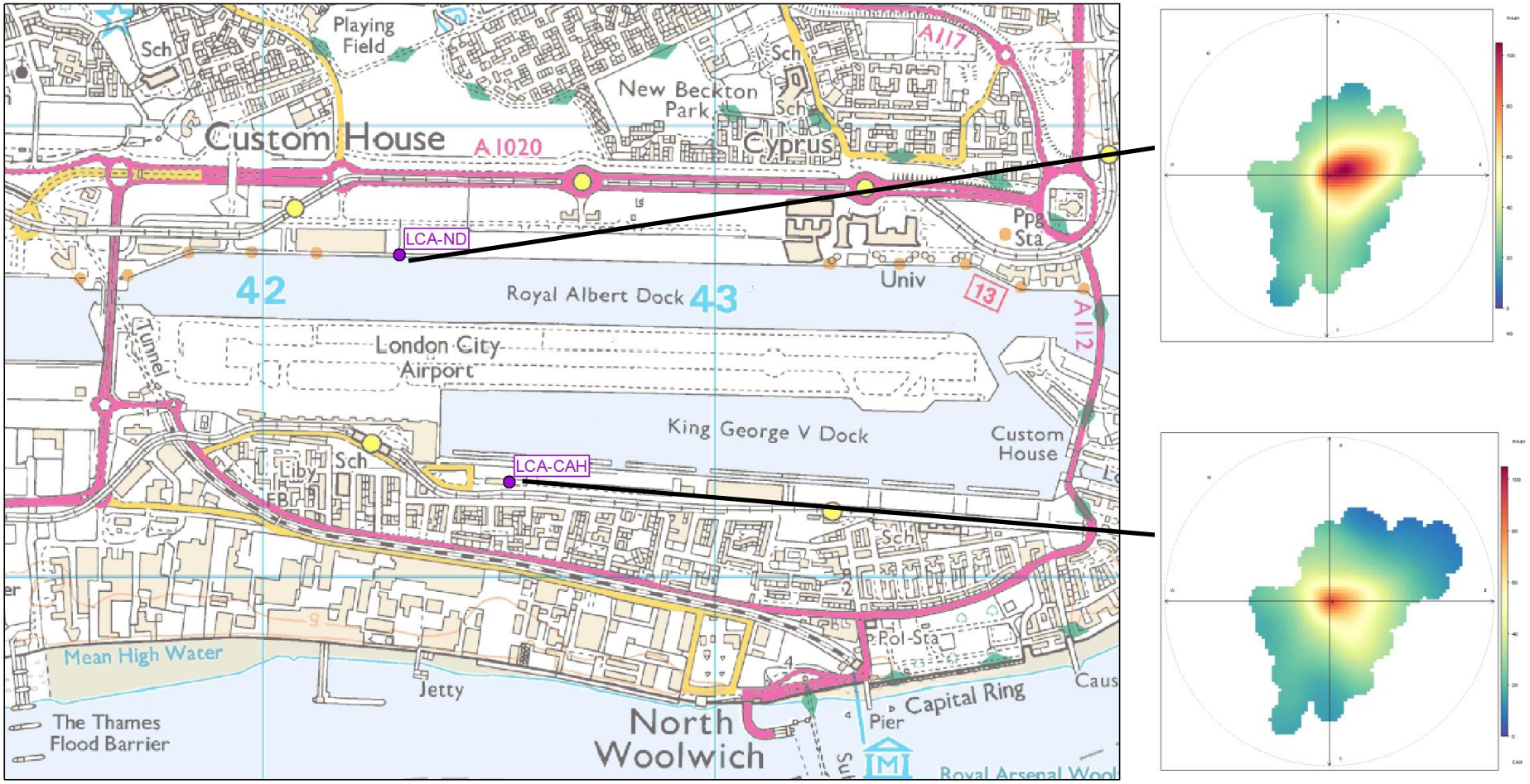

Figure 10: Bivariate Pollution Roses at LCA-CAH and LCA-ND Sites, 2011 (NO_x, µg/m^3)

5 References

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6 Glossary

Exceedence	A period of time where the concentration of a pollutant is greater than the appropriate air quality objective.
FDMS	Filter Dynamics Monitoring System.
LAQN	London Air Quality Network.
LCA-CAH	London City Airport – City Aviation House monitoring site.
LCA-ND	London City Airport – Newham Dockside monitoring site
$\mu g/m^3$	Micrograms per cubic metre.
NO_2	Nitrogen dioxide.
NO_x	Nitrogen oxides (taken to be NO_2 + NO).
NO	Nitric oxide.
Objectives	A nationally defined set of health-based concentrations for nine pollutants, seven of which are incorporated in Regulations, setting out the extent to which the standards should be achieved by a defined date, taking into account costs, benefits, feasibility and practicality. There are also vegetation-based objectives for sulphur dioxide and nitrogen oxides.
PM_{10}	Small airborne particles, more specifically particulate matter less than 10 micrometers in aerodynamic diameter.
Standards	A nationally defined set of concentrations for nine pollutants below which health effects do not occur or are minimal.
TEA	Triethanolamine – absorbent for nitrogen dioxide used in diffusion tubes.
TEOM	Tapered Element Oscillating Microbalance.
VCM	Volatile Correction Model.

A1 Appendix 1 – Nitrogen Oxides Results

A1.1 Nitrogen oxides (NO_x) concentrations, which are essentially the sum of nitrogen dioxide and nitric oxide, are presented in Table A1.1 for the automatic monitoring stations at London City Airport and for five sites across east London in Table A1.2. The trends over the last five years are shown in Figure A1.1 and are downward at all sites over the period 2007 to 2011. There are no relevant air quality criteria for nitrogen oxides in an urban area. Nitrogen oxides concentrations are included here for completeness, and because they are relevant for air quality modelling.

Table A1.1: Nitrogen Oxides (NO_x) Data Summary for LCA-CAH and LCA-ND, 2011

Site	LCA-CAH	LCA-ND
Maximum 1-Hour Mean	636 µg/m^3	684 µg/m^3
Annual Mean	52 µg/m^3	54 µg/m^3
Data Capture	96.3%	68.6 %

Table A1.2: Nitrogen Oxides (NO_x) Data Summary for London Monitoring Sites, 2011

Site	Bexley	Bloomsbury	Eltham	Canning Town	Stratford
Maximum 1-Hour Mean (µg/m^3)	650	555	369	740	621
Annual Mean (µg/m^3)	34	81	34	55	79
Data Capture %	97.6	49.1	97.3	84.4	95.0

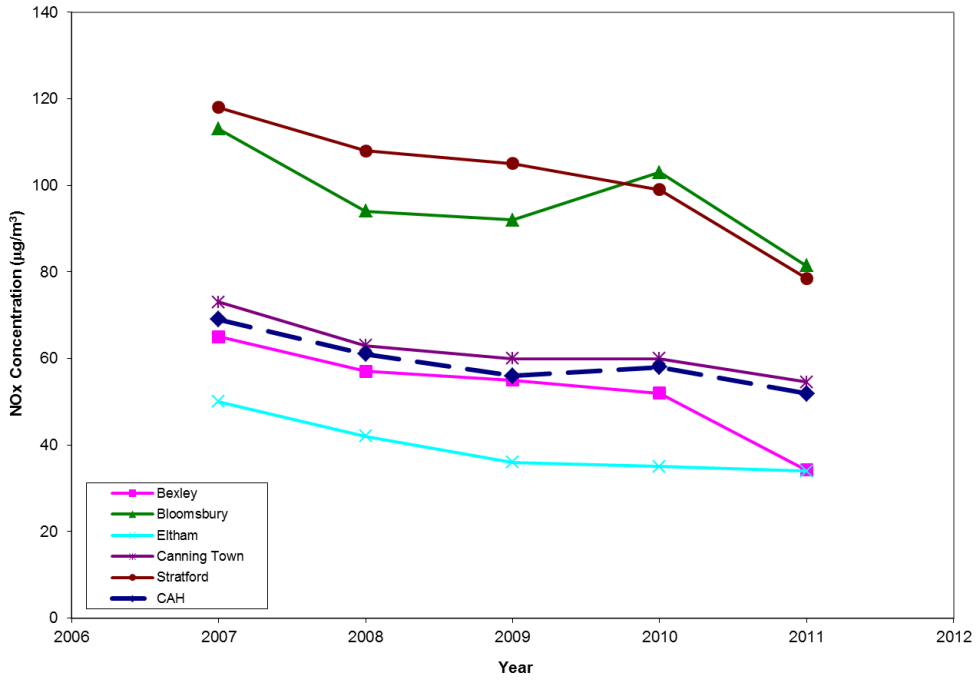

Figure A1.1: Annual Mean NO_x Concentrations, 2007- 2011

A2 Appendix 2 – Annualised LCA-ND Result

A2.1 As data capture for LCA-ND was low (66%), the data do not represent a full calendar year. Therefore, in accordance with the guidance set out in Box 3.2 of LAQM.TG(09), the data have been adjusted to provide an annual mean equivalent, based on the ratio of concentrations during the short-term monitoring period (9 months; January to March, and June to December 2011) to those over the 2011 calendar year at three of background sites operated as part of the LAQN and at LCA-CAH, where long-term data are available.

A2.2 The annual mean nitrogen dioxide concentrations and the period means for each of the four monitoring sites from which adjustment factors have been calculated are presented in Table 2.1, along with the Overall Factor.

Table A2.1: Data used to Adjust Short-term Monitoring Data at LCA-ND to 2011 Annual Mean

Period Mean Concentration (µg/m^3)	Bexley	Eltham	Wren Close, Canning Town	LCA-CAH	Overall Factor
2011	23.1	24.5	37.2	33.1	-
Jan to Apr, Jul to Dec 2011	24.5	26.6	39.2	34.0	-
Adjustment Factor	0.94	0.92	0.95	0.97	**0.95**

A2.3 The annualised nitrogen dioxide annual mean for LCA-ND is 29.5 µg/m^3.

A3 Appendix 2 – Diffusion Tube Data

A3.1 Raw monthly average diffusion tube data, along with the location details and monitoring periods, are presented in Table A3.1.

Table A3.1: Raw Monthly Diffusion Tube Data for 2011, Not Bias Adjusted (µg/m^3)

Site ID	Grid ref	08/01/11 to 08/02/11	08/02/11 to 04/03/11	04/03/11 to 01/04/11	01/04/11 to 06/05/11	06/05/11 to 03/06/11	03/06/11 to 01/07/11	01/07/11 to 05/08/11	05/08/11 to 02/09/11	02/09/11 to 10/10/11	10/10/11 to 04/11/11	04/11/11 to 01/12/11	01/12/11 to 06/01/12	Period Mean	Data Capture (%)
LCA 01	542142,180295	60.2	46.6	55.1	34.8	31.4	32.1	33.9	38.1	n/a	35.9	57.7	43.8	42.7	92%
LCA 02	541946,180296	64.1	43.2	59.0	17.7	n/a	n/a	40.4	38.0	44.2	44.4	54.4	46.3	45.2	83%
LCA 03	541587,180372	59.4	40.8	70.5	26.8	33.8	33.7	32.1	38.9	41.5	42.0	63.0	48.4	44.2	100%
LCA 04	542257,180710	82.3	52.0	61.2	25.6	57.3	27.2	41.9	55.2	50.8	61.0	72.2	81.3	55.7	100%
LCA 05	542838,180920	45.6	39.7	50.9	15.3	34.6	n/a	n/a	31.6	43.7	39.9	45.8	44.6	39.2	83%
LCA 06	543713,180869	65.5	49.5	66.2	20.4	36.0	35.1	37.8	40.8	42.1	49.2	58.9	43.8	45.4	100%
LCA 07	543640,180474	42.2	45.0	54.9	32.1	42.0	33.4	31.6	36.2	48.6	52.9	54.6	60.2	44.5	100%
LCA 08	543122,180136	46.7	39.9	47.7	35.8	32.2	28.6	27.8	30.2	36.9	43.7	48.4	48.5	38.9	100%
LCA 09	542527,180199	61.4	45.7	51.3	32.2	34.0	29.2	32.1	36.1	39.5	39.3	51.8	48.3	41.7	100%
		64.7	42.6	56.7	25.1	33.9	34.2	33.7	35.9	36.4	37.6	59.4	44.6	42.1	100%
		57.4	46.0	52.8	24.1	33.6	33.3	32.6	37.3	43.6	41.9	61.5	46.9	42.6	100%
LCA 10	541731,180419	75.4	58.9	65.8	46.4	46.8	46.2	38.1	46.2	49.7	54.0	62.7	51.4	53.5	100%
LCA 11	543560,180687	60.3	44.9	55.5	24.8	44.4	39.6	n/a	42.1	50.5	48.9	66.0	66.5	49.4	92%
LCA 12	542181,180561	59.9	39.6	41.5	38.5	33.1	33.5	29.6	35.2	40.2	62.5	62.9	49.3	43.8	100%
LCA 13	542291,180770	72.1	49.5	47.7	42.7	37.4	36.3	34.7	38.7	37.9	40.4	57.1	54.1	45.7	100%
LCA 14	542075,180714	59.9	50.7	58.5	40.3	n/a	36.2	35.0	40.2	40.3	55.4	67.0	54.7	48.9	92%
LCA 15	542430,180857	63.0	43.8	51.9	20.7	34.2	30.5	n/a	36.2	38.7	41.5	59.4	46.2	42.4	92%
LCA 16	542452,180710	58.7	50.7	59.1	25.0	34.7	37.0	34.0	36.5	39.5	57.0	66.9	47.2	45.5	100%
LCA 17	542483,180784	65.4	52.7	n/a	32.1	42.9	36.9	35.7	43.9	52.9	51.6	62.7	69.6	49.7	92%
LCA 18	542298,180684	69.0	50.6	52.5	37.8	30.4	n/a	31.5	34.6	36.3	34.3	60.2	45.4	43.9	92%
LCA 19	542757,180688	62.5	49.7	56.4	28.9	36.0	31.6	31.3	60.6	55.5	n/a [8]	69.5	80.1	51.1	92%

n/a – not available * Data removed, due to very high measured concentration, as tube likely to be contaminated.

A4 Appendix 3 – Bias Adjustment Factor for Diffusion Tubes

A4.1 Diffusion tubes are known to exhibit bias when compared to results from automatic analysers. Therefore diffusion tube results need to be adjusted to account for this bias. One of the main factors influencing diffusion tube performance is thought to be the laboratory that supplies and analyses the tubes. The diffusion tubes exposed at London City Airport are supplied and analysed by Gradko International Ltd (20% TEA in water).

A4.2 In order to determine the bias exhibited by these tubes, studies are carried out using triplicate tubes co-located at LCA-CAH and a single tube at LCA-ND. All diffusion tube data presented in this report have been adjusted using the overall factor calculated from the data presented in Table A4.1, with the optimum relationship defined using orthogonal regression.

Table A4.1: Results of Diffusion Tube and Continuous Monitor Co-location Studies in 2011 [a]

	Diffusion Tube	Automatic	Adjustment Factor
LCA-CAH	42.1	32.4	0.770
LCA-ND	46.0	30.9	0.671
Overall Factor [b]			**0.738**

[a] Diffusion tubes were exposed for the period between 8th January 2011 and 6th January 2012. The automatic monitoring data correspond to this period.

[b] The overall factor has been determined using orthogonal regression.

A4.3 Table A4.2 presents the bias adjustment factors applied to the data for the last three years. The factors have remained fairly consistent over this period.

Table A4.2: Previous Bias Adjustment Factors

Year	Factor
2007	0.764
2008	0.786
2009	0.717
2010	0.801
2011	0.738

A5 Appendix 4 – Diffusion Tube Precision

A5.1 Diffusion tube precision describes the ability of a measurement to be consistently reproduced, i.e. how similar the results of duplicate or triplicate tubes are to each other. It is an indication of how carefully the tubes have been handled in either the laboratory and/or the field. Tube precision is separated into two categories 'Good' or 'Poor' as follows: tubes are considered to have **'Good'** precision where the coefficient of variation (CV) of duplicate or triplicate diffusion tubes for eight or more periods during the year is less than 20%, and the average CV of all monitoring periods is less than 10%. Tubes are considered to have **'Poor'** precision where the CV of four or more periods is greater than 20% and/or the average CV is greater than 10%.

A5.2 Table A5.1 shows that for each of the twelve periods of monitoring there was 'Good' precision, with the average precision of <10% and none of the periods having a CV >20%. Overall, therefore, the precision of the diffusion tubes is 'Good', which is consistent with the performance of 20% TEA in water tubes supplied by Gradko International in other co-location studies (Defra, 2011b).

Table A5.1: Precision of Triplicate Diffusion Tubes

Period	Start Date	End Date	Tube 1	Tube 2	Tube 3	Mean	Standard Deviation	CV	Tube Precision
1	08/01/2011	08/02/2011	61.4	64.7	57.4	61	3.7	6	Good
2	08/02/2011	04/03/2011	45.7	42.6	46.0	45	1.9	4	Good
3	04/03/2011	01/04/2011	51.3	56.7	52.8	54	2.8	5	Good
4	01/04/2011	06/05/2011	32.2	25.1	24.1	27	4.5	16	Good
5	06/05/2011	03/06/2011	34.0	33.9	33.6	34	0.2	1	Good
6	03/06/2011	01/07/2011	29.2	34.2	33.3	32	2.7	8	Good
7	01/07/2011	05/08/2011	32.1	33.7	32.6	33	0.8	2	Good
8	05/08/2011	02/09/2011	36.1	35.9	37.3	36	0.8	2	Good
9	02/09/2011	10/10/2011	39.5	36.4	43.6	40	3.6	9	Good
10	10/10/2011	04/11/2011	39.3	37.6	41.9	40	2.1	5	Good
11	04/11/2011	01/12/2011	51.8	59.4	61.5	58	5.1	9	Good
12	01/12/2011	06/01/2012	48.3	44.6	46.9	47	1.9	4	Good
Average CV								**6.1**	**Good**