Detailed Assessment of Particulate Matter

London Borough of Ealing
May 2006

Table of Contents

1 Introduction

As part of the second round of Air Quality Review and Assessment, Faber Maunsell has been commissioned by the London Borough of Ealing to undertake a Detailed Assessment of fine particulate matter (PM_{10}) with regard to emissions associated with several industrial and commercial activities located near to Horn Lane, Acton.

There are two key aspects to the assessment; the monitoring of ambient air in the vicinity of Horn Lane, and the dispersion modelling of PM_{10}.

1.1 Overview of Air Quality Legislation and Policy

1.1.1 Overview of Recent Air Quality Legislation and Policy

The provisions of Part IV of the Environment Act 1995 establish a national framework for air quality management, which requires all local authorities in England, Scotland and Wales to conduct local air quality reviews. Section 82(1) of the Act requires these reviews to include an assessment of the current air quality in the area and the predicted air quality in future years. Should the reviews indicate that the standards prescribed in the National Air Quality Strategy (NAQS)[1] and the Addendum to the Strategy[2] will not be met, the local authority is required to designate an Air Quality Management Area (AQMA). Action must then be taken at a local level to ensure that air quality in the area improves. This process is known as 'local air quality management'.

1.1.2 The Phased Approach to Review and Assessment

The second round of the Review and Assessment process has been split into two phases: an Updating and Screening Assessment and a Detailed Assessment.

The first phase, the Updating and Screening Assessment, has been designed to review the changes in air quality issues that have occurred within each local authority since the first round of review and assessment. These changes are assessed using appropriate screening methods. Therefore, it should cover:

- new monitoring data
- new objectives
- new sources of pollution
- significant changes to existing sources of pollution.

The Updating and Screening Assessment also re-examines locations and sources, e.g. road junctions, bus stations, domestic burning, fugitive sources, etc., that have been highlighted as issues during the previous round of Review and Assessment.

Where the Updating and Screening Assessment has identified a risk that an air quality objective may be exceeded, the local authority must undertake a Detailed Assessment. The aim of this assessment is to determine with as much certainty as is possible whether or not an air quality objective will be exceeded. If an exceedence is predicted, the local authority should designate an AQMA to cover the area of the exceedence.

In addition, local authorities are required to produce annual air quality Progress Reports, but only for years when no Updating and Screening or Detailed Assessments are due. All monitoring data and other information important with regard to local air quality should be included in the Progress Reports.

1.1.3 National Air Quality Strategy (NAQS)

The NAQS identifies eight ambient air pollutants that have the potential to cause harm to human health. These pollutants are associated with local air quality problems, with the exception of ozone, which is instead considered to be a regional problem.

The Air Quality Regulations[3] set standards for the seven pollutants that are associated with local air quality (Table 1). These objectives aim to reduce the health impacts of the pollutants to negligible levels. Revised objectives for benzene, carbon monoxide and suspended particulate matter (PM_{10}), as detailed in the 'Air Quality (England)(Amendment) Regulations 2002'[4], are included.

Further provisional objectives have been proposed for 2010. For London these objectives are a 24-hour mean of 50 µg/m^3, with a maximum of 10 exceedences per year and an annual mean of 23 µg/m^3. These objectives are considerably more stringent than those for 2004, and it is likely that they will not be achieved throughout many areas of London. This is expected to be the case mainly due to typical predicted background concentrations being only slightly lower than the annual mean standard. It should be noted that there is currently no requirement for local authorities to attempt to meet these objectives, due to their provisional status.

Table 1: UK Objectives included in the Air Quality Regulations 2000 and (Amendment) Regulations 2002

Pollutant	**Air Quality Objective**		**Date to be achieved by**
	Concentration	**Measured as**	
Benzene	16.25 µg/m^3 *(All authorities)*	running annual mean	31.12.2003
	5.0 µg/m^3 *(Authorities in England and Wales only)*	annual mean	31.12.2010
1,3-Butadiene	2.25 µg/m^3	running annual mean	31.12.2003
Carbon monoxide	10.0 mg/m^3	maximum daily running 8-hour mean	31.12.2003
Lead	0.5 µg/m^3	annual mean	31.12.2004
	0.25 µg/m^3		31.12.2008
Nitrogen dioxide	200 µg/m^3 not to be exceeded more than 18 times a year	1 hour mean	31.12.2005
	40 µg/m^3	annual mean	31.12.2005
Particles (PM_{10}) (gravimetric) *All authorities*	50 µg/m^3 not to be exceeded more than 35 times a year	24 hour mean	31.12.2004
	40 µg/m^3	annual mean	31.12.2004
Provisional Particles (PM_{10}) (gravimetric) *(London)*	50 µg/m^3 not to be exceeded more than 10 times a year	24 hour mean	31.12.2010
	23 µg/m^3	annual mean	31.12.2010
Sulphur dioxide	350 µg/m^3 not to be exceeded more than 24 times a year	1 hour mean	31.12.2004
	125 µg/m^3 not to be exceeded more than 3 times a year	24 hour mean	31.12.2004
	266 µg/m^3 not to be exceeded more than 35 times a year	15 minute mean	31.12.2005

1.2 Background Information

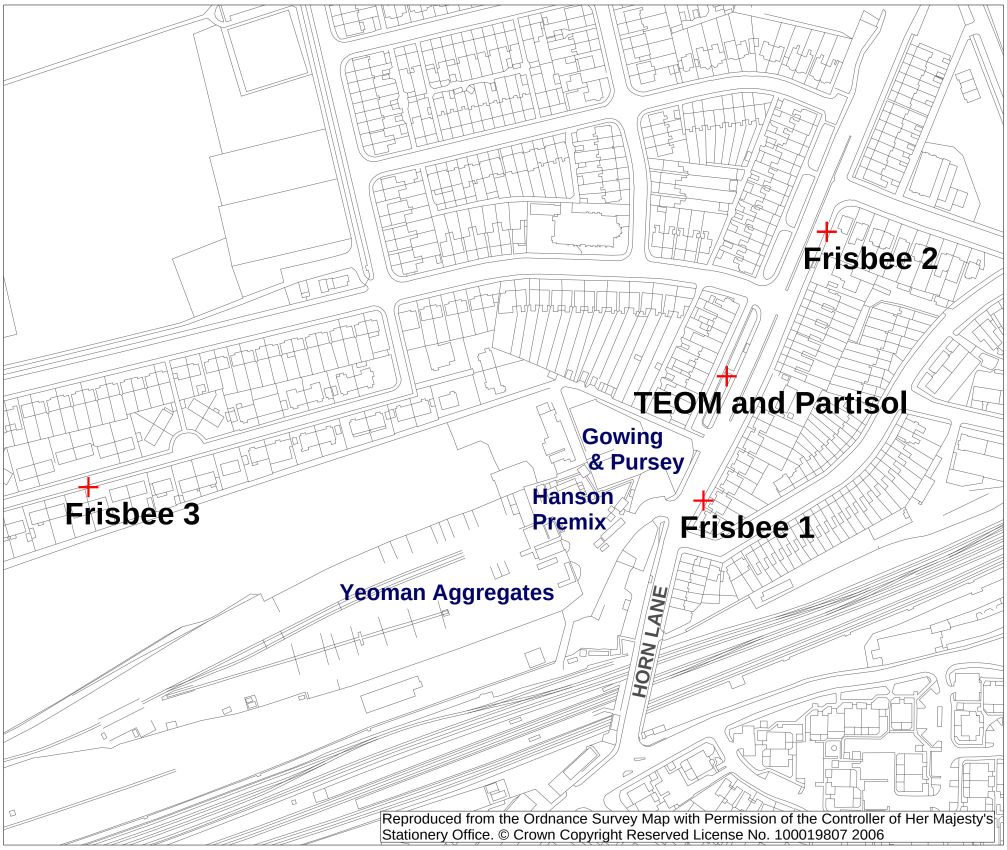
In December 2000, following the first round of Air Quality Review and Assessment, under Part IV of the Environment Act, 1995, the whole Borough was declared an Air Quality Management Area (AQMA) for PM_{10} and nitrogen dioxide (NO_2). Following the 2004 Updating and Screening Assessment[9], it was recommended that a Detailed Assessment be carried out with regard to PM_{10} emissions associated with several industrial and commercial activities adjacent to Horn Lane, Acton. This location had not been highlighted previously, within the framework of the Review and Assessment process, as an area of concern.

The three relevant industrial and commercial premises are:

- A waste transfer station operated by Bridgemarts Ltd (trading as Gowing & Pursey);
- A ready-mixed concrete batching plant operated by Hanson Quarry Products Europe Ltd. (trading as Hanson Premix); and
- A sand and aggregate distribution terminal operated by Yeoman Aggregates Ltd.

The locations of the industrial and commercial premises are shown in Figure 1. The locations of the monitoring sites are also indicated in the Figure.

Figure 1: Map of the Horn Lane Area



The three companies are subject to regulatory control in relation to particulate emissions control measures, as detailed in Table 2.

Table 2: Permit and Licence Details

Company	Regulated activity	Regulation type	Regulator	Permit/licence number
Gowing & Pursey	Waste transfer station	EPA waste management licence	EA	EAWML80060
Hanson Premix	Ready-mixed concrete batching plant	PPC Permit	Ealing Council	P-000009
Yeoman Aggregates	Mobile screening plant	PPC Permit	Ealing Council	P-000050
	Recycling of track ballast	EPA waste management licence	EA	EAWML80617

The Yeoman Aggregates PPC permit and EPA waste management licence relate to activities carried out at the western end of their site. These activities are unlikely to have a significant impact upon particulate concentrations in the Horn Lane area and so have not been considered further in this report.

1.3 Fine Particulate Matter (PM_{10})

The Government and the Devolved Administrations have adopted two Air Quality Objectives for PM_{10} (particles with an aerodynamic diameter of less than 10 µm), which were to be achieved by the end of 2004 [1-3]:

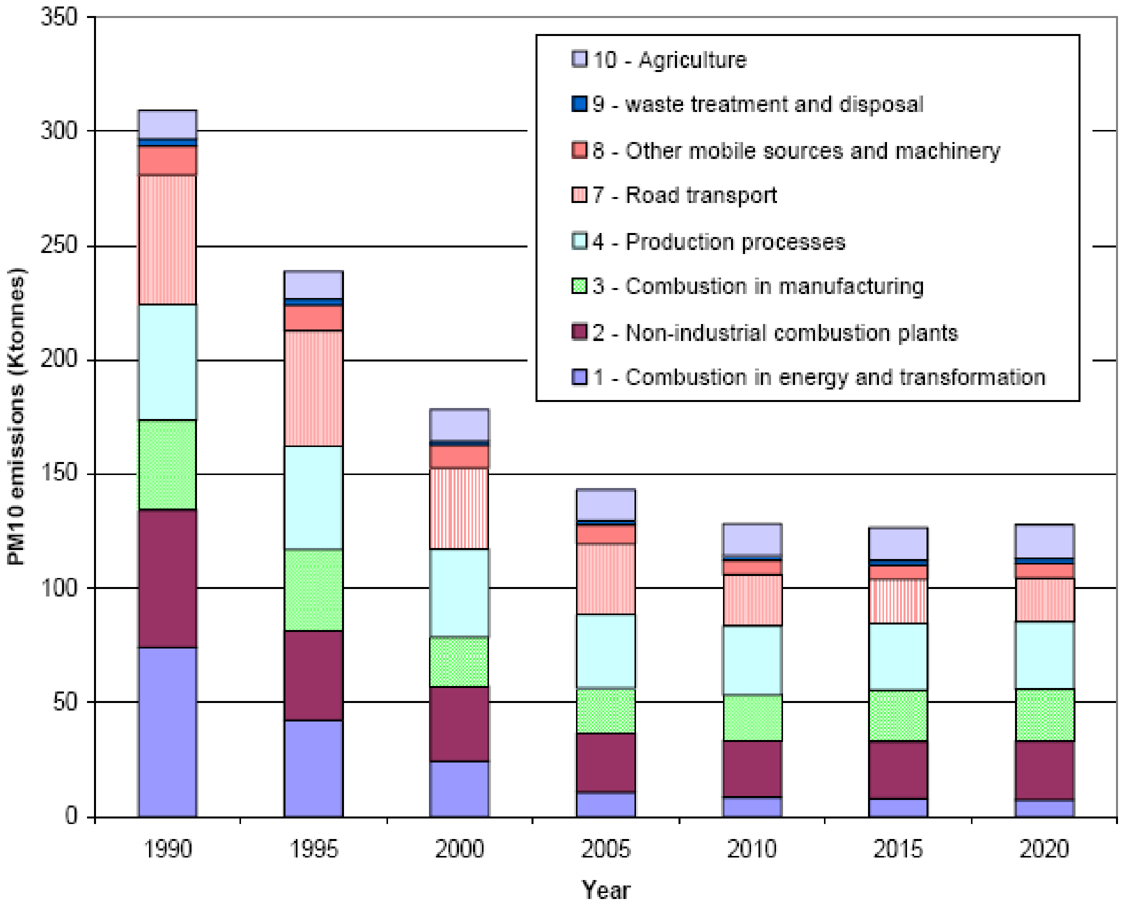
- An annual mean concentration of 40 µg/m^3 (gravimetric); and
- A 24-hour mean concentration of 50 µg/m^3 (gravimetric) to be exceeded no more than 35 times per year.

Further provisional objectives have been proposed for 2010. For London these objectives are a 24-hour mean of 50 µg/m^3, with a maximum of 10 exceedences per year and an annual mean of 23 µg/m^3. These objectives are considerably more stringent than those for 2004, and it is likely that they will not be achieved throughout many areas of London. This is expected to be the case mainly due to typical predicted background concentrations being only slightly lower than the annual mean standard. It should be noted that there is currently no requirement for local authorities to attempt to meet these objectives, due to their provisional status.

Particulate matter is composed of a wide range of materials arising from a variety of sources, and is typically assessed as total suspended particulates or as a size fraction. The European air quality standards have adopted PM_{10} for the assessment of fine particulate matter. The effect of airborne particles on health are largely linked with the worsening of pre-existing conditions in susceptible subgroups of the population, such as those with pre-existing lung, heart or other disease, and/or the elderly and children. Evidence suggests that it is combustion derived components of PM_{10} that are primarily responsible for the harmful effects. However there is generally a lack of information on quantitative relationships between adverse health effects and specific components of PM_{10}. The AQEG report on particulate matter[11] provides a thorough review of the available information on the health impact of particles.

Overall, particulate emissions are predicted to decrease by 28% between 2000 and 2010 [11]. This reduction is due to more stringent legislation and improved emission control technology both for road and industrial sources. Figure 2 shows that total national emissions of PM_{10} have decreased since 1990, but between 2010 and 2020 emissions are not predicted to decrease.

Figure 2: Historic and Projected UK PM_{10} Emissions (kT/yr) (1990 – 2020)



This figure has been reproduced from the Air Quality Expert Group (AQEG) Report on PM_{10} in the UK [11].

1.4 Report Layout

- Section 2 outlines the monitoring methodology that has been followed, and provides details regarding the instrumental techniques that have been employed.
- Section 3 provides a detailed explanation of the dispersion modelling that has been carried out as part of the assessment. The various inputs and parameters that are required by the models are provided and detailed.
- The results from the 12-month monitoring study are presented and analysed in Section 4, and comparison made with the National Air Quality Standards and Objectives.
- The results of the dispersion modelling study are presented and analysed in Section 5, and comparison made with the National Air Quality Standards and Objectives.
- The results of the assessment are discussed in Section 6 and the conclusions and recommendations presented in Section 7.

2 Monitoring Methodology

Monitoring of PM_{10} using TEOM and Partisol analysers commenced on 2 February 2005 at a site adjacent to Horn Lane, in front of domestic residences and shops, just to the northeast of the entrances to the various industrial and commercial premises. Data from a full 12 months have been analysed and included in this report. Frisbee gauge monitoring has been undertaken at three locations for 40 weeks; further details are provided in Section 2.3. Wind data have also been collected; further details are provided in Section 2.4. The monitoring site locations are shown in Figure 1.

2.1 Partisol PM_{10} Sampler

A Partisol Plus Model 2025 Sequential Reference Air Sampler, manufactured by Rupprecht & Patashnick Co., has been used during the study to determine daily gravimetric PM_{10} measurements. The instrument is housed in a walk-in security cage, and is powered via the TEOM enclosure.

The instrument draws ambient air through a size-selective (PM_{10}) inlet, and then through a pre-weighed 47 mm diameter filter. The air-flow is precisely controlled with a mass-flow controller. The filters are exchanged automatically every 24 hours, and the instrument can hold up to 16 pre-weighed filters. The exposed filters are collected and weighed, and the difference between the two weights is equal to the mass of particulate collected during the 24-hour period. The total volume of air that passes through the instrument is measured, allowing the mean 24-hour concentration to be calculated, to allow comparison with the UK national 24-hour PM_{10} standard.

To minimise potential data loss, the instrument is contacted via GSM modem on a daily basis, and its full diagnostics downloaded. This allows any problems to be identified quickly, and any necessary corrective measures to be carried out.

The instrument is serviced at six-monthly intervals, by qualified engineers, and is also audited at six-monthly intervals by the UKAS accredited National Physical Laboratory.

2.2 TEOM PM_{10} Monitor

Continuous PM_{10} monitoring has been carried out using a TEOM (Tapered Element Oscillating Microbalance) Series 1400 AB PM_{10} Monitor manufactured by Rupprecht & Patashnick Co.

The enclosure for the TEOM is an air-conditioned highly durable white stainless steel structure.

Data are downloaded remotely on a daily basis, using a GSM modem, allowing potential problems to be addressed promptly. The data are disseminated directly to the public via the Environmental Research Group website at King's College London.

The instrument draws a precisely controlled flow of ambient air through a size-selective (PM_{10}) inlet, and through a 16 mm diameter filter. The filter is connected to the top of the narrow end of a hollow tapered glass tube. As the particles collect on the filter, the tube's natural frequency of oscillation decreases. The change in this frequency is directly proportional to the added mass, and hence allows continuous measurements to be made. The instrument is microprocessor controlled and the mass concentration values are updated every 13 seconds with average concentrations provided every 15 minutes

The inlet including the sensing system is kept at a steady 50ºC to drive off any sampled water droplets. There is concern regarding the potential loss of volatile material at the stable temperature of 50ºC [12]. As a result, Defra has recommended that the PM_{10} data measured by TEOMs should be multiplied by 1.3 to derive a gravimetric equivalent concentration. However, where there is a collocated gravimetric reference sampler, as is the case in this study, a site specific factor is preferable.

The instrument is serviced at six-monthly intervals by qualified engineers, and is also audited at six-monthly intervals by the UKAS accredited National Physical Laboratory.

2.3 Frisbee Deposition Gauge

Three Frisbee-type depositional dust gauges were attached to lamp posts within the study area at a height of approximately three metres above street level. The site locations are shown in Figure 1. Frisbee gauges are composed of an aluminium plate with upturned edges and a central drain. A dry-foam trap is used to ensure large material, such as leaves, do not enter the sample whilst allowing smaller particulate matter to wash down the drain into a large capacity collecting bottle. Metal spikes and a nylon thread guard are used to prevent birds from landing on the collecting plate.

The collecting bottles were changed every four weeks. Monitoring was undertaken over ten periods between May 2005 and February 2006. The dry-foam trap and the collecting plate were rinsed with water to remove any remaining loose material, which was washed into the collecting bottle and included in the sample.

The samples were analysed by a UKAS accredited laboratory (TES Bretby) by vacuum filtering the material through a pre-weighed 47mm diameter quartz QMA filter to provide total mass and a deposition rate in mg/m^2/day. The samples were also analysed by TES Bretby for the total mass of the elements, barium, calcium, iron and magnesium, using acid digestion followed by Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES). Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) was used to determine the masses of cadmium, chromium, cobalt, lead, manganese, molybdenum, nickel and zinc.

No statutory or official air quality criterion for dust annoyance has been set at a UK, European or World Health Organisation (WHO) level. However, in England and Wales, a ‘custom and practice’ limit of 200 mg/m^2/day is used for measurements with dust deposition gauges. In the absence of any other criteria, this unofficial guideline has been used widely in environmental assessments and is similar to criteria set in other countries[21]:

- In the USA, Washington has set a state standard of 187 mg/m^2/day for residential areas;
- The German TA Luft criteria for ‘possible nuisance’ and ‘very likely nuisance’ are 350 mg/m^2/day and 650 mg/m^2/day, respectively;
- Western Australia also sets a two-stage standard, with ‘loss of amenity first perceived’ at 133 mg/m^2/day and ‘unacceptable reduction in air quality’ at 333 mg/m^2/day;
- Swedish limits promoted by the Stockholm Environment Institute, and used regularly in Scotland, range from 140 mg/m^2/day for rural areas to 260 mg/m^2/day for town centres.

There are no similar deposition guidelines or criteria for the elements for which analysis has been undertaken. Of the elements considered, there is only a national air quality standard for lead (an annual mean concentration of 0.25 μg/m^3 to be achieved by 2008). However, there are EU annual mean target values for arsenic (6 ng/m^3), cadmium (5 ng/m^3) and nickel (20 ng/m^3). These are to be met by the end of 2012. Emissions of the majority of the metallic elements for which analysis has been undertaken are associated with combustion industries and metal production. It is therefore unlikely that elevated concentrations would be expected in the study area. Elevated levels of calcium may be expected due to the handling and use of limestone within the sites. However, there is no specific health concern with regard to calcium.

2.4 Meteorological Instrumentation

As part of the study, an anemometer was positioned within the Yeoman Aggregates site. The instrumentation is compact and robust, relies on solid-state technology, and has no moving parts. Data logging equipment has been located within the site office. 15-minute wind speed and wind direction data has been collected, so as to enable direct analysis with the data collected by the TEOM instrument.

3 Modelling Methodology

3.1 Introduction

Air quality dispersion modelling has been used to predict concentrations of PM_{10} for the base year (2005) and the provisional air quality objective year (2010).

To model the dispersion of emissions from road traffic, the AAQuIRE 6.1.1 regional dispersion model was used. The model was developed by Faber Maunsell and has been used widely for the past 15 years. The model uses the dispersion algorithms CALINE4 (for line sources) and AERMOD (for point, area and volume sources), which have both been independently and extensively validated. A more detailed description of the AAQuIRE dispersion model is included in Appendix C. The following data and information are required by the AAQuIRE model:

- Meteorological data – Section 3.3; and
- Traffic data (AADT flows, HGV proportions, average speeds, emission factors) – Section 3.4.

To model the dispersion and deposition of emissions from fugitive sources associated with the industrial and commercial premises, the Breeze AERMOD modelling package has been used. Areas within which processes occur which give rise to particulate emissions have been modelled as ‘area’ sources; particulate emission rates within these areas have been calculated according to recognised procedures detailed in the US Environmental Protection Agency AP-42 report[14]. The following data and information are required by the Breeze AERMOD model:

- Meteorological data – Section 3.3;
- Traffic data associated with the sites – Section 3.4 and 3.5
- Information regarding dust generating activities – Section 3.5; and
- Particulate emission rates – Section 3.5.

Contributions from pollutant sources not explicitly included in the modelling were amalgamated into the background concentration (see Section 3.6). The output of the AAQuIRE and Breeze AERMOD models were combined, and added to the background contribution to give the total predicted concentration of PM_{10}.

3.2 Study Area

The study area stretches from south of the Horn Lane / Friary Road junction, to just south of the A40/Horn Lane junction. Residential areas to the east and west of Horn Lane have been included within the area. Due to the prevailing wind direction, the orientation of the sites and the access routes to the sites, areas to the south, west, and northwest of the Yeoman Aggregates site boundary have not been included within the study area. The impact of fugitive emissions on these areas is likely to be of minor significance.

All the modelling was performed on a two-dimensional receptor grid, with a grid spacing of 10 metres to ensure that a high level of spatial resolution was obtained, as recommended by the LAQM.TG(03) guidance[6]. The results produced allowed the generation of PM_{10} contour plots.

3.3 Meteorological Data

Wind data measured at Yeoman Aggregates, Horn Lane, Acton were used in this modelling study. The data did not cover a complete 12-month period, and therefore additional wind data were taken from the Heathrow airport meteorological station (2005). Information such as cloud cover data were also required for the modelling study, and were taken from Heathrow. The data consisted of the frequencies of occurrence of wind speed (0-2, 2-4, 4-6, 6-10, 10+ m/s), wind direction (30° resolution) and Pasquill stability classes. Pasquill stability classes categorise the stability of the atmosphere from A (very unstable) through D (neutral) to G (very stable).

The suppression of particles and dust through precipitation is highly important. Local precipitation data have therefore been considered during the modelling of fugitive emissions.

2005 precipitation data from Heathrow airport meteorological station have been used. During 2005 there were 136 days classified, for the purposes of the fugitive modelling study, as 'wet' (days where there was at least 0.254 mm precipitation).

3.4 Traffic Data

The traffic data required for the modelling were provided by London Borough of Ealing. 24-hour automatic traffic counts were taken on Horn Lane during a whole week in February 2004. The counts were taken just to the south of the Leamington Park junction. Average speeds were provided together with a detailed breakdown of vehicle types. Average speeds were reduced to account for acceleration/deceleration near to junctions. Although outside the study area, traffic flows on the A40 were incorporated in the model; automatic traffic count data from 2001 were used. Projected figures for Leamington Park flows in 2005 were obtained from the 2001 Rotating Traffic Census.

Manual traffic turning counts of vehicle movements to and from Gowing and Pursey were conducted over the course of six days during one week in April 2005 (Sunday excluded). Manual traffic turning counts of vehicle movements to and from the Yeoman Aggregates / Hanson Premix entrance were conducted over the course of six days during one week in July 2005 (Sunday excluded). Due to the effect of the London bombings on July 7th, the count had to be repeated for a further two days in September 2005. Detailed information regarding the types of vehicles and the ownership of the vehicles was recorded.

The traffic data used in the modelling are summarised in Tables 3 and 4.

Table 3: Traffic Data Used in the AAQuIRE Model

Road		**Vehicle Flows (AADT)**		**HGV %**		**Average Speeds (kph)**	
		NB	**SB**	**NB**	**SB**	**NB**	**SB**
Horn Lane	North of the site entrances	15,832	9,352	6.2	6.4	45	37
	Between site entrances	15,806	9,323	6.0	6.1	45	37
	South of the site entrances	15,794	9,321	5.9	6.1	45	37
A40	Between Wales Farm Road & Gipsy Corner	54,058	47,490	4.0	4.0	96	96
	At Mansfield Road	55,372	47,438	4.0	4.0	96	96
Leamington Park		13,090		9.9		40	

Notes: Zero growth in traffic flow has been assumed between 2005 and 2010.
Horn Lane flows between and south of the site entrances have been derived from the ATC data with reference to the flows in and out of the industrial and commercial premises (Table 4).

Table 4: Traffic Flows in/out of the Industrial and Commercial Premises

Site entrance	**AADT Flows**					
	Total Vehicles	**Cars and LGVs (up to 3.5t)**	**LGVs (up to 7.5t)**	**HGV (2&3 Axle)**	**HGV (4 Axle)**	**Artics**
Gowing & Pursey	279	3	31	207	26	12
Yeoman / Hanson	550	123	58	121	189	58

Notes: Zero growth in traffic flow has been assumed between 2005 and 2010.
Zero flow has been assumed on Sundays.

Speed related emission factors were derived from the latest factors supplied on the National Atmospheric Emissions Inventory website[15].

Emissions of some pollutants are higher when the engine is cold, yet cars take about 3 minutes or 1.6 km before the engine is 'hot'. This engine warming factor was accounted for by using a variable vehicle composition profile for each road, and for each year [19]. Enhancement of pollutant emissions due to cold starts is given in Table 5. This table summarises vehicle emissions testing, which has demonstrated, for example, that a Light Duty Vehicle (LDV) with a cold catalyst will emit 2 times the quantity of PM_{10} as the same LDV once the catalyst has warmed up.

Table 5: Ratio of Emissions of Cold Engines to Hot Engines

LDV Category	**PM_{10}**
Non catalyst petrol	1.0
Catalyst petrol	2.0
Diesel	1.0

3.5 Fugitive Dust Sources

3.5.1 Overview

This assessment was commissioned due to concern regarding the effects of emissions of fugitive dust. There is a history of complaints from local residents regarding nuisance dust in the area. Emissions associated with the following premises have been incorporated in the model:

- A waste transfer station operated by Bridgemarts Ltd (trading as Gowing & Pursey);
- A ready-mixed concrete batching plant operated by Hanson Quarry Products Europe Ltd. (trading as Hanson Premix); and
- A sand and aggregate distribution terminal operated by Yeoman Aggregates Ltd.

The locations of the industrial and commercial premises are shown in Figure 1.

3.5.2 Generation of Emission Factors

Particulate emission rates have been calculated according to recognised procedures detailed in the US Environmental Protection Agency AP-42 report[14]. Various procedures are provided in AP-42 to calculate fugitive dust emission rates. For the purposes of this study a different procedure has been used for sources arising from paved roads, unpaved roads, wind erosion of storage piles, and handling activities associated with storage piles. All of the factors calculated are particular to PM_{10} emissions.

A total of 51 area sources have been modelled; an emission factor has been calculated for each area. Tables of emission factors, together with the information required to calculate them, and maps showing the location and size of each area, are provided in Appendix C.

3.5.2.1 Paved Roads

Particulate emissions occur when vehicles travel over a paved surface due to the re-suspension of road surface material. The emissions have been found to depend on the average weight of the vehicles using the road, and the amount of silt present on the road. The following equation has been used to determine the particle emission factor:

$$E = k\left(\frac{sL}{2}\right)^{0.65} \times \left(\frac{W}{3}\right)^{1.5} - C$$

where: E = PM_{10} emission factor (having units matching the units of k);
k = particle size multiplier for PM_{10} (4.6 g/VKT) (VKT=vehicle kilometre travelled);
sL = road surface silt loading (g/m^2);
W = average weight of the vehicles travelling the road; and
C = emission factor for vehicle fleet exhaust, brake wear and tyre wear (0.1317 g/VKT).

A precipitation correction term has been applied to the equation as recommended in AP-42, based on the number of 'wet' days (refer to Section 3.3):

$$E_{Precipitation\ Correction} = E \times (1\text{-}(P/4N))$$

where: P = number of wet days with at least 0.254 mm of precipitation during the year; and
N = number of days in the year.

Road surface silt loading has been estimated on Horn Lane; at the site entrances a value of 3.5 g/m^2 has been assumed; this has been assumed to decrease steadily with distance down to zero at the junction with the A40 (Gipsy Corner). Higher silt loading values on paved roads within the sites, of up to 5 g/m^2 have been assumed.

Average vehicle weights on Horn Lane (1.3 tonnes) have been calculated based on the traffic data (Section 3.4) and typical weights for different categories of vehicle. Average vehicle weights within the sites have been estimated based on the manual traffic turning counts

(Section 3.4), and after consultation with the Yeoman Aggregates and Hanson Premix site managers. Average vehicle weights within the sites of between 5-20 tonnes have been assumed depending upon the exact location.

3.5.2.2 Unpaved Roads

The equation recommended to determine emissions on unpaved roads is similar to that for paved roads. Rather than being dependent on silt loading, emissions have been shown to be dependent on the percentage silt content of surface material:

$$E = k(s/12)^{0.9}(W/3)^{0.45}$$

where: E = PM_{10} emission factor (having units matching the units of k);
k = particle size multiplier for PM_{10} (423 g/VKT);
s = surface material silt content (%); and
W = average weight of the vehicles travelling the road.

As for paved roads, a precipitation correction term has been applied to the equation as recommended in AP-42, based on the number of 'wet' days (refer to Section 3.3). In addition, the mitigation measure of controlled watering, employed by each site, has been allowed for by enhancing the number of 'wet' days.

The surface material silt content of the various modelled unpaved areas has been estimated based on typical values determined at similar industrial sites[14]. Values used in the model range from 6-8%. As for paved roads, average vehicle weights have been estimated based on the manual traffic turning counts (Section 3.4), and after consultation with the Yeoman Aggregates and Hanson Premix site managers.

3.5.2.3 Wind Erosion of Storage Piles

Dust emissions may be generated by wind erosion of open aggregate storage piles and exposed areas within the industrial premises. Studies have found the erosion potential to increase rapidly with increasing wind speed, and therefore emissions are estimated based on wind gusts of the highest magnitude (this is represented by the 'fastest mile' of wind). Emissions are also dependent on the frequency of disturbance of the erodible surface; each time a surface is disturbed its erosion potential is restored. A disturbance can be taken to occur every time material is added to or removed from a storage pile. The emission factor can be calculated using the following equation:

$$\text{Emission factor} = k \sum_{i=1}^{N} P_i$$

where: k = particle size multiplier for PM_{10} (0.5);
N = number of disturbances per year; and
P_i = erosion potential corresponding to the observed fastest mile of wind for the i^{th} period between disturbances (g/m^2)

$$P = 58(u^*-u_t^*)^2 + 25(u^*-u_t^*)$$
$$P = 0 \text{ for } u^* \le u_t^*$$

where: u^* = friction velocity (m/s); and
u_t^* = threshold friction velocity (m/s)

Wind data collected within the Yeoman Aggregates site have been used in the calculations (refer to Section 3.3). It has been assumed that the Yeoman Aggregates storage piles are disturbed once per day. However, whilst most of the piles are actually disturbed on numerous occasions throughout the day, wind erosion is minimised due to the barriers around the piles. For each pile a threshold friction velocity of 0.6 m/s has been assumed.

3.5.2.4 Aggregate Handling and Storage Piles

In addition to the emissions through wind erosion, detailed above, emissions are also associated with the adding and removal of material to or from a storage pile. At the Yeoman Aggregates site, washed material is added to the piles using a continuous drop conveyor system, and also via truck dumping. Material is removed from the piles using trucks with front-end loaders. The quantity of particulate emissions generated by either type of operation (batch or continuous), per weight of material transferred, may be estimated using:

$$E = k(0.0016)\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

where: *E* = Emission Factor (kg per tonne material transferred)
k = particle size multiplier for PM_{10} (0.35);
U = mean wind speed (2.1 m/s); and
M = material moisture content (%).

Wind data collected within the Yeoman Aggregates site have been used in the calculations (refer to Section 3.3). The material moisture content has been estimated based on typical values given in AP-42[14]. Where the material has been washed prior to loading to the pile, the moisture content has been increased.

3.6 Background Concentrations

A large number of small sources of air pollutants exist which individually may not be significant, but collectively are significant, and need to be considered. These sources are accounted for by including a background concentration contribution. For this study the background values used were derived from measurements taken in 2005 at the nearest representative urban background monitoring location (HF2, Hammersmith & Fulham 2 – Brook Green). The 2010 value in Table 6 was calculated from the 2005 value according to the procedure recommended by Defra (using factors revised in 2006)[7].

Table 6: Background PM_{10} Concentrations used in the Modelling (µg/m^3)

Existing Year 2005	Objective Year 2010
24.5	22.8

3.7 Model Error and Verification

The results from the modelling study will be subject to error due to uncertainties in modelling dispersion algorithms and the input data. Therefore, it is imperative that the performance of any modelling study is verified by comparison with local monitoring data. The modelling results have been verified by comparison with data from the Horn Lane site.

3.8 Source Apportionment

A source apportionment study has been carried out to determine the relative contributions of the main emission source categories to the PM_{10} concentrations predicted on Horn Lane. This has allowed the decrease in PM_{10} that is required to meet the annual mean and daily objectives to be determined.

4 Monitoring Results

4.1 Partisol and TEOM PM_{10} Results

4.1.1 Overview

The Partisol and TEOM PM_{10} results for the 12-month study are summarised in Table 7.

Table 7: Partisol and TEOM Results Summary

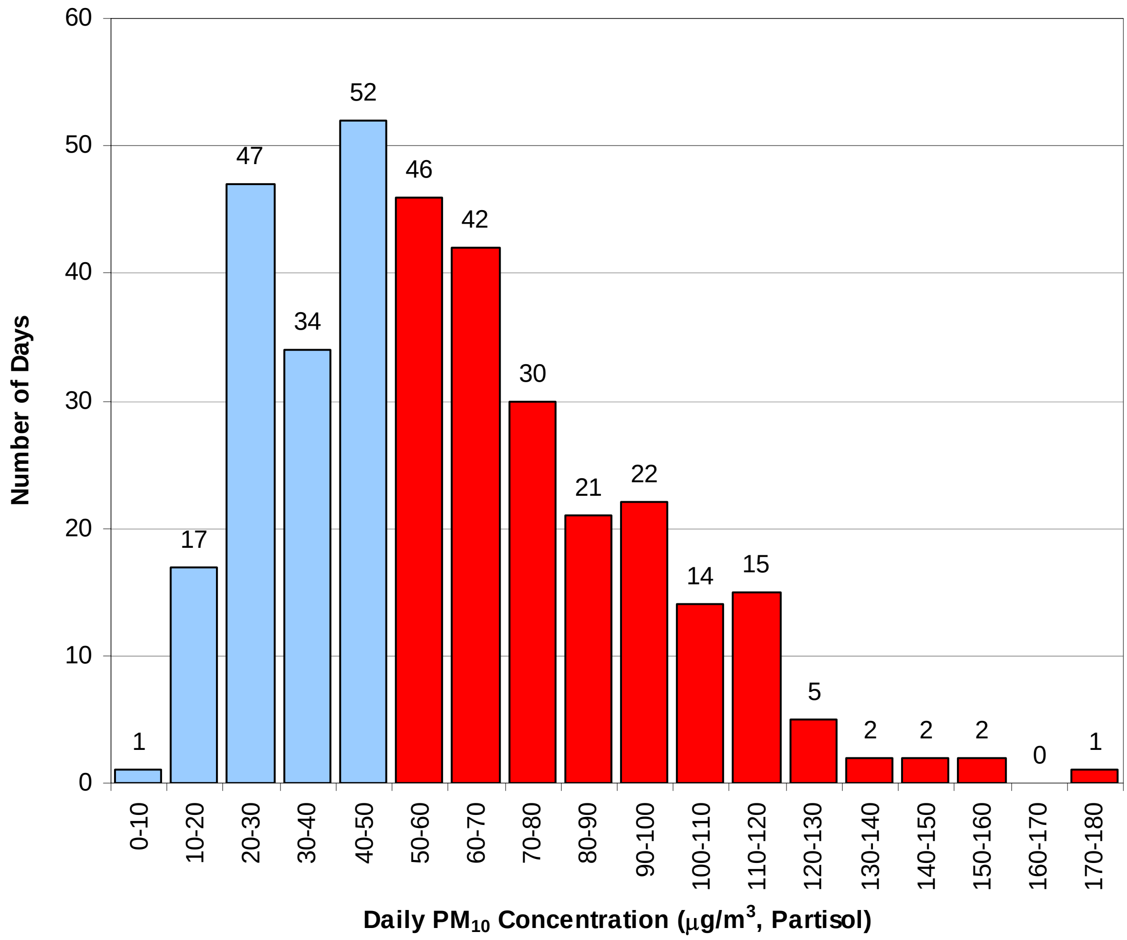
Instrument	12-month Mean (μg/m^3)	Number of daily exceedences	Data Capture
Partisol	60.1	202	97%
TEOM	61.6	201	100%

Note: The TEOM results have not been gravimetrically adjusted.

Over the course of the 12-month period the two techniques were shown to agree very closely; the TEOM mean was slightly higher than the Partisol mean, but the Partisol recorded one more exceedence day. Due to this close agreement, it is inappropriate to apply a gravimetric correction factor to the TEOM results (refer to Section 2.2). Section 4.1.6 compares the results from the two techniques further. Data capture was very high for both instruments.

It is clear that the mean concentrations recorded at the monitoring site are considerably higher than the UK 2004 annual mean objective (40 μg/m^3), and the provisional London 2010 annual mean objective (23 μg/m^3). More than 5 times as many exceedence days than those permitted (35) were recorded.

Figure 3: Frequency of Occurrence of Daily PM_{10} Concentrations (Partisol)



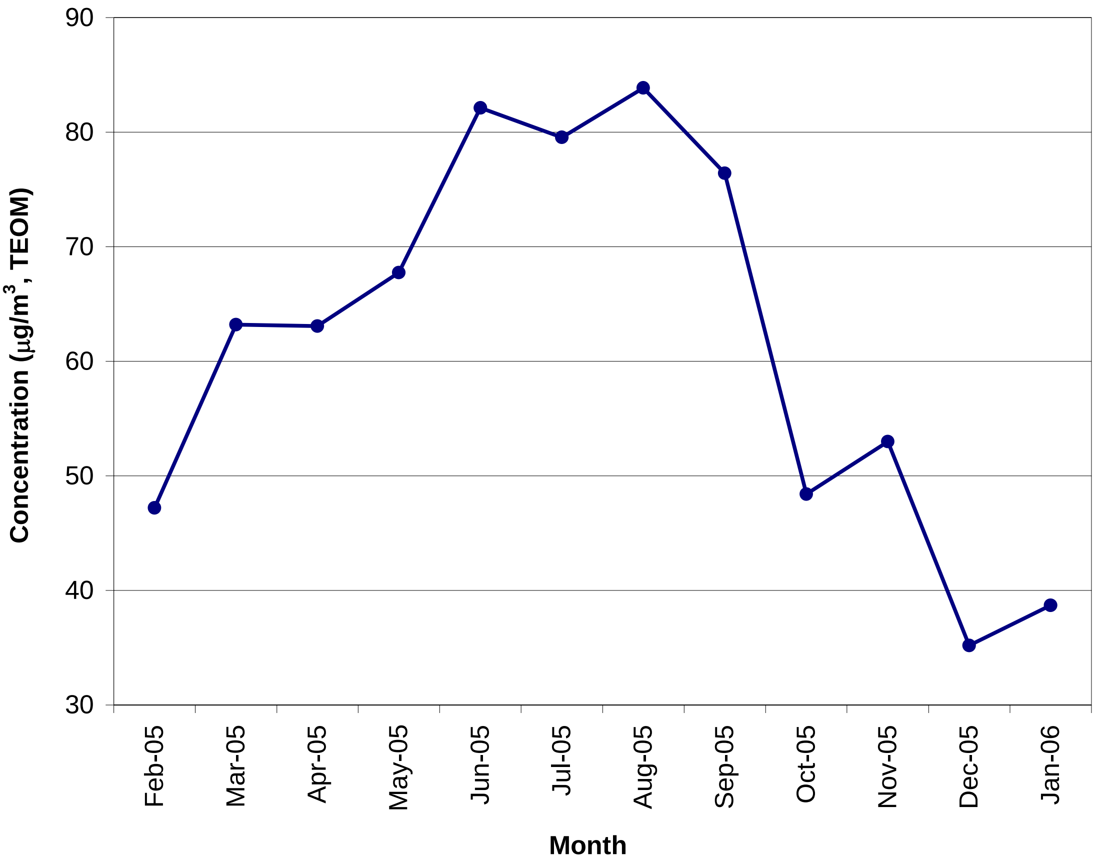
The chart in Figure 3 displays the frequency of occurrence of daily PM_{10} concentrations as measured by the Partisol. Concentrations have been grouped into 10 μg/m^3 bands. The exceedence days are coloured red.

Future year projections of PM_{10} concentrations have not been made due to the uncertainty in future emissions. Whilst background PM_{10} concentrations and emissions from road traffic are expected to fall in future years, these would be small in comparison to the local particulate sources.

4.1.2 *Seasonal Variation*

Figure 4 displays the averaged 15-minute TEOM results for each month of the study. As can be seen average monthly concentrations above 75 μg/m^3 were recorded between June and September, the summer months, and average concentrations below 55 μg/m^3 were recorded between October and February, the winter months. The TEOM recorded an annual mean of 61.6 μg/m^3.

Figure 4: Monthly averaged 15-minute PM_{10} Data (TEOM)



4.1.3 *Weekly and Diurnal Variation*

Figure 5 demonstrates how PM_{10} concentrations vary during the course of a day. 15-minute TEOM data from the whole 12-month period has been used to generate the plots. Three curves are shown: the first includes all data, the second only includes weekday data, and the third only includes weekend data.

During a typical working day concentrations rise sharply between 7-8 am and continue to rise until approximately midday. Concentrations then remain fairly steady for about two hours but then rise again to reach a peak of approximately 150-160 μg/m^3 between 2-5 pm. Concentrations drop sharply between 5-7 pm and then gradually fall throughout the night to a minimum of approximately 20 μg/m^3.

During weekends concentrations rise steadily between 7-9 am, and gradually reach a peak of approximately 70 μg/m^3 at about midday. After midday concentrations fall fairly steadily for a few hours, and then more gradually throughout the rest of the day and night. The relatively high concentrations during the morning are most likely attributable to the shortened opening hours at the industrial premises on Saturdays.

Figure 5: Weekly and Diurnal Variation in PM_{10} Concentrations

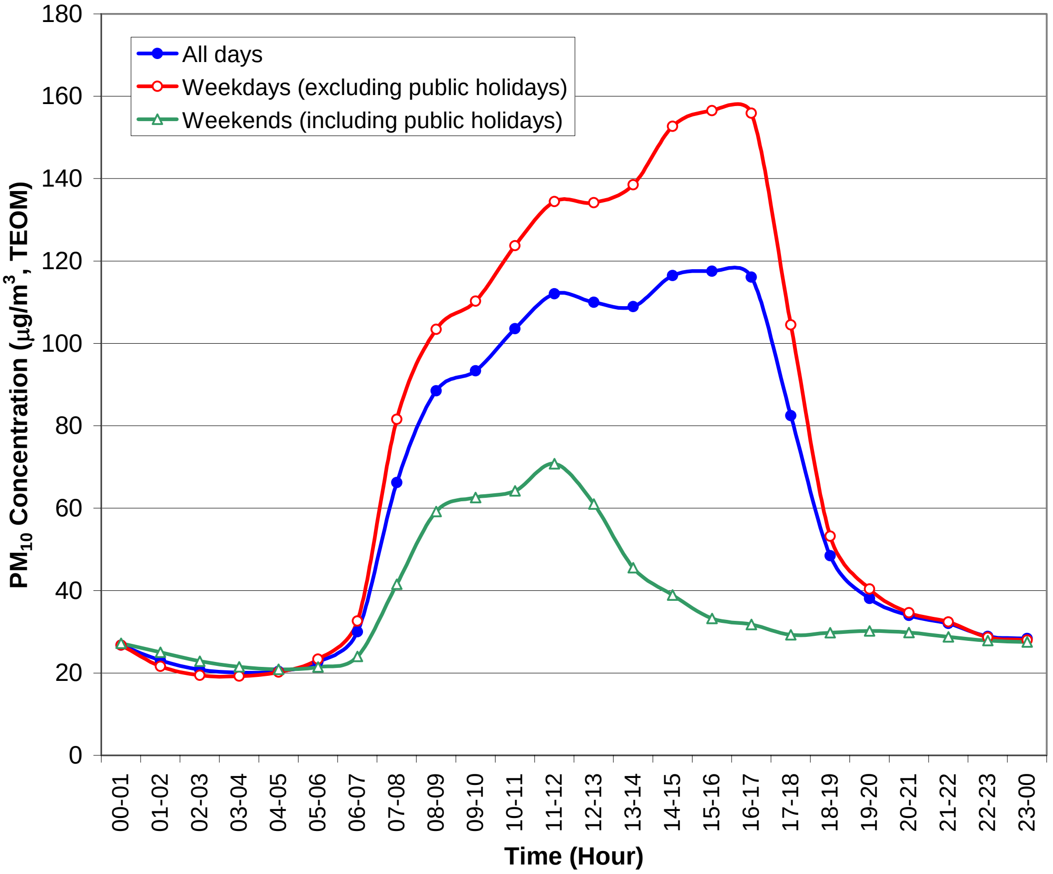


Figure 6: Diurnal Weekday PM_{10} compared with Diurnal Weekday Traffic Flows

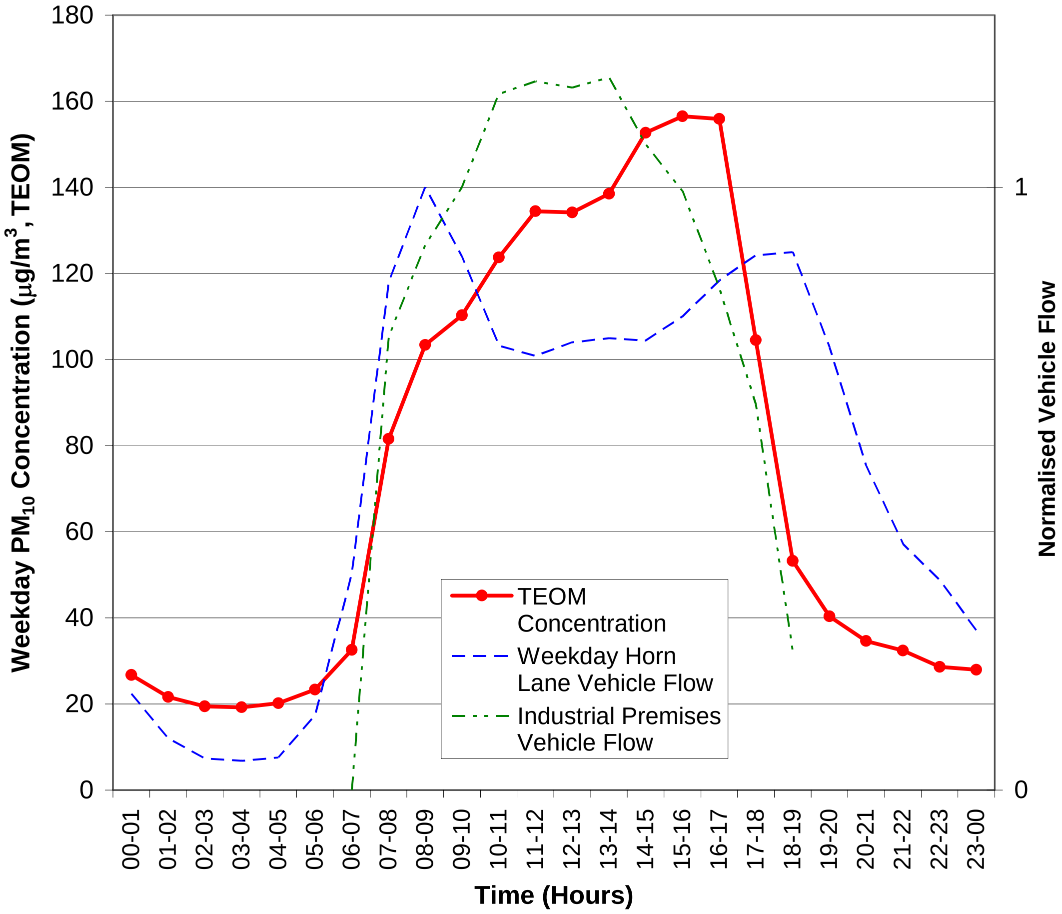


Figure 6 illustrates the weekday diurnal relationship between PM_{10} concentrations and traffic flows along Horn Lane, and traffic flows to/from the industrial premises. The Horn Lane traffic data have been derived from 24 hour automatic counts taken during one week in February 2005. The traffic flows in and out of the industrial premises are based on manual counts (between 6:30 am and 6:30 pm) taken during two weeks in April and July 2005.

Concentrations rise sharply at approximately the same time as the Horn Lane traffic flow increases, but do not reach a peak during the morning rush-hour. Concentrations drop sharply approximately two hours before the Horn Lane traffic flow drops after the evening rush-hour. It can therefore be deduced that the observed diurnal PM_{10} variation cannot be directly attributed to traffic flows on Horn Lane.

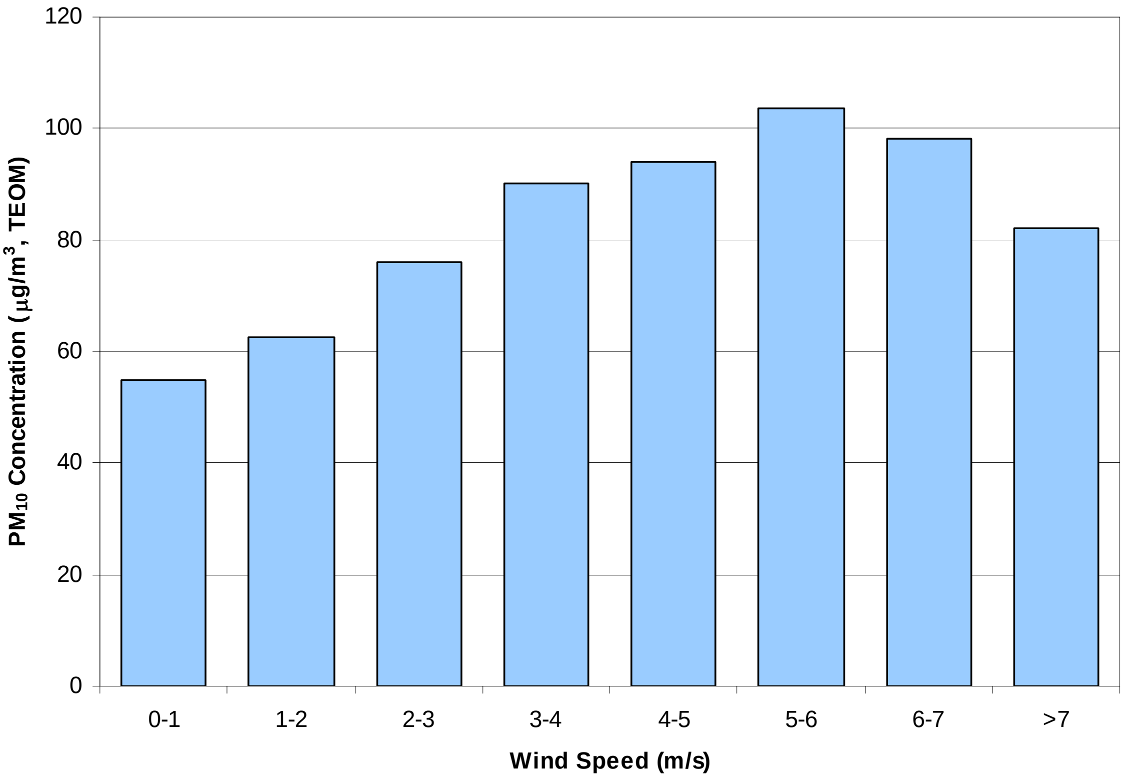
There would appear to be a stronger correlation between PM_{10} concentration and Horn Lane traffic associated with the industrial premises, than with general Horn Lane traffic. Most notably, concentrations drop in the late afternoon at approximately the same time as traffic flow to/from the industrial premises drops.

4.1.4 *Comparison with Wind Data*

Wind direction and speed data were collected from a site alongside the Yeoman Aggregates offices, between 26 February 2005 and 2 February 2006. Figure 7 illustrates the relationship between PM_{10} concentration and wind speed during this period. The chart was generated using 15-minute TEOM data and 15-minute met data.

As can be seen, PM_{10} concentrations were observed to increase with wind speed, until a speed of 5-6 m/s. As wind speed increases, particulate matter of greater size and weight can become airborne. However, stronger winds are often associated with rainfall, which removes particulate matter from the air; this is the likely reason why PM_{10} concentrations were observed to drop above 6 m/s.

Figure 7: Relationship between PM_{10} Concentration and Wind Speed



The windrose in Figure 8 indicates that the area is predominantly subjected to westerly and south-westerly winds. Figure 9 shows that the measured PM_{10} concentrations were greatest when the wind was from the west. Westerly winds are associated with cyclonic weather systems, which tend to result in stronger winds; conversely anti-cyclonic weather systems are often associated with weak easterly winds. Therefore, this can partially explain the higher concentrations observed with westerly winds. In addition, westerly winds would carry particulate matter from the industrial sites towards the monitoring station.

Figure 8: Windrose: Percentage Occurrence for each Wind Sector

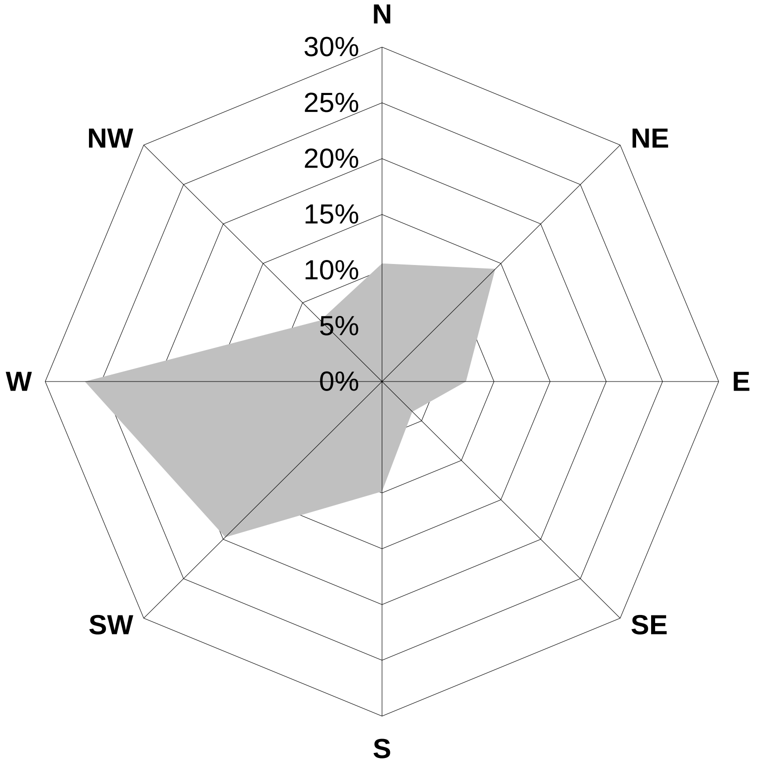
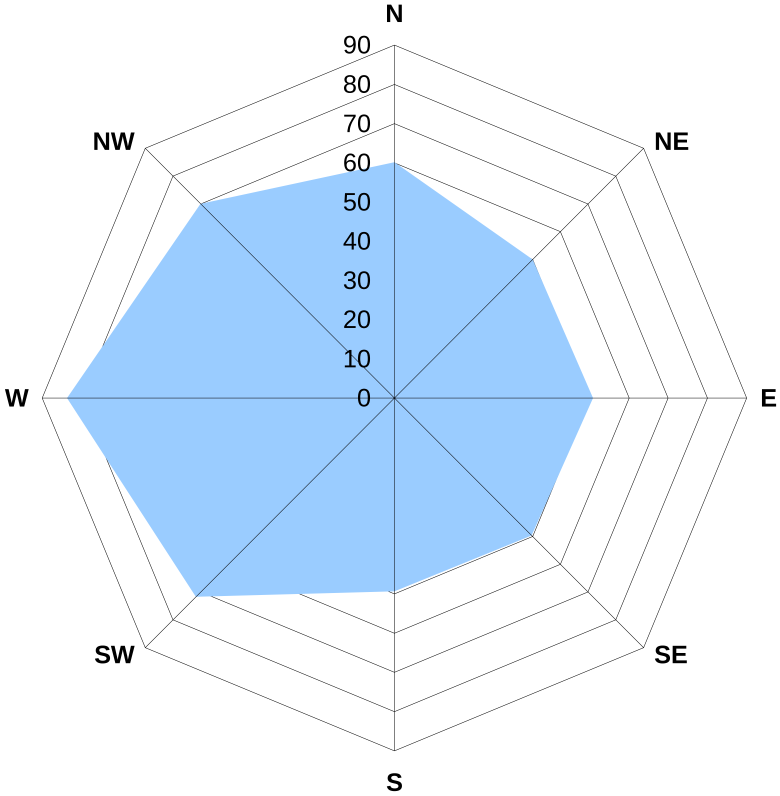


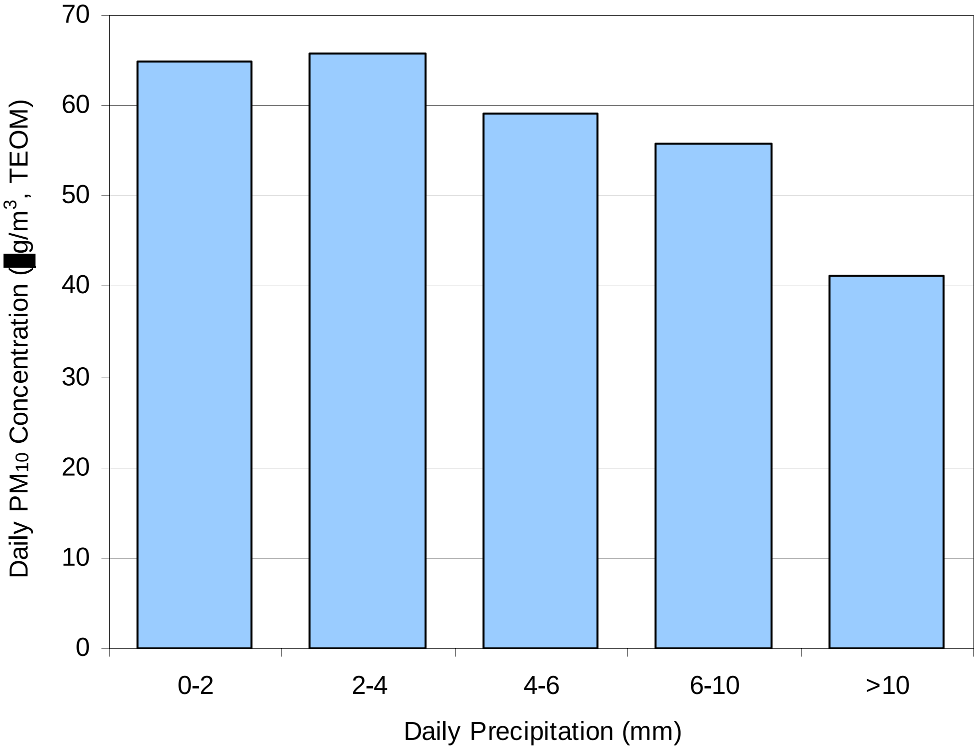
Figure 9: PM_{10} Windrose: Mean Concentration (TEOM $\mu g/m^3$) for each Wind Sector



4.1.5 *Comparison with Precipitation Data*

Precipitation measurements were not recorded at the Horn Lane site. However, daily 2005 precipitation data from the Meteorological station at Heathrow airport have been compared with PM_{10} measurements at Horn Lane, as shown in Figure 10. The greatest daily PM_{10} concentrations occurred on days with less than 4 mm of precipitation. PM_{10} concentrations then dropped with increasing precipitation. These observations are as would be expected; rainfall removes particulates from the air and makes it less likely to be resuspended, and hence reduces PM_{10} concentrations.

Figure 10: Relationship between Mean Daily PM_{10} Concentration and Daily Precipitation



4.1.6 *Detailed Comparison of the Partisol and TEOM Techniques*

As discussed at the start of this section, over the course of the 12-month monitoring period, the mean TEOM and Partisol results agreed closely. Therefore, it would be inappropriate to apply a gravimetric correction factor to the TEOM results. This close agreement can be readily rationalised by considering that the volatile particulate component is likely to be very small given the nature of the local industrial sources, and therefore the impact of the TEOM's heated inlet is likely to be minimal at this location.

However, when the daily data are examined it is clear that the relationship between the instruments does vary seasonally, and from day-to-day. Figure 11 illustrates the relationship between the instruments at the monitoring site, by taking the ratio of the daily Partisol and TEOM results.

During the warmer months (May-August) the TEOM typically recorded higher concentrations, whereas during the cooler months (November-March) the Partisol typically recorded higher concentrations (during the cooler months the relationship was also generally more erratic). These findings are broadly in line with recent nationwide studies[11,20].

Monthly correction factors have been calculated based on the data collected, as shown in Table 8. Whilst they are likely to change from year to year depending upon meteorological conditions, they could be used with caution to adjust future TEOM data at this site, in the absence of future Partisol data.

Figure 11: Daily Relationship between the Partisol and TEOM Results

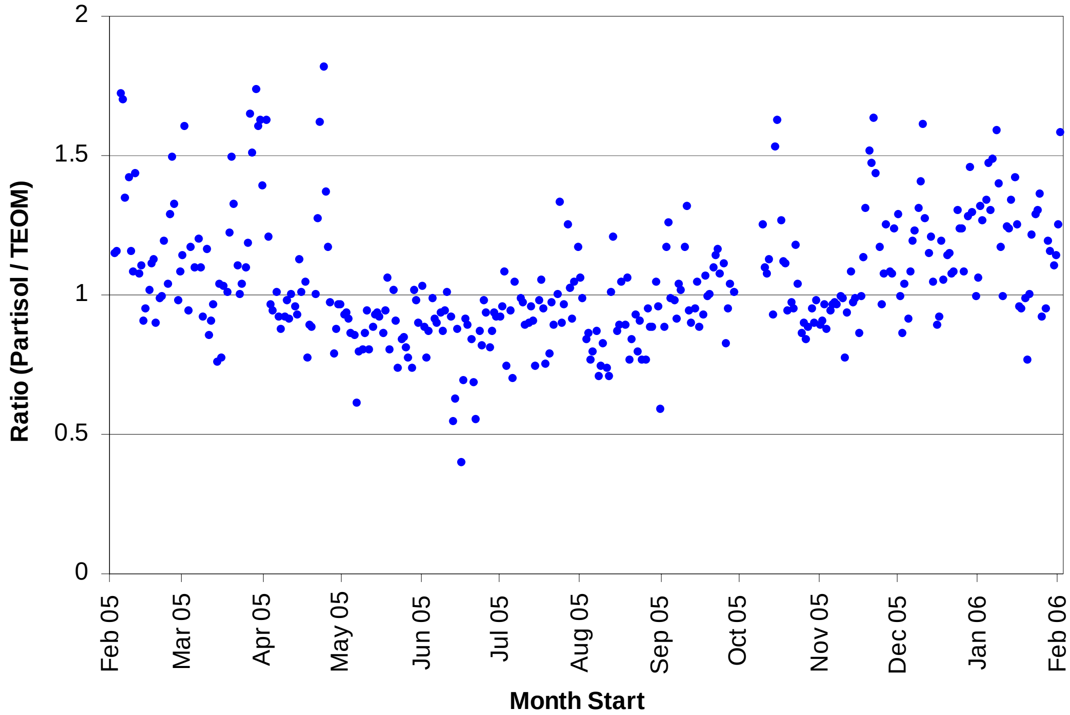


Table 8: Monthly TEOM Gravimetric Correction Factors

Month	Factor	Month	Factor
January	1.2	July	0.9
February	1.2	August	0.8
March	1.1	September	1.0
April	1.0	October	0.9
May	0.9	November	1.1
June	0.8	December	1.1

4.2 Frisbee Deposition Gauge

4.2.1 Overview

Frisbee dust deposition gauges were used to sample air quality for ten four-week periods. Two gauges were in place (Sites 1&2) for the first period, and a third gauge was put in place (Site 3) for the following nine periods. Data capture during the study was good.

Table 9 shows the average daily deposition rates at each of the sampling sites. Site 2 is directly opposite the entrances to the industrial premises, and as would be expected recorded the highest deposition rates. Site 3 is located to the north of the Yeoman Aggregates site on a quiet residential road, and as expected recorded the lowest deposition rates. The average deposition rate at all of the sites was higher than the 'custom and practice' limit of 200 mg/m^2/day.

Table 9: Average Total Deposition Rates

Site	Average Deposition Rate (mg/m^2/day)
Site 1 - Horn Lane (N)	676
Site 2 - Horn Lane (opposite industrial sites)	944
Site 3 - Lowfield Road	372

Table 10 shows the average daily deposition rate for each element during the whole sampling period. Iron and calcium were the most abundant elements at all sites. Figure 12 examines the percentage contribution of each element during the whole study period, and compares the three sites. Site 2 is closest to the industrial sites, and due to the high calcium content of the materials at the Yeoman Aggregates and Hanson Premix sites, calcium is the greatest contributor (56%). Particulate emissions from Gowing & Pursey are likely to be composed of a wider variety of materials, but there is still likely to be a high proportion of calcium due to the tipping and handling of domestic building waste. Further from the sites, the calcium contribution reduces.

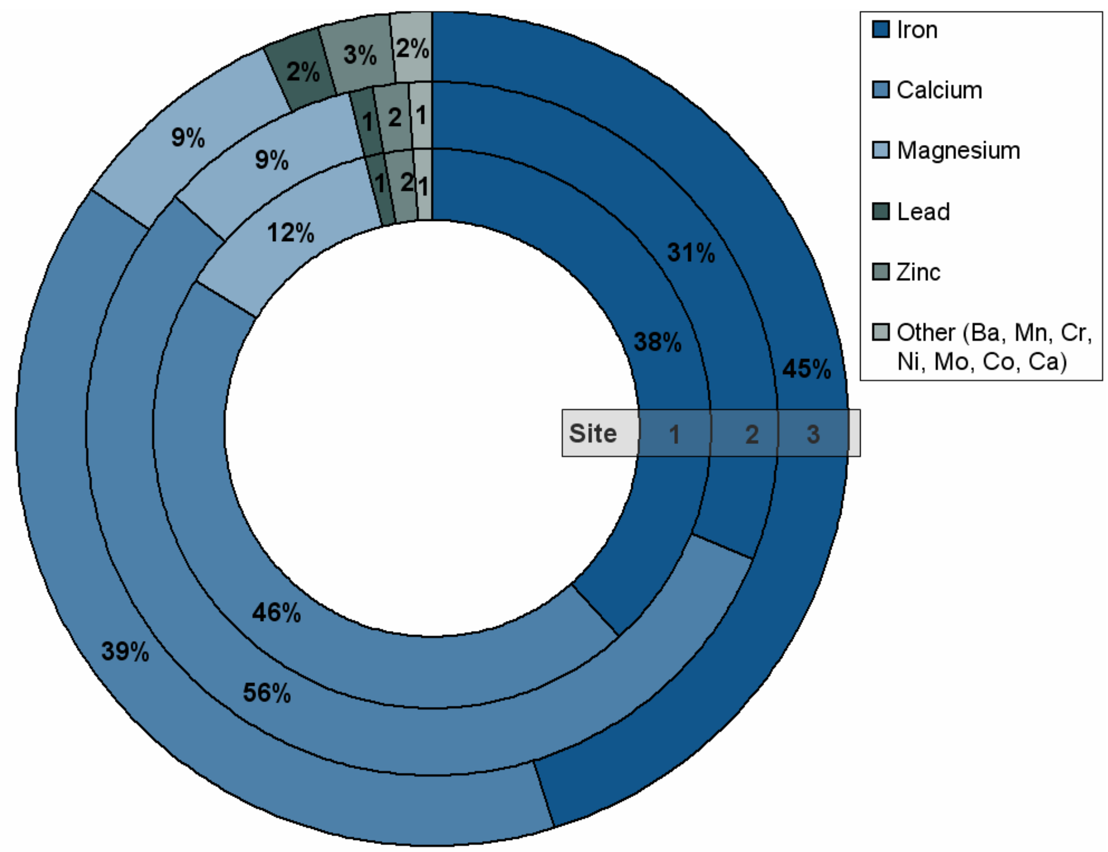
Table 10: Average Elemental Deposition Rates

Site	Iron	Calcium	Magnesium	Lead	Zinc	Barium	Manganese	Chromium	Nickel	Molybdenum	Cobalt	Cadmium
	mg/m²/day					µg/m²/day						
1	4.08	4.87	1.32	0.11	0.17	61.9	47.5	9.5	3.69	1.65	0.90	0.15
2	5.93	10.63	1.78	0.23	0.33	90.9	82.1	13.1	3.69	2.93	0.90	0.40
3	0.94	0.81	0.18	0.04	0.06	15.4	10.4	3.2	1.80	0.90	-	0.09

As discussed in Section 2.3, there are no deposition rate guidelines or criteria for the elements for which analysis has been undertaken. Of the elements considered, there is only a national air quality standard for lead (an annual mean concentration of 0.25 µg/m^3 to be achieved by 2008). However, there are EU annual mean target values for arsenic (6 ng/m^3), cadmium (5 ng/m^3) and nickel (20 ng/m^3). These are to be met by the end of 2012. Whilst these concentration values cannot be directly compared with the daily deposition rates, emissions of the majority of the metallic elements for which analysis has been undertaken are associated with combustion industries and metal production. It is therefore unlikely that elevated concentrations would be expected in the study area.

A recent review of heavy metal monitoring in the UK[22] revealed that there were no exceedences of either the arsenic or cadmium target values at any site in 2003. The target level for nickel was exceeded at one site (Pontardawe). The three metals are monitored at over 50 sites throughout the UK.

Figure 12: Percentage Elemental Contribution



4.2.2 *Period Analysis*

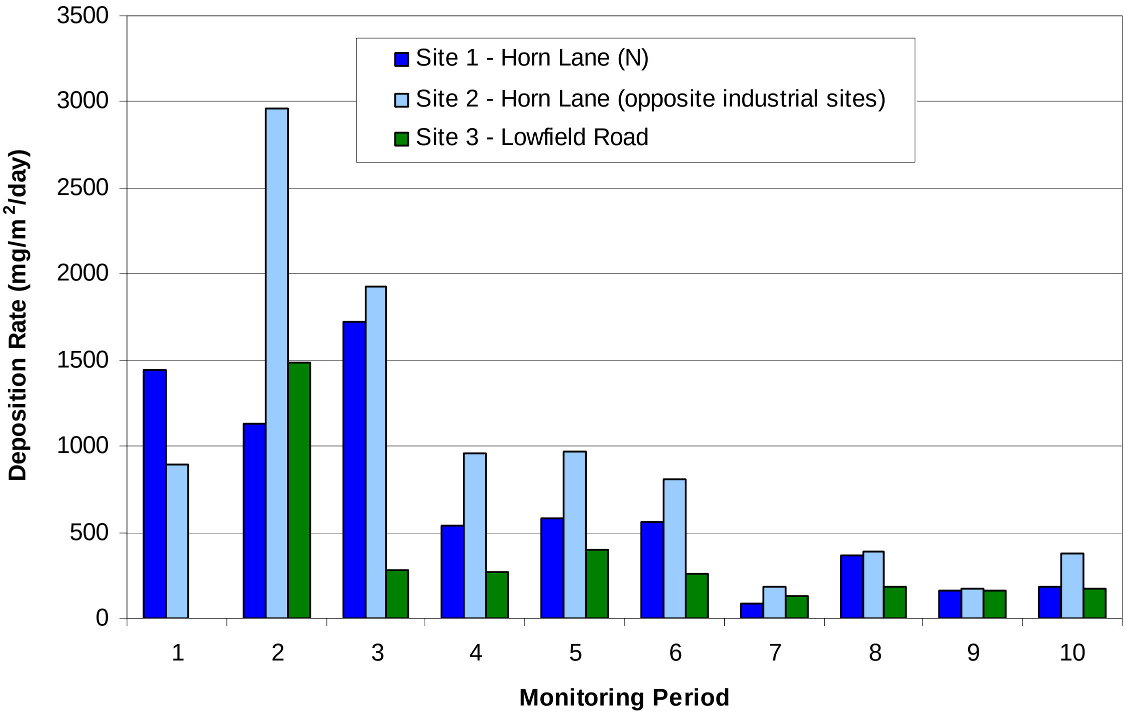
Table 11 details the start date of each period; the periods ran consecutively.

Table 11: Frisbee Deposit Gauge Sampling Periods

Period	Start Date	Period	Start Date
1	28/04/2005	6	16/09/2005
2	26/05/2005	7	14/10/2005
3	23/06/2005	8	11/11/2005
4	21/07/2005	9	08/12/2005
5	19/08/2005	10	05/01/2006

Figure 13 illustrates how deposition rates between each four-week period varied at each site. Deposition rates fell during the course of the study; rates were highest during the warmer, drier summer months and lowest during the cooler, wetter autumn and winter months. In Section 6.1 it is proposed that in addition to meteorological factors, improved on-site practices may have contributed to the lower deposition rates after September/October. Based on the available data and information it is not possible to state to what extent improved on-site practices were responsible for the lower deposition rates.

Figure 13: Total Deposition Rates



5 Modelling Results

5.1 Data Verification

As discussed in Section 3.7, when undertaking a dispersion modelling study, it is essential to make a comparison between the modelled results and the monitoring data, to ensure that the model is reproducing actual observations.

Modelling results are subject to systematic and random error; systematic error arises due to many factors, such as uncertainty in the traffic data and the composition of the vehicle fleet, and uncertainty in the meteorological dataset. This can be addressed and, if necessary, adjusted for by comparison with monitoring data. Table 12 compares the modelling and monitoring results for 2005.

Table 12: Model Verification

Annual Mean PM_{10} / µg/m^3			Difference compared with:	
Modelled	**Monitored - TEOM**	**Monitored - Partisol**	**TEOM**	**Partisol**
70.4	61.6	60.1	+12%	+15%

Note: The 12-month monitoring study covered the period 3 February 2005 – 2 February 2006

The model shows good agreement with the monitoring results, but does over-predict by 15% when compared with the Partisol result. Due to this discrepancy, the modelled results were adjusted by comparison with the Partisol result. The steps in the adjustment procedure are described below:

$PM_{10\ [monitored,\ traffic\ \&\ fugitive\ contribution]} = PM_{10\ [monitored]} - PM_{10\ [background]}$
$PM_{10\ [modelled,\ traffic\ \&\ fugitive\ contribution]} = PM_{10\ [modelled]} - PM_{10\ [background]}$

$\text{Adjustment Factor} = PM_{10\ [monitored,\ traffic\ \&\ fugitive\ contribution]} / PM_{10\ [modelled,\ traffic\ \&\ fugitive\ contribution]}$

$PM_{10\ [model\ adjusted,\ traffic\ \&\ fugitive\ contribution]} = PM_{10\ [modelled,\ traffic\ \&\ fugitive\ contribution]} \times \text{Adjustment Factor}$
$PM_{10\ [model\ adjusted]} = PM_{10\ [model\ adjusted,\ traffic\ \&\ fugitive\ contribution]} + PM_{10\ [background]}$

Therefore, the modelled PM_{10} traffic and fugitive contribution data were multiplied by the adjustment factor (0.78), and the background PM_{10} added to give the adjusted PM_{10} concentrations ($PM_{10\ [model\ adjusted]}$).

5.2 Results

This assessment considers the annual mean and 24-hour air quality standards, as specified in the Air Quality (England) Regulations 2000[3]. The PM_{10} standards which were to be achieved by the end of 2004 are an annual mean of 40 µg/m^3 (gravimetric), and a 24-hour mean concentration of 50 µg/m^3 (gravimetric) to be exceeded no more than 35 times per year.

Reference is also made to the 2010 provisional objectives (an annual mean of 23 µg/m^3 and a 24-hour mean of 50 µg/m^3, with a maximum of 10 exceedences per year).

Pollutant contour maps, generated from the output of the modelling study, are presented in Appendix A.

Pollutant concentrations for the future year (2010) are predicted to be slightly lower than those for the base year (2005). These decreases are due to reductions in the background concentrations and greater vehicle emission controls.

5.2.1 Road Traffic Sources

Figure A.1 in Appendix A shows the impact of road traffic on concentrations of PM_{10} for the base year. Maximum roadside concentrations of 28-29 µg/m^3 are predicted. If the background sources are ignored this equates to a maximum contribution from road traffic of approximately 4-5 µg/m^3. When compared to the PM_{10} measurements recorded at the monitoring site, it is clear that road traffic is not the major source of PM_{10} in the area.

5.2.2 *All Sources*

Figure A.2 in Appendix A shows the cumulative impact of road traffic, fugitive emissions and background sources on concentrations of PM_{10} for 2005. The highest concentrations are predicted outside the entrances to the industrial premises, and within the boundaries of the premises.

The residential properties opposite the entrances to the industrial premises are predicted to be subjected to annual mean PM_{10} concentrations of up to approximately 80 µg/m^3. Concentrations at sensitive receptors are predicted to fall with distance from the site entrances:

- the residential terrace just to the south of York Road is likely to be subjected to concentrations of approximately 60-70 µg/m^3;
- the façades of the properties above the shops on Horn Lane are predicted to experience concentrations of between 40 µg/m^3 near to Noel Road, and 65 µg/m^3 next to Gowing and Pursey;
- the row of properties opposite Noel Road are predicted to experience concentrations of between 55-60 µg/m^3;
- to the north of Noel Road, concentrations at the properties set back from the road are predicted to be between 35-40 µg/m^3;
- concentrations at the properties to the north of the Leamington Park junction were predicted to be between 40-45 µg/m^3;
- roadside concentrations to the south of the railway bridge were predicted to drop rapidly to about 30-35 µg/m^3.

Concentrations on the east side of Horn Lane were predicted to be higher than those on the west side, due to the prevailing westerly/south westerly winds.

The contour of the 2004 annual mean standard (40 µg/m^3) has been indicated in Figure A.2 with a solid white line. Sensitive receptors predicted to experience concentrations over 40 µg/m^3 include all properties on the east side of Horn Lane, from the railway bridge to the junction with the A40, all properties between Gowing and Pursey and Noel Road, and several properties to the north of Noel Road. In addition, approximately 10 properties on York Road, near to the junction with Horn Lane, are expected to experience concentrations over 40 µg/m^3, and 2-3 residential buildings on Leamington Road, near to the junction with Horn Lane.

Based on PM_{10} data collected at AURN sites throughout the country, a relationship has been derived between the number of 24-hour exceedences, and the annual mean concentration[6]. Using this relationship it is possible to make the approximation that the annual mean concentration at which the daily objective would be breached is 32 µg/m^3. The 32 µg/m^3 contour has been indicated in Figure A.2 by a dashed white line. In addition to the sensitive receptors within the 40 µg/m^3 contour, all properties on the west side of Horn Lane between Noel Road and the A40, several properties on Noel Road, and a large number of properties on York Road and Leamington Park, are all predicted to be within the 32 µg/m^3 contour.

In 2010 (Figure A.3), concentrations throughout the study area are predicted to be approximately 1.7 µg/m^3 lower than in 2005 due to the forecasted lower background concentrations. Further reductions of up to approximately 1.5 µg/m^3 are predicted down the centre of Horn Lane due to predicted improved vehicle emission controls. Concentrations are predicted to exceed the provisional 2010 annual mean standard throughout the whole study area; further from the industrial premises this is largely as a result of the high background concentrations. In 2010, the area over which exceedences of the 2004 objectives are predicted is slightly smaller than in 2004.

5.3 Source Apportionment

A source apportionment study has been carried out to determine the relative contributions of the main emission source categories to the PM_{10} concentrations predicted on Horn Lane. Contributions have been calculated at the façade of the sensitive receptor where the highest concentration is predicted (2005: 81 µg/m^3), opposite the site entrances.

Table 13 shows the relative contributions of the background sources, road traffic sources and fugitive sources to the predicted PM_{10} concentration at the receptor.

Table 13: Source Apportionment Modelling Study Results

Sensitive Receptor	X	Y	% Contribution from		
			fugitive sources	road traffic	background sources
Property opposite industrial premises entrances	520421	181348	67	3	30

At the receptor studied, an annual mean decrease of 49 µg/m^3 should ensure that both of the 2004 objectives would be met. To enable such a decrease, an approximate 90% reduction in fugitive emissions associated with the industrial and commercial premises is required (this includes all emissions from with the site, and emissions due to the re-suspension of dust by vehicles on Horn Lane). Of the fugitive source contribution (67%), approximately two-thirds (66%) can be attributed to the re-suspension of dust by vehicles on Horn Lane, and one-third (34%) to emissions from within the site boundaries.

6 Discussion

6.1 Monitoring

Both the TEOM and the Partisol have recorded concentrations of PM_{10} considerably in excess of the National Air Quality Standards. The Partisol recorded a 12-month mean concentration of 60.1 µg/m^3, 20 µg/m^3 over the 2004 annual mean standard. Daily mean concentrations in excess of 50 µg/m^3 have been recorded by the Partisol on 202 days during the 12-month monitoring period, almost six times as many days as permitted (35).

During the course of the year PM_{10} levels have fluctuated. Whilst this is expected given the relationship between meteorological conditions and PM_{10} concentrations, it should also be noted that several measures have been taken to reduce fugitive emissions. Therefore it is likely that these measures have contributed to the lower concentrations observed since October. In addition to the lower PM_{10} concentrations, dust deposition rates, as determined by the Frisbee gauges, fell significantly throughout the monitoring period, but particularly so after September/October.

In particular, it is likely that the regular road sweeping that has been taking place since the autumn has been responsible for reductions in recorded dust and PM_{10}. In addition, during the monitoring period, improved wheel washing facilities have been introduced at Yeoman Aggregates and at Hanson Premix, and sections of the Yeoman site have been hard-surfaced. These measures are likely to have contributed to the lower PM_{10} and dust levels.

Whilst there have been seasonal and daily variation between the two PM_{10} monitoring techniques, over the course of the monitoring period they have agreed well. As a result a TEOM gravimetric correction factor was not deemed necessary or appropriate. The good agreement was attributed to the relatively low fraction of volatile particulate due to the nature of the industries, and therefore the minimal impact of the TEOM's heated inlet on the PM_{10} determination. However, due to the variations observed between the Partisol and TEOM throughout the year, monthly gravimetric correction factors have been calculated. This may allow future TEOM results to be corrected in the absence of gravimetric results, if such a situation should arise.

6.2 Modelling

The modelling study produced results that agreed well with the monitoring. Due to the assumptions that must be made when conducting such a study, and the inherent uncertainties in predicting fugitive emissions, it is essential that the results are compared with local monitoring, and the results adjusted to account for any discrepancy. Therefore the modelling results had to be adjusted, but by only 15%.

The highest concentrations predicted by the modelling study were found outside the entrances to the industrial sites. These high concentrations are likely to be mainly due to the re-suspension of surface material due to the action of traffic on Horn Lane. The predominant wind direction is such that material and dust is likely to be blown out of the sites and on to Horn Lane. In addition material is likely to be brought out of the sites on vehicles, and deposited on Horn Lane. Concentrations were predicted to fall with distance from the site entrances; however, concentrations leading to breaches of the 24-hour objective were predicted along the whole of Horn Lane, up to Gipsy Corner.

The source apportionment study found that at the residential property predicted to be subjected to the highest PM_{10} concentration, fugitive emissions associated with the industrial premises were predicted to be the greatest contributor (67%) to the overall concentration. Of this contribution, approximately two-thirds were predicted to be attributable to the re-suspension of dust by the action of vehicles on Horn Lane. It was calculated that at this location an approximate 90% reduction in fugitive emissions associated with the industrial premises would be required to meet the 2004 PM_{10} objectives.

6.3 Mitigative and Preventative Controls

As discussed above, significant reductions in fugitive emissions are required to reduce ambient concentrations of PM_{10} to levels below the 2004 objectives. Measures to reduce fugitive emissions can be split into mitigative and preventative controls[14,16,17].

6.3.1 Mitigative Controls

Mitigative control involves the removal of material that has been deposited on roads, and is generally most applicable to paved roads. There are various ways of removing material, such as vacuum sweeping, water flushing, and broom sweeping. Currently a road sweeping vehicle is employed by Gowing & Pursey, and it is likely that since its deployment in the autumn it has had a significant impact upon dust deposition rates, and PM_{10} concentrations. Caution should be taken when employing such techniques, as sweeping of gutters and kerb areas can in the short term actually increase the silt loading on the travelled portion of the road. It is especially important that any accidental spillages (from trucks for example) are removed as soon as possible, before material is spread over a greater area.

6.3.2 Preventative Controls

Preventative controls are generally found to be more cost effective than mitigative controls. Such controls include the prevention of material being deposited on a road surface, or the prevention of material being disturbed or re-suspended by vehicle movements.

With regard to emissions from paved roads, preventative controls include the sheeting of all vehicle loads, the washing of vehicles (wheels especially) when leaving an unpaved area, and the paving of routes that lead to paved roads. Currently, although the majority of vehicles that use Yeoman Aggregates and Hanson Premix do sheet their loads, not all do, and therefore emissions could be reduced in this way. Similarly, not all vehicles using Gowing & Pursey sheet their loads. Wheel washing facilities at Yeoman Aggregates and Hanson Premix have improved in the past year; it is important that the effectiveness of these facilities is checked regularly, and that strict procedures are adhered to. Gowing & Pursey have no such facilities other than manual hosing of wheels.

The enforcement of the speed limit, and possibly the imposition of reduced speed limits on Horn Lane, would limit the amount of re-suspended material. Average speeds on the stretch of road between Gipsy Corner and the site entrances are high, and currently many vehicles exceed the speed limit (30 mph). Similarly, on-site speed restrictions may significantly reduce the re-suspension and spread of surface material.

To prevent or reduce emissions due to wind erosion, or emissions whilst loading to, or removal from piles, windbreaks and pile enclosures are highly effective. On the Yeoman Aggregates site the piles are currently partially enclosed on two or three sides. However, the heights of the piles may exceed the heights of the enclosure walls; therefore an increase in the height of the walls could further reduce emissions. Other ways of sheltering the piles further without hindering operational activities could be explored. Due to its relatively open aspect with respect to the predominant wind direction, strategic positioning of windbreaks elsewhere on the Yeoman site could also be considered.

Watering is the most common way of controlling dust on unpaved roads and areas between storage piles (although watering of the surfaces of storage piles is generally considered to be relatively ineffective). Watering increases the moisture content of the surface material, which reduces the likelihood of the material becoming airborne. The effectiveness of watering depends on the amount of water added, the time between applications, the weight, speed and number of vehicles using the road, and meteorological conditions (temperature, wind speed and cloud cover affect evaporation rates). On a windy, hot, sunny day it may be necessary to water continuously to suppress dust. Due to the size of the site (such as Yeoman Aggregates) and the availability of water, continuous watering may not be possible. Currently all of the sites utilise watering as a means of dust suppression. Surfactants may be added to the water to increase its effectiveness and reduce its evaporative capacity.

The application of chemical dust suppressants to unpaved roads is an effective method of controlling dust. It is more expensive than watering, but less frequent application is required. Chemical dust suppressants act by forming a hard surface, by binding particles together. However, the use of chemicals can lead to other environmental problems.

Watering of storage piles may only have a slight impact on emissions; the application of wetting agents is more effective. Yeoman Aggregates wash the majority of material before adding it to a storage pile, which, given that the majority of their piles are frequently disturbed, is likely to be an effective control method.

Emissions from paved roads are typically lower than emissions from unpaved roads. Therefore the paving of roads is an effective way of reducing emissions. It is however important that these paved roads are swept to prevent a build up of surface material, especially at points where vehicles join the road from unpaved areas. A less expensive improvement option would be to cover an unpaved surface with coarse gravel or aggregate. It is important that regular maintenance is carried out to ensure that the larger aggregate is returned to the travelled portion of the road.

Emissions from the Gowing and Pursey transfer shed may be reduced by intensive use of their Mist-Air system, and by the use of longer ‘curtains’ to minimise the egress of airborne particulate, as recommended in a recent report commissioned by Gowing and Pursey[16].

Hanson Premix is due to have a new up-to-date wet batch plant installed in the following year. This will replace the current dry batch plant. It is likely that this will reduce emissions from the site.

7 Conclusions

7.1 General Conclusions

7.1.1 Monitoring

- Concentrations considerably in excess of the National Air Quality Standards and Objectives were recorded on Horn Lane.
- The Partisol recorded a 12-month mean concentration of 60.1 μg/m^3, and 202 exceedences of the 24-hour standard.
- The TEOM recorded a 12-month mean concentration of 61.6 μg/m^3, and 201 exceedences of the 24-hour standard.
- Due to the good agreement between the two measurement techniques, a gravimetric correction factor for the TEOM results was not deemed appropriate.
- Measured concentrations were generally higher during the warmer drier months.
- Concentrations were shown to vary to a great degree on a daily basis, to a maximum average hourly weekday concentration of almost 160 μg/m^3 in the afternoon.
- The general diurnal trend in measured PM_{10} concentrations was found to be closely correlated with vehicle movements to and from the various industrial premises.
- Concentrations were found to be greatest in dry weather, with higher wind speeds, and when the predominant westerly and south-westerly winds were blowing.
- During the summer months the TEOM typically recorded higher concentrations, whereas during the winter months the Partisol typically recorded higher concentrations.
- The greatest dust deposition rates and the greatest proportions of calcium were recorded opposite the entrances to the sites.
- Dust deposition rates since October have been considerably lower than those prior to October, potentially, in part, as a result of increased road-sweeping.

7.1.2 Modelling

- The modelling results were compared with the monitored PM_{10} results and adjusted to account for a slight over-prediction by the model.
- Annual mean concentrations in 2005 were predicted to reach a maximum of approximately 80 μg/m^3 at residential properties opposite the site entrances.
- Exceedences of the 24-hour objective were predicted at all properties along Horn Lane to the north of the railway bridge, at several properties on Noel Road (where it meets Horn Lane), and the majority of properties on York Road and Leamington Park.
- Concentrations in 2010 were predicted to be slightly lower than those in 2005 due to lower background concentrations and improved vehicle emission controls.
- At the residential property predicted to be subjected to the highest PM_{10} concentration, fugitive emissions associated with the industrial premises were predicted to be the greatest contributor (67%) to the overall concentration. Of this contribution, approximately two-thirds were predicted to be attributable to the re-suspension of dust by vehicles on Horn Lane. At this location a 90% reduction in fugitive emissions associated with the industrial premises would be required to meet the 2004 PM_{10} objectives.

7.2 Recommendations

7.2.1 Monitoring

- It is recommended that monitoring of PM_{10} is continued at the Horn Lane monitoring site.
- The Council may consider removing either the TEOM or the Partisol instrument. Retention of the TEOM would be advantageous seeing as it provides real-time continuous measurements, and it may be assumed that the gravimetric conversion factors calculated in this report may be used in future years at the site.
- The Council may consider additional real-time continuous monitoring at several locations near to the site boundaries and near to residential properties, to better understand the dispersion of PM_{10} and other size fractions. Instruments employing light-scattering techniques might be suitable for such a purpose (instruments are available that can also

make concurrent determinations of PM_1, $PM_{2.5}$ and TSP (total suspended particulate)). Such instruments could also be used within the sites, near to the entrances or boundaries, to help determine which sources contribute to high particulate concentrations. These instruments can also be equipped with anemometers.

7.2.2 *Preventative and Mitigative Controls*

To reduce fugitive emissions the following measures may be employed:

Mitigative

- Road cleaning/sweeping
- Effective removal of spillages (on and off-site)

Preventative

- Sheeting of all vehicle loads
- Washing of vehicle wheels
- Reduction of on-site speeds limits
- Enforcement and possible reduction of speed limit on Horn Lane
- Improved pile enclosures
- Positioning of windbreaks
- Watering of unpaved roads and areas between storage piles
- Application of chemical dust suppressants to unpaved roads
- Application of wetting agents to (infrequently used) piles
- Paving of unpaved roads, or the covering of unpaved roads with coarse gravel or aggregate

7.2.3 *Local Air Quality Management (LAQM) Process*

- Based on this Detailed Assessment there is no requirement to amend the current AQMA for PM_{10}, which covers the entire Borough.
- The Council should consider reviewing or amending their Action Plan in order to strengthen specific policies relating to the Horn Lane area.

8 References

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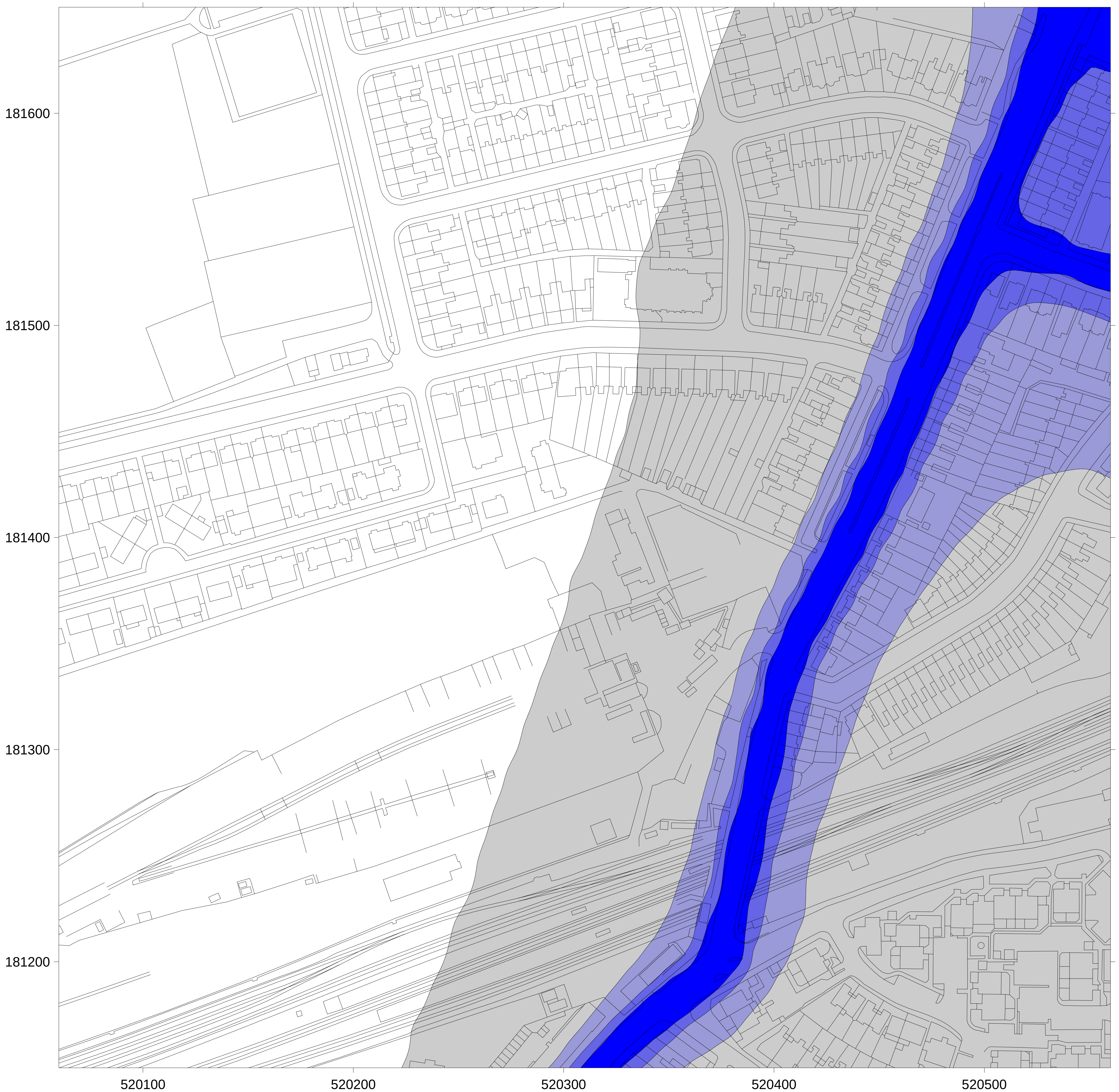
Appendix A: PM_{10} Concentration Plots



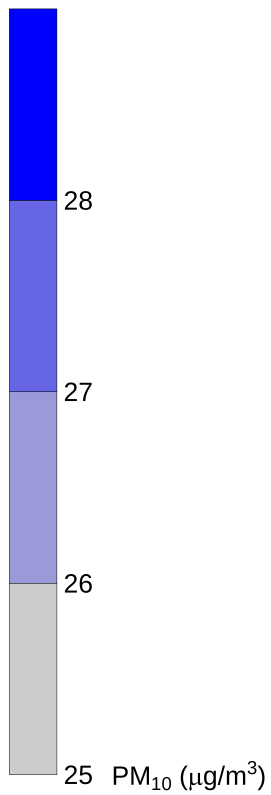


Figure A.1

PM_{10} Concentration Plot, 2005:
Road Traffic and Background Sources Only

Client:
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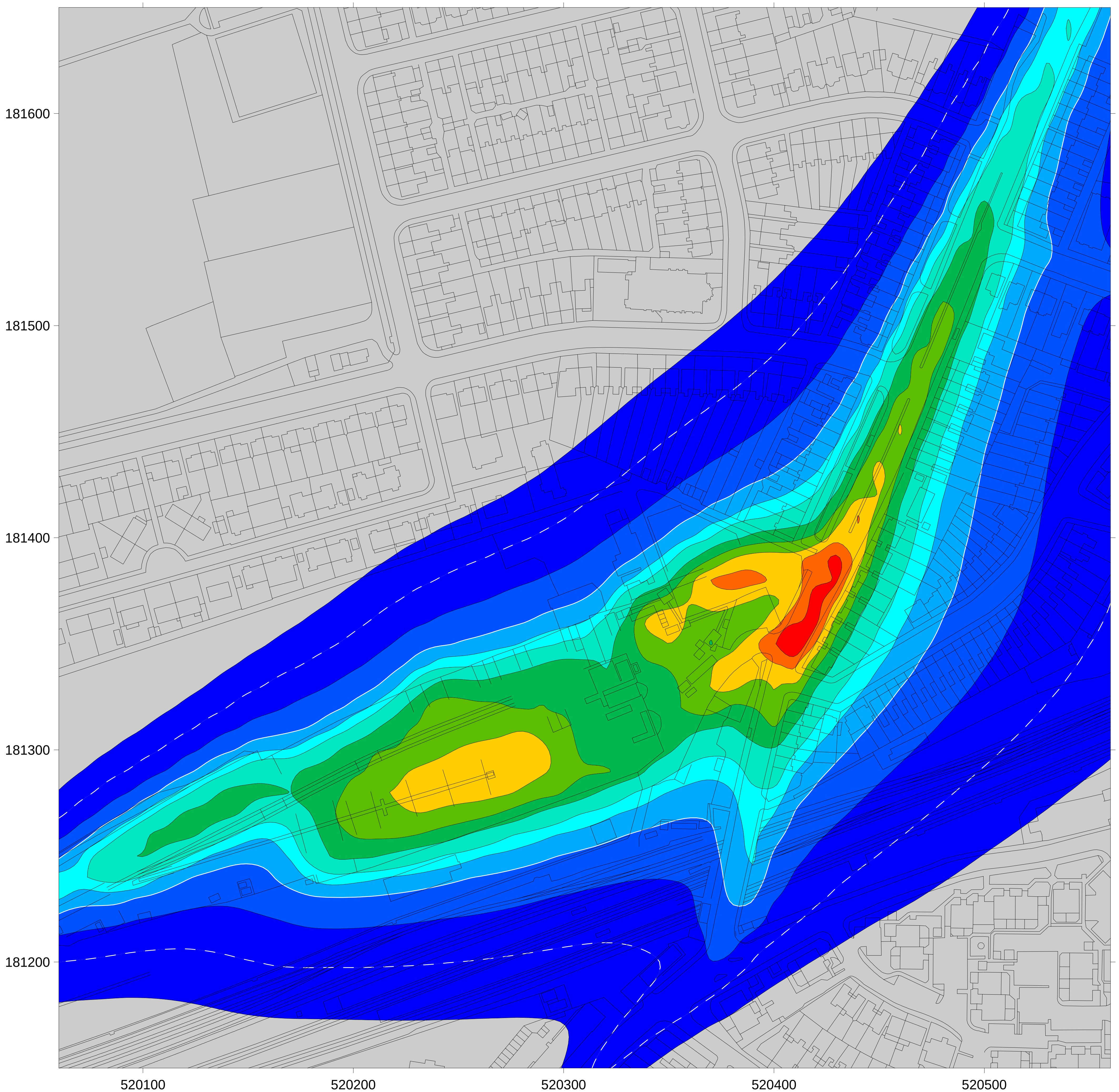
Notes:

The contour of the 2004 annual mean standard (40 μg/m³) is indicated with a solid white line.

The contour at which the 2004 24-hour mean objective is likely to be breached (32 μg/m³) is indicated with a dashed white line.
(Refer ro main text for further details)



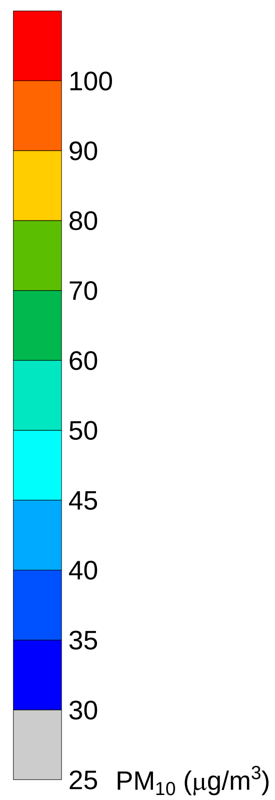


Figure A.2

PM_{10} Concentration Plot, 2005:
All Sources Included

Client:
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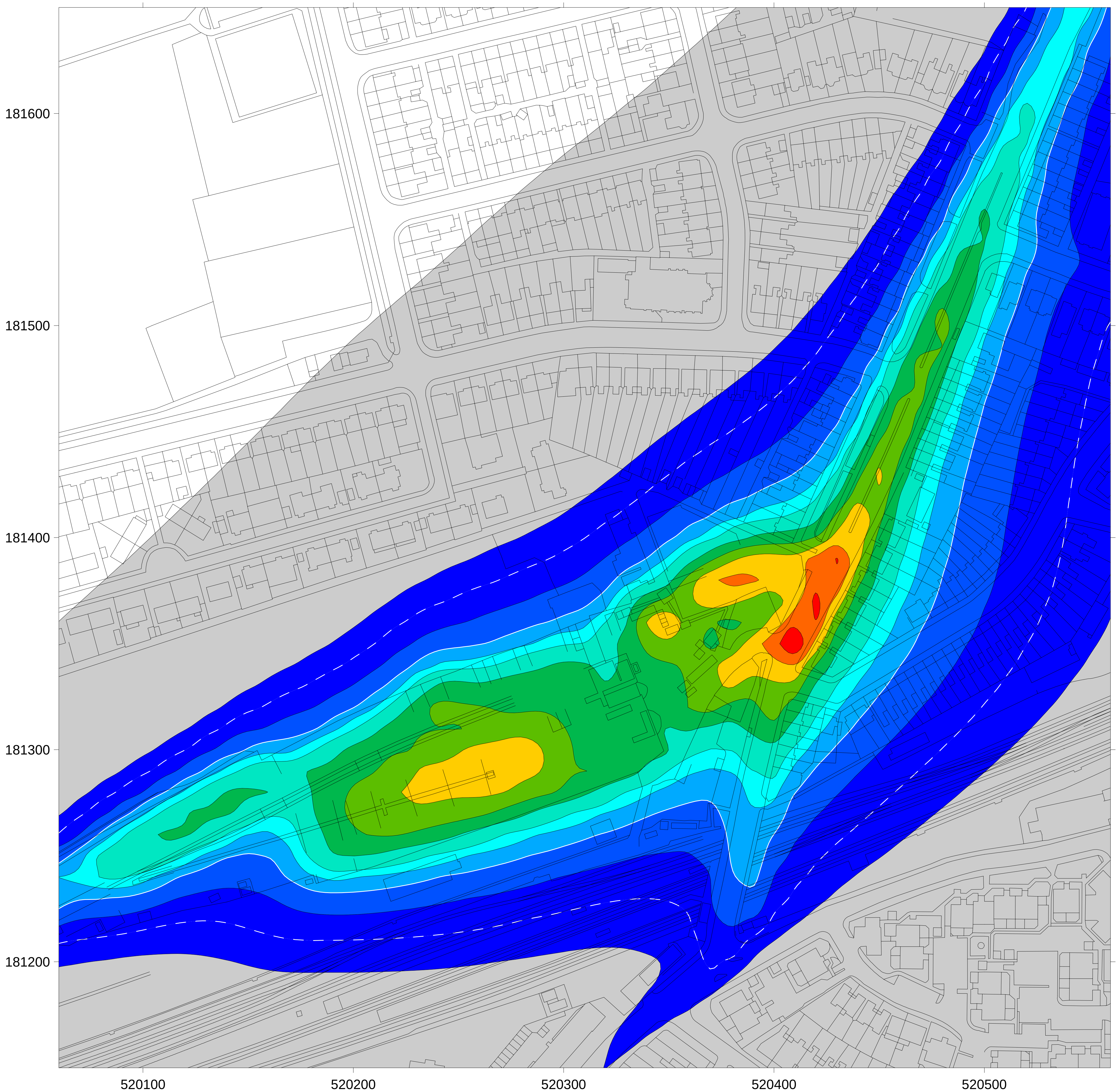
Notes:

The contour of the 2004 annual mean standard (40 $\mu g/m^3$) is indicated with a solid white line.

The contour at which the 2004 24-hour mean objective is likely to be breached (32 $\mu g/m^3$) is indicated with a dashed white line.
(Refer ro main text for further details)



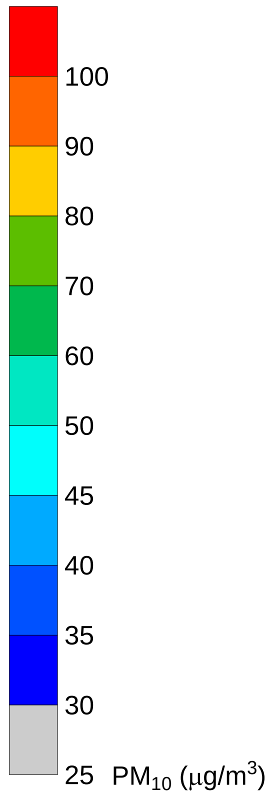


Figure A.3

PM$_{10}$ Concentration Plot, 2010:
All Sources Included

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Appendix B: AAQuIRE Modelling Software

The AAQuIRE 6.1.1 software is a system that predicts Ambient Air Quality in Regional Environments and comprises a regional air quality model and statistical package.

AAQuIRE was developed by Faber Maunsell Ltd to meet three requirements in predictive air quality studies. The first requirement was an immediate need for a system that produced results that could be interpreted easily by non-air quality specialists to allow for proper informed inclusion of air quality issues in wider fora, the main example being to allow consideration of air quality issues in planning processes. This was achieved by allowing results to be generated over a sufficiently large study area, and at an appropriate resolution, for the issue being considered. The results are also presented in a relevant format, which is normally a statistic directly comparable with an air quality criterion or set of measured data being considered. For example, the UKNAQS PM_{10} 24-hour objective level of 50 µg/m^3 is expressed as a 90th percentile of hourly means. AAQuIRE can also produce results directly comparable with all ambient air quality standards.

The second requirement was for a system to be based, initially, on existing and well-accepted and validated dispersion models. This has two advantages. The primary one is that it avoids the need to prove a new model against the accepted models and therefore enhances acceptability. The second advantage is that when appropriate new models are developed they can be included in AAQuIRE and be compared directly with the existing models, and sets of measured data, using the most appropriate statistics.

The final primary requirement for AAQuIRE was a consideration of quality assurance and control. An important aspect of modelling is proper record keeping ensuring repeatability of results. This is achieved within AAQuIRE by a set of log files, which record all aspects of a study and allow model runs to be easily repeated.

The ways in which AAQuIRE and the models currently available within it operate are discussed below.

The operation of AAQuIRE can be divided into five main stages. These are:
- the preparation of the input data;
- the generation of model input files;
- dispersion modelling;
- the statistical treatment of dispersion modelling results; and
- the presentation of results.

The first step in operating AAQuIRE is to prepare the input data. The following data are needed for the year and pollutant to be modelled:
- meteorological data expressed as occurrence frequencies for specified combinations of wind speed, direction, stability and boundary layer height;
- road system layout and associated traffic data within and immediately surrounding the study area;
- industrial stack locations and parameters; and
- a grid of model prediction locations (receptors).

The modelling is always carried out to give annual average results from which appropriate shorter period concentrations can be derived.

The second stage is the generation of the model input files required for the study. All the data collated in the first stage can be easily input into AAQuIRE, using the worksheets, drop down boxes and click boxes in the Data Manager section of the software. Data from spreadsheets can be easily pasted into worksheets, so that any complicated procedures required for data manipulation can be achieved before entry into AAQuIRE. Several diurnal and seasonal profiles can be defined for each separate source. The relevant meteorological data can also be specified at this stage.

The third stage is executing the models. The study area will usually be divided up into manageable grids and run separately using the Run Manager in AAQuIRE. The results from the separate files can be combined at a later stage. Pollutant concentrations are determined for each receptor point and each meteorological category and are subsequently combined.

The fourth stage is the statistical processing of the raw dispersion results to produce results in the relevant averaging period. Traffic sources and industrial sources can be combined at this stage provided the same receptor grid has been used for both. Background concentrations should also be incorporated at this stage.

The final stage is presentation of results. Currently the result files from the statistical interpretation are formatted to be used directly by the SURFER package produced by Golden Software Inc. Alternative formats are available to permit interfacing with other software packages. On previous projects the results have been imported into a GIS (e.g. ArcView and Map Info).

Currently AAQuIRE uses the CALINE4 model for the dispersion of road-traffic emissions and AERMOD for all other sources. Both these models are fully validated and have been extensively used worldwide. These are relatively complex models designed for detailed studies of local areas, which are used within AAQuIRE for both local and larger scale studies. This is considered necessary because of the frequent importance of local effects, such as traffic junctions, in properly assessing ‘regional’ effects.

Appendix C4: Fugitive Dust Area Emissions

A total of 51 area sources have been modelled. The location and size of each area is indicated in Figures 14 and 15. The emission factors used for each area are tabulated in Tables 14-16, together with the information required to calculate them.

Figure 14: Horn Lane Area Sources

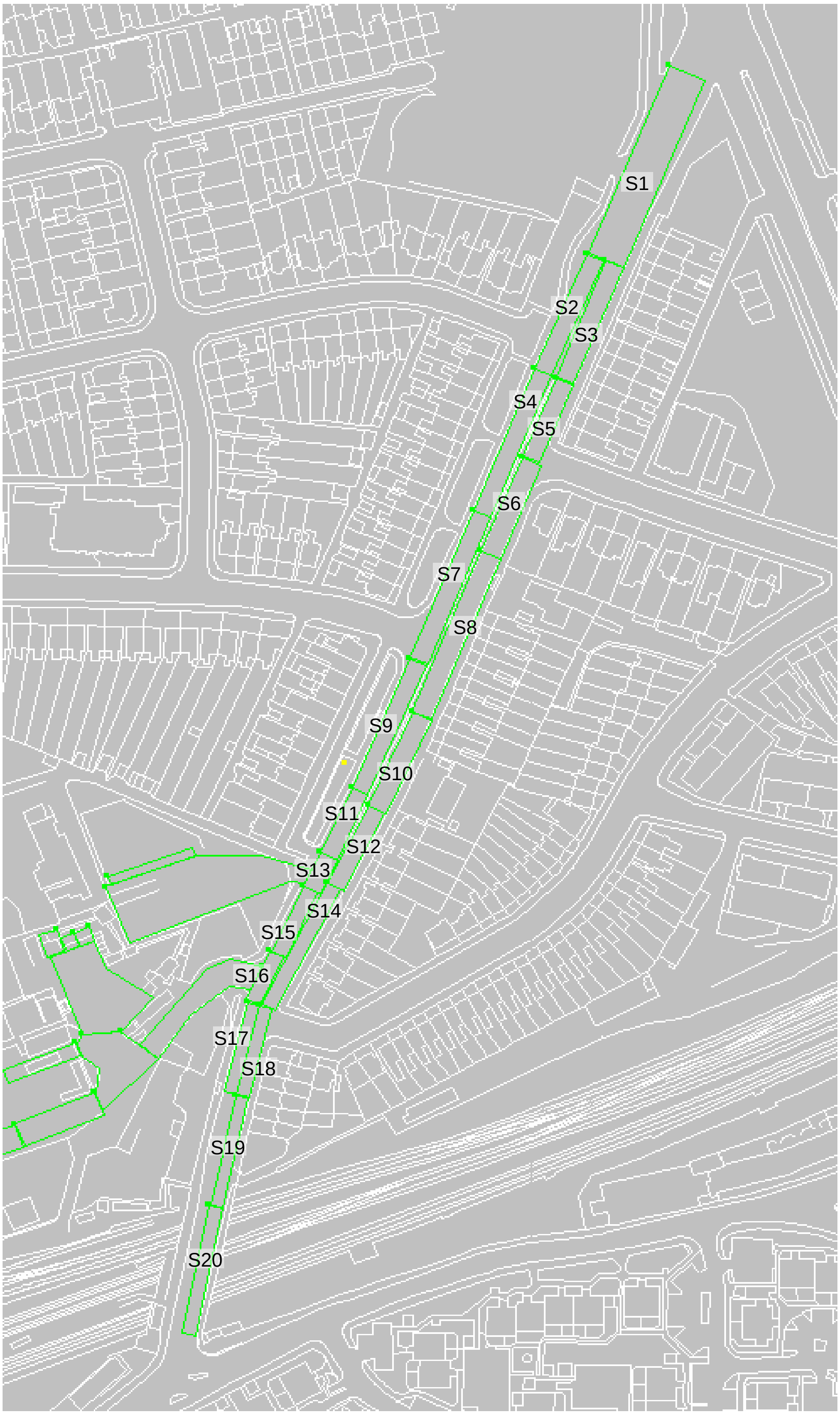

Figure 15: Industrial Premises Area Sources

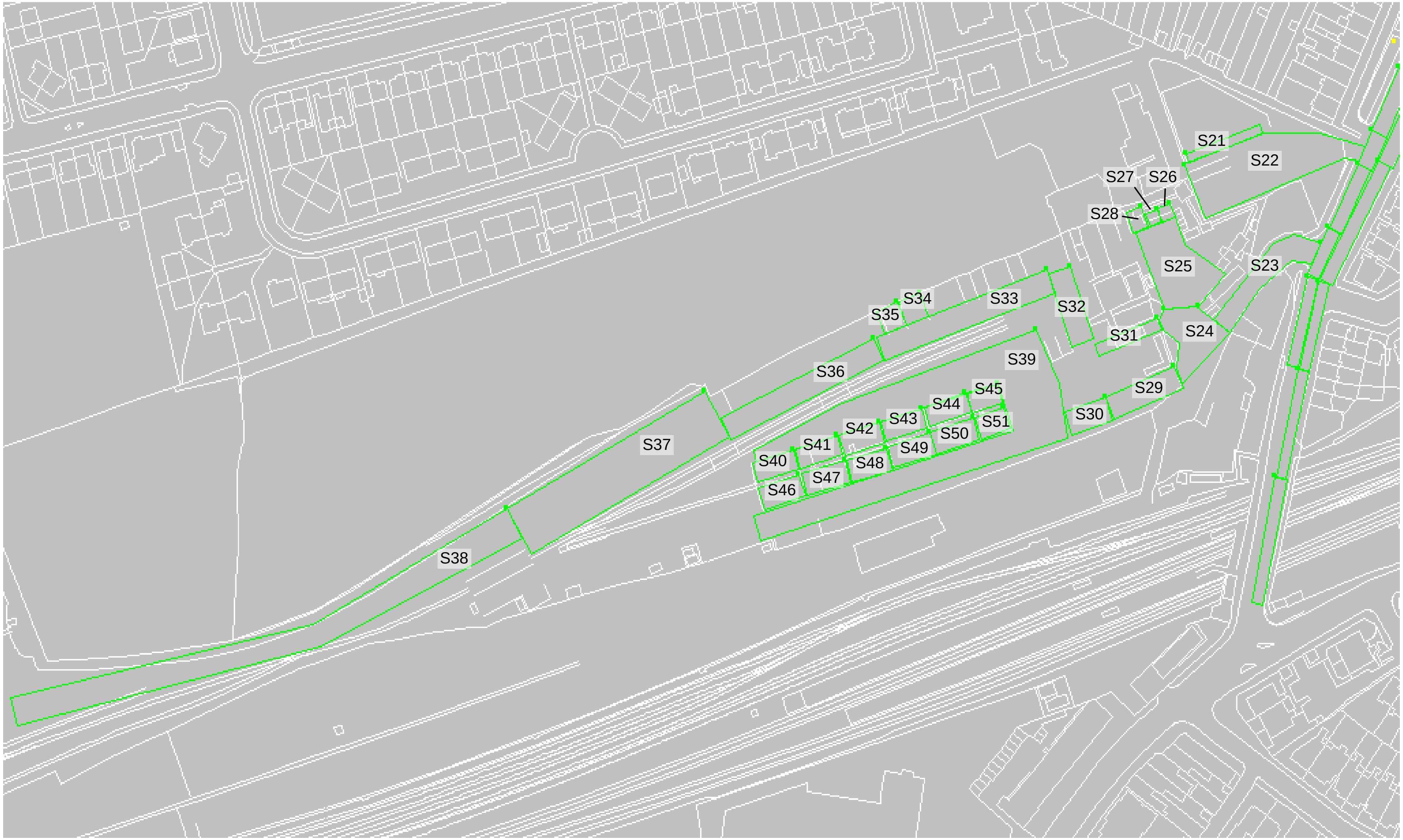

Table 14: Paved Roads Emission Rates

Source number	Area (m^2)	Silt loading (g/m^2)	Vehicle weight (t)	E (g/VKT)	Vehicle Flow (s)	Distance travelled (km)	Emission rate ($g/s/m^2$)
s1	1028	1	1.25	0.57	0.2415	0.075	0.000010
s2	302	1.25	1.25	0.68	0.1832	0.047	0.000019
s3	325	1	1.25	0.57	0.0582	0.046	0.000005
s4	368	2	1.25	0.97	0.1832	0.057	0.000027
s5	205	1.25	1.25	0.68	0.0582	0.032	0.000006
s6	283	1.25	1.25	0.68	0.1082	0.039	0.000010
s7	389	3	1.25	1.29	0.1832	0.059	0.000036
s8	477	1.25	1.25	0.68	0.1082	0.064	0.000010
s9	331	3.25	1.25	1.37	0.1832	0.053	0.000040
s10	276	1.25	1.25	0.68	0.1082	0.038	0.000010
s11	167	3.5	1.25	1.44	0.1832	0.027	0.000042
s12	209	1.75	1.25	0.88	0.1082	0.032	0.000015
s13	88	3.75	1.25	1.51	0.1832	0.014	0.000044
s14	273	2.5	1.25	1.14	0.1082	0.051	0.000023
s15	144	3.5	1.25	1.44	0.1832	0.027	0.000049
s16	102	3.5	1.25	1.44	0.1832	0.020	0.000051
s17	158	1.25	1.25	0.68	0.1829	0.034	0.000027
s18	153	1.75	1.25	0.88	0.1079	0.034	0.000021
s19	181	1.25	1.25	0.68	0.1079	0.042	0.000017
s20	235	1	1.25	0.57	0.1079	0.049	0.000013
s23	525	4	12.2	53.35	0.0064	0.050	0.000032
s24	378	6	12.2	69.48	0.0064	0.018	0.000021
s25	432	12	11	93.74	0.0021	0.045	0.000021
s29	276	6	14	82.79	0.0021	0.030	0.000019
s30	157	6	14	82.79	0.0021	0.017	0.000019
s31	137	3	14	52.72	0.0021	0.027	0.000022
s32	261	10	8	49.80	0.0030	0.029	0.000017
s33	703	10	8	49.80	0.0030	0.074	0.000016
s36	649	10	8	49.80	0.0030	0.069	0.000016
s37	1832	6	12	65.67	0.0040	0.092	0.000013
s38	2376	6	12	65.67	0.0020	0.216	0.000012

Table 15: Unpaved Roads Emission Rates

Source number	Area (m^2)	Surface material silt content (%)	Vehicle weight (t)	E (g/VKT)	Vehicle Flow (s)	Distance travelled (km/veh)	Emission rate ($g/s/m^2$)
s22	1239	6.4	10.7	214	0.0032	0.040	0.000022
s39	3250	7.1	10	227	0.0020	0.090	0.000013

Table 16: Aggregate Handling Emission Rates

Source number	Area (m^2)	Material moisture content (%)	Emissions (kg/ton transferred)	Material transferred (ton /day)	Emissions (g/day)	Emission rate ($g/s/m^2$)
s21	105	11	0.00005	233	11	0.000001
s26	31	2.1	0.0005	200	99	0.000037
s27	26	2.1	0.0005	200	99	0.000044
s28	56	2.1	0.0005	400	198	0.000041
s34	88	4	0.0002	650	130	0.000017
s35	85	4	0.0002	650	130	0.000018
s40	128	4	0.0002	450	90	0.000008
s41	136	4	0.0002	375	75	0.000006
s42	136	4	0.0002	550	110	0.000009
s43	130	4	0.0002	550	110	0.000010
s44	138	4	0.0002	650	130	0.000011
s45	100	4	0.0002	450	90	0.000010
s46	144	4	0.0002	375	75	0.000006
s47	158	4	0.0002	375	75	0.000005
s48	151	4	0.0002	550	110	0.000008
s49	150	4	0.0002	375	75	0.000006
s50	154	4	0.0002	650	130	0.000010
s51	106	4	0.0002	375	75	0.000008

For the purposes of the modelling study, emission rates associated with the wind erosion of storage piles (Section 3.5.2.3) have been added to the emission rates in Table 16. An emission rate of $7x10^{-6}$ $g/s/m^2$ has been calculated for each pile, based on the assumptions made in Section 3.5.2.3.

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Approved by: .... James Richer Technical Director

Detailed Assessment of Particulate Matter

Rev No	Comments	Date
1		

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