DETAILED ASSESSMENT REPORT

(Local Air Quality Management Round 2)

City Of Edinburgh Council
Environmental and Consumer Services Department

December 2004.

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EXECUTIVE SUMMARY

Under the regime of Local Air Quality Management (LAQM) Round 2, local authorities are required to undertake further work in the form of a Detailed Assessment report if they have concerns that air quality targets might be exceeded. The Updating and Screening Assessment report identified that the tighter air quality objectives for particles (PM_{10}) might not be achieved city-wide and that the annual average nitrogen dioxide objective was likely to be exceeded at St John's Road for traffic associated sources.

Work contained in this report has been carried out in accordance with the government guidance document LAQM. TG(03). The City of Edinburgh Council has also undertaken additional monitoring studies to determine if Edinburgh is at risk of exceeding the more stringent PM_{10} objectives. This was due to the uncertainty associated with adjustment factors applied to current monitoring methods and the lack of local background monitoring data. The University of West of England, Scottish Environment Protection Agency and the Scottish Executive agreed the scope of the studies.

The findings of this report regarding PM_{10} show that Edinburgh is likely to meet with the more onerous air quality objectives and therefore there is no requirement to declare an Air Quality Management Area (AQMA) for this pollutant.

The additional assessment work at St John's Road, Clermiston Road junction has shown that there is likely to be a risk of exceeding the annual average nitrogen dioxide target on the westbound side of the road. Therefore, it will be necessary to extend the existing AQMA to cover this area of concern.

The existing AQMA includes the city centre and most main radial routes to the city centre. The western boundary of the AQMA ends at Roseburn Terrace. Although the area of likely exceedence is very localised the proposed extended AQMA is likely to be from the west end of Roseburn Terrace to the west of St John's Road, subject to consultation with appropriate stakeholders.

1.0 INTRODUCTION

1.1 Local Air Quality Management regime

Part IV of the Environment Act 1995 places a statutory duty on local authorities to periodically review and assess air quality within their areas. The review and assessment process plays a major role in the Local Air Quality Management (LAQM) regime.

In terms of LAQM, a local authority must assess the following pollutants against air quality objectives, which have been prescribed in regulations and set out in the Air Quality Strategy for England, Scotland, Wales and Northern Ireland. [1]

1,3-butadiene	Sulphur dioxide
Benzene	Nitrogen dioxide
Carbon monoxide	Particles PM_{10}
Lead	

Air quality objectives are derived from air quality standards, based on medical and scientific knowledge of the effect of the pollutants on health. Standards, as defined by the Expert Panel on Air Quality Standards (EPAQS) are concentrations below which there is not likely to be a significant risk to health. The concentration of a pollutant together with the target date for compliance is known as an objective. Target dates have been set to take account of the costs and the practicability of attaining the air quality standard.

If an air quality objective is not likely to be achieved at a location, which is relevant in terms of public exposure, the local authority must declare an Air Quality Management Area (AQMA) and produce a written Action Plan. The Action Plan should set out measures, which aim to address the level of air quality improvement that is required.

The Act does not place an absolute obligation on local authorities to meet the prescribed air quality targets, only to 'act in the pursuit of achieving' them.

Local authorities are expected to undertake reviews and assessments every three years up to 2010. Round 1 of the LAQM process has been completed which has led to the declaration of AQMAs throughout the UK; the majority are due to the risk of exceedences of the nitrogen dioxide and particle (PM_{10}) objectives. Local authorities are now at Round 2 of the process. The initial step in Round 2 is to complete an **Updating and Screening Assessment (U&SA)**. If any of the pollutants are not likely to meet their air quality objectives then a local authority is required to progress to a **Detailed Assessment (DA)** of the pollutant/s of concern. This assessment involves undertaking a more robust approach to provide assurance that an exceedence will definitely occur, and ultimately whether or not an AQMA or amendments to existing AQMAs are required.

1 Air Quality (Scotland) Regulations 2000 and the Air Quality (Scotland) Amendment Regulations 2002

The major significant change for Scotland since Round 1 of LAQM is the setting of more onerous air quality objectives for PM_{10}. The new targets are based on indicative Stage 2 values set by the EU and have been adopted by the Scottish Executive and incorporated into the Air Quality (Scotland) Amendment Regulations 2002. Only Scottish Authorities have to consider the new objectives at this time.

Whilst Edinburgh meets the EU limit value for PM_{10} prescribed in earlier regulations, the U&SA report concluded we are likely to fail the indicative values city-wide.

1.2 LAQM summary for City of Edinburgh Council

Round 1

- The pollutants PM_{10}, 1,3-butadiene, benzene, lead, carbon dioxide and sulphur dioxide are expected to meet with their respective air quality objectives.
- The annual average nitrogen dioxide air quality objective is likely to be exceeded at a number of city centre locations, Queen Street, Princes Street, West Maitland Street, George Street, Leith Walk, North Bridge, Roseburn Terrace and Gorgie Road.
- Areas where exceedences occur are due to road traffic emissions and the majority is at or close to busy junctions.
- A single AQMA was declared for the city centre in 2000 as detailed in appendix Map 1
- Further work undertaken for Stage 4 identified that buses are responsible for the majority of NO_X emissions within the AQMA.
- The Council's Air Quality Action Plan was produced and approved in July 2003.

Round 2

- The U&SA report was completed in July 2003 and concluded that a Detailed Assessment was necessary city-wide for Particles (PM_{10}) due to high back ground levels and a significant tightening of the air quality objectives for Scotland. The annual average nitrogen dioxide objective is also likely to be exceeded at St John's Road Corstorphine, due to traffic emissions. Further work was therefore required with a view to extending the existing nitrogen dioxide AQMA.
- The pollutants, 1,3-butadiene, benzene, lead, carbon dioxide and sulphur dioxide are expected to meet with the air quality objectives.

Details of the Council's air quality reviews and assessments are contained in the following reports:

Round 1 LAQM

Review and Assessment of Air Quality in the City of Edinburgh Stage1 and 2 (1999)
City of Edinburgh Council Review and Assessment of Air Quality Stage 3 (2000)
City of Edinburgh Council Review and Assessment of Air Quality Stage 4 (2002)

Round 2 LAQM

City of Edinburgh Council Updating and Screening Assessment
Local Air Quality Management Phase 2 (2003)

City of Edinburgh Council Action Plan (2003)

Stage 3 and 4, the Updating and Screening Assessment and The Action Plan can be viewed on the Council's web page:

www.edinburgh.gov.uk/airquality

2.0 Detailed Assessment approach

2.1 Methodology for PM_{10}

Two additional monitoring studies have been undertaken to determine if Edinburgh is at risk of exceeding the more stringent PM_{10} air quality objectives. Both of the studies were outlined in the U&SA report and have been approved by the University of West of England (external assessors of all local air quality review and assessment reports).

Comparison study between TEOM and Partisol (gravimetric sampler)

The type of measurement which is required (PM_{10} or $PM_{2.5}$) and the instrument that should be used for monitoring particulate matter generates much debate in the UK. This is due to the complex nature of this pollutant and lack of detailed knowledge regarding the exact component, which is associated with adverse health effects.

The EU limit values and the UK objectives are based upon measurements using a gravimetric sampler, where particulate matter is collected on a filter and weighed.
In the UK the Tapered Element Oscillating Membrane (TEOM) method of measurement for particles is widely used. However, one of the concerns is that the filter mechanism of the instrument operates at 50°C, which can lead to the loss of the volatile particulate such as sulphate and nitrate. The benefit of using the TEOM is that it provides real-time data, which is considered essential for public information and knowledge on current levels. Gravimetric methods can only provide a daily mean and data can take up to a month to process. Thus pollution episodes will not be known of until much later. Studies have also shown that gravimetric type methods measure water from moisture bound particles under certain atmospheric conditions, which can lead to higher concentrations being, reported [2]. It is generally assumed that PM_{10} measurements from TEOM instruments tend to be lower because of the loss of sulphates, nitrates and possibly moisture. For the purpose of review and assessment, local authorities are advised to multiply TEOM generated data by 1.3 to provide a gravimetric equivalent concentration. However, inter comparison studies have demonstrated that the under read associated with TEOM instruments is variable and the factor of 1.3 is considered to be conservative. (Personal communication)[3]

Monitoring data gathered for Edinburgh has shown that we meet the air quality objectives using the TEOM method of measurement. Multiplying the data by a general factor of 1.3 results in annual exceedences and increases the number of daily exceedences. Therefore the purpose of running a TEOM co-located with a Partisol sampler was to establish what the factor would be at a typical roadside site in Edinburgh.

All monitoring data would then be reviewed using the results obtained from the study as well as the recommended factor of 1.3.

2 A comparison of PM_{10} monitors at a kerbside site in the north east of England. Monica Price et al.Atmospheric Environment 37(2003) 4425-4434

3 Richard Maggs Casella Stanger

Monitoring PM_{10} concentrations at a background location

The estimated-modelled PM_{10} background concentrations for 2010 obtained from the UK Air Quality Maps indicate that the majority of areas within Edinburgh will be at or close to the annual objective.[4] The values range from 14μg/m^3 to 19μg/m^3. There are no background sites, which monitor PM_{10} concentrations in Edinburgh. Therefore the UK maps for Edinburgh are based on modelling techniques and not on actual background measured data. Air quality traffic models, such as the screening model Design Manual for Roads and Bridges (DMRB) require the input of background concentrations. Where PM_{10} background concentrations are high in relation to the annual air quality objective, it is likely that exceedences of the objective will occur. Therefore it was considered necessary to establish PM_{10} monitoring at a background location. The measured value obtained at this location will be compared with the modelled estimated value and if necessary adjustments will be made to reflect more accurate background levels for the city centre and surrounding areas.

The appropriate adjusted background concentration will be used to determine if exceedences are likely to occur from activities at Hillwood Quarry.

The background real time concentrations obtained from this site will also be compared with the city centre roadside monitoring locations to assess the likely contribution from long-range and regional transboundary sources and the significance of road traffic associated PM_{10}.

The impact from road traffic will be also assessed using the DMRB screening model and adjusted background PM_{10} concentrations where traffic flows are greater than 10,000 vehicles per day and where there is relevant public exposure.

Partisol filter analyses

The particle mass obtained from the exposed filters will be analysed for sulphate, nitrate and chloride to estimate the likely percentage of secondary particles and their contribution to the overall PM_{10} annual concentration in Edinburgh.

Wind direction and PM_{10} concentrations

The direction of the wind may influence PM_{10} concentrations in Edinburgh; this is likely to be relevant with respect to long range transport of secondary particles. Therefore wind direction data obtained from the monitoring stations at Currie and Haymarket will be evaluated with matched PM_{10} data.

Relationship between NO_x and PM_{10} concentrations

Values of NO_X and PM_{10} concentrations at each site will be examined to establish whether or not there is any correlation associated with the two pollutants. Earlier work which was undertaken for Round 1 identified that the majority of NO_X emissions were attributed to road traffic.[5] Therefore if road traffic is significant in terms of PM_{10} concentrations a relationship should be apparent between the two pollutants. Diurnal patterns of NO_x, PM_{10} and traffic flow will also be studied.

4.Estimated UK government annual mean background PM_{10} maps accessed from the Internet site www.airquality.co.uk/archive/aqm/tools.php.
5.Review and Assessment of Air Quality in the City of Edinburgh Stage 1 and 2

Summary of the approach to the Detailed Assessment for PM_{10}

The approach to determine whether or not an AQMA for PM_{10} is required for Edinburgh and to evaluate the significant sources is outlined below:

- Co-location of a Partisol sampler and TEOM instrument at a roadside site to determine a local area gravimetric equivalence factor.

- PM_{10} concentrations will be monitored at an Urban/suburban background location to enable comparisons to be made with roadside measurements and determine more accurate background concentrations for the city.

- Assessment of new and historical monitoring data using the factor derived from the co located study and the general correction factor of 1.3.

- Assessment of road traffic using the DMRB model with adjusted background concentrations to identify any potential traffic related hot spots.

- Comparison between real time background data with roadside data to assess the influence of long range transport of $PM_{10.}$

- Correlation Studies with NO_X and PM $_{10}$ at background and roadside sites.

- Influence of wind direction on PM_{10} concentrations in Edinburgh.

- Exposed partisol filter analysis of sulphate, nitrate and chloride to assess secondary particle contribution.

2.2 Methodology for traffic related nitrogen dioxide at St John's Road

St John's Road is predicted to marginally exceed the nitrogen dioxide annual average objective at the junction of Clermiston Road based on passive diffusion tube measurements. However, an additional site at St John's road (513m west from Clermiston Road junction) currently meets the objective. The two sites are different, in that the former is located on the stretch of road, which forms a small canyon and is closer to residential properties, the other site is more open. Both locations experience slow moving traffic. It would be difficult to site an air quality monitoring station at the location of concern due to lack of pavement space and therefore additional passive diffusion tubes will be placed at the building facades of residential properties on both sides of the road carriageway.

A real time monitoring unit for nitrogen dioxide and particles was located at Roseburn Terrace 7.7 metres from the kerbside in July 2003; data from this unit will also be assessed.

Summary of approach to the detailed assessment for nitrogen dioxide at St John's Road:

- Further monitoring at residential building facades with passive diffusion tubes

- Assessment of new and old passive diffusion tube data in accordance with Technical Guidance LAQM. TG (03) document.

- Assessment of real - time monitoring data from new site at Roseburn.

Relevant Exposure

Local authorities are required to focus their reviews and assessments at locations where there is likely to be relevant public exposure. Thus, if there is no relevant public exposure than there is no requirement to progress any further. The guidance in TG (03) refers to public exposure for both short-term and long-term objectives. It is generally accepted that the pollution measured at the building façade will be similar to the concentration inside the building. Thus for exposure along a busy road it is considered to be appropriate to measure at the building façade of residential properties that are closest to the road to assess pollutants with 24- hour and annual mean objectives. All monitoring locations in Edinburgh are close to the facades of residential property. Where kerbside monitoring has been undertaken i.e. with respect to passive diffusion tubes, façade corrections have been applied.

3.0 Detailed Assessment of PM_{10}

3.1 Comparison study between a TEOM instrument and a Partisol

A Partisol 2025 sampler was located adjacent to Edinburgh's roadside air quality monitoring station at Haymarket Terrace. To ensure that the sampling head was raised above the height of the air quality monitoring station, the instrument was installed in a protective cage, which was mounted on a platform. The sampling heads of both instruments were approximately the same height and 1.5 metres apart. The arrangement is illustrated in photograph 1.

Photograph 1 TEOM Partisol sampler co located study at Haymarket.

Filter handling

Quartz fibre filters were used for the study. The filters were provided and weighed by Casella CRE Air laboratories. The laboratory operates a robotic system of weighing to reduce human error. Filters were conditioned for 48 hours pre and post exposure prior to weighing in accordance with LAQM. TG (03). The filters were dispatched in batches of sixteen, fourteen of which were exposed sequentially for a 24-hour period in the partisol unit. The remaining two filters were used as field blanks and were unexposed in the partisol unit.

The daily mass of PM_{10} material collected on the filters was reported in milligrammes (mg). The weights from the exposed filters were corrected to take account of the blank filter weights, which were specific to each filter batch. The corrected filter weights were divided by the volume of air which the partisol sampled during the period of filter exposure and multiplied by 1000 to provide a concentration in microgrammes per cubic metre $\mu g/m^3$.

Calculation (PM_{10} mass mg / volume of air) x 1000 = $\mu g/m^3$

160 matched daily pairs of TEOM and partisol data were gathered over the study period, 22nd January 2004 to 21st July 2004.

3.1.1 Data analysis

The matched daily pairs from the Partisol and TEOM were used to determine the difference between the two methods and consequently establish the factor required to provide a gravimetric equivalent for TEOM data at Haymarket. The daily average concentrations from the TEOM were only used if data capture was greater than 95%.

The results of the study are reported in table 3.1

Table 3.1 TEOM and Partisol co located study results

Study Period	**TEOM (T) $\mu g/m^3$**	**Partisol (P) $\mu g/m^3$**	**Factor (P/T)**
22/01/04 to 21/07/04	14.34	16.3	1.14

The matched data sets were evaluated to assess how well they correlated using scatter plots and daily values were compared graphically Fig 3.1 and Fig 3.2

All data for this study is shown in appendix 3
QC and QA procedures are detailed in appendix 1A

Fig 3.1 Correlation of PM_{10} matched daily data pairs obtained from the TEOM and Partisol 2025

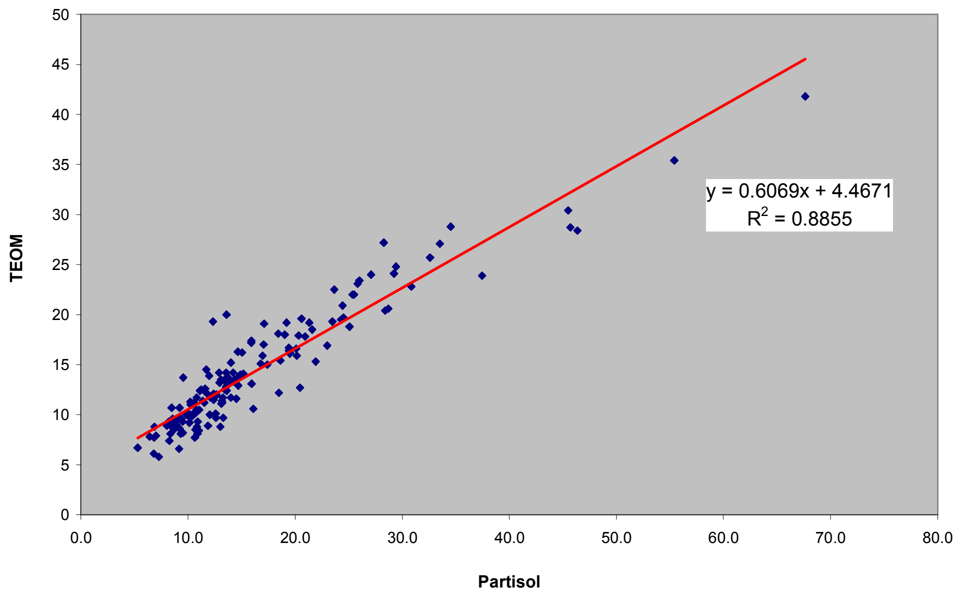

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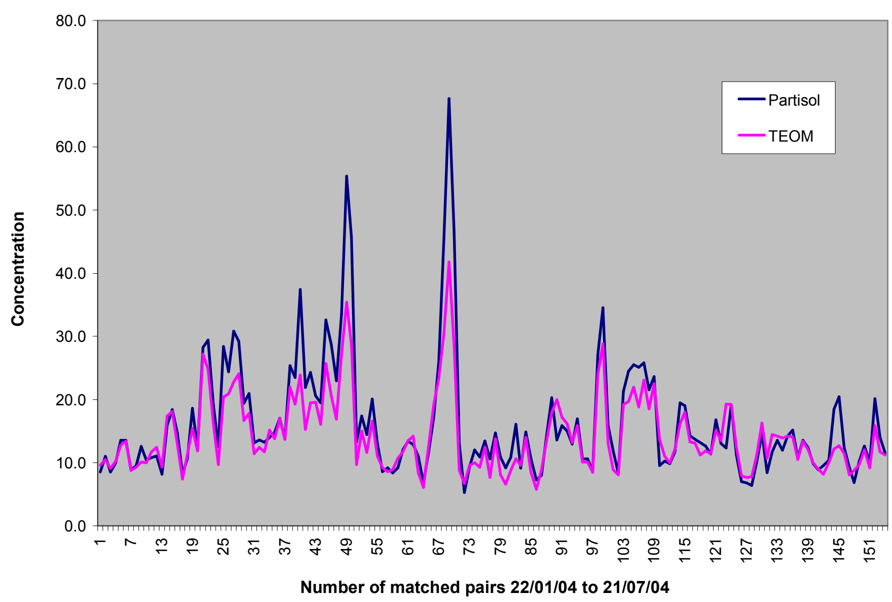
Fig 3.2 Comparison of matched Partisol and TEOM daily data from 22/01/04 to 21/07/04



3.1.2 Comparison study discussion

The study has shown that the Partisol 2025 sampler over reads the TEOM analyser by 14% giving a correction factor of 1.14 to be applied to the TEOM data. This factor is based on calculating the mean of the daily values of the matched pairs over the study period. When the factors for each of the paired daily means are averaged the factor is 1.10. The difference between the two instruments is greater when the concentrations of PM_{10} are exceptionally high. This may be due to particle water absorption or perhaps a greater contribution of sulphate and nitrate mass.

It would be a useful exercise to investigate the relationship between PM_{10} concentrations obtained from the Partisol sampler and humidity levels to assess the degree of particle bound moisture. However this investigation is beyond the scope of this report.

The scatter plot of the two methods of measurement gave a reasonable correlation of 0.89. It appears that the instruments correlate well with lower concentrations of PM_{10}

The difference between the two instruments on a daily basis ranged from 0.64 to 1.63. On a few occasions when daily PM_{10} concentrations were low, the TEOM instrument over read the Partisol sampler.

To err on the side of caution the factor of 1.14 was considered to be the most appropriate to equate the TEOM data to a gravimetric equivalent.

This factor is in keeping with a similar roadside study undertaken in London, which gave a factor of 1.15. (Personal communication)[6]

6 Richard Maggs Casella Stanger.

3.2 PM_{10} background monitoring study

3.2.1 Site description

The criteria required for establishing a background location for monitoring PM_{10} were discussed with the review and assessment help desk. The most important factors were that the site should not be effected by major sources of pollution and should be 500 metres from a major road. The location, which was considered to be suitable, was at the rear of Currie High School adjacent to residential properties. Currie is situated 16 km south west of the city centre; the area is described as suburban. The site is shown below in photograph 2 and map 2 Appendix 9.

Photograph 2 Background monitoring location at Currie

Grid reference:
Northing 317595
Easting 667908

The distance of the Air quality monitoring unit at Currie High School in relation to major roads and their respective annual average daily traffic (AADT) are shown in table 3.2

Table 3.2 Proximity of background site to major roads

Road	Distance from monitoring site	AADT count
A71	1000m	36280
A70	438m	23654
City By Pass	2932m	64605

3.2.2 Background monitoring data

PM_{10} was measured using the TEOM method. For the purpose of this exercise the TEOM data was multiplied by the general factor of 1.3 to provide a gravimetric equivalent.

The monitoring period for the assessment of background levels was from 16th January 2004 to 31st July 2004. When data has not been collected for a full calendar year there is a requirement to adjust this data to provide an estimated annual equivalent. The approach to the estimation of annual mean PM_{10} concentrations from short term monitoring data is detailed in the technical guidance document LAQM TG(03); Box 8.5.

Using the above approach, the adjustment factors for Edinburgh vary from year to year. This issue was discussed with the review and assessment help desk and it was suggested that a factor of 1 should be used to estimate the annual average based on the seven months of monitoring data gathered. The annual adjustment factors for Edinburgh sites and Loch Navar (rural background) are tabulated in appendix 2

Corrected monitoring data for the Currie background site is shown in table 3.3

Table 3.3 Data obtained from background site at monitoring unit at Currie High School

Monitoring period	TEOM µg/m^3 PM_{10}	Estimated 2003 TEOM	Estimated 2003 PM_{10} grav annual mean µg/m^3
16/01/04 to 31/07/04	9.3	9.3 x 1 = 9.3	9.3 x 1.3 = 12
16/01/04 to 31/12/04*	9.2	9.2 x 1 = 9.2	9.2 x 1.3 = 11.9
Data capture	95% 16/01/04 to 31/07/04		

* Data ratified to 31/08/04.

NOTE : The extended monitoring at Currie to December 2004 shows that the PM_{10} data remains unchanged.

All QC/ QA proceedures are detailed in appendix 1A

3.2.3 Determining PM_{10} 2010 background concentrations for Edinburgh

The modelled background values for 2010 PM_{10} concentrations obtained from the UK Air Quality maps indicate that the majority of areas within Edinburgh will be at or close to the objective. Monitoring at Currie has demonstrated that the concentration obtained from this typical suburban/urban background site is much lower (20%) than the estimated values for 2010 at the same location.

1km square estimated values 2010 Grav = 15.0
1km square measured value 2004 Grav = 12.0

Guidance was sought from the Review and Assessment help desk regarding the most appropriate method of extrapolating the measured data to provide more reliable background values for the remaining areas of Edinburgh. The factor for estimating PM10 values based on the measured data for 2004 at Currie is shown below:

12/15 = 0.8

Using this factor to multiply the original values on the 1km air quality map the estimated predicted values for 2010 range from 11 to 15µg/m^3 compared with the previous values of 14 to 19µg/m^3. The adjusted background concentrations have not been estimated to the year 2010 and therefore give a more conservative approach. The concentrations are shown below:

Old values	Adjusted values
19 x 0.8	= 15.2 µg/m^3
18 x 0.8	= 14.4 µg/m^3
17 x 0.8	= 13.6 µg/m^3
16 x 0.8	= 12.8 µg/m^3
15 x 0.8	= 12.0 µg/m^3
14 x 0.8	= 11.2 µg/m^3

The original estimated background maps and adjusted background maps from the measured data obtained from the monitoring station at Currie High School are shown in fig 3.3 and fig 3.4 respectively.

3.2.4. Discussion of background adjusted data

It is considered that the UK netcen modelled PM_{10} 2010 background values for Scotland are high and that the Scottish Executive should assemble data to look at this issue. It is also preferable to use measured data where possible, rather than the UK modelled estimated concentration maps. Personal communication.[7]

The values extrapolated from the measured data at the Currie background site are therefore more representative of what concentrations are likely to be in Edinburgh and the surrounding area in 2010.

The adjusted background values will be used in the screening model DMRB to assess the impact of road traffic in Edinburgh where measured data is unavailable.

There is a lack of background and rural monitoring locations throughout the UK, which has been highlighted in the draft document, Particulate Matter in the United Kingdom by the Air Quality Expert Group. Therefore this site will be retained to enable further data to be assembled.

7 Tim Chatterton Air Quality Review and Assessment Help Desk University West Of England and Duncan Laxan Air Quality Consultants.

Fig 3.3 Estimated annual mean background PM_{10} concentrations for 2010 from UK maps

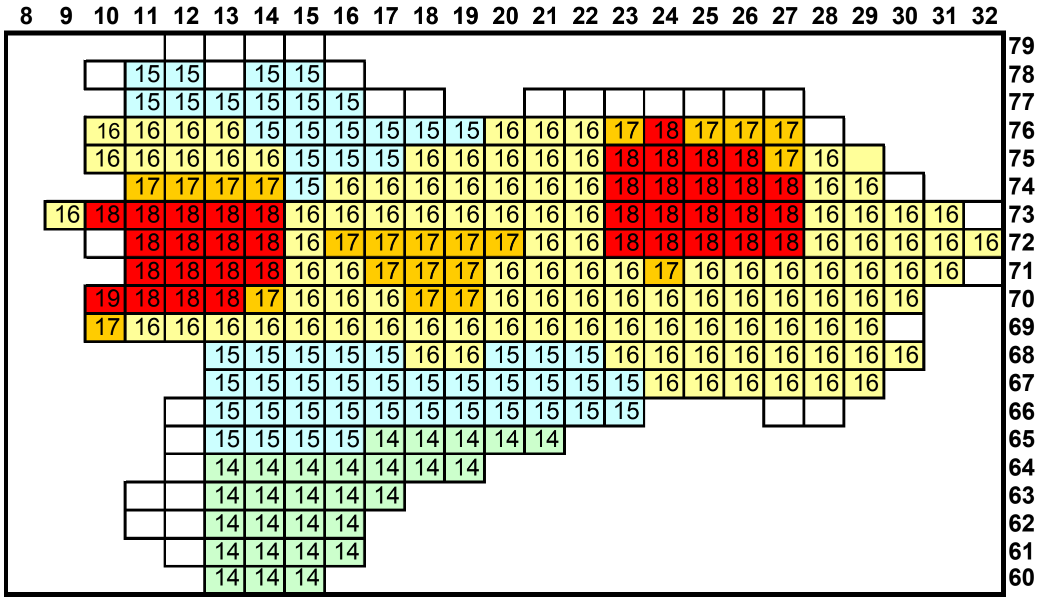
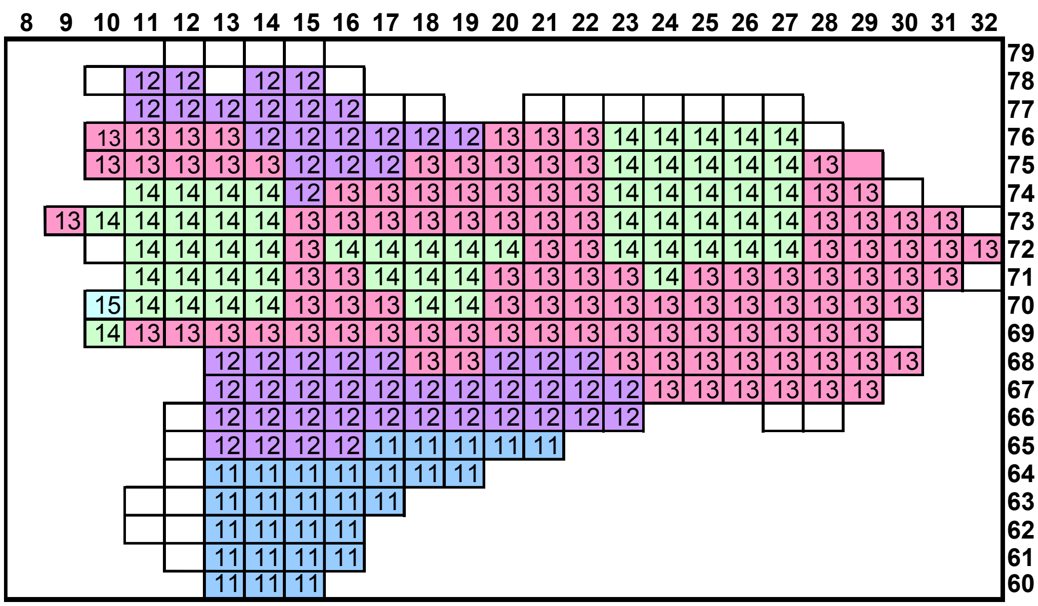


Fig 3.4 Adjusted PM_{10} background concentrations for 2010 using measured data from Currie High School.



3.3 PM10 monitoring data

3.3.1 Description of monitoring locations

Princes Street Gardens (Edinburgh Centre)

The air quality monitoring station in Princes Street Gardens is described as an urban centre; it is part of the national network. The site was established in 1993. Unfortunately, the PM_{10} data from this location has been compromised since January 2000, due to dust emissions from major construction work at the adjacent National Art Gallery.The expansion of the galleries resulted in the decommissioning of the station in 2002. To ensure continuity of data, a mobile monitoring unit was temporarily located closer to the roadside on Princes Street, until a new permanent site could be found. However, the monitoring unit was moved to facilitate the Edinburgh Hogmanay events and data was not gathered for the months April, November and December 2002. Additional work in Princes Street Gardens was scheduled for 2003, consequently data was only gathered for May and June of that calendar year.

West Richmond Street Gardens (Edinburgh St Leonards)

A new location for the national network site was established at West Richmond Street Gardens (Edinburgh St Leonards). Department for Environment, Food and Rural Affairs (Defra) commissioned the site in January 2004. It is south of the city centre, located in a small car park of a Medical Centre (GP surgery) surrounded by residential properties and 45 metres from a busy road. It is described as an urban centre.

Haymarket Terrace

The air quality monitoring station at Haymarket Terrace is located in a car parking area of Haymarket Station. The unit is line with the façade of adjacent residential tenement property and is 5.5 metres from the main road. Haymarket Terrace has an AADT of approximately 26,000 and a high percentage of bus movements. The total percentage of HGVs is 15%. The site is described as a roadside location and monitoring commenced in 1999.

Queen Street / North Castle Street

The air quality-monitoring unit is situated at North Castle Street at the junction of Queen Street. It is line with the façade of adjacent residential tenement property and is 5.8 metres from the road. There is no vehicle access from North Castle Street to Queen Street. Queen Street is the busiest main traffic route through the city centre. The AADT is in excess of 37,000 vehicles and the total percentage of HGVs is 2%. This site is described as a roadside location and monitoring commenced in 1999.

Roseburn Terrace

This site was established in July 2003. The air quality monitoring unit is 7.7 metres from the road and is located in a residential area on a footbridge over the Water of Leith close to traffic lights and residential tenement property. The road (A8) is one of the main traffic routes to the west of the city. The site is described as a roadside location. Monitoring commenced in July 2003. The TEOM instrument was removed in January 2004 and installed in the monitoring unit at Currie to enable background data to be assembled.

Currie High School

This site was established in 2004 to monitor background concentrations for the Detailed Assessment report. It is situated in an open location at the rear of Currie High School close to residential property on the outskirts of the city. It is described as a suburban background location.

All real time monitoring locations are shown in Map 3

3.3.2 Monitoring data and air quality objective comparisons.

Air Quality Objectives:

An annual mean of 18 μg/m^3 (gravimetric) to be achieved by the end of 2010 Scotland only

A 24-hour mean of 50 μg/m^3 (gravimetric) not to be exceeed more than 7 times per year by the end of 2010

The above air quality objectives are based on indicative Stage 2 values set by the EU and have been adopted by the Scottish Executive and incorporated into the Air Quality (Scotland) Amendment Regulations 2002.The annual mean for Scotland is more onerous than the indicative level of 20 μg/m^3 advised by the EU. The Stage 2 values are considered to be more stringent and have yet to be incorporated into regulations in England, Wales and Northern Ireland. Therefore it is only Scottish Local Authorities who are required to consider the new objectives for Round 2 of the review and assessment process.

An annual mean of 40 μg/m^3 (gravimetric) to be achieved by the end of 2004

A 24 hour mean of 50 μg/m^3 (gravimetric) not to be exceeded more than 35 times by the end of 2004

The above air quality objectives which have been adopted by the Government and the Devolved Administrations and are equivalent to the EU Stage 1 limit values.

Monitoring data

Gravimetric equivalence factors 1.3 and 1.14 for each site and calendar year of monitoring have been applied to the annual PM_{10} TEOM measured concentrations. The number of daily exceedences has been calculated using the 1.3 factor. Where data has not been collected for a full calendar year a factor of 1 has been used to adjust 2003 and 2004 data to provide estimated annual values as detailed in section 3.2.

TEOM data corrected to the EU gravimetric equivalent from monitoring locations is shown in tables 3.4 to 3.9

Table 3.4 Princes St Gardens PM_{10} annual mean values and number of daily exceedences

Princes St Urban centre	**1998**	**1999**	**2000**	**2001**	**2002**
TEOM µg/m^3	15	15	18	20	21
1.3 grav	19.5	19.5	23.4	26	27.3
1.14 grav	17.1	17.1	20.5	22.8	23.9
No of daily exceedences (1.3)	1	3	4	10	14

Table 3.5 St Leonards PM_{10} annual mean values and number of daily exceedences

St Leonards Urban Centre	**2004 01/01/04 to 31/07/04**	**2004* 01/01/04 to 31/12/04**
TEOM µg/m^3	14.5	14.6
1.3 (grav)	18.9	19.0
1.14 (grav)	16.5	16.6
No of daily exceedences (1.3)	0	0

* Data provisional from July 2004

Table 3.6 Haymarket Terrace PM_{10} annual mean values and number of daily exceedences

Haymarket Terrace Roadside	**1999**	**2000**	**2001**	**2002**	**2003**	**2003/4***	**2004****
TEOM µg/m^3	16.1	15.3	16.9	17.7	17.4	14.6	14.4
1.3 grav	20.9	19.9	22.0	23.0	22.6	18.9	18.7
1.14 grav	18.3	17.4	19.3	20.2	19.8	16.6	16.4
No of daily exceedences (1.3)	7	0	5	8	15	2	1

* Data from 01/08/03 to 31/07/04
** Data estimated for calendar year monitoring period 01/01/04 to 31/07/04

Table 3.7 North Castle Street / Queen Street PM_{10} annual mean values and number of daily exceedences

North Castle Street/Queen St Roadside	**1999**	**2000**	**2001**	**2002**	**2003**	**2003/4***	**2004****
TEOM µg/m^3	16.9	15.4	17.6	17.7	18.5	15.5	15.2
1.3 grav	22.0	20.0	23.0	23.0	24.1	20.1	19.8
1.14 grav	19.3	17.5	20.1	20.1	21.1	17.7	17.3
No of daily exceedences(1.3)	6	0	7	11	22	3	2

* Data from 01/08/03 to 31/07/04
** Data estimated for calendar year monitoring period 01/01/04 to 31/07/04

Table 3.8 Roseburn Terrace PM_{10} annual mean values and number of daily exceedences

Roseburn Terrace Roadside	**2002 estimated 18/07/03 to 31/12/03**
TEOM $\mu g/m^3$	15.2
1.3 (grav)	19.8
1.14 (grav)	17.3
No of Exceedences (1.3)	1

Table 3.9 Background data Currie PM_{10} annual mean values and number of daily exceedences

Currie Background	**2003 estimated 16/01/04 to 31/07/04**
TEOM $\mu g/m^3$	9.3
1.3 (grav)	12.0
1.14 (grav)	10.6
No of Exceedences (1.3)	0

All TEOM data used in this report has been ratified to 31/07/04 . Data capture was greater than 90% . Appendix 4
QC/QA protocol is detailed in appendix 1A

PM_{10} concentrations from the Partisol sampler Haymarket

The PM_{10} concentrations measured by the partisol sampler at Haymarket are shown in table 3.10. The monitoring was extended until 02/08/04. Unfortunately filter blanks were not provided for this exposure period and TEOM data was not gathered due to a data logger fault.

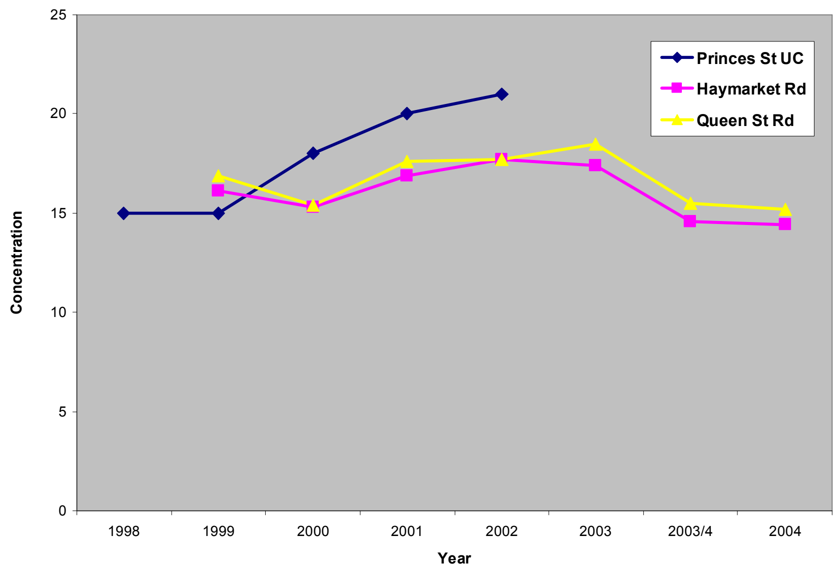
Table 3.10 Partisol sampler Haymarket Terrace.

Monitoring Period	**PM_{10} $\mu g/m^3$ grav**	**No exceedences**
22/01/04 to 21/07/04	16.3	2
22/01/04 to 02/08/04	17.1	2

Assessment of PM_{10} TEOM data trends

Data trends in Edinburgh from 1999 to 2004 at the roadside sites, Haymarket and Queen Street show a rise in PM_{10} (TEOM) concentrations for the years 2001, 2002 and 2003. Pollution levels were considered to be exceptionally high throughout the UK for 2003. High levels of PM_{10} were noted for the months of February, March and April at most monitoring networks including Loch Navar, a rural location in Northern Ireland, which may be a result of long range transport or unusual persistent meteorological conditions. The elevated concentrations over the three months will have given rise to a higher annual mean and exceedences of the daily mean. Data gathered after the month of April 2003 is much more in keeping with the two roadside locations. Data trends for the established sites are shown in fig 3.5

Fig 3.5 Comparison of annual meanTEOM data µg/m³ gathered from an urban centre and two roadside locations in Edinburgh from 1998 to 2004



A local factor, which may also have contributed to the apparent increase, is dust from widespread construction work in the city centre. The fact that levels increased significantly (40%) during the period 2000 to 2002 at Princes Street Gardens when the national trend is showing a decline, demonstrates that that the nearby reconstruction of the National Galleries has had a significant impact at this location. Construction work and activities which are likely to have resulted in increased dust emissions are shown in table 3.11.

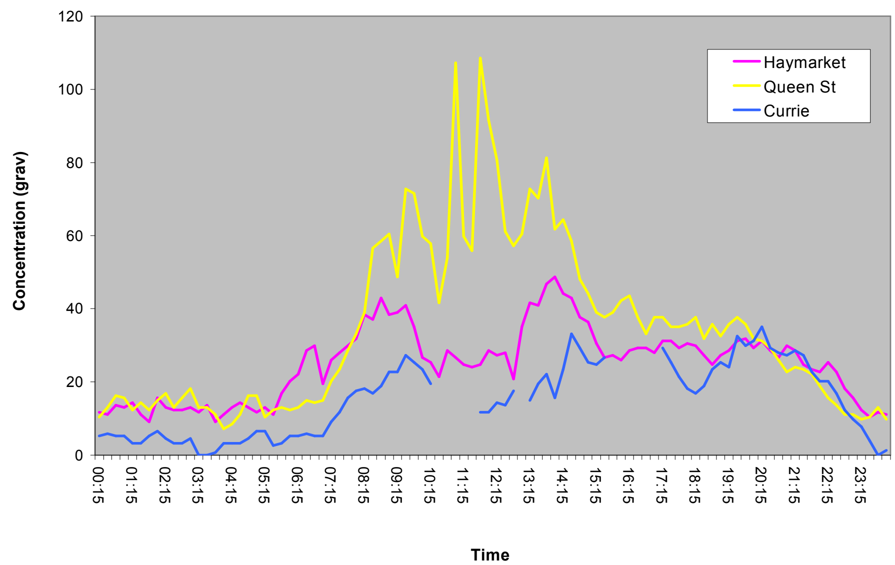
Table 3.11 Construction and activities likely to generate dust emissions

Location	Activity	Year	Distance AQ unit
Princes Street	Reconstruction Galleries	2000/04	5m
Princes Street	Demolish C&A	2002/03	40m
Haymarket Terrace	Office block construction	2002/03	20m
North Castle St	Stone replacement tenement	2001	20m
North Castle St/Queen St	Pavement replacement*	2002	5m
Queen Street	Resurfacing Rd	2002	6m
Haymarket /Dalry	Construction Housing dev	2001	110m

* The highest hourly mean PM_{10} recorded during stone cutting was 899.5 µg/m³

Higher PM_{10} concentrations have recently been recorded at the Queen Street monitoring unit due to renovation works at an adjacent top storey flat. Dust emissions were evident during a site visit on 14/10/04. The effect which this has had on the daily PM_{10} concentrations is illustrated in fig 3.6

Fig 3.6 Effects of construction activity at Queen Street on PM_{10} concentrations 14/10/04 (15 minute means)



Daily concentrations from the roadside locations at Queen Street and Haymarket are similar and tend to follow an identical trend. The graph shows elevated values at Queen Street, which is out of keeping for this location. The daily mean at Queen Street is 38% greater than the daily mean for Haymarket. PM_{10} concentrations are shown in table 3.12

Table 3.12 Effects of construction site dust on PM_{10} concentrations at Queen Street.

14/10/04		Haymarket 1.3	Haymarket 1.14	Queen Street 1.3	Queen Street 1.14	Currie 1.3	Currie 1.14
Daily mean	μg/m³ grav	25.0	21.9	34.5	30.1	16.5	14.5
Max 15 min	μg/m³ grav	48.8	42.8	108	95.0	35.0	30.1
Min 15 min	μg/m³ grav	9.1	8.0	7.15	6.3	0.7	0.6

3.3.3 Evaluation of 2010 PM_{10} concentrations and data discussion.

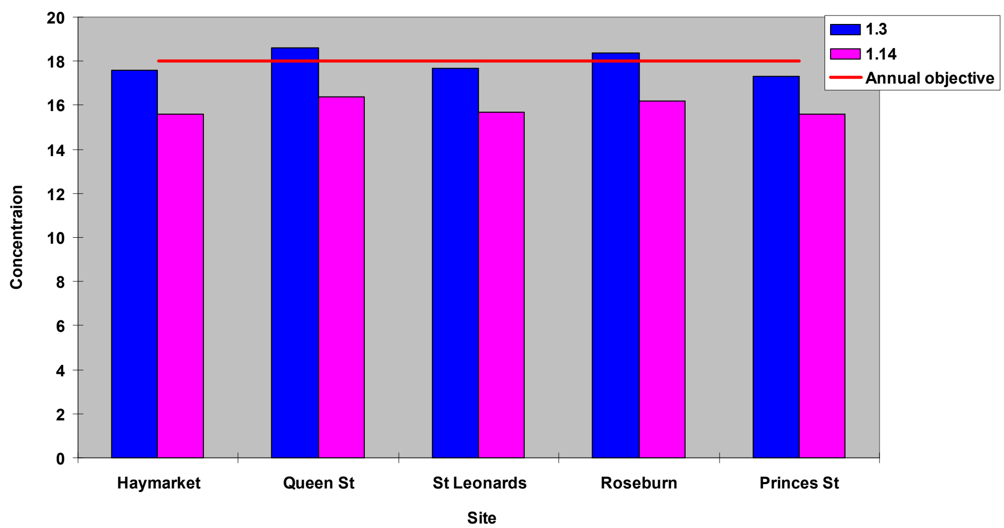
Particle emissions from road transport and industry are expected to decline in future years as a result of EU legislation and National policies. Therefore levels of PM_{10} are likely to be lower by 2010. To estimate future concentrations current monitoring data, was adjusted to the target year of 2010 for secondary and primary combustion PM_{10} using guidance in Box 8.6 and the relevant factors in Box 8.7 LAQM TG (03). Projected values were estimated on both sets of data calculated from the gravimetric equivalent factors 1.3 and 1.14. Partisol data was also adjusted to the target year. Due to issues associated with construction dust at the Princes Street site 1999 values were used to estimate PM_{10} to 2010. An example of the calculation and factors used are detailed in appendix 5

The 2010 estimated concentrations for all sites are shown in table 3.13 and fig 3.7

Table 3.13 Estimated annual mean 2010 PM_{10} concentrations for all montitoring sites adjusted from 2003/4 monitoring data.

Site	Monitoring period	2003/4 PM_{10} µg/m^3		2010 PM_{10} µg/m^3	
		PM_{10} 1.3	PM_{10} 1.14	PM_{10} 1.3	PM_{10} 1.14
Princes St Gardens	01/01/99 to 31/12/99	19.3	17.1	17.3	15.6
St Leonards	01/01/04 to 31/07/04	18.9	16.5	17.7	15.7
Haymarket	01/08/03 to 31/07/04 01/01/04 to 31/07/04	18.9 18.7	16.6 16.4	17.8 17.6	15.7 15.6
Queen St	01/08/03 to 31/07/04 01/01/03 to 31/07/04	20.1 19.8	17.7 17.3	18.8 18.4	16.7 16.4
Roseburn	18/07/03 to 31/12/03	19.8	17.3	18.4	16.4
Partisol Haymarket	22/01/03 to 02/08/04	17.1		16.2	

Fig 3.7 Estimated 2010 PM_{10} annual mean concentrations µg/m^3 at Edinburgh monitoring sites



All current monitoring PM_{10} concentrations that have been adjusted using the 1.14 gravimetric equivalent correction factor meet with the air quality objectives and therefore are likely to meet in 2010. The PM_{10} concentrations that have been corrected using the general 1.3 gravimetric equivalent do not currently meet, but are likely to meet by 2010 if current projections are correct. It is considered that Queen Street marginally exceeds the annual average using the 1.3 factor. However PM_{10} concentrations using the partisol sampler currently meet and are estimated to meet by 2010 at Haymarket.The difference between the annual means at each location is not more than 1µg/m^3. Therefore it can be assumed that all sites are likely to meet the objectives based on the gravimetric monitoring.

4.0 Sources of particles PM_{10} in Edinburgh

4.1 Particle component.

The particle components of PM_{10} are complex, comprising of natural and manmade sources. Natural sources, which contribute to PM10 concentrations in the UK, are sea salt, wind blown soil, sand, dust and biological matter such as pollen. Manmade sources are derived from the combustion of fossil fuel, road traffic emissions, construction activities and quarrying processes.

The emission sources can be divided into 3 main categories:

Primary particles	- Combustion sources including road traffic and power generation.
Secondary particles	- Formed by chemical reactions in the atmosphere largely in the form of sulphates and nitrates.
Coarse particles	- Wide range covering resuspended dust from road traffic - Construction site works. - Mineral extraction processes i.e. quarries. - Wind blown dusts and soils. - Sea salt and biological particles.

In terms of the review and assessment of PM_{10}, local authorities are advised to focus their efforts on the identification of the contribution of local sources to the overall PM_{10} concentrations if an exceedence is likely. Although Edinburgh is likely to comply with the air quality objectives a number of sources have been considered which will be examined in this section.

Edinburgh is a smoke-control area; therefore local domestic coal burning is not likely to be a significant source of PM10.

Construction site dust has been identified as influencing PM_{10} concentrations, which has been discussed at length in section 3.3.2

Other sources, which will be investigated and estimated, are traffic emissions, quarrying, secondary particle composition and the contribution of transboundary particles.

4.2 Estimating traffic associated PM_{10} concentrations using the DMRB model

The DMRB model version 1.02 (November 2003) was used to estimate traffic related sources of PM_{10}. Roads were selected that have an excess of 10,000 vehicles AADT and where relevant public exposure is within 10 metres of the kerb. The adjusted PM_{10} background concentrations for Edinburgh were used in the DMRB model. Predicted 2010 concentrations are shown in tables 4.2 and fig 4.1. Where measured data is available comparisons have been made with modelled values obtained from the DMRB model Table 4.1.

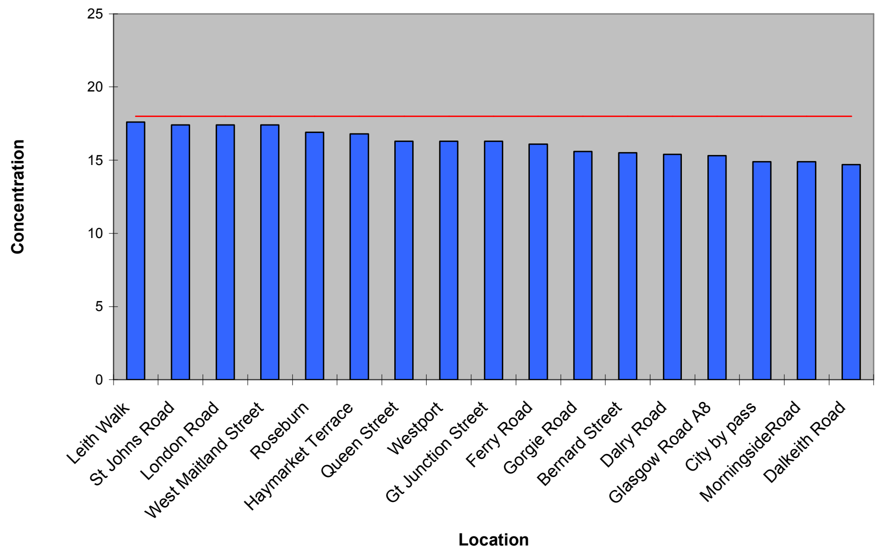
Table 4.1 Comparison of predicted 2010 PM_{10} annual mean concentrations and values derived from the DMRB model.

Monitoring Location	Predicted annual average 2010 PM_{10} concentrations based on measured data µg/m³ (1.14)	Predicted 2010 PM_{10} based on DMRB model µg/m³			
		Annual mean	**Bk ground**	**Road traffic component**	**expected exceedences**
Queen Street	16.4	16.3	14.4	1.87	0
Haymarket Terrace	15.6	16.8	12.8	3.99	1
Roseburn	16.4	16.9	12.8	4.14	1

Table 4.2 DMRB model estimated 2010 PM_{10} annual mean concentrations µg/m³ at relevant receptors

Location	**2010 Annual mean**	**Expected Exceedences**
City By Pass	14.9	0
Glasgow Road A8	15.3	0
St Johns Road	17.4	1
Leith Walk	17.6	1
London Rd	17.4	1
Ferry Road	16.1	0
West Maitland St	17.4	1
Westport	16.3	0
Bernard St	15.5	0
Gorgie Rd	15.6	0
Dalry Rd	15.4	0
Dalkeith Road	14.7	0
Gt Junction Street	16.3	0
Morningside Road	14.9	0

Fig 4.1 DMRB modelled 2010 PM_{10} annual mean concentrations µg/m^3 at a number of locations compared to the annual average air quality objective.



Raw data, which was used in the DMRB model, is tabulated in appendix 7.

Comments

The DMRB modelled PM_{10} concentrations at the 'worst case' selected locations in Edinburgh are likely to meet with the 2010 air quality objectives. PM_{10} concentrations range from 17.6 to 14.9 µg/m^3. The DMRB model is considered to provide a conservative assessment and therefore the modelled concentrations will be higher. To err on the side of caution the adjusted background PM_{10} concentrations were not estimated to 2010. Projecting the concentrations to 2010 would lead to lower predicted background levels across the city. The subsequent use of lower background data in the DMRB model would have given lower modelled PM_{10} concentrations.

4.3 Reassessment of Hillwood Quarry

The U&SA identified that the quarry at Hillwood required further assessment based on the UK modelled background concentrations of PM_{10}. The criteria in LAQM TG (03) document for assessing the likely impact from quarries is detailed below in table 4.3

Table 4.3 Assessment criteria requirement for quarries

Relevant exposure from Source distance in metres	2004 PM 10 background level μg/m^3	2010 PM10 background level μg/m^3
1000 or > than	No reqirement to proceed to a detailed assessment (DA)	
400 - 1000	< 27 No requirement for DA	< 17 No requirement for DA
200 - 400	< 26 No requirement for DA	< 16 No requirement for DA

For this assessment, distances from the quarry operations to the nearest relevant receptor were measured using the Geographical Information System (GIS).
Quarrying operations require to be assessed if the 2010 PM_{10} background concentration is 16 μg/m^3 or greater. The remodelled background concentration for this location is 14.4 μg/m^3 therefore it can be assumed that quarrying activities at Hillwood are not likely to result in any exceedences of the air quality objectives. Table 4.4

Table 4.4 Hillwood quarry assessment

Quarry location	Closest relevant exposure	PM_{10} background μg/m^3 2004	2010	2010 adjusted
Hillwood	Hillwood N 313253 Cottage E 671963 232 metres from source	19	18	14.4
2004 & 2010 background concentrations derived from Netcen modelled map (Fig 3.3) 2010 adjusted background concentrations derived from measured data at background site (Fig 3.4)				

4.4 Comparison of PM_{10} concentrations at background and roadside locations.

The daily average PM_{10} concentrations at Currie (background), Haymarket and Queen Street (roadside) locations follow an identical trend over the monitoring period January to July 2004. Figs 4.2 and 4.3.

Fig 4.2 Comparison of daily PM_{10} (grav) concentrations µg/m^3 from January to April 2004 at roadside and background sites in Edinburgh.

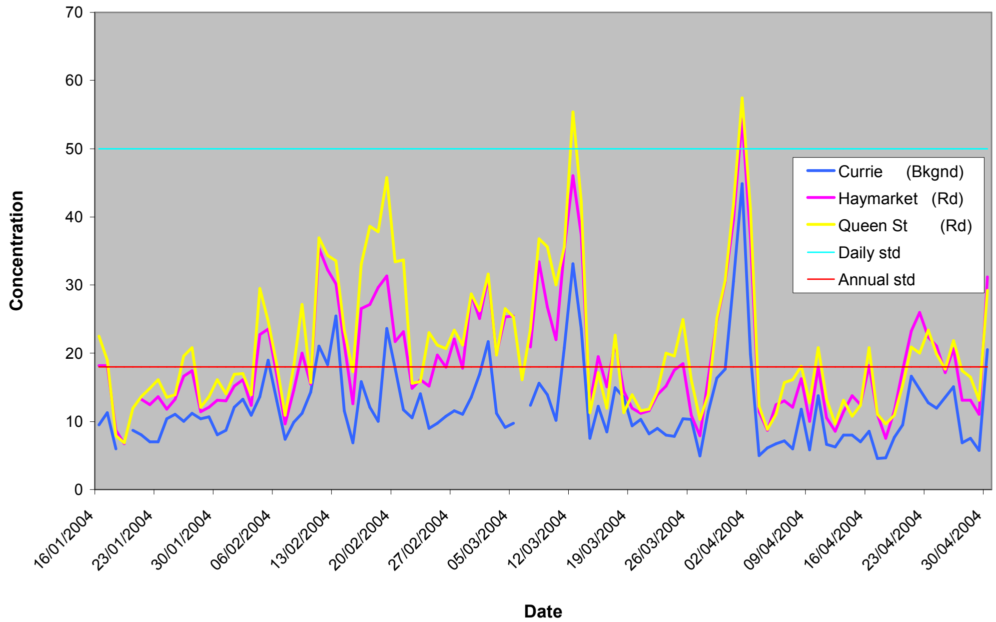
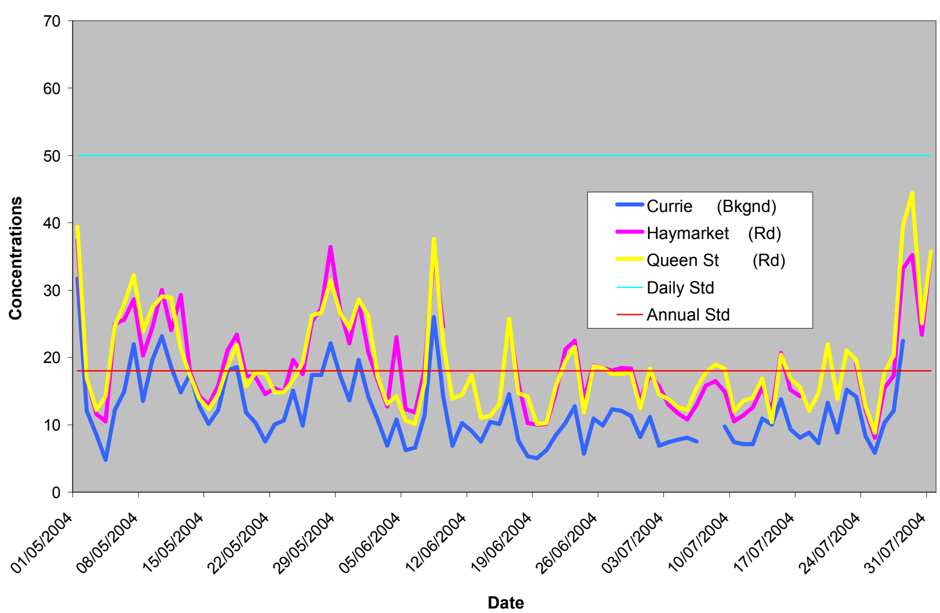


Fig 4.3 Comparison of daily PM_{10} (grav) concentrations µg/m^3 from May to July 2004 at roadside and background sites in Edinburgh



The trend is also evident when assessing 15-minute concentrations and hourly concentrations. Examples are shown in Figs 4.4 to fig 4.

Fig 4.4 Comparison of 15 minute PM_{10} (grav) concentrations μg/m^3 at roadside and background sites 1st to 2nd May 2004

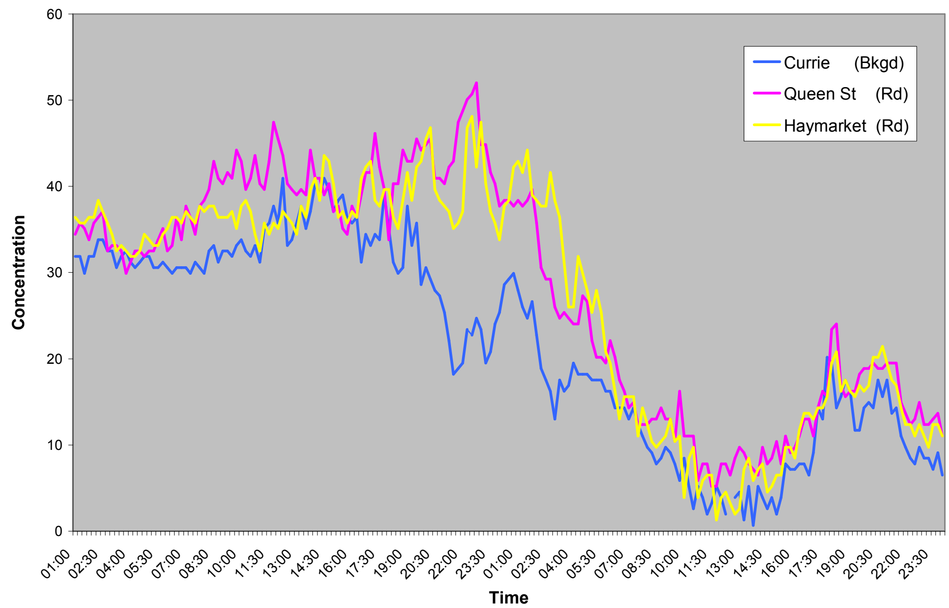


Fig 4. 5 Comparison of 15 minute PM_{10} (grav) concentrations μg/m^3 at roadside and background sites on the 8th June 2004

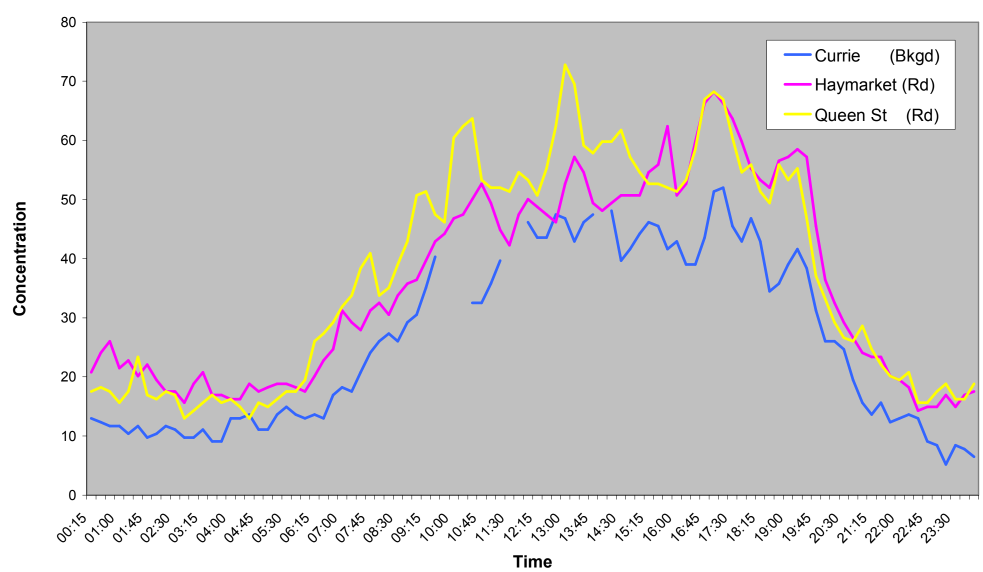
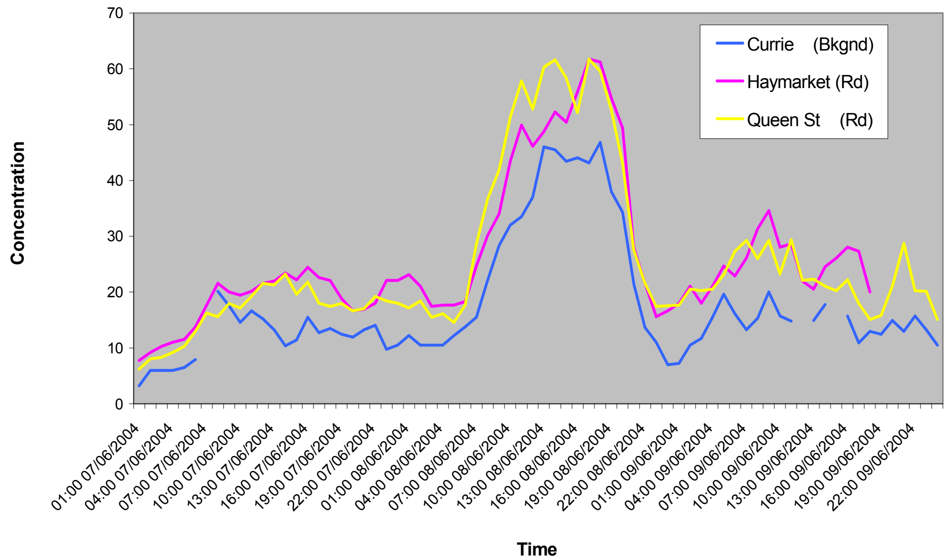


Fig 4. 6 Comparison of hourly PM_{10} (grav) concentrations µg/m^3 at roadside and background sites 7th June to the 9th of June 2004



The data represented in the above graphs shows a strong relationship between the background sites and the city centre roadside locations indicating that PM_{10} concentrations in Edinburgh are not all locally derived.

4.5 Diurnal variation of PM_{10}, NO_x and traffic flows

The diurnal variation of PM_{10} and NO_x for the month of May was investigated at two locations, Haymarket (roadside) and at Currie (background). Hourly means for the hours 01:00 to 24:00 were averaged over the period of 1st to 31st of May for both pollutants. Similarly, hourly averages for the traffic flows at Haymarket were averaged over the same time period. All concentrations are in µg/m^3 and PM_{10} concentrations are expressed as a gravimetric equivalent. The diurnal trends are represented in fig 4.7 to fig 4.9.

Fig 4.7 Diurnal variation of NO_x and PM_{10} concentrations µg/m^3 at Haymarket (roadside) and Currie (background) locations for May 2004

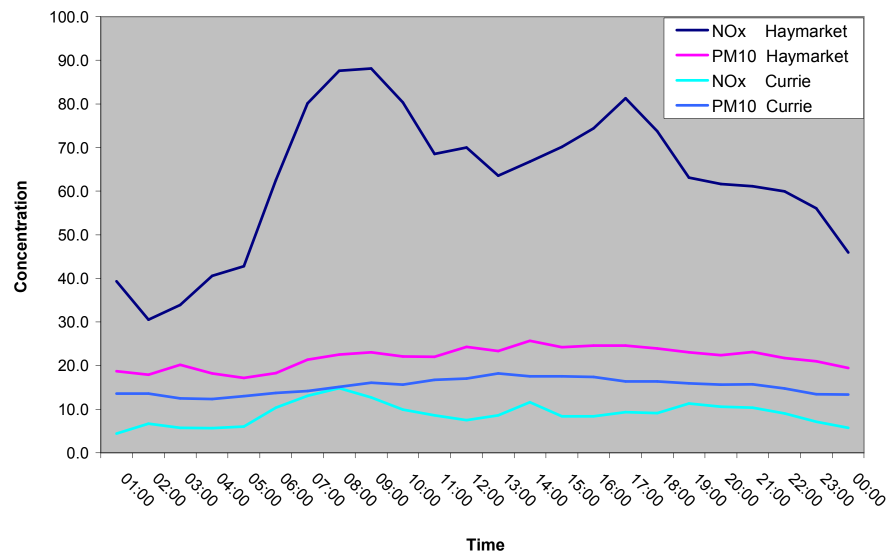


Fig 4.8 Diurnal traffic flow and NOx concentrations µg/m^3 at Haymarket for May 2004

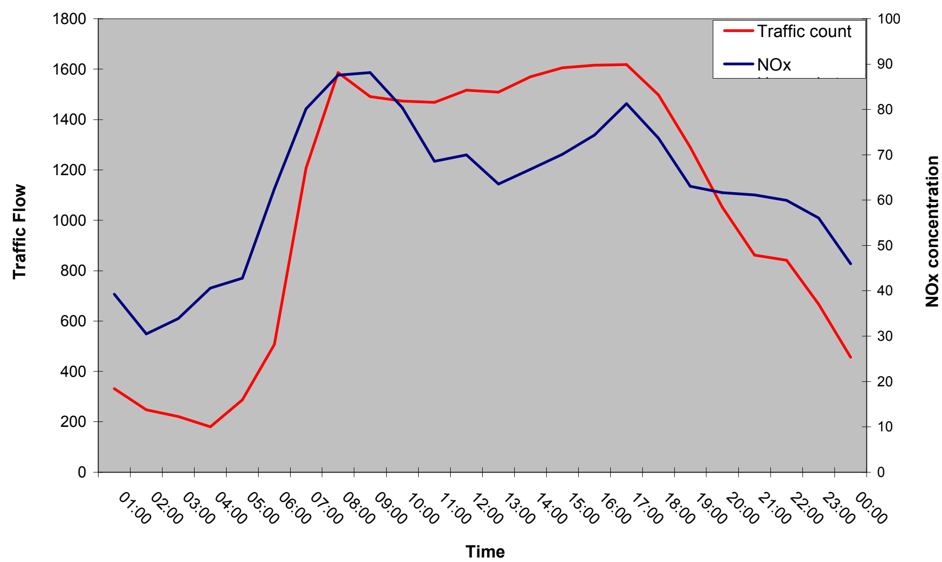
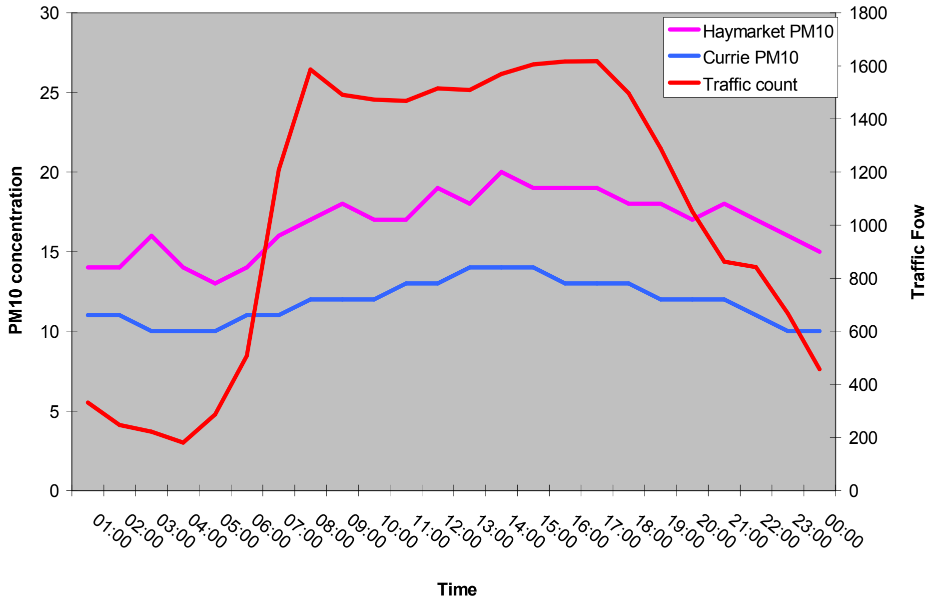


Fig 4.9 Diurnal traffic flow and PM_{10} concentrations µg/m^3 at Haymarket (roadside) and diurnal PM_{10} concentration µg/m^3 at Currie (background) for May 2004.



The graphic representations show well defined NO_x am and pm peaks for the Haymarket roadside site which coincides, with peaks associated with typical daily traffic flows. As one would expect, levels of NO_x at the Currie background site are relatively low and do not demonstrate any significant daily variation.

The diurnal PM_{10} concentrations at both roadside and background locations show that levels increase during the day. Maximum concentrations occur approximately at midday to 14:00 hours. Whereas the am and pm peak traffic flows occur at 07:00 and 17:00 hours respectively.

One would expect the diurnal PM_{10} concentration pattern to be similar to that of NO_x if this pollutant were essentially derived from traffic emissions

4.6 NO_x and PM_{10} correlation studies

Earlier reports have shown that the majority of NO_2 concentrations in Edinburgh are derived from NOx emissions, which originate from road traffic.

Therefore, if the majority of PM_{10} concentrations were from road traffic emissions a relationship between NOx and PM_{10} concentrations would be apparent. The relationship between NOx and PM_{10} at Currie, Haymarket and Queen Street is shown in figs 4.9 to 4.11.

Fig 4.9 Correlation of daily NO_x and PM_{10} concentrations µg/m^3 at Queen Street /North Castle St (roadside) January to July 2004

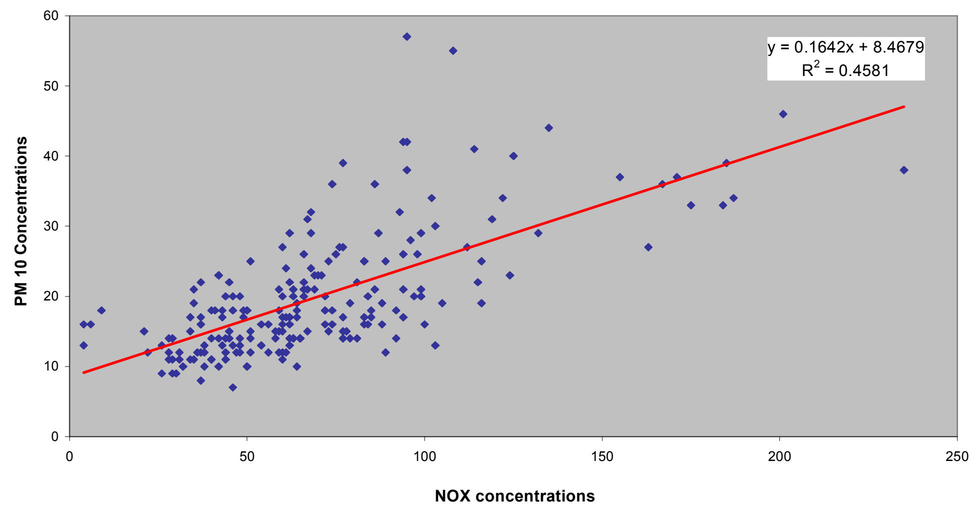


Fig 4.10 Correlation of daily NO_x and PM_{10} concentrations µg/m^3 at Haymarket (roadside) January to July 2004

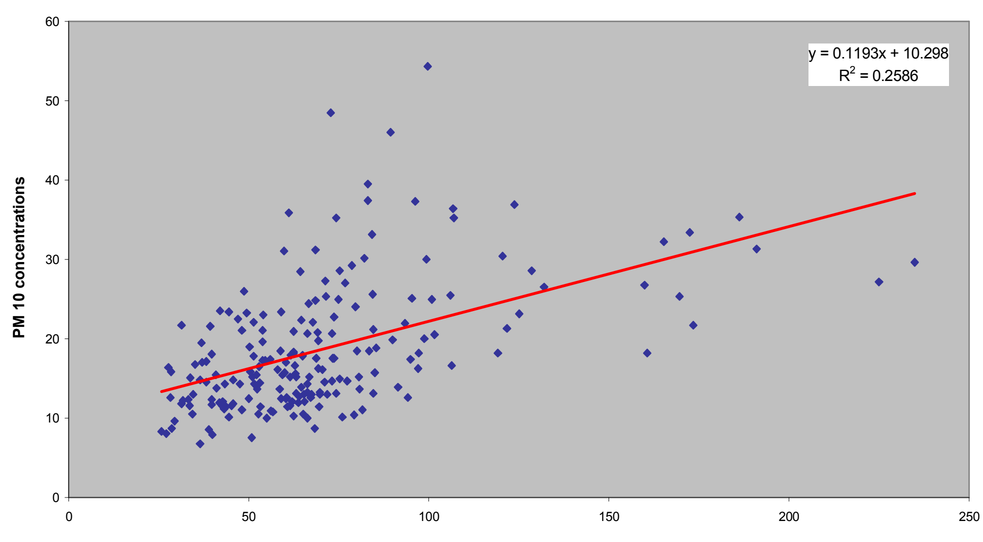
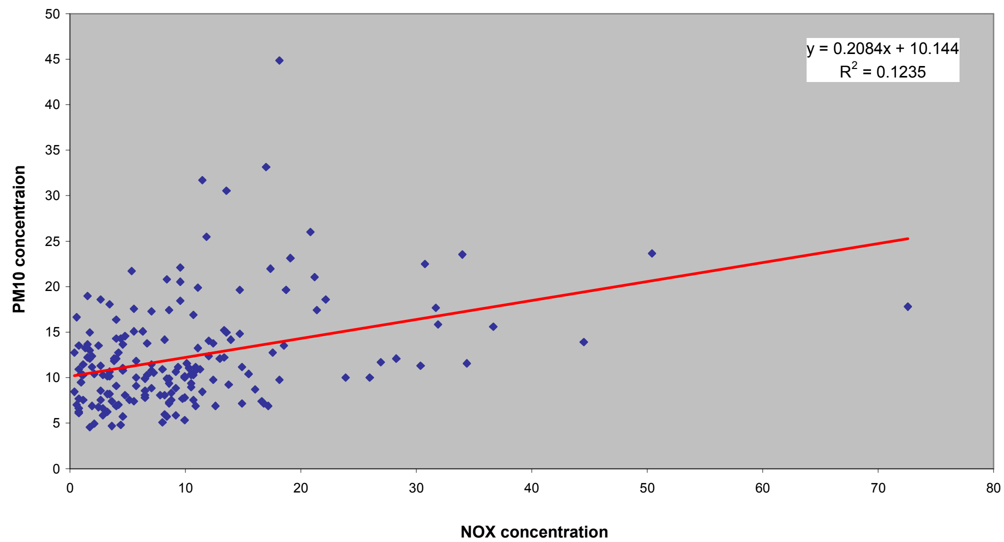


Fig 4.11 Correlation of daily NO_x and PM_{10} concentration μg/m^3 at Currie (background) January to July 2004.



The above roadside and background site scatter plots show no strong correlation between NOx and PM_{10} concentrations. (R^2 is less than 0.5 in each case. In order to demonstrate a relationship R^2 should be close to 1).

4.7 Influence of wind direction on PM_{10} concentrations.

The air quality monitoring stations at Currie and Haymarket both have basic meteorological instruments, including an anemometer. Assessment of the wind direction and PM_{10} data indicates that PM10 levels are elevated when the wind is blowing in an easterly, south easterly, southerly direction and is sustained for a period of time. Examples are shown in figs 4.12 to 4.16.

Fig 4.12 Comparison of hourly wind direction (degrees) and PM_{10} concentrations µg/m^3 (grav) at Currie 29th March to 2nd April 2004

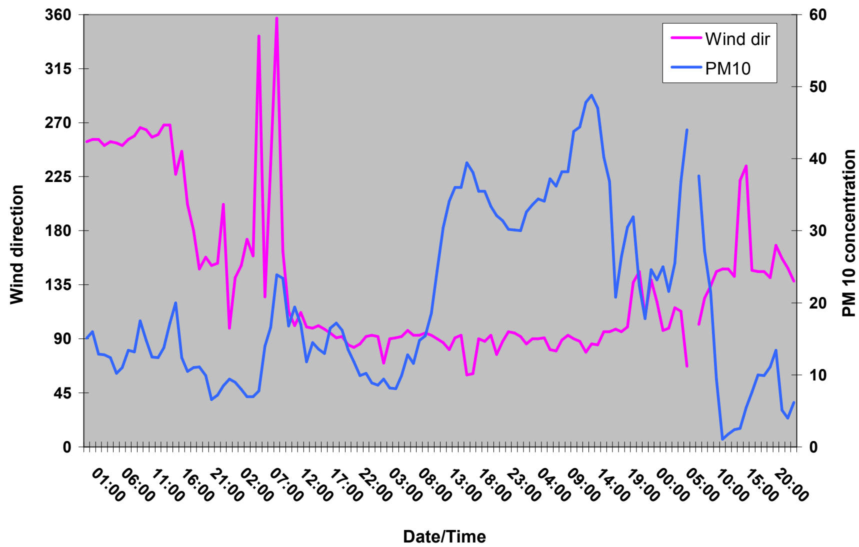


Fig 4.13 Comparison of hourly wind direction (degrees) and PM_{10} concentration µg/m^3 (grav) at Currie 30th April to 2nd May 2004.

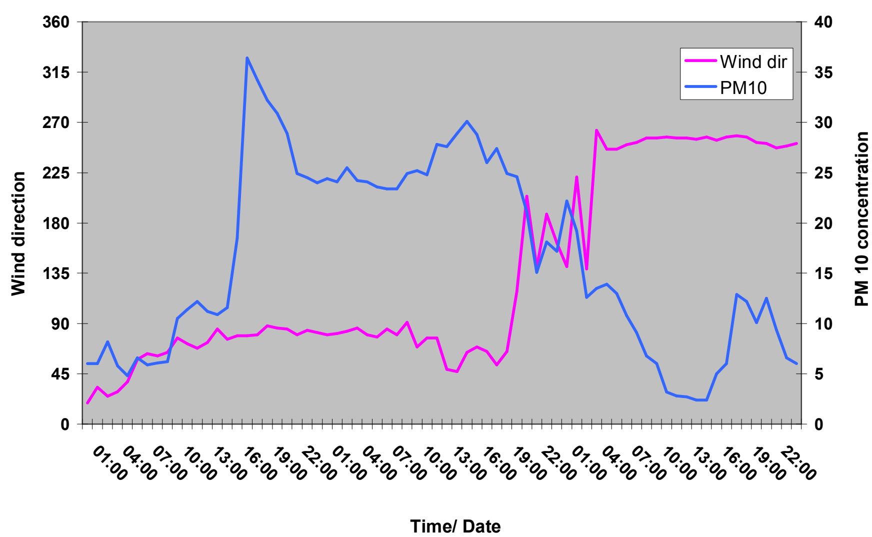


Fig 4.14 Comparison of 15 minute averages of wind direction (degrees) and PM_{10} concentrations $\mu g/m^3$ (grav) at Currie 1st to 2nd May 2004

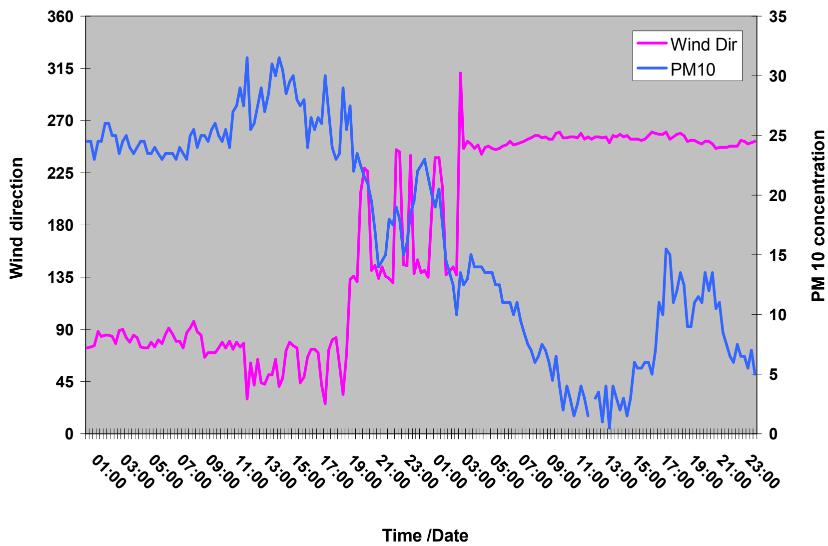


Fig 4.15 Comparison of hourly wind direction (degrees) and PM_{10} concentration $\mu g/m^3$ (grav) at Haymarket 10th to 11th September 2004

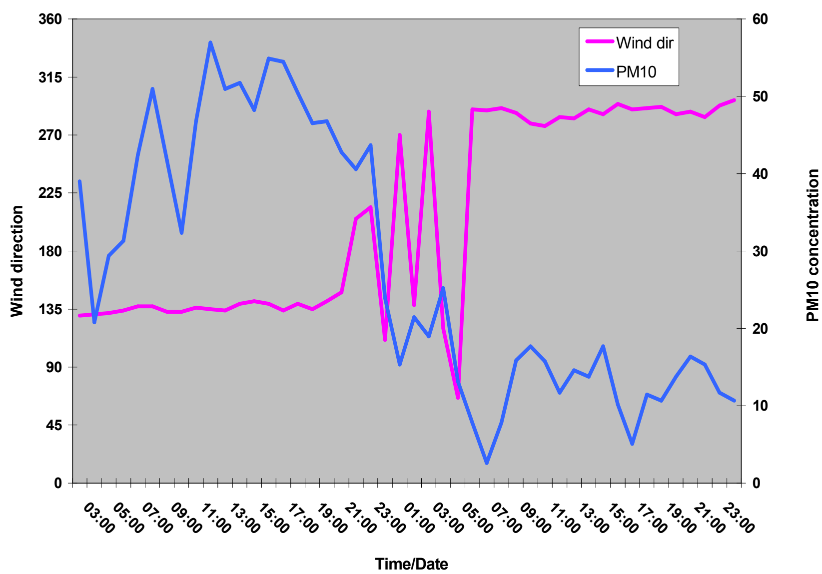
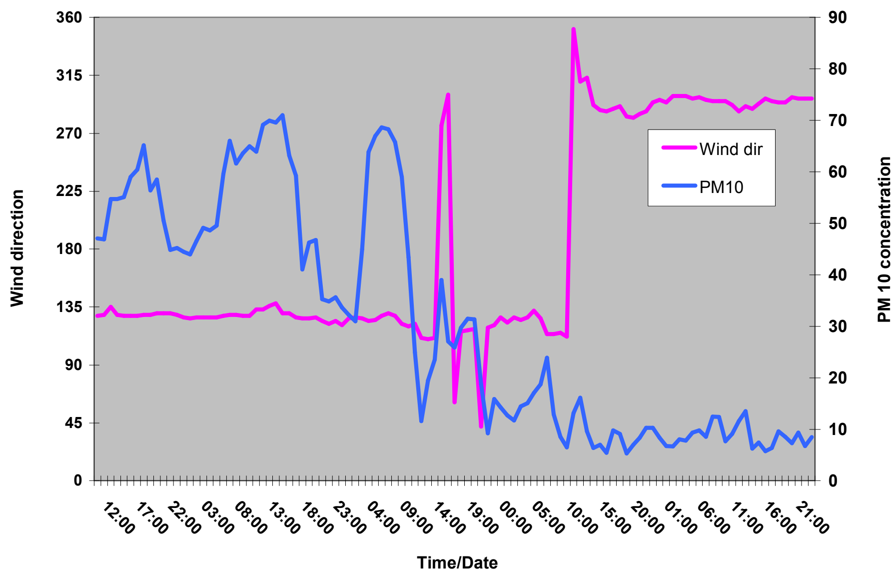


Fig 4.16 Comparison of hourly wind direction (degrees) and PM_{10} $\mu g/m^3$ (grav) concentrations at Haymarket 31st March 2004.



Comments provided by the University of West of England on the Council's Updating and Screening Assessment 2003 report advised that Edinburgh should consider the potential impacts from emission sources in neighbouring authorities.

The coal-fired power station at Cockenzie is outside the Edinburgh boundary and lies to the northeast, approximately 16 km from the city centre (Princes Street). Map 4. Initially, it was thought that emissions from combustion might influence PM_{10} levels in Edinburgh, depending on wind direction and plume dispersion. However, recent modelling studies which have been undertaken by Scottish Power suggest that this is extremely unlikely and SEPA supports this view. Personal communication.[8]

8 John Lamb Air Quality Management Specialist Scottish Environment Protection Agency

4.8 Analyses of ions from exposed partisol filters

The mass of PM_{10} material deposited on the exposed filters from the Partisol sampler was examined for sulphate (SO_4), nitrate (NO_3) and chloride (Cl) content with a view to assess the likely percentage that is derived from secondary particles. Capsule CRE laboratories performed the analyses of ions using a chromatography method.

To ensure that sufficient material was available, the daily exposed filters were pooled in weekly batches. Data was reported in total µg for each of the anions.

Ion assessment

In order to have comparable data sets, weekly PM_{10} concentrations µg/m^3 were calculated from the daily mean partisol values and the weekly ion mass weights were divided by the equivalent weekly volume of air which was sampled by the partisol. The average weekly ions in PM_{10} and respective % contribution are shown in table 4.5.

Ion data and calculations are detailed in excel spread sheets appendix 8

Table 4.5 Average weekly contributions of SO_4, NO_3 and Cl to average weekly PM_{10} concentrations at Edinburgh Haymarket

Site	SO_4 µg/m^3	NO_3 µg/m^3	Cl µg/m^3	% SO_4	% NO_3	% Cl	% Sum
Edinburgh	1.8	1.4	1.0	9.6	7.0	6.5	23
PM_{10} weekly average for 25 weeks of viable data					= 17.3 µg/m^3		
Average contribution from secondary aerosols SO_4 and NO_3					= 6.0 µg/m^3 (34%) *		

* Scaling factors were used to provide an estimated average contribution of secondary aerosols to PM_{10} at Haymarket. Dr Mat Heal, Department of Chemistry Edinburgh University on the behalf of the Council, undertook the calculations.[9]

It is considered that the Edinburgh ion data is in line with recent measurements in other UK cities and that the contribution from secondary sulphate and nitrate aerosol (approximately one third) is in agreement with accepted expectations for urban PM_{10} personal communication .[10]

Scatter plots of the relationship between individual weekly SO_4 , NO_3 and Cl and PM_{10} concentrations are shown in figs 4.17 to 4.19.

9 Harrison, RM., Jones, AM. And Lawrence, RG (2003) A pragmatic mass closure model for airborne particulate matter at urban background and roadside sites, Atmos. Environ.37, 4927 – 4933.

10 Dr Mat Heal Edinburgh University member of the Air Quality Expert Group AQEP

Fig 4.17 Relationship between SO_4 and PM_{10}

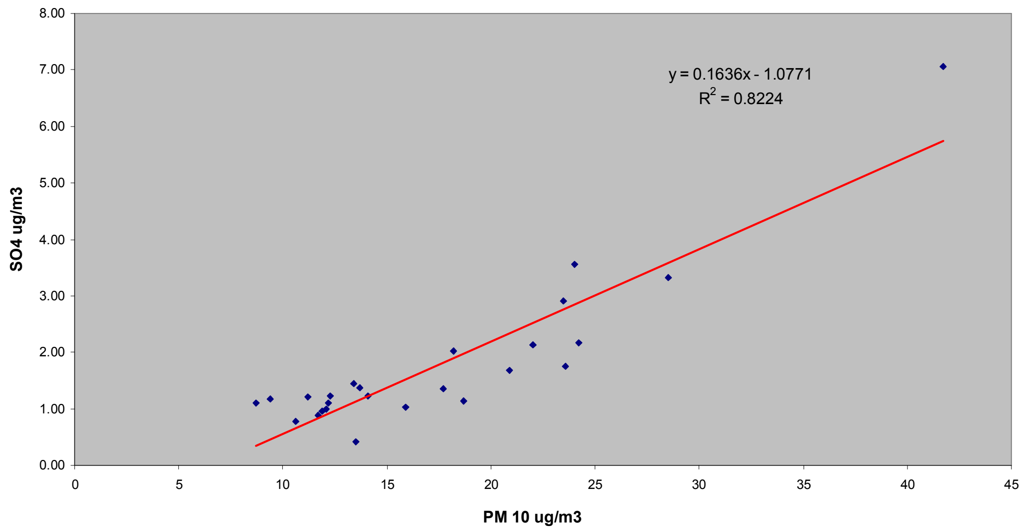


Fig 4.18 Relationship between NO_3 and PM_{10}

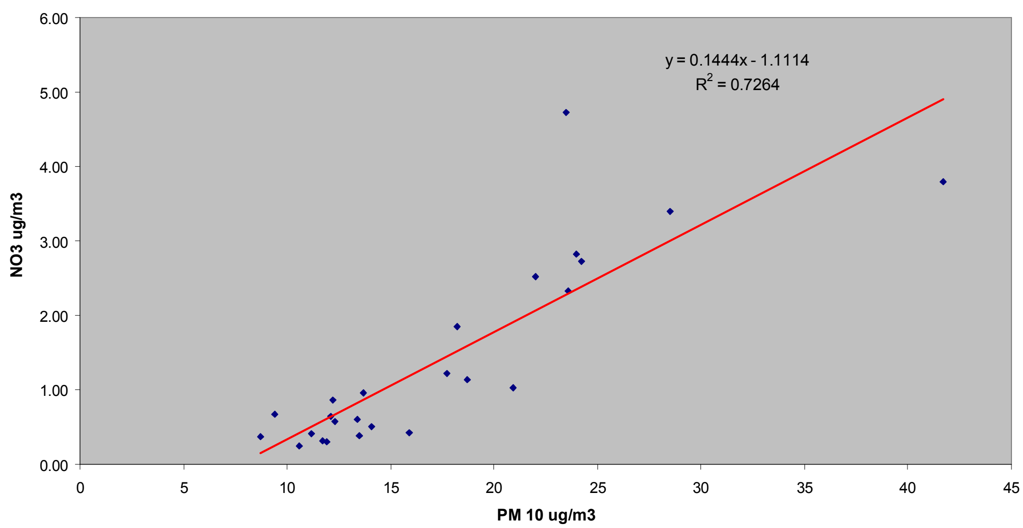
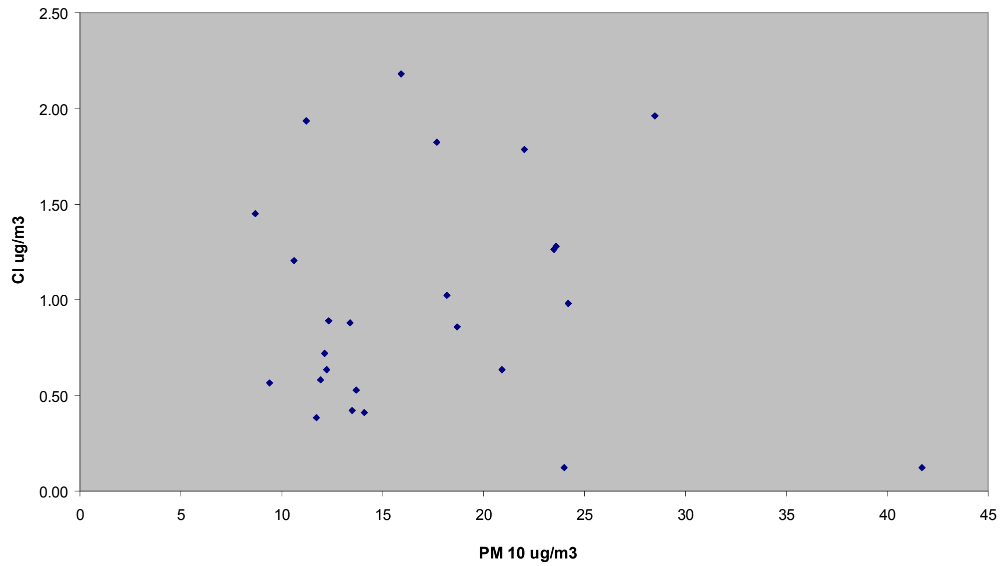


Fig 4.19 Relationship between Cl and PM_{10}



Plots for SO_4 and also for NO_3 (although there are some outliers) show that the proportion of SO_4 and NO_3 in PM_{10} is greater when the overall PM_{10} concentration is high and lower when the overall PM_{10} concentration is low. This suggests that periods of higher PM_{10} levels in Edinburgh are likely to be driven by secondary particulate episodes. Higher PM_{10} levels tend to be associated with wind blowing from a south easterly, easterly and southerly direction. Levels of PM_{10} are lower when winds blow from the north or west as previously discussed in section 4.9. This is consistent with other analysis that shows a tendency for higher PM_{10} in Edinburgh when air mass trajectory comes from the UK or European landmass. Personal communication [11]

Therefore it is likely that higher concentrations of PM_{10} in Edinburgh are associated with the import of secondary particulate pollution and are not from local sources.

There appears to be no relationship between weekly Cl and weekly PM_{10} concentrations.

11 Dr Mat Heal Department of Chemistry Edinburgh University

5.0 Detailed Assessment of nitrogen dioxide at St John's Road

5.1 Detailed Assessment location.

St John's Road (Corstophine) is one of the main arterial traffic routes from the west into Edinburgh City centre. The route (A8) begins at Haymarket Terrace (city centre) and joins the M8/M9 links to Glasgow and Stirling. This road serves Edinburgh Airport and the Corstophine and Roseburn areas. The AADT traffic flow at St Johns Road is approximately 25,000.

The U&SA report based on earlier work concluded that traffic emissions are the most significant source of nitrogen dioxide concentrations in Edinburgh. There are no point sources in the area of concern. The location where there is a likely exceedence of the annual average objective is on the stretch of road, which forms a small canyon adjacent to the junction of Clermiston Road. At this point residential tenement properties are much closer to the road. There are two sets of traffic lights nearby, the traffic is slow moving and traffic queues are evident.

5.2 Nitrogen dioxide monitoring data

Air Quality objectives:

Annual mean concentration of 40 μg/m^3 to be achieved by the end of 2005

1 hour mean concentration of 200 μg/m^3 not to be exceeded more than 18 times per year to be achieved by the end of 2005

EU Directive limit values:

Annual mean concentration of 40 μg/m^3 to be achieved by the 1 January 2010

1 hour mean concentration of 200 μg/m^3 not to be exceeded more than 18 times per year to be achieved by the 1 January 2010

Passive diffusion tube monitoring data

In the Corstophine area there are three passive diffusion tube (pdt) sites, two of which are roadside sites, St John's Road/Victor Park Terrace (1A) and St Johns Road/Clermiston Junction (1 1x). The latter site has duplicate pdts. The location at Hillview Terrace (3A) is classed as a background site. All monitoring locations are in close proximity to residential property. The two roadside pdt sites are 513m apart and are located on the eastbound carriageway. The background site is 315m from St Johns Road. Monitoring locations are shown on map 5

All passive diffusion tube monitoring data has been corrected for diffusion tube bias in accordance with Box 6.4 LAQM TG (03). The monthly exposed passive diffusion

tubes have been found to over read real time analysers by between 8.5% and 10 %. Appendix Technical 6A. The data has also been adjusted for relevant future years using the roadside and background factors detailed in Box 6.6 and Box 6.7 respectively. Appendix 6D/1 and 6D/2
The roadside passive diffusion tubes have been corrected to the façades of adjacent residential property where appropriate. Correction factors, which have been used, are shown in appendix 6C

St Johns Road/ Victor Park Terrace (1A) and Hillview Terrace (3A)

The corrected nitrogen dioxide concentration at the above locations currently meet and are therefore likely to meet with the annual air quality objective and the EU limit values.

St Johns Road/ Clermiston Road junction (1/1X)

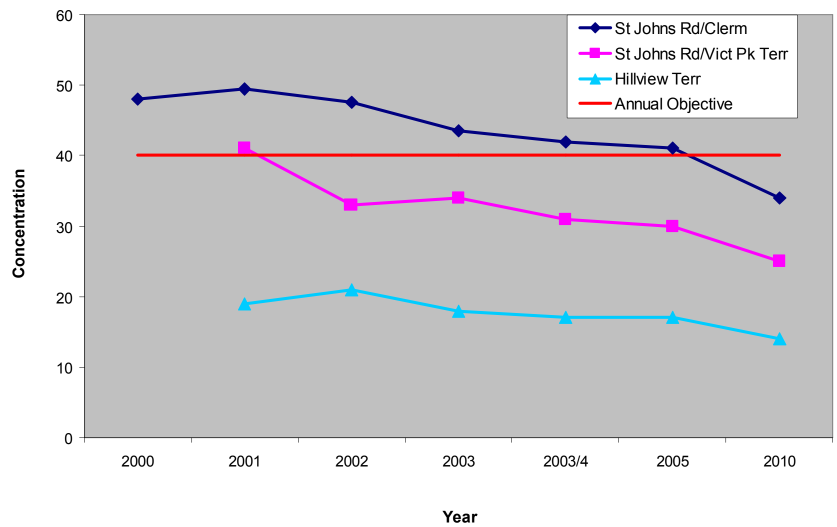
The corrected annual mean nitrogen dioxide concentration at this location is considered to be marginal by the target year of 2005 but likely to meet the air quality standard by 2010. Concentrations for 2003/4 are 41 to 43 $\mu g/m^3$ estimated to be 40 to 42 $\mu g/m^3$ at 2005 and 33 to 35 $\mu g/m^3$ by 2010.

The corrected passive diffusion tube monitoring data obtained from the aforementioned locations is shown in table 5.1 and the trend is illustrated in fig 5.1

Table 5.1 Nitrogen dioxide concentrations at roadside and background sites Corstophine

Monitoring year and target years		**Corrected NO_2 measured data estimated to target years at roadside sites St Johns Rd (1/1x, 1A) and background site Hillview Terr (3A) $\mu g/m^3$**				
		1	1x	1/1x mean	1A	3A
2000	01.01.00 to 31.12.00	48		Weekly pdts no bias correction		
2005		41		For monthly tubes		
2010		34				
2001	31.12.00 to 31.12.01	51	48	49.5	41	19
2005		45	43	44.0	37	17
2010		37	35	36.0	30	15
2002	31.12.01 to 30.12.02	48	47	47.5	33	21
2005		44	43	43.5	30	20
2010		36	36	36.0	25	17
2003	31.12.02 to 30.12.03	43	44	43.5	34	18
2005		41	42	41.5	32	17
2010		34	34	34.0	27	15
2003/4	30. 09.03 to 28.09.04	43	41	42.0	31	17
2005		42	40	41.0	30	17
2010		35	33	34.0	25	14

Fig 5.1 Annual average nitrogen dioxide trends at listed passive diffusion tube sites from year 2000 to 2003/4 and projected to 2005 and to 2010.



The annual average nitrogen dioxide concentrations at all monitoring locations show a downward trend, which is in keeping with UK wide predictions.

Additional monitoring sites at St Johns Road /Clermiston Road junction

The passive diffusion tubes at St Johns Road/ Clermiston Road junction are close to the kerb edge. Concentrations of nitrogen dioxide diminish with increasing distance from source. Thus concentrations at the edge of the road are greater than at the rear of the pavement or façade of a residential property. Local authorities are therefore advised to correct all roadsides monitoring data to the nearest relevant location, which in the case of the annual average objective assessment is at the façade of residential property. The correction factors are considered to be conservative and may overestimate levels at building facades.

The concentrations at Clermiston junction are borderline, therefore to overcome the kerb to façade correction issue additional passive diffusion tubes were located at the façade of the adjacent tenement residential properties on both the west and east bound carriageway, as discussed in the U &SA report. Map 5

The additional monitoring passive diffusion tubes sites are listed below

1b	St Johns Road façade (post office)	Eastbound.	Start October 2003
1c/1d	St Johns Road façade duplicate	Westbound.	Start October 2003
32	St Johns Road facade	Westbound.	Start January 2004

Corrected data gathered from the above additional sites over the monitoring period show that the locations on the east bound carriage of the junction area of St Johns Road /Clermiston Road are likely to meet with the annual average air quality objective. The passive diffusion tube at the façade is currently 37μg/m^3 and estimated to be 36.0 μg/m^3 by 2005. However, the passive diffusion tubes on the westbound carriage are likely to exceed the air quality objective. The concentrations are almost double the levels on the eastbound carriage. Table 5.2

Table 5.2 Nitrogen dioxide passive diffusion tube monitoring data and projected values to 2005 and 2010.

Monitoring locations	**Current corrected NO_2 concentrations estimated to relevant target years μg/m^3**		
	2003/04 30.09.03 to 28.09.04	2005	2010
1 roadside east bound carriage	43	42	35
1x roadside east bound carriage	41	40	33
1A roadside east bound carriage	31	30	25
1b roadside east bound carriage (façade)	37	36	27
1c roadside west bound carriage (façade)	67	65	54
1d roadside west bound carriage (façade)	67	65	54
32 roadside west bound carriage (façade) *	69	67	56
3A background	17	16	14

* Site established January 2004 incomplete year

The reason for the huge differential in this area could be due to local topography and idling traffic being closer to the façade.

Real time monitoring of nitrogen dioxide at Roseburn.

The air quality monitoring station at Roseburn (roadside location) is 2.8 km from the passive diffusion tube sites. The nitrogen dioxide data (real time) currently meets with the objectives. Table 5.3

Table 5.3 Nitrogen dioxide monitoring at Roseburn real time analysers

Monitoring period	**No of exceedances**	**NOx μg/m^3**	**NO_2 μg/m^3**
01/09/03 to 31/08/04	0	63	32.5
01/01/04 to 30/11/04*	0	61	32.0

5.3 DMRB screening model results St Johns Road.

The DMRB version 1.02 (November 2003) screening model was used to assess the impact from traffic at locations on St Johns Road.Table 5.4

Table 5.4 DMRB traffic modelling results

Location and site description	Nox Background 2005 µg/m^3	NO_2 background 2005µg/m^3	Traffic Component 2005µg/m^3	Annual Mean 2005 µg/m^3	No exceedences
1A	42.0	25.3	11.1	36.4	0
1c/d	42.8	25.6	13.1	38.7	0
32	42.8	25.6	13.1	38.7	0
1/1x canyon	42.8	25.6	13.1	38.7	0
1b canyon	42.8	25.6	13.1	38.7	0

Input data used in the DMRB model is shown in Appendix 7

The Highways Agency carried out a validation study of the DMRB model. Their findings indicated that the model might significantly under predict concentrations of nitrogen dioxide along urban city centre roads classified as Street Canyons. To avoid missing potential exceedences at canyon locations, local authorities are advised to multiply the DMRB predicted traffic component by a factor of 2 and then add this value to the background nitrogen dioxide concentration.

A small canyon exists on the eastbound side of the road where passive diffusion tubes 1 /1x and 1b are located.

The westbound side of the road, where the passive diffusion tubes 1c/1d and 32 are located is not part of the canyon. Tubes 1c/1d are positioned at the corner of a 4-storey high tenement building; tube 32 is located at the façade of an adjoining two storey residential property. The buildings at the opposite side of the road are two storeys high.

The results from the DMRB traffic assessment have been corrected for the canyon effect and compared with the measured passive diffusion tube data. Table 5.5

Table 5.5 DMRB annual and canyon corrected annual means compared with measured data

Site	Estimated * annual mean data 2005 µg/m^3	DMRB Annual mean 2005 µg/m^3	Canyon corrected DMRB annual mean Annual mean 2005 Traffic component * 2 + background µg/m^3
1/1x canyon	41	39	13.1 * 2 + 25.6 = 51.8
1b canyon	36	39	13.1 * 2 + 25.6 = 51.8
1c/1d	65	39	
32	69	39	
1A	30	36	

* Estimated data for 2005 is based on annual measured data gathered 2003/4

The DMRB model gives conflicting results when compared with the measured data, i.e. the canyon corrected modelled PM_{10} is higher than the measured PM_{10} on the eastbound side of the road and on the westbound side of the road the measured data is greater than the modelled values.

5.3 Discussion of nitrogen dioxide data and proposed extension of existing AQMA

The data suggests that the annual average exceedence at St Johns Road is only likely on the westbound side of the road, where the residential properties are close to traffic lights and slow moving traffic. Therefore it is very localised. The Review and Assessment help desk were consulted on this matter and they were of the opinion that the existing AQMA should be extended to cover this area of concern. It is plausible that exceedences can be on one side of the road and not the other, due to differences in circulation of air and stationary traffic.

The western boundary of the existing AQMA ends at Roseburn Terrace where the real time air quality monitoring station is located. This road (A8) is the main route to Corstophine (St Johns Road) which joins with the M8/M9 links to Glasgow and Stirling. It is initially proposed that the existing AQMA be extended from the west end of Roseburn Terrace to the Drum Brae roundabout, west of St Johns Road.

However, consultation with Transport Engineers in the Council's City Development Department and other stakeholders will be undertaken. Following from this process, a report will be submitted to the Executive of the Council to decide on the extent of the amended AQMA.

6.0 Discussion and conclusion

6.1 PM_{10}

The City of Edinburgh Council has undertaken two additional studies to ascertain if the risk of exceeding the more stringent PM_{10} air quality objectives is likely. The studies involved monitoring PM_{10} at a background location and co locating a partisol sampler (EU gravimetric reference method) with a TEOM instrument at an existing monitoring site. This work was approved by University West of England (Defra and devolved administrations appointed UK external assessors for all air quality review and assessment reports), Scottish Environment Agency (SEPA) and the Scottish Executive (SE).

This work was prompted by the adoption of tighter air quality objectives by the Scottish Executive; the uncertainty associated with the current monitoring methods and the lack of local background PM_{10} data. The annual average PM_{10} standard of 18 $\mu g/m^3$ is more onerous than the recommended EU indicative value of 20 $\mu g /m^3$. It is only Scottish local authorities that have to review and assess PM_{10} against the new objectives. The indicative values have not been adopted by other parts of the UK.

The major issue surrounding the measurement of PM_{10} is the requirement to correct all TEOM measured data to the EU gravimetric reference method to account for the volatile loss of sulphates and nitrates. This equivalence factor was derived from the results of small study undertaken some years ago at six different sites in the UK. The study showed that the equivalence factor varied between different locations and therefore a general factor of 1.3 was recommended. This factor is considered to be conservative. The gravimetric equivalence factor derived from the roadside co location study in Edinburgh was 1.14. All the monitoring locations are likely to meet with the PM_{10} objectives if the 1.14 local gravimetric equivalence factor is applied to the TEOM measured data.

Data gathered from the Partisol sampler (gravimetric reference method) also meets with the air quality objectives. The concentration for 2004 is 17.1$\mu g/m^3$ estimated to be 16.1 $\mu g/m^3$ by 2010. The differences between the annual averages obtained by the TEOM instrument at each of the roadside and urban centre monitoring locations are not greater than 1$\mu g/m^3$. The estimated 2010 values range from 15.6 to 16.7 $\mu g/m^3$. Therefore, it can be assumed that all monitoring locations are likely to meet with the targets based on the gravimetric measurement.

The PM_{10} background monitoring at Currie has resulted in lower background concentrations citywide, which is more representative of Edinburgh centre and surrounding areas. Using the adjusted background concentrations has enabled more accuracy with regard to using the DMRB screening model for traffic associated emissions. The roads, which were studied, were based on ‘worst case scenarios’ and the model demonstrated that they would meet the air quality objectives.

Assessment of PM_{10} and NOx diurnal trends, along with traffic data for Haymarket indicate that there is not a relationship between PM_{10} and NOx and PM_{10} and traffic volumes. There is however, a clear relationship between NOx and traffic flows. Correlation studies with NOx and PM_{10} at both roadside sites and the background location were not significant; again indicating that road traffic sources are not a major component of PM_{10} in Edinburgh.

Daily, hourly and 15 minute interval trends between background and roadside city centre sites have been assessed. The trend data follows an identical pattern of troughs and peaks, which suggests that the main bulk of PM_{10} in Edinburgh may not be locally derived. The overall urban background PM_{10} data is lower than that obtained at roadside locations. The PM_{10} background levels at Currie are approximately 61% to 65% of the total observed PM_{10} roadside city centre concentrations based on TEOM measured data for the same monitoring period.

PM_{10} concentrations are elevated when the wind is blowing in an east, south easterly direction which indicates that long range transport i.e. from Europe is likely to influence the overall concentrations in Edinburgh.

The small study, which looked at the composition of ions, indicated that levels of sulphate and nitrate were higher when the overall PM_{10} concentrations were elevated and vice versa. This suggests periods of higher PM_{10} levels in Edinburgh are being driven by secondary particulate episodes.

The bulk of PM_{10} in Edinburgh is likely to come from regional sources, construction site dust and a small proportion from road traffic emissions. Resuspended dust is considered to be significant, but there is no conclusive data to advise local authorities of how to deal with this issue.

The draft report, Particulate matter in the United Kingdom compiled by the Air Quality Expert group identified that there is a need to undertake a huge program of monitoring in rural and background locations in the UK to make more accurate judgements on long range transport issues. It is considered that regional background contribution to PM_{10} is substantial and must form a central component of any mitigation strategies. There is also a need to look at particulate sulphate, particulate nitrate in a more uniform and accurate manner if these components are considered to be important in terms of health effects. Issues relating to particle bound moisture also requires to be addressed as there is no evidence to link this component to health effects. The report concluded that further research studies were needed, as there is too much uncertainty and not enough known regarding our basic understanding of PM_{10} to allow policy to be set.

Based on the additional work contained in this Detailed Assessment report it is likely that the air quality objectives for PM_{10} will be met and therefore there is no requirement to declare an AQMA for this pollutant.

6.2 Nitrogen dioxide St Johns Road Clermiston junction

The additional passive diffusion tube monitoring at St Johns Road, Clermiston junction has shown that the eastbound side of the road is likely to meet with the objectives. However, there is likely to be a risk of exceeding the annual average nitrogen dioxide on the westbound side of the road. This phenomenon can occur due to differences in the circulation of air and stationary traffic. The road junction is congested and is one of the main radial routes to the city centre. There are a mixture of 4, 3 and 2 storey residential properties with commercial premises at ground floor level at this location.

It will therefore be necessary to extend the existing AQMA to cover this area of concern. The Review and Assessment Helpdesk share this opinion.

Although the area of likely exceedence is very localised, the proposed AQMA extension is likely to be from the west end of Roseburn Terrace to the Drum Brae roundabout, west of St Johns Road. A single AQMA will enable an integrated approach with respect to the Council's Action Plan. Consultation with the Council's Transport Engineers and other stakeholders will take place prior to the proposed extension of the AQMA.

The area of likely exceedence and proposed extension of the existing AQMA is shown in Map 6.

APPENDIX 1A QA /QC procedures Real time analysers

Staff competence

Two officers are trained as local site operators in relation to the management of the Defra National Network site and undertake the necessary calibrations and basic maintenance at all the automated sites. Both operators have been trained to fulfil the requirements associated with passive diffusion tube samplers.

Real-Time Analysers

Calibration procedures

The two ML 9841 B NO_x analysers perform an autocalibration each day with zero air and NO gas. Warning limits are set at +/- 5 % on the software program All sites are visited weekly, apart from the National Network site, which is visited fortnightly and manual calibration checks are carried out using certified NO gas at approximately 500ppb plus a zero check. All cylinders are replaced at 12 - 18 month intervals. NO cylinders are supplied by Air Liquide UK.

Servicing

All instruments are serviced and recalibrated every six months by the appropriate supplier

The service contracts include a support package for software and replacement parts, plus any necessary call outs to the sites.

The TEOM heads on the automatic PM_{10} units are cleaned fortnightly and filters are changed regularly (approximately every 2 weeks).

All visits to the monitoring stations, actions which are taken and activities adjacent to the site are recorded in the site logbook.

Data validation and ratification

All data, including calibration data is scrutinised on a daily basis (Monday to Friday) by visual examination, to see if they contain unusual measurements. Any data which is considered to be suspicious i.e large spikes, is flagged to undergo further checks. Data sets which are considered to require further investigation are checked with respect to the following:

- Assessment of calibration records for drift precision /accuracy of analyser
- Negative values ie during /after TEOM filter change
- Spikes generated by analysers.
- Time/date of manual calibration no out of service switch Mobile AQ unit
- Examination of data gathered from other sites to ascertain if high values are caused by pollution episodes.
- Assessment of local activity construction/ roadworks.

- Data capture rates distribution of missing or suspect data.

Any data which is considered to be erroneous is deleted.

The monitoring station located in Princes Street Gardens until 2000 and St Leonards since 2004, is part of the Automated Urban and Rural Network, (AURN). All AURN sites are subject to an independent audit and stringent QA/QC procedures which are undertaken by Casella Stanger and A.E.A Technology on behalf of DEFRA.

Details of manual calibration checks, precision and accuracy of instruments are available on request either in electronic or paper format.

Site details and type of equipment used for the Council automated analysers table AP 1

Table 1 Council's automated monitoring equipment used for the Detailed Assessment report

Site	**NO_x analyser Model**	**PM_{10}**	**Supplier**	**Software**
Queen St Nrth Castle St Rollalong	ML 9841B	TEOM Operated at 50 ^{oc}	Casella ETI (E.M.C)	Enview Data collected daily via modem
Haymarket Terrace Rollalong	ML 9841B	TEOM Operated at 50 ^{oc}	Casella ETI (E.M.C)	Enview Data collected daily via modem
Currie Mobile Trailer	AP1 M200A	TEOM Operated at 50 ^{oc}	Casella ETI (E.M.C) E.T NOx	Enview Data collected daily via modem
Roseburn Terrace Rollalong		TEOM Operated at 50 ^{oc}	Casella ETI (E.M.C)	Enview Data collected daily via modem
Haymarket		Partisol 2025	Rupprecht& Patashnick Co (R&P)	RPCOMM Data downloaded via laptop

Partisol 2025 sampler

The partisol 2025 sampler was operated in accordance with the instruction manual. The sampler head was changed every 2 weeks and cleaned. The instrument was serviced by the supplier (Casella ETI) within 1 week of it being installed. The software programe was set to sample from midnight to midnight 24 hours. Sample air flow rate was set at 16.7 L/min

The unit recorded the following parameters, exposure time, flow of air ambient temperaure and filter temperature for each filter exposed .

Regular visits to the site were made to ensure that the filters were changed every 24 hours.

Data was downloaded every 2 weeks and files were made of the appropriate data in excel spreadsheets to match filter reference numbers and the appropriate mass weights provided by the laboratory.

Filters

Quartz filters were used for the study.They were provided, equilibrated and weighed by Casella CRE Air laboratories. The laboratory is UKAS accredited for this task.

All filters were preconditioned for 48 hours in an air conditioned weighing room with a temperature of 20 ± 1° and a relative humidity of 50 ± 3% prior to weighing (pre and post exposure). The field blanks were preconditioned in exactly the same way.

Filters batches arrived every 2 weeks in a sealed plastic filter cassette which was contained in metal container two days before being placed in the partisol sampler.

Exposed batches of filters were dispatched to the laboratory every 2 weeks in the sealed plastic cassette holder on the day they were removed from the partisol sampler.

APPENDIX 1B QC/QA procedures passive diffusion tubes

Passive diffusion tubes were supplied and analysed by Analytical and Scientific Services, City of Edinburgh Council. The laboratory is UKAS accredited for this task and participates in the Workshop Analysis Scheme for Proficiency (WASP) inter laboratory QC/QA.The laboratories performance was considered to be satisfactory over the monitoring periods 2000, 2001, 2002, 2003/04

The laboratory uses 50% v/v Triethanolanine (TEA) in acetone for the adsorbent; the grids are dipped into this solution and allowed to dry before insertion into the tube. The method has remained unchanged during the monitoring periods. Acrylic diffusion tubes were used for the exposure periods.

NO_2 diffusion tube monitoring has been conducted in accordance with the quality requirements contained in the UK NO_2 Survey Instruction Manual for local/unitary authorities and government guidance document LAQM.TG (03). The diffusion tubes are located within 1 metre of the edge of the kerb or close to the façade of residential property. The tubes are attached to sign posts/lampposts, at a height of 2.0m above ground level. All exposure times and dates are recorded and retained as paper documents. Copies of which are sent with the exposed diffusion tubes to the laboratory.
Three diffusion tubes from each monthly batch are used as blanks. These tubes are not exposed and are stored in the refridgerator during the exposure period. They are analysed along with the appropriate batch of exposed tubes. The purpose of blanks is to determine whether or not NO_2 contamination occurred during tube preparation.

APPENDIX 2 Adjustment factors for estimating annual mean from a period mean.

Roadside sites Edinburgh

Queen St Year	Annual mean TEOM µg/m	Period mean taken	Period Mean TEOM µg/m
2000	15.4	16.01.00 to 31.07.00	15.8
2001	17.6	16.01.01 to 31.07.01	18.7
2002	17.7	16.01.02 to 31.07.02	17.1
2003	18.5	16.01.03 to 31.07.03	21.3

Haymarket Year	Annual mean TEOM µg/m	Period mean taken	Period mean TEOM µg/m
2000	15.3	16.01.00 to 31.07.00	15.4
2001	16.9	16.01.01 to 31.07.01	18.0
2002	17.7	16.01.02 to 31.07.02	16.9
2003	17.4	16.01.03 to 31.07.03	19.9

Loch Navar , Northern Ireland background /rural site

Loch Navar Year	Annual mean TEOM	Period mean taken	Period mean TEOM
2000	9.2	16.01.00 to 31.07.00	10.3
2001	10	16.01.01 to 31.07.01	11.5
2002	11	16.01.02 to 31.07.02	13.5
2003	11.5	16.01.02 to 31.07.03	10.4

The values for the short term monitoring periods tend to be greater than the annual mean concentrations for the same year apart from the roadside sites year 2002 and the background site 200311. Using the guidance proceedure in LAQM TG (03) Box 8.5 Approach to the estimation of annual mean PM 10 concentrations from short term monitoring data , the ratios are shown for years 2000 to 2004 in the following tables.

Site	**Annual mean 2000 (TEOM)**	**Period mean 2001 (TEOM)**	**Ratio (Am/Pm)**
Queen St	15.4	18.7	0.823
Haymarket	15.3	18.0	0.850
Loch Navar	9.23	10.3	0.896
Mean ratio			0.856

Site	**Annual mean 2001 (TEOM)**	**Period mean 2002 (TEOM)**	**Ratio (Am/Pm)**
Queen St	17.6	17.1	1.023
Haymarket	16.9	16.9	1.000
Loch Navar	10.0	11.5	0.869
Mean ratio			0.964

Site	Annual mean 2002 (TEOM)	Period mean 2003 (TEOM	Ratio (Am/Pm)
Queen St	17.7	21.3	0.830
Haymarket	17.7	19.9	0.889
Loch Navar	11.0	13.5	0.815
Mean ratio			0.845

Site	Annual mean 2003 (TEOM)	Period mean 2004 (TEOM	Ratio (Am/Pm)
Queen St	18.5	14.4	1.28
Haymarket	17.4	15.2	1.14
Loch Navar	11.5	10.4*	1.10
Mean ratio			1.17

The factors are high for 2004 due to pollution episodes during 2003.
Review and Assessment help desk advised that a factor of 1 would be appropriate to use for estimating an annual mean for 2004.

* Data provisonal, ratified until August 2004.

APPENDIX 3 TEOM / Partisol matched pairs of data

Date	Partisol	TEOM	Factor
22/01/2004	8.6	9.6	0.89
23/01/2004	11.0	10.5	1.05
24/01/2004	8.5	9.1	0.94
25/01/2004	10.0	10.2	0.98
26/01/2004	13.6	12.8	1.06
27/01/2004	13.6	13.4	1.01
28/01/2004	8.9	8.8	1.01
29/01/2004	9.5	9.3	1.02
30/01/2004	12.6	10.1	1.24
31/01/2004	10.4	10	1.04
01/02/2004	10.8	11.7	0.92
02/02/2004	11.1	12.4	0.89
03/02/2004	8.2	9.3	0.88
04/02/2004	15.9	17.4	0.91
05/02/2004	18.4	18.1	1.02
06/02/2004	14.7	12.9	1.14
07/02/2004	8.3	7.4	1.12
08/02/2004	10.6	11.2	0.94
09/02/2004	18.6	15.4	1.21
10/02/2004	12.2	11.9	1.03
11/02/2004	28.3	27.2	1.04
12/02/2004	29.4	24.8	1.19
14/02/2004	19.4	16.4	1.18
15/02/2004	12.6	9.7	1.3
16/02/2004	28.4	20.4	1.39
17/02/2004	24.4	20.9	1.17
18/02/2004	30.8	22.8	1.35
19/02/2004	29.2	24.1	1.21
20/02/2004	19.4	16.7	1.16
21/02/2004	20.9	17.8	1.18
22/02/2004	13.2	11.4	1.15
23/02/2004	13.6	12.4	1.10
24/02/2004	13.3	11.7	1.13
25/02/2004	14.0	15.2	0.92
26/02/2004	14.8	13.8	1.08
27/02/2004	17.1	17	1.00
28/02/2004	13.7	13.7	1.00
29/02/2004	25.4	22	1.15
01/03/2004	23.5	19.3	1.22
02/03/2004	37.5	23.9	1.57
03/03/2004	21.9	15.3	1.43
04/03/2004	24.3	19.5	1.25
05/03/2004	20.6	19.6	1.05
07/03/2004	19.5	16.10	1.21
08/03/2004	32.6	25.7	1.27
09/03/2004	28.7	20.6	1.39
10/03/2004	23.0	16.9	1.36
11/03/2004	33.5	27.1	1.24
12/03/2004	55.4	35.4	1.56
13/03/2004	45.7	28.7	1.59
14/03/2004	13.3	9.7	1.37
15/03/2004	17.4	15	1.16

16/03/2004	14.5	11.6	1.25
17/03/2004	20.1	16.6	1.21
18/03/2004	13.1	11.1	1.18
19/03/2004	8.6	9.2	0.93
20/03/2004	9.2	8.6	1.07
21/03/2004	8.4	8.9	0.94
22/03/2004	9.2	10.7	0.86
23/03/2004	12.1	11.7	1.03
24/03/2004	13.4	13.5	0.99
25/03/2004	12.9	14.2	0.91
26/03/2004	11.0	8.4	1.31
27/03/2004	6.8	6.1	1.11
28/03/2004	11.6	12.6	0.92
29/03/2004	17.1	19.1	0.90
30/03/2004	26.0	23.4	1.11
31/03/2004	45.5	30.4	1.50
01/04/2004	67.6	41.8	1.62
02/04/2004	46.4	28.4	1.63
03/04/2004	13.0	8.8	1.48
04/04/2004	5.3	6.7	0.79
05/04/2004	9.4	9.6	0.98
06/04/2004	12.0	10	1.20
07/04/2004	10.9	9.3	1.17
08/04/2004	13.4	12.5	1.08
09/04/2004	10.6	7.7	1.38
10/04/2004	14.7	13.8	1.07
11/04/2004	10.9	8.1	1.34
12/04/2004	9.2	6.6	1.39
13/04/2004	10.8	8.8	1.23
14/04/2004	16.1	10.6	1.52
15/04/2004	9.1	9.6	0.95
16/04/2004	14.9	14	1.06
17/04/2004	10.7	8.5	1.26
18/04/2004	7.3	5.8	1.26
19/04/2004	8.0	8.9	0.90
20/04/2004	14.3	13.5	1.06
21/04/2004	20.3	17.9	1.14
22/04/2004	13.6	20	0.68
23/04/2004	15.9	17.2	0.92
24/04/2004	15.0	16.2	0.93
25/04/2004	12.9	13.2	0.98
26/04/2004	17.0	15.9	1.07
27/04/2004	10.6	10.1	1.05
28/04/2004	10.6	10.1	1.05
29/04/2004	8.7	8.5	1.02
30/04/2004	27.1	24	1.13
01/05/2004	34.5	28.8	1.20
02/05/2004	15.9	13.1	1.22
03/05/2004	11.9	8.9	1.33
04/05/2004	8.3	8.1	1.03
05/05/2004	21.3	19.2	1.11
06/05/2004	24.5	19.7	1.24
07/05/2004	25.5	22	1.16
09/05/2004	25.1	18.8	1.33
10/05/2004	25.8	23.1	1.12

11/05/2004	21.6	18.5	1.17
12/05/2004	23.6	22.5	1.05
13/05/2004	9.6	13.7	0.70
14/05/2004	10.2	11	0.93
15/05/2004	9.9	10	0.99
16/05/2004	11.7	12.2	0.96
17/05/2004	19.5	16.2	1.20
18/05/2004	19.0	18	1.06
19/05/2004	14.2	13.3	1.07
20/05/2004	13.7	13.1	1.04
21/05/2004	13.2	11.2	1.18
22/05/2004	12.6	11.9	1.06
23/05/2004	11.4	11.4	1.00
24/05/2004	16.8	15.1	1.11
25/05/2004	13.1	13.5	0.97
15/06/2004	12.3	19.3	0.64
16/06/2004	19.2	19.2	1.00
17/06/2004	11.2	12.5	0.90
18/06/2004	7.0	7.9	0.89
19/06/2004	6.8	7.7	0.89
20/06/2004	6.4	7.8	0.82
21/06/2004	10.2	11.3	0.90
22/06/2004	14.7	16.3	0.90
24/06/2004	8.5	10.7	0.79
25/06/2004	11.7	14.5	0.81
26/06/2004	13.6	14.2	0.96
27/06/2004	12.0	13.9	0.86
28/06/2004	14.2	14.2	1.00
29/06/2004	15.2	14.1	1.08
30/06/2004	10.8	10.5	1.03
01/07/2004	13.6	13.4	1.01
02/07/2004	12.4	12.1	1.02
03/07/2004	9.8	10	0.98
04/07/2004	8.9	9	0.99
05/07/2004	9.5	8.2	1.16
06/07/2004	10.4	10	1.04
07/07/2004	18.5	12.2	1.51
08/07/2004	20.4	12.7	1.61
09/07/2004	12.4	11.5	1.08
10/07/2004	9.3	8.1	1.15
11/07/2004	6.9	8.8	0.78
12/07/2004	10.2	9.7	1.06
13/07/2004	12.7	12	1.05
14/07/2004	10.1	9.2	1.10
15/07/2004	20.2	15.9	1.27
16/07/2004	14.0	11.7	1.20
17/07/2004	11.5	11.2	1.03
Mean	16.3	14.34	1.10
Factor	16.3/14.34 1.14		1.10
Max			1.63
min			0.64

APPENDIX 4 % Data capture Real time analysers

Site/ Pollutant	1999	2000	2001	2002	2003	2003/4	2004*
Princes St PM_{10}	92%	96%	97%	82%	44%	-	-
Haymarket PM_{10}	94%	95%	94%	96%	94%	95%	94%
Queen Street PM_{10}	90%	97%	93%	95%	97%	98%	99%

Site/ Pollutant	2003
Roseburn PM_{10}	98%

Site/ Pollutant	2004*
Currie PM_{10}	95%
St Leonards PM_{10}	

Site/ Pollutant	2004*
Haymarket Partisol 22/01/04 to 02/08/04	90%

Site/ Pollutant	2003/04
Roseburn NO_2	91%

* Until 31/07/04 unless stated.

APPENDIX 5

Calculation of estimated 2010 PM_{10} concentraions from 2003/04 data.

Example of calculation to estimate PM_{10} concentrations to 2010 using measured data from 2003/4 (Haymarket)		
Correction factors used from Box 8.7 to project to year 2010	2003/4 measured data (1.3)	2003/4 measured data (1.14)
secondary	0.795 / 0.932 = 0.853	0.795 / 0.932 = 0.853
primary	0.815 / 0.930 = 0.876	0.815 / 0.930 = 0.876
Correction of secondary 2001 to 2003/4	x 0.932	x 0.932
TEOM measured data corrected to gravimetric (1.3) and (1.14)	14.6 $\mu g/m^3$ x 1.3 = 18.9 $\mu g/m^3$	14.6$\mu g/m^3$x 1.14 = 16.6 $\mu g/m^3$
Secondary PM_{10} 2001 from UK background maps	4 x 0.932 =3.73$\mu g/m^3$	4 x 0.932 =3.73$\mu g/m^3$
Estimated secondary PM_{10} to 2010	3.73 x 0.853 =3.18$\mu g/m^3$	3.73 x 0.853 =3.18$\mu g/m^3$
Coarse fraction (remains unchanged)	= 10.5$\mu g/m^3$	= 10.5$\mu g/m^3$
Primary fraction of PM_{10} Total –secondary - coarse	18.9- 3.73-10.5 = 4.67 $\mu g/m^3$	16.6- 3.73-10.5 = 2.37$\mu g/m^3$
Primary fraction of PM_{10} to 2010	4.67 x 0.876 = 4.09$\mu g/m^3$	2.37 x 0.876 = 2.08$\mu g/m^3$
Total estimated PM_{10} at 2010	4.09 + 3.18 +10.5 = 17.8$\mu g/m^3$	2.08 + 3.18+10.5 = 15.8 $\mu g/m^3$

Measurement year	Secondary to year of measurement	Secondary to 2010	Primary to 2010
2004	4 x 0.932 = 3.73	0.795/0.932 = 0.853	0.815/0.930 = 0.876

APPENDIX 6A Passive diffusion tube bias corrections

Passive diffusion tubes are exposed in triplicate on the sampler head cage of the air quality monitoring stations on the side closest to the road. The data from the triplicate sets which show the best agreement are used to calculate the passive diffusion tube mean. Passive diffusion tube bias has been calculated according to Box 6.4 Approach to bias correction of nitrogen dioxide diffusion tube data LAQMA. TG(03).

Queen St/ North Castle Street 2003

Start	End	analyser	Mean pdt
31.12.03	05.02.03	38.7	38.0
05.02.03	05.03.03	54.4	47.7
05.03.03	02.04.03	54.8	61.0
02.04.03	30.04.03	45.5	57.0
30.04.03	04.06.03	36.3	41.0
04.06.03	03.07.03	31.5	38.5
03.07.03	30.07.03	29.9	35.0
30.07.03	03.09.03	37.4	34.7
03.09.03	01.10.03	34.6	40.5
01.10.03	05.11.03	40.8	49.0
05.11.03	03.12.03	43.4	45.0
03.12.03	31.12.03	46.4	54.0
mean		41.1	45.1
% Bias	9.70%	overread	
Factor	0.911		

Queen Street/ North Castle St 2003/04

Start	End	Analyser	mean pdt
01.10.03	05.11.03	40.8	49
05.11.03	03.12.03	43.4	45
03.12.03	31.12.03	46.4	54
31.12.03	04.02.04	41.8	45
04.02.04	03.03.04	47.4	50
03.03.04	31.03.04	42.6	42
31.03.04	05.05.04	34.4	36.5
05.05.04	02.06.04	34.6	34.5
02.06.04	30.06.04	32.7	32
30.06.04	04.08.04	32.5	43
04.08.04	01.09.04	41.8	43
01.09.04	29.09.04	27.3	38.3
mean		38.8	42.7
% bias		10%	
bias		0.907	

Queen Street Site 1

	Start	End	Analyser	mean pdt
Jan	31.12.03	04.02.04	41.8	45
Feb	04.02.04	03.03.04	47.4	50
Mar	03.03.04	31.03.04	42.6	42
Apr	31.03.04	05.05.04	34.4	36.5
May	05.05.04	02.06.04	34.6	34.5
Jun	02.06.04	30.06.04	32.7	32
Jul	30.06.04	04.08.04	32.5	43
Aug	04.08.04	01.09.04	41.8	43
Sept	01.09.04	29.09.04	27.3	38.3
mean			37.2	40.5
% bias			8.90%	
bias			0.919	

Haymarket Site 2

	Start	End	Analyser	mean pdt
Jan	30.12.03	03.01.04	39	47.5
Feb	03.01.04	02.03.04	41.3	47
Mar	02.03.04	30.03.04	40.1	44.5
Apr	30.03.04	04.05.04	35.5	37
May	04.05.04	01.06.04	36.3	38
Jun	01.06.04	29.06.04	34.2	35.6
Jul	29.07.04	03.08.04	32.1	39
Aug	03.08.04	31.08.04	39.3	50
Sep	31.08.04	28.09.04	28.1	34
mean			36.2	41.4
% bias			14.3	
bias			0.874	
mean bias			0.895	

The above mean bias was used for passive diffusion tube 32 this site was established in Jan 2004

Raw passive diffusion tube data at Clermiston µg/m^3

1	**1x**	**1b**	**1c**	**1d**	**1a**	**3a**	**32**
50.2	48.1	41.0	75.5	74.1	37.7	18.7	78.7

2000 data (12 months of data)

Site	Analyser	Pdt 1	Pdt 2	Pdt 3	Mean Pdt	% Bias
Queen Street /Castle St	37.8	48.7	50.7	-	49.7	31.6
Gorgie Road	37.8	49.4	45.5	-	47.4	25.5
Haymarket Terrace	37.1	45.0	44.8	-	44.9	21.0
AURN Princes Street	44.6	50.1	47.6	50.3	49.3	10.5
Mean bias = 22.15 % (weekly exposed tubes)						

2001 data 11 months of data only (Comparison dates 03/01/01 to 4/12/01 for both analyser and pdts)

Site	Analyser	Pdt 1	Pdt 2	Pdt 3	Mean Pdt	% Bias
Queen Street/Castle St	38.2	42.0	42.4	-	42.2	10.5
Leith Walk	34.7	38.7	39.4	-	39.1	12.7
Haymarket Terrace	40.5	43.6	42.8	-	43.2	6.7
AURN Princes Street *	42.1	43.9	41.7	47.5	44.3	5.4
Mean bias % all sites = 8.9 % Mean bias% AURN site = 9.9 % (monthly exposed tubes) **Note 9.9% was the bias factor used due to data still requiring ratification at the AURN**						

*** Data sets require to be ratified**

2002 data (12 months data)

Site	Analyser	Pdt 1	Pdt2	Mean Pdt	% Bias
Queen Street/Castle St	43	47.5	47.2	47	8.5
% bias = 8.5 % (monthly exposed tubes) Bias data from only one site was considered to be realiable, due to theft of pdts at the Gorgie Rd site, down time and relocation of the AURN site and errors in values caused by other research establishments siting additional ptds and equipment to close to the exposed end of the Council's own pdts					

Calculation of bias correction for the diffusion tubes was as follows:

Example:

Mean annual analyser value = 43µgm/m^3 . Mean annual passive diffusion tubes = 47µg/m^3

47 – 43/47 x 100 = 8. 5 % overread

Data capture for the real time analysers over the monitoring periods was greater than 90%

Passive diffusion tube collection analysis was 95 - 100% .

APPENDIX 6B % Data Capture NO_2 passive diffusion tubes

St John's Road Sites	2001 Jan- Dec	2002 Jan - Dec	2003 Jan- Dec	2003/4 Oct- Sept	2004 Jan -Sept
1	83%	92%	83%	92%	100%
1x	-	92%	83%	92%	90%
1A	83%	92%	75%	92%	100%
1b	-	-	-	83%	89%
1c	-	-	-	92%	89%
1d	-	-	-	83%	78%
32	-	-	-	-	78%

APPENDIX 6C Passive diffusion tube kerb to façade distance corrections

Code	**Location**	**Distance pdt from kerb(m)**	**Distance from pdt to façade (m)**	**Factor used**
1	St Johns Road	0.54	1.9	0.95
1x	St Johns Road Duplicate	0.54	1.9	0.95
1A	St Johns Rd /Victor Park Terrace	1.7	9.0	0.90
3A	Hillview Terrace	1.0	9.0	
1b	St Johns Road Post Office	2.5	facade	
1c	St Johns Road (Williamson Florist)	2.1	facade	
1d	Duplicate	2.1	facade	
32	St Johns Road no 131	2.1	facade	

APPENDIX 6D/1 Correction factors used to estimate annual average NO_2 concentrations to future years at roadside locations (Box 6.6 LAQM TG(03))

Year of measured data	Projection to 2005 Factor used	Projection to 2010 Factor used
2000	0.892/1.033 = 0.8635	0.734/1.033 = 0.7105
2001	0.892/1.000 = 0.8920	0.734/1.000 = 0.7340
2002	0.892/0.969 = 0.9205	0.734/0.969 = 0.7574
2003	0.892/0.941 = 0.9479	0.734/0.941 = 0.7800
2003/4	0.892/0.915 = 0.9749	0.734/0.915 = 0.8022
2004	0.892/0.915 = 0.9749	0.734/0.915 = 0.8022
Example measured data for 2000 = 48μg/m^3 Projection to 2005 48 x 0.8635 = 41μg/m^3		

APPENDIX 6D/2 Correction factors used to estimate annual average NO_2 concentrations to future years at background locations (Box 6.7 LAQM TG(03))

Year of measured data	Projection to 2005 Factor used	Projection to 2010 Factor used
2001	0.908/1.000 = 0.908	0.778/1.000 = 0.778
2002	0.908/0.973 = 0.933	0.778/0.973 = 0.800
2003	0.908/0.948 = 0.958	0.778/0.948 = 0.821
2003/4	0.908/0.927 = 0.980	0.778/0.927 = 0.839
2004	0.908/0.927 = 0.980	0.778/0.927 = 0.839
Example measured data for 2001 = 19μg/m^3 Projection to 2005 19 x 0.908 = 17μg/m^3		

APPENDIX 7 DMRB inputs PM_{10}

Location	PM_{10} bckgrnd	Speed km/hr	Distance from link centre to receptor	AADT combined	Road type	% HGV	Link
City By Pass	12.8	60	29.0	64605	A	10	1
Glasgow Rd	12.8	50	18.1	46988	A	10	1
Roseburn Terrace	12.8	30	8.9	26040	A	12	1
Queen St	14.4	40	14.0	37356	A	2	1
Haymarket Terrace	12.8	40	9.1	26568	A	15	1
West Maitland St	14.4	40	12.1	20775	A	12.5	1
St Johns Road Clermiston Road	12.8 12.8	30 30	8.2 8.8	24852 9840	A B	9.8 0.1	2
Ferry Road	13.6	40	9.2	19000	A	8.1	1
London Road	14.4	40	9.2	18184	A	11.7	1
Leith Walk	14.4	40	13	25879	A	12.7	1
Dalry Road	12.8	30	8.8	15602	B	12.0	1
Gorgie Road	12.8	30	7.1	17469	B	12.0	1
West Port	14.0	30	5.3	13000	B	5.2	1
Gt Junction St (Leith)	13.6	30	9.4	12992	B	12.2	1
Bernard St (Leith)	12.8	30	5.8	18946	B	9.2	1
Morningside Road	12.8	30	8.6	15887	B	6.5	1
Dalkeith Road	12.8	40	8.8	20932	B	6	1

DMRB inputs St Johns Road

Location	NOx/ NO_2 BG	Speed km/hr	Distance from link centre to receptor	AADT combined	Road type	% HGV	Link
St Johns Road Clermiston Road	42.8 25.6	30 30	8.2 8.8	24852 9840	A B	9.8 0.1	2

APPENDIX 8 Ion data from partisol study

	Total mass microgra				Conc in microgra M^3		
	SO4	NO3	Cl	Wk vol air	SO4	NO3	Cl
wk1	194	66	257	177.1	1.10	0.37	1.45
wk2	211	72	337	174.3	1.21	0.41	1.93
wk3	181	74	386	177.1	1.02	0.42	2.18
wk4	358	451	162	165.9	2.16	2.72	0.98
wk5	244	221	329	180.6	1.35	1.22	1.82
wk6	384	452	321	179.9	2.13	2.51	1.78
wk7	316	419	230	179.9	1.76	2.33	1.28
wk8	585	597	345	175.7	3.33	3.40	1.96
wk9	138	44	212	175.7	0.79	0.25	1.21
wk10	201	201	151	176.4	1.14	1.14	0.86
wk11	510	826	221	175	2.91	4.72	1.26
wk12	194	152	111	175.7	1.10	0.87	0.63
wk13	172	112	124	172.2	1.00	0.65	0.72
wk14	238	168	92	174.3	1.37	0.96	0.53
wk15	348	320	177	172.9	2.01	1.85	1.02
wk16	615	487	20	172.9	3.56	2.82	0.12
wk17	250	104	152	172.9	1.45	0.60	0.88
wk18	73	68	74	175.7	0.42	0.39	0.42
wk19	Lab error						
wk20	Lab error						
wk21							
wk22	202	115	97	172.2	1.17	0.67	0.56
wk23	212	98	153	172.2	1.23	0.57	0.89
wk24	164	51	100	172.2	0.95	0.30	0.58
wk25	153	54	66	172.2	0.89	0.31	0.38
wk26	208	87	70	170.1	1.22	0.51	0.41
wk27	289	177	109	171.5	1.69	1.03	0.64
wk28	1210	650	20	171.5	7.06	3.79	0.12
					1.8	1.4	1.0

20 - values reported as being less than 40 therefore 20 ia an assumed concentration.

		conc	in microgra m3		%ions in PM10			**%Sum**
	PM10 con	**SO4**	**NO3**	**Cl**	**%SO4**	**% NO3**	**%Cl**	
wk1	8.7	1.10	0.37	1.45	12.6	4.3	16.7	33.6
wk2	11.2	1.21	0.41	1.93	10.8	3.7	17.3	31.8
wk3	15.9	1.02	0.42	2.18	6.4	2.6	13.7	22.8
wk4	24.2	2.16	2.73	0.98	8.9	11.3	4.0	24.2
wk5	17.7	1.35	1.22	1.82	7.6	6.9	10.3	24.8
wk6	22	2.14	2.52	1.79	9.7	11.4	8.1	29.3
wk7	23.6	1.76	2.33	1.28	7.5	9.9	5.4	22.8
wk8	28.5	3.33	3.40	1.96	11.7	11.9	6.9	30.5
wk9	10.6	0.79	0.25	1.21	7.4	2.4	11.4	21.2
wk10	18.7	1.14	1.14	0.86	6.1	6.1	4.6	16.8
wk11	23.5	2.91	4.72	1.26	12.4	20.1	5.4	37.9
wk12	12.2	1.10	0.87	0.63	9.1	7.1	5.2	21.3
wk13	12.1	1.00	0.65	0.72	8.3	5.4	6.0	19.6
wk14	13.7	1.37	0.96	0.53	10.0	7.0	3.9	20.9
wk15	18.2	2.02	1.86	1.03	11.1	10.2	5.6	26.9
wk16	24	3.57	2.82	0.12	14.9	11.8	0.5	27.1
wk17	13.4	1.45	0.60	0.88	10.8	4.5	6.6	21.9
wk18	13.5	0.42	0.39	0.42	3.1	2.9	3.1	9.1
wk19								
wk20								
wk21								
wk22	9.4	1.17	0.67	0.56	12.5	7.1	6.0	25.6
wk23	12.3	1.23	0.57	0.89	10.0	4.6	7.2	21.9
wk24	11.9	0.95	0.30	0.58	8.0	2.5	4.9	15.4
wk25	11.7	0.89	0.31	0.38	7.6	2.7	3.3	13.6
wk26	14.1	1.22	0.51	0.41	8.7	3.6	2.9	15.2
wk27	20.9	1.69	1.03	0.64	8.1	4.9	3.0	16.0
wk28	41.7	7.06	3.79	0.12	16.9	9.1	0.3	26.3
Mean	**17.3**	**1.8**	**1.4**	**1.0**	**9.6**	**7.0**	**6.5**	**23.0**

APPENDIX 9