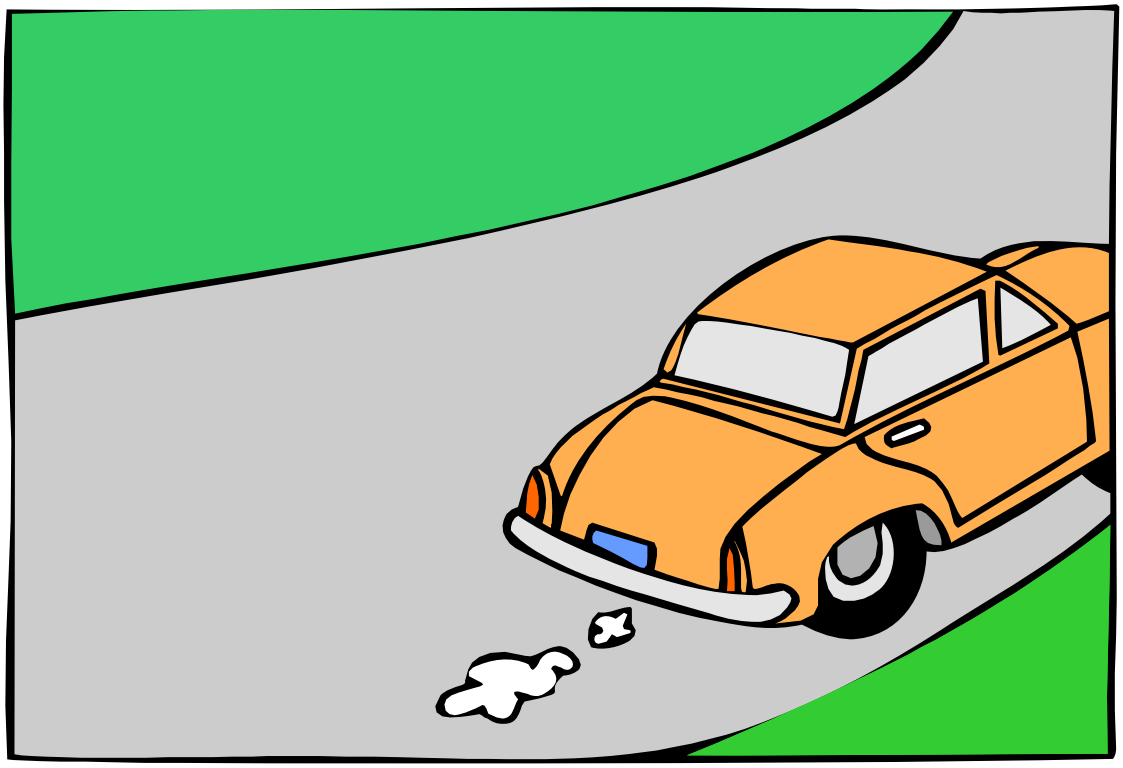
CARLISLE CITY COUNCIL

LOCAL AIR QUALITY MANAGEMENT

SECOND STAGE REVIEW AND ASSESSMENT



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SECOND STAGE AIR QUALITY REVIEW AND ASSESSMENT

1. INTRODUCTION

1.1 AIM AND OBJECTIVES

This document is the second stage review and assessment of local air quality in the Carlisle City Council area. As such, its aim is to examine air pollution and the public's exposure in more detail, focussing on particulates and nitrogen dioxide.

The review and assessment will address the following objectives:

- Review conclusions from stage one study
- Review recent air quality monitoring data
- Review computer modelling results
- Assess the likelihood of achieving air quality objectives by 2005
- Consider need for stage three review and assessment work

1.2 LEGISLATION

The legislative background to the UK's National Air Quality Strategy (NAQS) is explained in Carlisle City Council's "Local air quality management - First stage review and assessment", published in September 1998. The strategy is targeted at the quality of ambient air, i.e. the outdoor air that the public breathes. It does not consider occupational or indoor air.

The core reference remains the Air Quality Regulations 1997. Further direction is provided to local authorities in DETR Circular 15/97 and eight accompanying volumes of guidance.

1.3 MAIN FINDINGS OF FIRST STAGE REVIEW AND ASSESSSMENT

The first stage review and assessment was a screening exercise examining all seven pollutants of concern. Five were assessed not to be at significant risk of exceeding their relevant objectives. These were benzene, 1,3-butadiene, carbon monoxide, lead and sulphur dioxide. They will not be considered further in the main body of this review and assessment process.

Two pollutants were considered to be at significant risk of exceeding their objectives; nitrogen dioxide (NO_2) and fine particulates (PM_{10}) and the report will consider these pollutants in more detail. The areas of concern were:

Nitrogen dioxide

Most local nitrogen dioxide is generated by road transport and high annual means (over the 2005 objective) were measured in 1997 on all of the four inner city roads

that have diffusion tube monitoring sites. 14 roads are predicted to have high traffic flows of over 25,000 vehicles per day by the year 2005 and may therefore be at risk of exceeding the objectives.

Particulates

There has been no recent particulate monitoring in Carlisle, but national data indicates a high likelihood of the authority breaching the 2005 objective.

1.4 REVIEW OF NATIONAL AIR QUALITY STRATEGY

Following the change of government in May 1997, a review of the NAQS was announced and proposals to amend the strategy were published in January 1999. Consultation has now closed and final decisions will be published "by the end of the year". Of the seven pollutants, five have had their target dates brought forward or limits tightened and one (particulates) relaxed. A summary of the review's recommendations as applicable to local authorities is as follows:

TABLE 1: PROPOSED CHANGES TO NAQS OBJECTIVES

Pollutant	Objective by 2005	Measured as	Proposed new objectives
Benzene	5ppb	Running annual mean	5 ppb by 2003 Indicative level of 1 ppb by 2005
1,3 – butadiene	1ppb	Running annual mean	1 ppb by 2003
Carbon monoxide	10ppm	Running 8-hour mean	10 ppm by 2003
Lead	0.5 ug/m^3	Annual mean	0.5 ug/m^3 by 2004 0.25 ug/m^3 by 2008
Nitrogen dioxide	150 ppb 21 ppb	1-hour mean Annual mean	104.6 ppb by 2005 (max. 18 exceedences) 21 ppb retained as provisional objective by 2005
Particulates	50 ug/m^3 (99^{th} percentile)	Running 24-hour mean	New annual objective of 40 ug/m^3 and 24-hour objective of 50 ug/m^3 (max. 35 exceedences) for 2004 50 ug/m^3 as 99^{th} percentile of running 24-hour mean retained as indicative level for 2005 New indicative annual level of 20 ug/m^3 and 24-hour level of 50 ug/m^3 (max. 7 exceedences) for 2009
Sulphur dioxide (SO_2)	100 ppb (99.9^{th} %ile)	15 minute mean	100 ppb as 15-minute means adopted as firm objective for 2005 New 1-hour objective of 131 ppb (max. 24 exceedences) and 24-hour objective of 46.8 ppb (max. 3 exceedences) for 2004

ppm = parts per million by volume ppb = parts per billion by volume ug/m^3 = micrograms per cubic metre

Note: Each date is for the end of the year e.g. 2005 is 31.12.2005

This revision may therefore lead to a change in air quality objectives during the two year review and assessment period. The implications for the work completed in Carlisle so far are as follows:

Benzene

The estimated annual mean by 2005 is 2.0 ppb. The revised objective two years earlier in 2003 is expected to be met.

1,3-butadiene

The estimated annual mean by 2005 is 0.7 ppb. The revised objective two years earlier in 2003 is expected to be met.

Carbon monoxide

The estimated maximum 8-hour mean by 2005 is 4 ppm. The revised objective two years earlier in 2003 is expected to be met.

Lead

The estimated annual mean level by 2005 is 0.05 ug/m^3. The revised objective one year earlier in 2004 is expected to be met.

Nitrogen dioxide

- Hourly mean: The current provisional 150 ppb 1-hour mean will reduce to an EU limit of 104.6 ppb, but 18 exceedences per year will be allowed. Surrogate statistics projected a maximum hourly mean on Scotland Road in 1997 of 150 ppb, so the revised objective may well not be met by 2005.

- Annual mean: The annual mean of 21 ppb is unchanged and recent monitoring shows this is currently exceeded at some kerbside monitoring sites.

Particulates

New EU-defined objectives by 2004 are of 40 $\mu g/m^3$ and 50 $\mu g/m^3$ for annual and daily levels respectively. Due to smaller percentiles (99 to 90%), the revised daily limit represents a relaxation of the current objective.

Sulphur dioxide

The estimated annual mean level by 2005 is below 2 ppb. The new 1- and 24-hour EU objectives one year earlier in 2004 are expected to be met.

1.5 SECOND STAGE METHODOLOGY

The DETR publication “Framework for review and assessment of air quality” states that the second stage should be a further screening of pollution concentrations in the area. Authorities should select areas where the highest concentrations are

likely to occur ("hotspots") and base their review and assessment here. There are two core elements to this review:

1.5.1 Monitoring

Monitoring is the measurement of ambient air quality and quantifies current pollution levels. Measurement must be over the relevant averaging times; for NO_2 these are periods of 1-hour and one year, for PM_{10} they are 24-hours and one year. These periods define the monitoring locations; for 1-hour averaging times the assessment should consider near-ground level outdoor locations where the public may be found. This would include parks, bus stops and pavements. Pollutants with longer averaging periods, especially those of one year, must be assessed where people spend a reasonable portion of a year, for example schools and residential areas. Two types of monitoring can be used; passive samplers and automatic point analysers:

Passive samplers

Diffusion tubes are used to passively sample nitrogen dioxide. (They cannot sample particulates). These low cost tubes are mounted on street furniture and adsorb NO_2 onto a substrate. They are changed monthly and analysed by laboratory. This provides the data for the NAQS NO_2 annual averages. There are 22 diffusion tubes distributed around the authority area.

Automatic analysers

Automatic analysers contain sophisticated monitoring equipment that runs continuously to generate real-time data on pollution levels at a single point. This is the only way to measure pollution over the shorter-term periods. This method is not required for a stage two assessment, but can be used to gather accurate pollution information for subsequent review work.

1.5.2 Modelling

DETR publication "Selection and use of dispersion models" states that screening models should be used for a stage two review. These are simple mathematical equations in a chart or spreadsheet that allow estimations of pollutant concentrations from data such as traffic counts. No account is taken of meteorology. Results are approximate, but the models provide cheap and prompt estimates for preliminary assessment purposes. Individual sources only are considered; either point sources (e.g. stacks) or line sources (e.g. roads). Models appropriate to stage two are:

Point sources

"Guidance for estimating the air quality impact of Stationary Sources" (GSS) is a new publication from the Environment Agency. It is a collection of charts generated using a sophisticated computer model that considers stack height, weather and duration to estimate local pollution concentrations. It replaces the D1 model previously used.

Line sources

The “Design Manual for Roads and Bridges” (DMRB) is a paper-based model originally designed for rural trunk road design, which can be employed to calculate pollution levels near to roads. The revised edition issued by DETR in May 1999 is more suitable for urban situations.

2. CONSULTATION

Schedule II of the Environment Act 1995 requires local authorities to consult externally as part of their review and assessment exercises and the following bodies have been contacted:

- Eden District Council
- Copeland Borough Council
- Tynedale District Council (Northumberland)
- Scottish Environmental Protection Agency (Borders and Dumfries & Galloway area offices)
- Cumbria County Council
- Environment Agency
- Carlisle Business Forum
- Friends of the Earth
- Carlisle Association of Parish Councils

Responses have been received from the Environment Agency, Cumbria County Council and the Scottish Environmental Protection Agency. The Air Quality, Transport and Planning Working Group for air quality issues within Carlisle City Council meets quarterly to discuss air quality policies and its involvement in established council functions.

3. REVIEW & ASSESSMENT OF NITROGEN DIOXIDE

Objectives: 21 ppb or less when expressed as an annual mean
150 ppb or less when expressed as an hourly mean

(For background information on the health effects of nitrogen dioxide, see the stage one air quality report)

3.1 NATIONAL DATA

Nitrogen dioxide is produced by the reaction between nitrogen and oxygen during high temperature combustion. Most oxides of nitrogen (NO_x) are generated as nitric oxide (NO), which is oxidised in the atmosphere by local ozone to produce nitrogen dioxide (NO_2). At kerbsides, the NO:NO_2 ratio is about 2:1, rising at background levels to about 1:1. It is one of the most widespread pollutants in the UK. National emissions of NO_x in 1996 were 2.06 million tonnes, 46% produced by vehicles and 22% by power stations.

Current UK trends show a slow reduction in NO_2 levels, as since 1987 annual average urban values have fallen by 0.7 ppb per annum and 1-hour maximum urban values by 9 ppb per annum. Levels nationally are forecast to continue declining until 2010 as a result of national policies; primarily the introduction of catalytic converters on petrol engine cars in 1993.

Much information is available at the UK National Air Quality Information Archive (NAQIA), a government internet site with comprehensive information on pollutants, mapping and measurement. One section estimates total annual emissions using data on pollution sources like traffic and factories. The map attached at Annex 7.1 gives this information for the Carlisle area. This shows emissions highest in urban areas and on major routes. Separate data on NO_2 annual background means in Cumbria predicts levels as follows:

Rural area	under 5 ppb
M6 surroundings	5-10 ppb
City	10-20 ppb
Trunk roads and M6	30-35 ppb

These are only *estimates*, but provide an illustration of likely levels of air pollution experienced by the public.

3.2 LOCAL SOURCES

The total amount of NO_2 in the Carlisle area is derived from point, line and area sources.

3.2.1 Point sources

Point sources are usually industrial in nature. The industrial processes with greater potential for pollution emissions to air are regionally controlled by the

Environment Agency ("Part A" processes) and the smaller ones by the local authority ("Part B" processes).

Part A processes within authority area

There are no current Part A processes in the authority area. Outline planning permission has been granted to Border Biofuels Ltd for a Part A process; a wood-burning power station near Rockcliffe. The developers have predicted the plant's emissions with a computer model and this is discussed in section 3.4.

Part A processes beyond authority area

There are two Part A processes in neighbouring authorities that are significant emitters of oxides of nitrogen and within 25 km of the Carlisle authority's boundary – UCB Films Ltd, Wigton and Chirex Ltd, Annan. The modelling of their emissions is discussed in section 3.4.

Part B processes within authority area

There are 61 Part B processes in the authority area which cover a range of light industrial and commercial activities; they are listed in Annex 7.2. The DETR publication "Review and assessment: pollution specific guidance" indicates which processes may release significant quantities of nitrogen dioxide. None of these 61 sites are within the listed categories as significant emitters of NO_2.

3.2.2 Line sources

Vehicle traffic exhausts represents the majority local source of NO_x. Emissions are dependant on speed, congestion and flow, with flow volumes the most significant. Seven roads in Carlisle currently exceed 25,000 vehicles per day and another seven are projected to do so by 2005. Essentially these are most of the major inner-city roads. These highways will therefore be significant line sources of NO_x.

3.2.3 Area sources

Area sources are diffuse in character. Often they are multiple small individual sources summed within an area, such as a number of domestic combustion boilers in a residential zone. These contribute about 10% towards NO_x pollution levels locally.

3.3 LOCAL MONITORING

This second stage review and assessment is targeted at areas of highest pollution concentration – the hotspots – where there is the highest likelihood of the 1-hour or annual objectives being exceeded. The monitoring programme has therefore been structured to assess this issue with sites grouped as follows:

1-hour objective: roadside sites e.g. bus stops, pavements, shops
Annual objective: schools, hospitals and residential areas

Monitoring for NO_2 in this stage two report is conducted using passive samplers (diffusion tubes) as recommended in DETR publication "Monitoring for air quality review and assessments". As an economical technique, these are useful for identifying local hotspots and trends in NO_2 pollution. They produce data that can be averaged to generate annual levels. They cannot provide information for assessment of hourly objective; this can be estimated with surrogate statistics.

11 monitoring sites were established under Phase One in October 1995 (sites 1-11) and a further 11 under Phase Two in September 1998 (sites 12-22). Sites are distributed to measure in different types of location, such as roadsides, shopping areas and suburbs. The locations are classified as follows (and are marked on the maps at Annex 7.3):

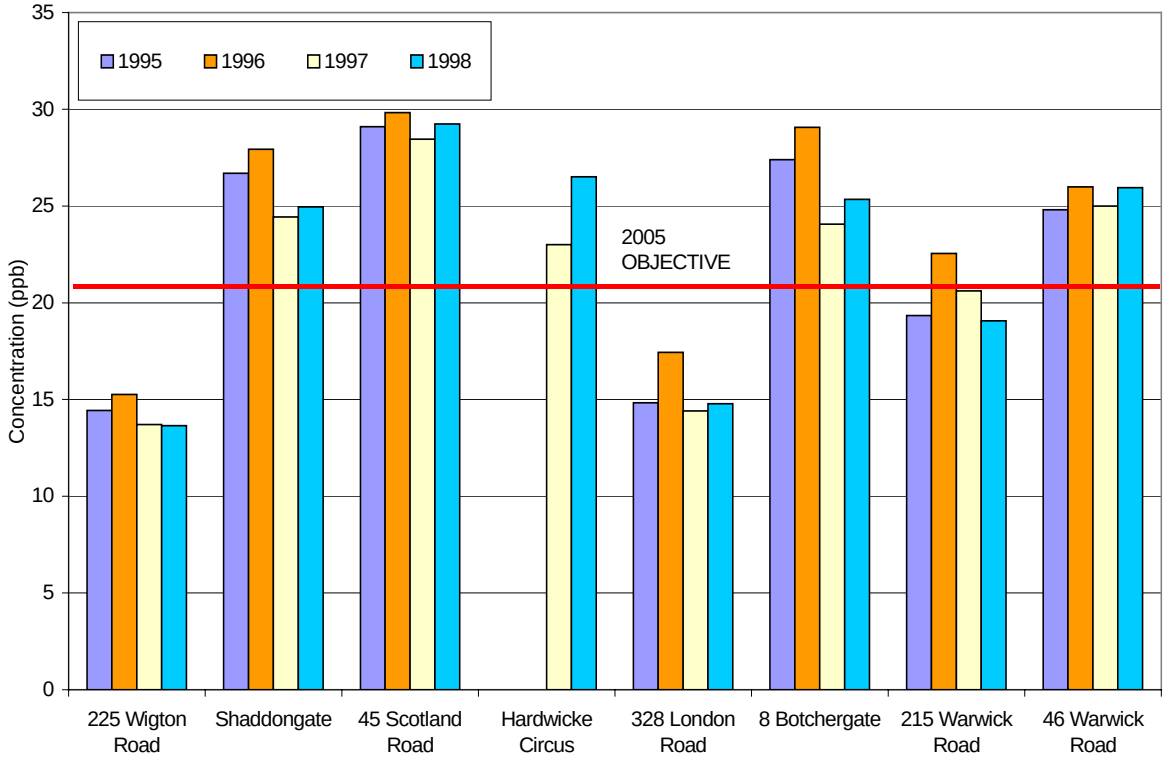
TABLE 2: NO_2 DIFFUSION TUBE CATEGORIES AND LOCATIONS

Site number	Site type	Site address	Remarks
2	Urban – Kerbside	Hardwicke Circus	Under 1m from kerb
4	Urban – Roadside	Shaddongate	Inner-city road
19+20	Urban – Roadside	Lowther Street	Inner-city road (2 tubes)
8	Urban – Roadside	8 Botchergate	Inner-city road
7	Urban – Roadside	45 Warwick Road	Inner-city road
1	Urban – Roadside	225 Wigton Road	Arterial road
3	Urban – Roadside	45 Scotland Road	Arterial road
5	Urban – Roadside	328 London Road	Arterial road
6	Urban – Roadside	215 Warwick Road	Arterial road
11	Urban - Centre	Tourist Info. Centre	City centre
18	Urban - Background	Strand Road	Trinity school
12	Urban - Background	Fusehill Street	City Hospital
14	Urban - Background	Dale Street	Denton Holme
10	Suburban	Sanderson Close	Lowry Hill
9	Suburban	Palmer Road	Belle Vue
16	Suburban	Croft Terrace	Botcherby
15	Suburban	Silverdale Road	Harraby
17	Suburban	Montreal Street	Currock
13	Suburban	Crosshill Drive	Morton
21	Urban – Roadside	Tourist Info. Centre	Brampton
22	Urban – Roadside	English street	Longtown

3.3.1 Phase one sites (1995 onwards)

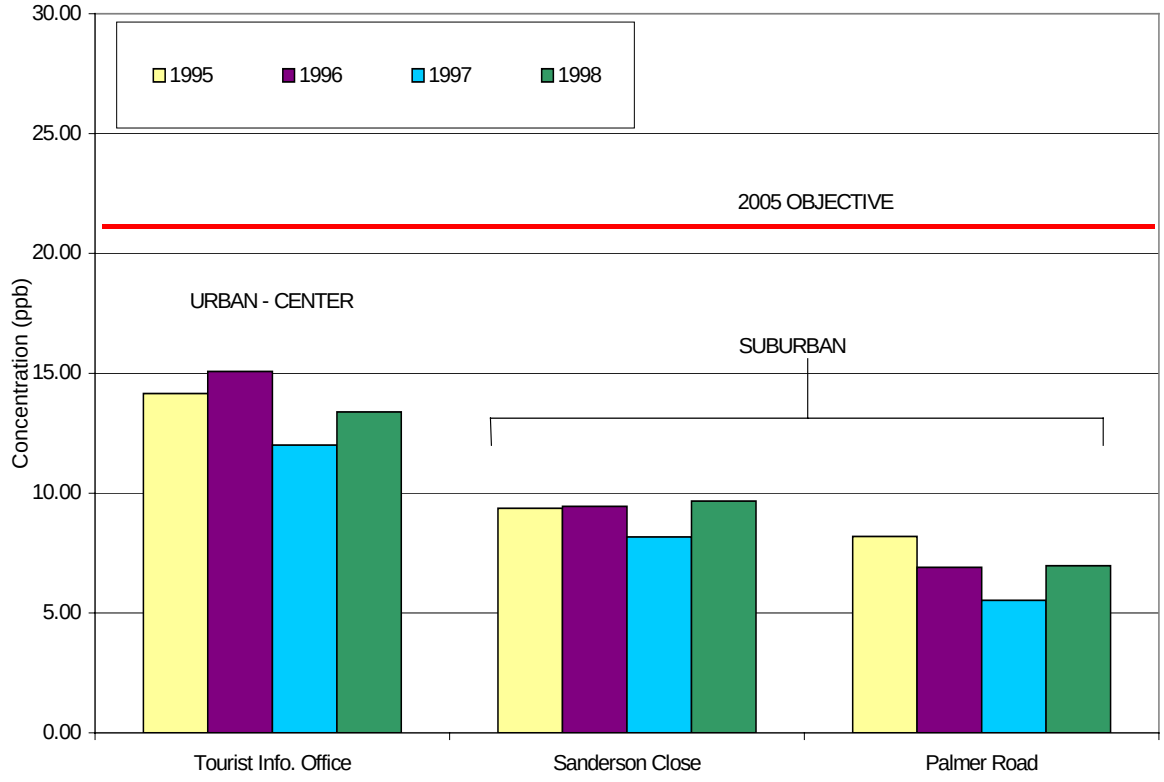
The 11 original monitoring sites were established primarily on main roads around the city. Annual averages have been determined for these sites, with graph one showing the eight roadside sites and graph two the other three locations; one urban (city centre) and two suburban:

GRAPH 1: NO_2 ANNUAL MEANS - ROADSIDE SITES



This shows the substantial presence of NO_2 at roadside sites and most columns on the graph exceed the annual 2005 objective line, with some of these sites in locations where people are exposed for a significant percentage of the year-long period.

GRAPH 2: NO_2 ANNUAL MEANS – URBAN (CENTRE) & SUBURBAN SITES

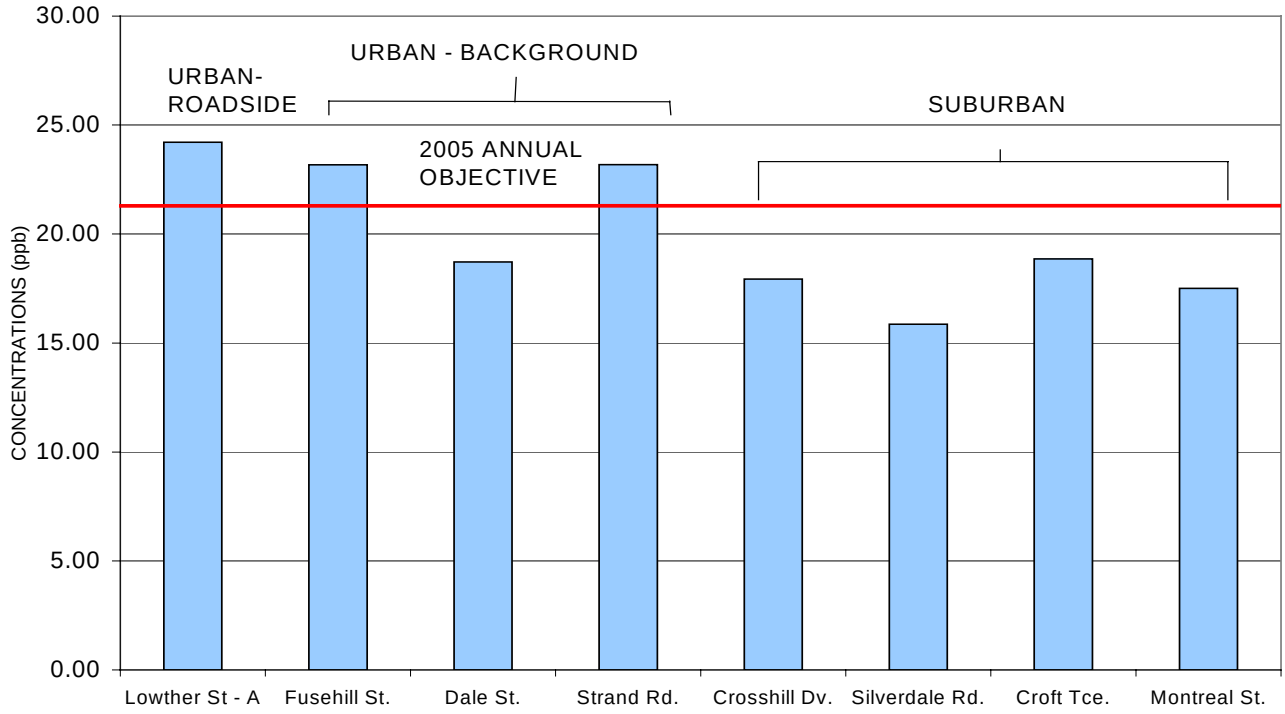


This graph illustrates two different classifications of site. The Tourist Information Centre is a central site within the pedestrianised area of the city centre where large numbers of people will experience noteworthy exposure. Over the four-year period, pedestrians breathed air polluted to an average of 65% of annual objective level. The two suburban sites, which best represent locations relevant to the annual objective, experienced air polluted to 33% and 44% of the limit. Neither categories of location are therefore at significant risk of breaching the NAQS objective.

3.3.2 Phase two sites (1998 onwards)

Annual means can not be determined for the 10 additional sites established in September 1998 as data has only been generated for 7 months. However the results to date have been averaged to give an indication of likely levels, although this includes the winter period when episodes of higher pollution are more likely. Graph 3 shows the eight newer sites in Carlisle city:

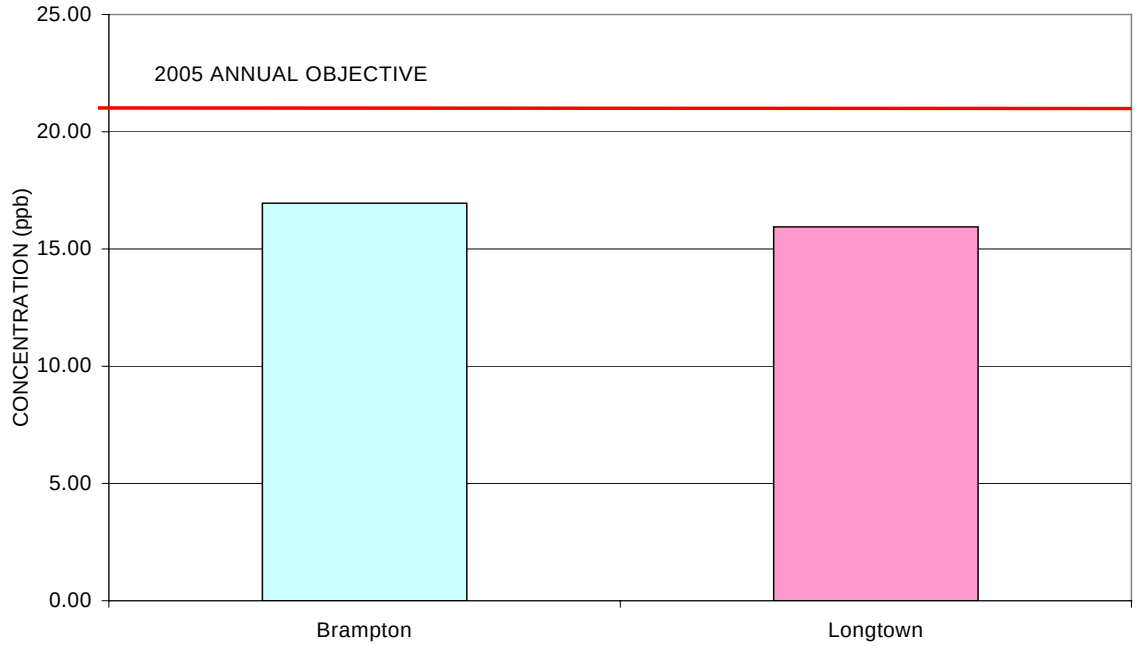
GRAPH 3: NO_2 SEVEN MONTH MEANS – URBAN & SUBURBAN SITES



The graph shows relatively high levels at many of these additional sites, with 3 urban locations exceeding the 2005 annual objective. The Lowther Street site is 2m from a busy city centre road carrying 15,000 vehicles per day, but the pollution average here is matched at two of the urban background sites. These are at Fusehill Street (by the City Maternity Hospital) and Strand Road (by Trinity School). These sites are in central areas of Carlisle, but represent urban locations mainly of residential use. Population densities are high e.g. Victorian-era terraced housing, so there are substantial numbers of people exposed to these levels. The levels at suburban sites are also elevated, with only Silverdale Road in Harraby comfortably under the limit. So even suburban sites 2-4 km from the city centre are close to the objective level. The other two new sites were established in Brampton (population 4,000) and Longtown (population 3,000). Both diffusion tubes are in town centre locations with moderate traffic levels and show the

presence of significant nitrogen dioxide; at levels of 84% and 79% of the annual objective respectively.

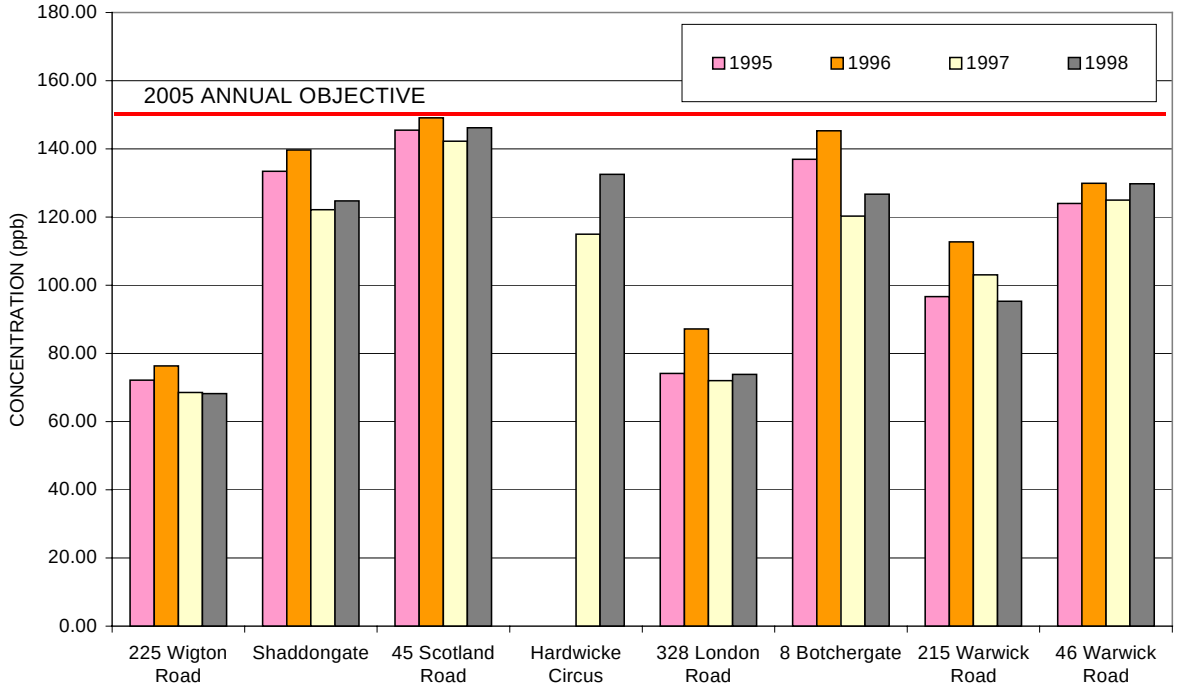
GRAPH 4: NO_2 SEVEN MONTH MEANS – RURAL TOWN SITES



3.3.3 Surrogate statistics

The NAQS also defines an hourly standard for NO_2 of 150 ppb and it is possible to estimate hourly means from monthly measurements by the use of surrogate statistics. The DETR publication "Design Manual for Roads and Bridges" (DMRB) states that the maximum hourly NO_2 mean is typically five times the NO_2 annual mean. Applying this adjustment factor to the 1995-98 annual mean data predicts hourly figures as in graph 5:

GRAPH 5: ESTIMATED MAXIMUM NO_2 HOURLY MEANS



This suggests that the hourly NO_2 objective is currently at or close to the 2005 limit at some roadside sites; the worst case being on Scotland Road.

3.3.4 Measurement uncertainty

Uncertainty in measurement comes from variations in accuracy and precision. They are defined thus:

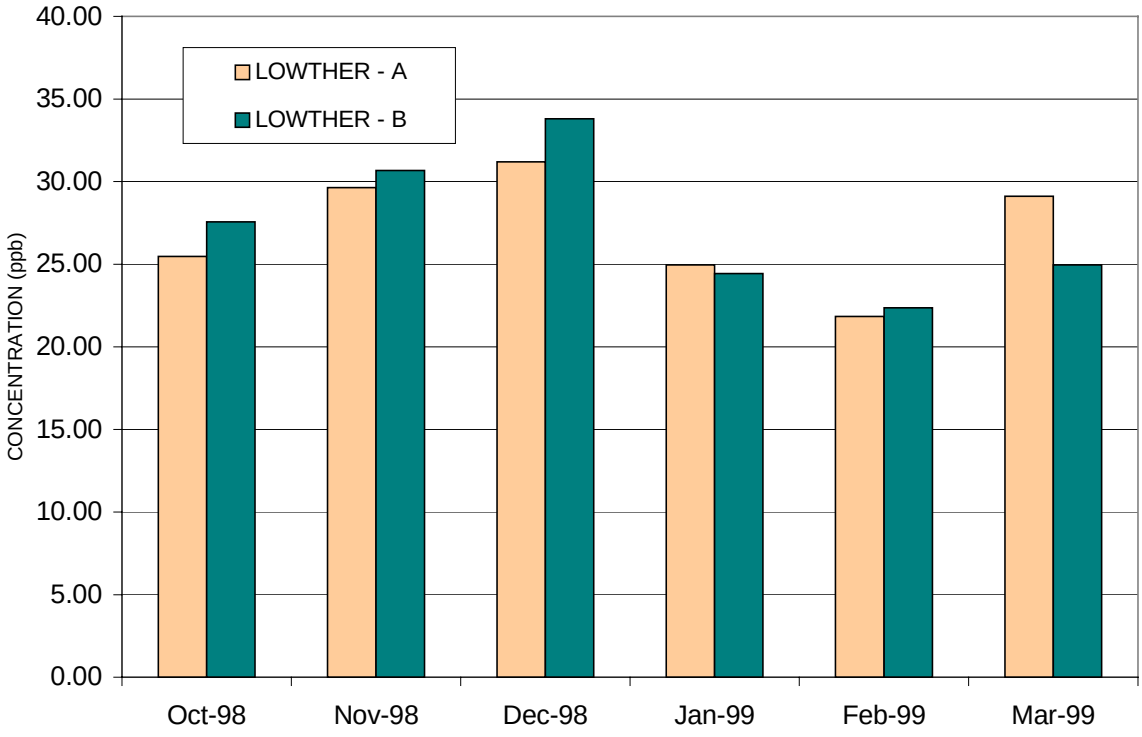
- Accuracy – the closeness of agreement between a single measured value and the actual characteristic. It is expressed as a percentage of measured value.

- Precision – the closeness of agreement between separate measured values of the same characteristic. It is expressed as a constant.

The diffusion tubes used are supplied by Greater Manchester Scientific Services, who quote an accuracy of ±5.4% (over 160 determinations), but could not quote data on precision. This accuracy figure is well within the DETR recommendation (for stage two) of below 30%.

To test precision locally, two tubes were located at the same monitoring point on Lowther Street. These are both exposed to the same ambient air pollution, so any variations in measurement are attributable to errors in precision. Graph 6 illustrates the data gathered over first six months:

GRAPH 6: CO-LOCATED NO_2 DIFFUSION TUBE MEANS



This shows that the diffusion tubes' variation in precision is a maximum of ±2.08 ppb per month; which when expressed as a percentage is ±7.7% of measured value.

3.4 MODELLING

3.4.1 Point sources

Modelling has been considered for stack emissions from three Part A processes; the possible Rockcliffe power station and factories at Wigton and Annan (situated in neighbouring local authorities).

Planned Rockcliffe power station

Outline planning permission has been given for a wood-burning power station at Rockcliffe, 4 km North West of Carlisle. The planning application from the developers Border Biofuels Limited includes air pollution estimates for the surrounding area using the Atmospheric Dispersion Modelling System (ADMS), which is a sophisticated and validated computer model. The predicted maximum ground level concentrations for NO_2 adjacent to the plant are as follows:

TABLE 3: PREDICTED MAXIMUM NO_2 GROUND LEVEL CONCENTRATIONS

Measurement	Background concentration NO_2 (ppb)	Predicted process concentration NO_2 (ppb)	Background + process concentration NO_2 (ppb)	% of NAQS standard
Annual average	7.8	5.4	13.2	64
Worst hour	7.8	104	111.8	74

Under the current NAQS NO_2 hourly objective of 150 ppb, the developer's estimate of 111 ppb falls within this limit. However the NAQS review proposes a new hourly objective of 104.6 ppb, with 18 exceedences per year, which their figure would then be above. There is insufficient data in the developer's proposal to estimate the number of exceedences, but is unlikely that there would be significant exposure to NO_2 over this new limit because:

- The model assumes that all oxides of nitrogen emerge as NO_2 - a pessimistic assumption. A simple estimate is that the average ratio of NO_2:NO at the point of maximum ground impact is 1:4.

- The dispersion plot shows peaks concentration of pollutants occurring in open countryside away from any dwellings.

Out-of-district factories

The need for modelling has been considered using the Environment Agency's workbook "Guidance for estimating the air quality impact of Stationary Sources" (GSS) for the Part A processes at Wigton and Annan. These are the only industrial installations within 25km of the Carlisle authority's boundary which are significant emitters of oxides of nitrogen. Their emissions as detailed by the Environment Agency are shown in Table 4:

TABLE 4: PART A PROCESSES EMITTING SIGNIFICANT NO_x

Site address & process number	Process	Distance in km to authority boundary	Carlisle city centre	Emissions of NOx 1998 (kg)
UCB Films Ltd, Wigton, Cumbria [AF 8378]	Combustion- Gas boiler	7	17	26,017
ChiRex Ltd, Three Trees Road, Newbie, Annan, DG12 5QH [IPC/058/1993]	Combustion- Oil boiler	6	23	25,500

UCB Films Ltd emits 71 kg of NO_x per day and their stack is 7km from this authority's boundary. The concentration of these emissions will be reduced by dilution prior to reaching our boundary and will add only slightly to existing background levels. The Annan plant's emissions are comparable in both amount and distance to this authority's boundary. Neither plant's emissions have therefore been considered necessary candidates for modelling.

3.4.2 Line sources

Road traffic is the main source of urban NO_x, so a simple line model that examines for this is of greatest value. The most suitable is the Design Manual for Roads and Bridges (DMRB) and this has been used in two stages:

- Current pollution levels can be predicted by the model at existing diffusion tube sites. Actual pollution levels measured by the tubes can then be compared with the model's predictions.

- Future pollution levels are then estimated for 2005 using the same methodology.

Current levels

The DMRB model has been run for the 5 long-term (phase 1) diffusion tube sites where there is a single significant line source (i.e. a road) nearby. Some sites with a complex of nearby roads, such as Shaddongate, cannot be simply modelled in this way because there are multiple sources affecting one receptor site. The spreadsheet results are detailed at Annex 7.4.1 (The background level in 1998 for NO_2 of 11 ppb has been taken from the NAQIA).

TABLE 5: MEASURED AND MODELLED NO_2 ANNUAL MEANS 1998

Site	Measured annual mean (ppb)	DMRB predicted annual mean (ppb)	Model error (%)
225 Wigton Road	13.65	30.79	+126
45 Scotland Road	29.24	46.4	+59
328 London Road	14.77	34.9	+136
215 Warwick Road	19.06	40.3	+111
46 Warwick Road	25.95	28.75	+10
Average	22.07	36.23	+88

This shows that the model consistently over-estimates the annual mean, on average by 88% of the measured amount. This issue has been discussed with Dr Vawda of Stanger Science & Environment on the DETR-sponsored modelling helpline. She confirms that DMRB is the only low-cost traffic model suitable for stage two work and that it is designed to give pessimistic results. Typically the model will over-estimate pollution levels by 30-40%. The larger than expected over-estimate of 88% may result from two factors:

- Individual Heavy Goods Vehicles (HGVs) are modelled to produce about ten times as much NO_x as a car. HGVs therefore contribute an amount of NO_x to the model's estimate that is disproportionately large compared to their numbers. This makes DMRB very sensitive to the accuracy of HGV percentages in the traffic flow counts.

- Carlisle is in a predominately rural area with prevailing south-westerly winds from the Lake District and the Irish Sea. Little NO_x pollution will be brought into the area and the 11 ppb background figure for Carlisle from the NAQIA may be too high.

This over-estimation does erode DMRB's validity and it is used henceforth to prove only indications, rather than predictions, of future pollution levels.

Future levels

DMRB can also be used to estimate levels in 2005; the objective date against which pollutants must be assessed. It considers the growth in traffic levels (+2.2% per annum) and future trends in emissions (declining until 2010). The spreadsheet results are detailed at Annex 7.4.2 and the main roads' hourly and annual means are shown below in Table 6:

TABLE 6: MODELLED NO_2 HOURLY AND ANNUAL MEANS 2005

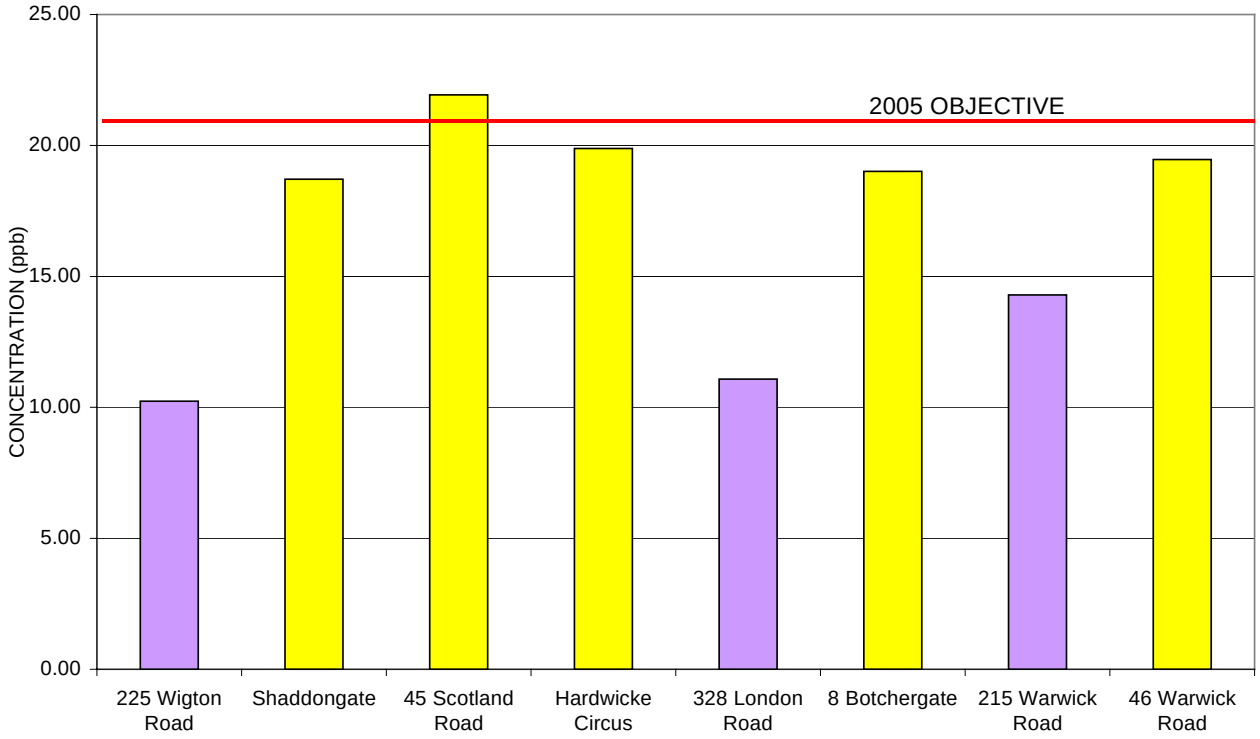
Site	DMRB predicted maximum hourly mean (ppb)	DMRB predicted annual mean (ppb)
225 Wigton Road	100.0	20.0
45 Scotland Road	172.1	34.42
328 London Road	111.0	22.0
215 Warwick Road	134.5	26.9
46 Warwick Road	93.0	18.6
Average	122.1	24.38

This indicates annual and hourly means decreasing by 33% on average. Although the means themselves are not considered particularly accurate, the trends (of declining levels) should be reliable.

3.5 PREDICTED LEVELS

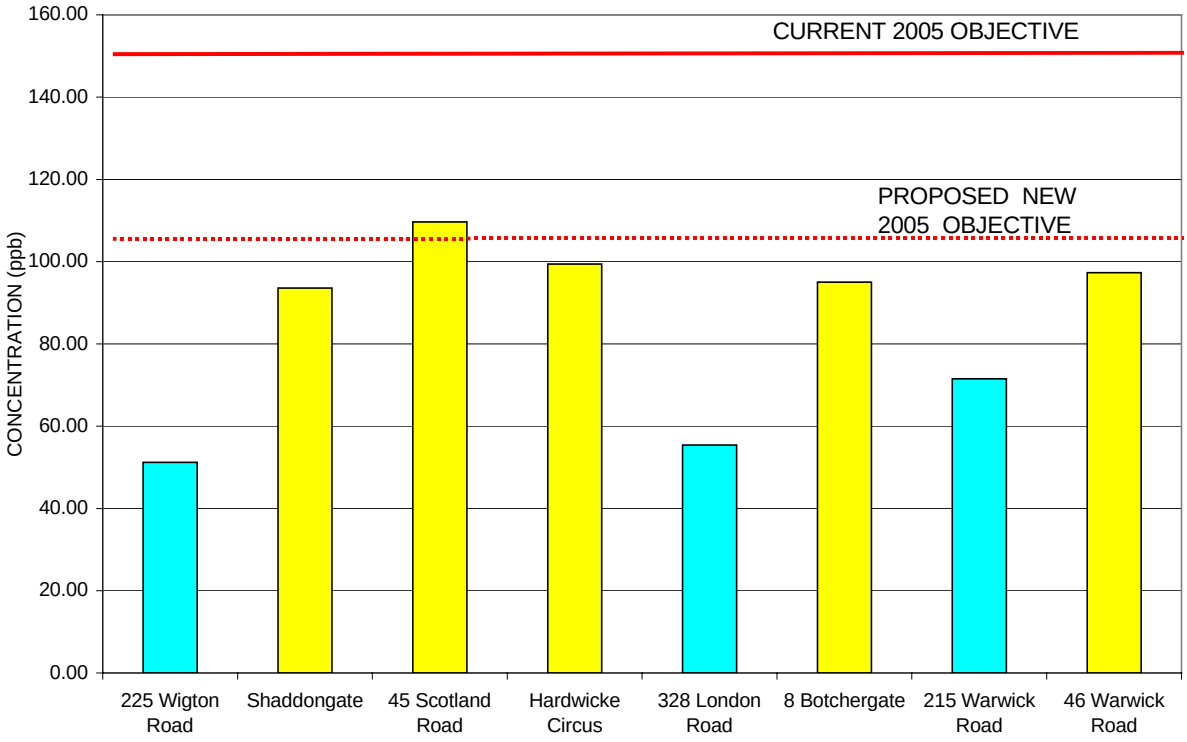
The national perspective for NO_2 is that emissions are expected to fall, with 2005 levels being 75% of 1998 figures (according to the Pollution Specific guidance). Applying this correction to the measured annual means (graph 1) gives an estimate of annual means by 2005 as graph 7 shows:

GRAPH 7: ESTIMATED NO_2 ANNUAL MEANS 2005



This predicts that five of the long-term monitoring locations (with yellow columns) will exceed, or be at risk of exceeding, the 2005 objective. The maximum hourly means at 2005 can also be estimated (by using the same factor of 75%) as graph 8 illustrates:

GRAPH 8: ESTIMATED MAXIMUM NO_2 HOURLY MEANS 2005



This is a product of two correction factors being consecutively applied to current data, so the potential for error is significant. However it represents the "best guess" available at present and predicts no sites as failing the current 150 ppb objective. Note that the NAQS review proposes a reduced limit of 104.6 ppb, albeit with 18 exceedences per year. The same 5 sites (again marked in yellow) may then fail, or be at risk of failing, this stricter test based on the above projection.

3.6 ASSESSMENT

The authority is conducting widespread monitoring for nitrogen dioxide with diffusion tubes to assess concentrations against the annual (21 ppb) 2005 objective and, by using surrogate statistics, estimating hourly (150 ppb) levels. The situation at present is that:

- Inner-city roadside sites are exceeding the annual objective; most are in the range 25-30 ppb. The peak estimated maximum hourly averages are around 120-150 ppb.

- Some urban residential areas' annual averages are over or near to the annual objective; suburban sites are in the range 10-20 ppb.

Hence there is evidence of many current exceedences of the annual mean in the city. The modelling results from DMRB are not considered sufficiently reliable to be employed for prediction purposes. Estimation of levels at 2005 using DETR reduction factors predict that:

- Inner-city roadside sites will be at or around the annual objective, but under the hourly limit.

- Urban residential areas will be under the annual objective at 15-20 ppb; suburban sites should be comfortably under both limits.

Overall, the prediction for 2005 is that the hourly limit is not at risk of being breached. The annual objective is being breached at present in relevant locations and there is significant risk of this remaining the case by 2005. This justifies further study, especially real-time monitoring, to more accurately quantify nitrogen dioxide levels in the city.

Nitrogen dioxide will be considered for a stage 3 review and assessment.

4. REVIEW & ASSESSMENT OF PARTICULATES

Objective: 50 μg/m^3 PM_{10} or less, when expressed as the 99th percentile of daily maximum running 24-hour means

(For background information on the health effects of particulates, see the stage one air quality report)

4.1 NATIONAL DATA

Particles are fundamentally different from nitrogen dioxide because they consist of solid matter. There are three categories:

- Primary particles, which are emitted directly to the atmosphere. These come mainly from fuel combustion in road transport and industry.

- Secondary particles, which are mostly sulphates or nitrates formed by natural processes in the air from other pollutants such as SO_2 or NO_2. Their production is not locally controllable.

- Coarse particles, which are natural e.g. windblown sea-salt or soil.

All Particulate Matter (PM) is grouped according to its size. The NAQS refers to PM_{10}; these are particles which are 10 microns or less in diameter [one micron = 1 μm = one millionth of a metre]. This very fine dust is minute enough to be inhaled into the lungs. National emissions of PM_{10} in 1996 were 213 thousand tonnes. Most primary particulate matter in Carlisle is likely to come from traffic.

UK trends show a slight reduction in particulate levels, as since 1993 annual average urban levels have fallen by 1 μg/m^3 per annum. However data from the national monitoring network indicates that the large majority of urban sites are still expected to fail the current NAQS standard.

Data on the NAQIA web pages shows estimated local PM_{10} concentrations from information on sources such as transport and industry. The map of particulate background concentrations in North Cumbria is attached at Annex 7.5 (for all 3 categories of particle combined), with the bandings roughly as follows:

Rural area	15-17 μg/m^3
City	17-22 μg/m^3
Trunk roads and M6	25-27 μg/m^3

(These figures represent all areas except those near roadsides or factories)

Secondary PM_{10} concentration is rated at 8 μg/m^3; this is material mostly blown into the UK from mainland Europe. These figures are only *estimates*, but provide a useful illustration of likely levels. The NAQIA also provides a map of PM_{10} annual emissions at Annex 7.6. This shows that each square kilometre within Carlisle city annually emits more than a tonne of PM_{10}.

4.2 LOCAL SOURCES

The total amount of PM_{10} in Carlisle is derived from point, line and area sources.

4.2.1 Point sources

Point sources are usually commercial or industrial in nature.

Part A processes within authority area

There are no Part A processes currently in the authority area. Outline planning permission has been granted to Border Biofuels for a Part A process as outlined in section 3.2.1 and the developer's emissions modelling is discussed in section 4.4.

Part A processes beyond authority area

There are four Part A processes in surrounding areas that are within 25 km of the Carlisle authority's boundary. None of these conduct processes listed in the Pollution Specific guidance as significant emitters of particulates.

Part B processes within authority area

Regarding the 61 Part B processes in the authority area (listed in Annex 7.2), the Pollution Specific guidance indicates which processes may release significant quantities of particulates. 10 of these are appreciable emitters of PM_{10} and are listed below:

TABLE 7: PART B PROCESSES EMITTING SIGNIFICANT PM_{10}

Site address & process number	Process
Carlisle Coated Stone Ltd, Stephenson Industrial Estate, Carlisle. EPA/023	Roadstone coating
Esk Building Products Ltd, Brisco, Carlisle. EPA/024	Brickworks
Carrs Billington Feeds Ltd, Kingstown Industrial Estate, Carlisle. EPA/036	Animal feeds manufacture
Tilcon Ltd, Willowholme Industrial Estate, Carlisle. EPA/027	Concrete batching
ARC Northern Premix Ltd, Willowholme Industrial Estate, Carlisle. EPA/020	Concrete batching
Willowholme Mini-Mix, Stephenson Industrial Estate, Carlisle. EPA/031	Concrete batching
Readymix Concrete Ltd, Kingstown Industrial Estate, Carlisle. EPA/022	Concrete batching
Pirelli Ltd, Dalston Road, Carlisle. EPA/039	Rubber process
Hargreaves Industrial Services Ltd, London Road, Carlisle. EPA/026	Coal distribution
W & M Thompson (Quarries) Ltd, Hallbankgate, Brampton, Carlisle. EPA/045	Stone quarry

Those eight sites in the city urban district are marked on the map at Annex 7.7. These Part B processes cover polluting activities that are relatively minor in size (compared to the industrial-sized activities that fall under the Environment Agency's Part A regulation). As such, the operators are not required to produce any data on the emissions to air resulting from their processes. Overall, it is considered that these few dust-generating processes add only slightly to background levels of PM_{10} in the authority area and will not require individual computer modelling because:

- Particles generated by man-made processes tend to be coarse in size and, as larger than 10 microns in diameter, outside the scope of this PM_{10} review.

- The processes are on industrial estates or in rural areas where people are unlikely to be exposed for the relevant averaging period (24-hours).

4.2.2 Line sources

Vehicle traffic represents the major line sources for PM_{10}, mainly from exhaust emissions. These are dependant on speed, congestion and flow, with flow volumes the most significant. Seven roads in Carlisle currently exceed 25,000 vehicles per day and another seven are projected to do so by 2005. These will all be significant line sources of PM_{10} and are assessed to be the majority source of fine particles in Carlisle.

4.2.3 Area sources

Area sources are diffuse; often they are multiple small individual sources considered collectively within an area e.g. domestic coal fires in a residential zone. These are estimated to contribute about 20% of local PM_{10} pollution.

4.3 LOCAL MONITORING

Particulate monitoring is an involved exercise because of the complexity of airborne physical matter. Simple diffusion tubes cannot be used for particulate sampling. Measurement requires equipment where a pump draws air through a separator (to eliminate particles over 10 microns) and then passes the remaining matter through a filter, which is then weighed. No measurement is presently carried out for particulates because the authority does not have any real-time monitoring equipment for that purpose. Such equipment is being purchased and the results will be incorporated in later stage three review and assessment work.

4.4 MODELLING

4.4.1 Point sources

Modelling has been undertaken by the developers of the planned Rockcliffe power station. The air pollution estimates from the ADMS model predict maximum ground level concentrations for PM_{10} as detailed in Table 8 below:

TABLE 8: PREDICTED MAXIMUM PM_{10} GROUND LEVEL CONCENTRATIONS

Measurement	Background Concentration ($\mu g/m^3$)	Predicted process concentration ($\mu g/m^3$)	Background + process concentration ($\mu g/m^3$)	% of NAQS standard
99th percentile	10	18	28	56

This modelling predicts the combustion process, in the worst instance, as adding 18 $\mu g/m^3$ of PM_{10} to a background of 10 $\mu g/m^3$. Although this produces a total level of nearly three times the background, this would only be 56% of the national objective.

4.4.2 Line sources

Road traffic is the main source of PM_{10}, so the line model DMRB can be used to indicate current and future particulate levels. The model has been rerun at the same sites as used for the nitrogen dioxide modelling in section 3.4.2. (The background levels of PM_{10} used in this model are 19 $\mu g/m^3$ for 1996 and 17$\mu g/m^3$ for 2005). The results are shown in Table 9:

TABLE 9: MODELLED PM_{10} ANNUAL MEANS

Site	Annual mean predicted for 1999 ($\mu g/m^3$)	Annual mean predicted for 2005 ($\mu g/m^3$)
225 Wigton Road	20.99	17.9
45 Scotland Road	25.16	19.79
328 London Road	21.78	18.28
215 Warwick Road	23.22	18.95
46 Warwick Road	20.89	17.86
53 Lowther Street	24.79	19.6
Average	22.8	18.73

This indicates that current PM_{10} levels on the city's arterial roads are under the NAQS 50$\mu g/m^3$ objective and should fall by 2005 as further vehicular and industrial pollution controls commence.

4.5 PREDICTED LEVELS

The modelling results indicate future levels as being under the existing NAQS objective for 2005. However these are only estimates from a simple model – which did not give accurate results for NO_x measurements - and should be confirmed by measurement.

4.6 ASSESSMENT

DETR advice at the time of this authority's stage one review and assessment (October 1998) was of national data indicating that most local authorities in Great

Britain would be at risk of exceeding the PM_{10} objective. They would therefore need to progress to at least a stage 2 review and assessment for PM_{10}. However following the review of the NAQS, the Government is now considering the adoption of looser EU-based particulate limits; most significantly by raising the number of 50µg/m^3 24-hour exceedences allowed from 4 to 35 occasions per annum. A letter from DETR on 12 March 1999 advised that authorities should give consideration to these possible revisions during their future reviews. So at this moment in time, this authority still has a legal duty to assess particulate levels against the existing (stricter) NAQS limit, while giving consideration to the potentially forthcoming (laxer) EU limits.

Overall there are two issues of uncertainty with particulates at this second stage of the air quality assessment process:

- PM_{10} modelled levels are unverified by monitoring

- PM_{10} objective levels may change in the future

For these reasons it is assessed that further study, especially the monitoring of PM_{10} levels, should be undertaken.

PM_{10} will be considered for a stage three review and assessment.

5. SUMMARY OF FINDINGS

This stage two review and assessment of local air quality in the Carlisle City Council area has examined the two pollutants – nitrogen dioxide and fine particulates – which were assessed at stage one to be at risk of exceeding the objectives in the Air Quality Regulations 1997.

The annual objective limit for nitrogen dioxide is currently exceeded at most inner-city sites and in some urban residential zones; with projections to 2005 showing a continuing risk of the limit being breached. Hourly levels should not exceed the higher hourly objective by 2005. It is considered necessary to examine the issue of nitrogen dioxide in more detail.

Particulate levels have not been accurately measured in the city and traffic, with its attendant rising volumes, will continue to be a major local source. The UK perspective remains of elevated PM_{10} levels nationwide, but there is uncertainty about which objective authorities will ultimately be obliged to meet. Particulate levels therefore justify further investigation.

It is recommended that a stage 3 review and assessment is undertaken for nitrogen dioxide and particulates.

6. THIRD STAGE REVIEW AND ASSESSMENT

The third stage review and assessment will focus on nitrogen dioxide and particulates. DETR Guidance Note 1 “Framework for review and assessment of air quality” states that a third stage review and assessment should undertake an accurate and detailed review and assessment of current and future air quality. DETR recommends that the third stage is based on more sophisticated monitoring and modelling; the extent depending on each authorities individual circumstances.

6.1 MONITORING

More detailed monitoring is now necessary to gather accurate data on the existing levels of pollution to which the public are exposed. DETR Technical Guidance Note 1 “Monitoring for air quality reviews and assessments” recommends specific methodology for stage three work.

6.1.1 Nitrogen dioxide

Nitrogen dioxide should be monitored using automatic, continuously-operating equipment capable of 1-hour resolution. The common method is to use chemiluminescence, where nitric oxide is reacted with ozone to generate a photon that can be detected by a photomultiplier tube. Nitrogen dioxide in the incoming air stream is reduced to nitric oxide by a catalyst to be rendered detectable. These analysers are the standard equipment in DETR’s Automated Urban Network (AUN) and are fully ISO compliant. This equipment provides instantaneous readings of NO, NO_2 and NO_x, plus all hourly or daily averages desired. The wide network of diffusion tubes will be maintained to provide data on city-wide levels.

6.1.2 Fine particulates

For PM_{10} monitoring, gravimetric sampling with 24-hr resolution, or preferably continuous automatic monitoring equipment with 1-hour resolution, should be used. The most commonly employed analyser in UK is the latter; the Tapered Element Oscillating Microbalance (TEOM). This consists of a filter cartridge located on top of a vibrating, hollow tapered glass tube. The sample air stream is drawn through the filter and tube and, as particles are deposited on the filter, it becomes heavier and the element vibrates more slowly. TEOMs are the standard equipment of the AUN. This equipment provides instantaneous readings of PM_{10} concentration, plus hourly or daily averages as desired.

6.2 MODELLING

There is one intermediate model acceptable for stage three; AEOLIUS, written by the Meteorological Office. These will be applied to scenarios in Carlisle as part of the review and assessment process. Advance computer model such as ADMS offer more sophistication, but at high cost and are probably overly complex for this authority’s requirements.

7.9 SUPPLEMENTARY INFORMATION FOR THE STAGE ONE REVIEW

The stage one review and assessment by Carlisle City Council will issued on 6 October 1998 and a copy forwarded to DETR. On 19 April 1999 an appraisal report was received from DETR, the report having been examined by a contractor Air Quality Consultants, who are at the University of the West of England, Bristol. Their report identified some areas where additional information would be valuable to support the review's summaries. Accordingly this extra data is detailed below:

7.9.1. Carbon Monoxide

One criterion for reviewing carbon monoxide detailed in the Pollution Specific Guidance (TG4) is whether there are any roads which by 2005 will carry over 50,000 vehicle a day and are in locations where individuals may be exposed for 8 hours (the "relevant averaging period"). Using the projection of local traffic growth of 2.2% per annum (a compound figure of 19% over 8 years), two roads in the city will exceed this flow accordingly (and are illustrated at Appendix A):

TABLE 10: ROADS EXCEEDING 50,000 VPD BY 2005

Road	24 hr traffic flow (all vehicles)	
	1997	2005
Castle Way	48134	57280
Eden Bridge	49343	58718

Castle Way

This is a dual carriageway forming part of the city's inner ring road. The north side is bordered by the non-residential site of Carlisle Castle, the south by the commercial fringe of the city centre, with Finkle Street the nearest road. Given that the relevant averaging period for carbon monoxide is 8-hours, the castle – as a tourist attraction – is not a location where people would be exposed for that duration. The dwelling frontage on Finkle Street is 17 m from the centreline of Castle Way and modelling at this location with DMRB predicts a maximum 8-hour mean in 2005 of 0.52 ppm (NAQS objective 10 ppm).

Eden Bridge

This is the sole crossing point over the River Eden in Carlisle and consequently is a bottleneck. Although flow rates exceed 50,000 vehicles per day, there are no buildings alongside the bridge. The only exposure is therefore transient for pedestrians and cyclists and well under the 8-hour period.

7.9.2. Sulphur Dioxide

Two of the criteria in the Pollution Specific Guidance for the stage one review of sulphur dioxide relate to large combustion plant and domestic coal burning and additional evidence is attached:

Combustion plant

The Part B processes in the authority area are listed in Annex 7.2 and their categories identified. Any significant processes for the emission of SO_2 as listed in the Pollution Specific guidance would require further consideration; however there are none of these in the authority.

Domestic coal burning

The above guidance states that sulphur dioxide emissions from domestic coal burning will be significant where there are more than 300 houses per square kilometre area that burn coal. This is most likely in older parts of the city such as the district of Denton Holme, which comprises Victorian terraced housing and is not a smoke control area. Being likely to experience the greatest amount of coal consumption, this represents the worst-case scenario in the city. Coincidentally the authority's eight-port sampler measures daily SO_2 levels and is sited on Denton Street, in the centre of Denton Holme. Results from that site were detailed in the stage one review and assessment, with the annual mean in 1997 of 2 ppb and the maximum day's measurement of 9.7ppb.

The annual 99.9^{th} percentile of 15-minute averages (the NAQS objective) can be estimated using the formula stated in the Pollution Specific Guidance thus:

$P_{99.9}$ = [daily maximum] * 1.655 + 19.45

= [9.7] * 1.655 + 19.45

= 35.5 ppb

This surrogate statistic is an estimate, but even allowing for uncertainty this figure is well below the 100 ppb NAQS objective. This confirms the decision to conclude the review and assessment of SO_2 at stage one.

7.9.3. Overview of whole authority area

The stage one review focussed only on the city of Carlisle, having considered this location to be where people would experience the most exposure to pollution. A map is at Appendix B and illustrates the authority area and identifies all settlements of population over 1,000 which are as follows:

Carlisle	71,000
Brampton	4,000
Longtown	2,000
Dalston	1,500
Houghton	1,500
Wetheral	1,200

Villages below 1,000 are all in rural areas and not considered appreciable producers of pollution; nor sites where exposure would be extensive. The monitoring programme has been extended into the next two largest settlements listed above, with NO_x tubes at Brampton and Longtown as explained in section 3.3.2, which show levels under the annual objective.

7.10 REFERENCES

1. The Environment Act Part IV, The Stationery Office, 19 July 1995

2. “The United Kingdom National Air Quality Strategy”, Department of the Environment, The Stationery Office, March 1997.

3. The Air Quality Regulations 1997 S.I. 3043, The Stationery Office, 16 December 1997.

4. “The United Kingdom National Air Quality Strategy and Local Air Quality Management: Guidance for Local Authorities (Circular 15/97)”, Department of the Environment, Transport and the Regions, 17 December 1997.

5. “Local Air Quality Management - First Stage Review and Assessment”, Carlisle City Council, October 1998.

6. “Framework for Review and Assessment of Air Quality G1(98)”, Department of the Environment, Transport and the Regions, December 1997.

7. “Monitoring for air quality reviews and assessments TG1(98)”, Department of the Environment, Transport and the Regions, December 1997.

8. “Selection and use of dispersion models TG3(98)”, Department of the Environment, Transport and the Regions, December 1997.

9. “Review and Assessment: Pollutant-Specific Guidance TG4(98)”, Department of the Environment, Transport and the Regions, March 1998.

10. Department of the Environment, Transport and the Regions, internet site http://www.environment.detr.gov.uk/airq/aqinfo.htm

11. “Source apportionment of airborne particulate matter in the United Kingdom”, Airborne Particles Expert Group, January 1999.

12. “Assistance with the review and assessment of PM_{10} concentration in relation to the proposed EU Stage 1 Limit Values”, Department of the Environment, Transport and the Regions, March 1999.

13. “Design Manual for Roads and Bridges”, (volume 11, section 3, part 1, air quality), Department of the Environment, Transport and the Regions, May 1999.

7.11 GLOSSARY

Accuracy	A statistical definition for defining how well measured data fits the true values
AEA	Atomic Energy Authority
AQMA	Air Quality Management Area
AUN	Automated Urban Network
BS	British Standard
CO	Carbon Monoxide
DETR	Department of the Environment, Transport and the Regions (formerly Department of the Environment)
EA	Environment Agency
EPAQS	Expert Panel on Air Quality Standards
Mean	The average value of a data set
mg/m^3	Milligrams per metre cubed
NAQIA	UK National Air Quality Information Archive
NAQS	National Air Quality Strategy
NETCEN	National Environmental Technology Centre
NO_2	Nitrogen Dioxide
PM_{10}	Particulate Matter of 10 microns or less in diameter
ppb	Parts per billion
ppm	Parts per million
Precision	A statistical definition of how closely a set of repeated measurements taken independently are to one another
SO_2	Sulpher Dioxide
µg	microgram (one millionth of a metre)
$\mu g/m^3$	microgram per cubic metre