Detailed Assessment of

Air Quality

A85 at Crieff

Perth & Kinross Council

August 2013

PERTH & KINROSS COUNCIL

The Environment Service

Contract Page

Title

Air Quality Detailed Assessment

Customer

Perth & Kinross Council

Customer Reference

Detailed Assessment

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File Reference

AEAT/ENV/R/3286

Reference Number

AEA/ED45590/Issue 1

Contact Details

Dr Scott Hamilton
AEA Technology plc
Lochshore Business Park
GLENGARNOCK
KA14 3DD

Tel 0870 1905307
Email scott.hamilton@aeat.co.uk

AEA is a business name of AEA Technology plc
AEA is certificated to ISO9001 and ISO14001

Author Dr Scott Hamilton

Approved by Dr Stuart Sneddon  8 May 2012

Executive Summary

This report is a Detailed Assessment which investigates the magnitude and spatial extent of exceedences of the nitrogen dioxide (NO_2) and fine particle (PM_{10}) annual mean along the A85 in Crieff, Perth and Kinross.

The study concludes that exceedances of the NO_2 annual mean objective of 40 μgm^{-3} occurred at locations with relevant exposure in 2011. The exceedances are in quite small areas along East High Street and West High Street.

The study also concludes that exceedances of the Scottish PM_{10} annual mean objective of 18 μgm^{-3} occurred at locations with relevant exposure in 2011. The exceedance areas for PM_{10} are slightly larger than for NO_2, but are still confined to short stretches of East High Street and West High Street.

Therefore, in light of this Detailed Assessment, it is recommended that Perth & Kinross Council should consider declaring an AQMA for the NO_2 and PM_{10} annual mean objectives in the areas of the East High Street and West High Street.

After declaration Perth & Kinross Council should undertake a Further Assessment within 12 months for both pollutants in this area, and take the opportunity to minimise uncertainty in the modelling by:

- ***undertaking traffic counts along the A85;***
- ***undertaking queuing surveys along the A85;***
- ***conducting a background monitoring campaign.***

1 Introduction

1.1 National Air Quality Strategy

All local authorities (LAs) in the UK are obliged to *"review and assess"* air quality within their boundaries under responsibilities laid out in the Environment Act 1995. A requirement of the Act was that the UK Government prepares an Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland. The AQS was published in January 2000 with a revised version published in July 2007.

Within the AQS, national air quality objectives are set out and LAs are required to assess air quality against these objectives following a prescribed timetable along a three year cycle. Table 1.1 lists the objectives for NO_2 and PM_{10} that are included in Regulations for the purposes of Local Air Quality Management (LAQM).

Table 1.1: Objectives for the Purpose of Local Air Quality Management (Scotland)

Pollutant	Air Quality Objective	
	Concentration	Measured as
Nitrogen dioxide	200 µg m^{-3} not to be exceeded more than 18 times a year	1 hour mean
	40 µg m^{-3}	Annual mean
Particulates	50 µg m^{-3} not to be exceeded more than 7 times a year	24hr mean
	18 µg m^{-3}	Annual mean

1.2 Purpose of the Detailed Assessment

This study aims to assess the presence, magnitude and spatial extent of any exceedances of the air quality objectives for NO_2 and PM_{10} in the vicinity of West High Street, High Street and East High Street, Crieff in Perth and Kinross. These streets are part of the A85 trunk road which passes through the centre of Crieff.

1.3 Locations Where the Air Quality Objectives Apply

When carrying out the review and assessment of air quality it is only necessary to focus on areas where the public are likely to be regularly present and are likely be exposed over the averaging period of the objective. Table 1.2 summarises examples of where air quality objectives for NO_2 and PM_{10} should and should not apply.

Table 1.2 Examples of where the NO2 and PM10 Air Quality Objectives should and should not apply

Averaging Period	Pollutants	Objectives *should* apply at …	Objectives should not generally apply at …
Annual mean	NO_2 PM_{10}	All locations where members of the public might be regularly exposed. Building façades of residential properties, schools, hospitals, care homes etc.	Building facades of offices or other places of work where members of the public do not have regular access. Hotels, unless people live there as their permanent residence. Gardens of residential properties. Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.
24hr mean	PM_{10}	As above	As above
1 hour mean	NO_2	All locations where the annual mean objectives apply. Kerbside sites (eg pavements of busy shopping streets). Those parts of car parks and railway stations etc which are not fully enclosed. Any outdoor locations to which the public might reasonably be expected to have access.	Kerbside sites where the public would not be expected to have regular access.

1.4 Overview of the Approach Taken

The general approach taken to this Detailed Assessment was to:

- *collect and interpret data from previous and current review and assessment reports;*
- *collect and analyse all available traffic data, air quality monitoring data and background concentration data for use in the models;*
- *model NO_2 and PM_{10} concentrations;*
- *produced contour plots of the modelled pollutant concentrations;*
- *recommend whether Perth & Kinross Council should declare an AQMA and provide guidance on its minimum extent.*

The methodologies outlined in Technical Guidance LAQM.TG(09)[1] were used throughout this Detailed Assessment.

2 Study Location

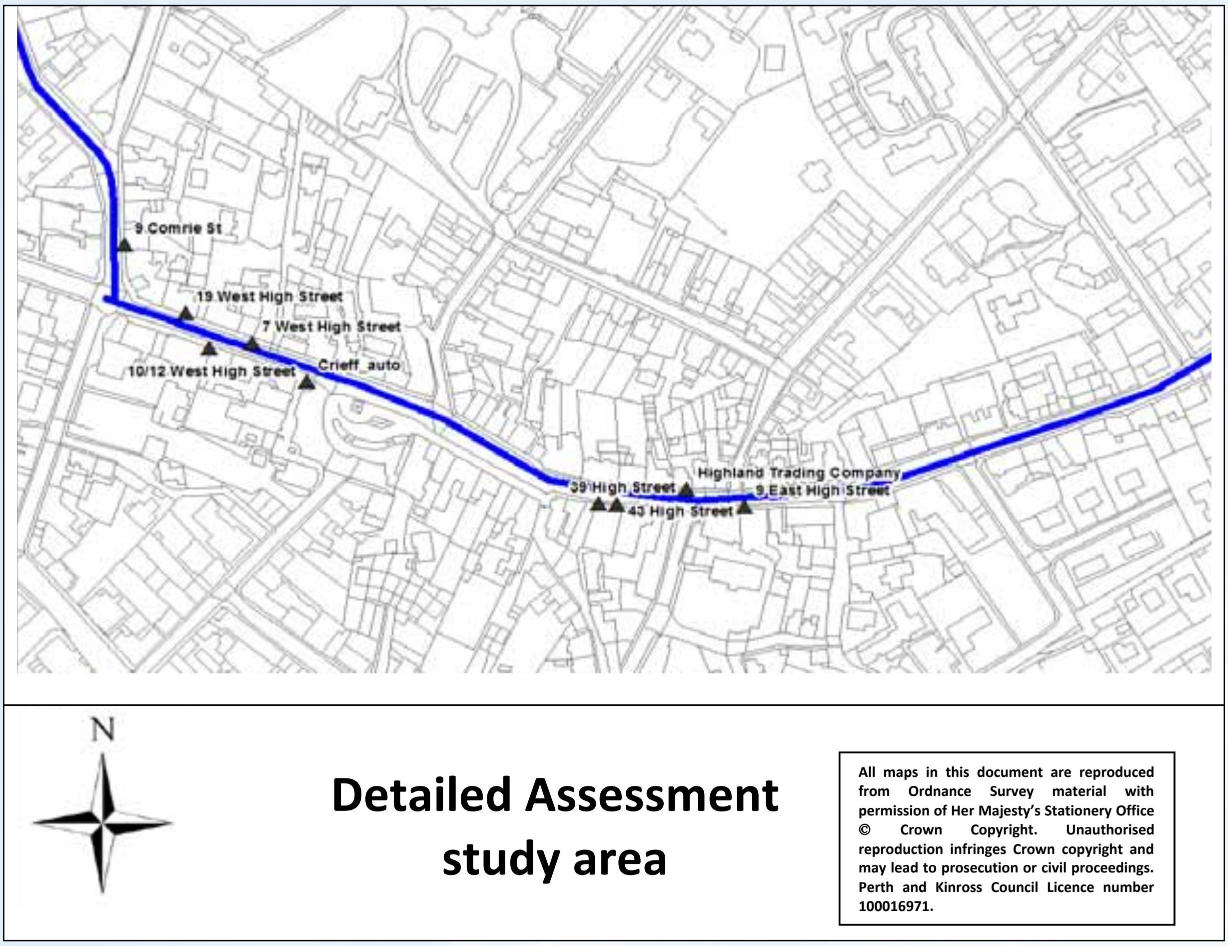
The market town of Crieff is located approximately 15 miles west of Perth along the A85 trunk road. The town is a popular tourist area and has a resident population of approximately 6,000. Crieff is the second largest town in Perthshire.

Figure 2.1 shows the study area and includes locations of the PM_{10} and NO_2 monitoring sites with the automatic monitoring being located at the corner of West High Street and James Square (denoted Crieff_auto on the map below).

The assessment estimates NO_2 and PM_{10} concentrations in the area of the A85 as it passes through the centre of the town; including West High Street, High Street and East High Street. The area has many three storey buildings on both sides of the road with commercial properties on the ground floor and residential properties on the first floor and above.

A consequence of the multi-storey buildings is the existence of narrow street canyons within the model area - a topography which is known to limit dispersion of air pollution.

Figure 2.1 Study Area for the Detailed Assessment



[1] Local Air Quality Management Technical Guidance LAQM.TG(09), Defra, 2009 [Online] Available from http://www.airqualityni.co.uk/documents/guidances/5090309_tech-guidance-laqm-tg-09.pdf [Accessed on 01/04/2012]

3 Information Used to Support this Assessment

3.1 Maps

Perth & Kinross Council provided OS Landline data of the model domain shown above. This enabled accurate characterisation of the study area in the GIS system.

3.2 Road Traffic Data

3.2.1 Average flow, speed and fleet split

The base year of 2011 was used for this assessment, and annual average daily traffic (AADT) traffic data was sourced from Transport Scotland's nationwide automatic count data. Data was available for the A85 East and West of the town but none was available for the centre of the town. For the purposes of this assessment we have assumed that (going from east to west) the flow on the east of the town is representative of town centre flows up to the junction with Comrie Street, and that the western flows are prevalent after this point.

Speed data and queue data were not available for the study area so professional judgement has been used to estimate speeds around known areas of congestion which were outlined by Perth & Kinross Council, eg parking areas, bus stops and traffic lights. Consultation with Perth & Kinross Council informed the assumptions which were that typical traffic flows are below the speed limit for the road due to the aforementioned obstructions to flow. We have assumed a maximum of 3 hours of queuing at the most congested areas, spreading this across the 8 hour working day. At more free flowing areas we have assumed 1 or 2 hours of queuing depending on the proximity to junctions or obstacles. Appendix 1 shows the location of potential obstacles to free flowing traffic.

A consequence of having to make these estimates, in the absence of locally collected data, is that a degree of uncertainty has been added to the model predictions. In order to reduce this uncertainty in future modelling studies, it is recommended that Perth & Kinross Council carry out additional traffic surveys to better characterise traffic flows and fleet compositions in the area.

Table 3.2 summarises annual average daily traffic flows (AADF) used for this study. A more detailed breakdown of the traffic data, including speeds and queuing, is detailed in Appendix 1.

Table 3.2 Annual Average Daily Flow – A85 Crieff

Street	2011 AADF	% Cars	% light goods vehicles	% buses	% HGV	% motorcycle
West High Street	6,284	81.5	13.4	0.8	3.9	0.4
High Street	6,284	81.5	13.4	0.8	3.9	0.4
East High Street	6,284	81.5	13.4	0.8	3.9	0.4
Comrie Street	3,482	79.4	13.0	1.2	5.9	0.5

3.2.2 Emissions factors

The most recent version of the Emissions Factors Toolkit[2] (EfT V4.2.2) was used in this assessment and the factors derived were used in the ADMS-Roads. Parameters such as traffic volume, speed and fleet composition are entered into the EfT tool and an emissions factor in grams of NO_x/kilometre/second (gkm^{-1} s^{-1}) is generated for input into the dispersion model. The version of the EfT used incorporates the latest emission factors published in 2009 by Department for Transport.

3.3 Ambient Monitoring

3.3.1 NO_2 and PM_{10}

Concentrations of NO_2 are monitored at sites throughout Perth and Kinross using both automatic techniques and diffusion tubes. Nine of these sites lie within the area modelled in this assessment, as shown in Figure 2.1. PM_{10} is also monitored within the study area at James Square. Details of the type, locations, and concentrations measured in the study area are given in Chapter 4. A triplicate diffusion tube site is co-located with an automatic monitoring site at James Square.

These monitoring data were used in the assessment for the purposes of model verification and adjustment.

4 Monitoring Data

4.1 New Monitoring Data

Perth & Kinross Council monitors NO_2 using diffusion tubes at 9 locations along the A85 in the area of interest. Automatic monitoring of NO_2 is also carried out at James Square. This site also measures PM_{10}. A summary of relevant monitoring data for 2011 are presented in Table 4.1 and Table 4.2 - these data are consistent with those presented in Perth & Kinross Council's 2012 Updating and Screening Assessment.

[2] Department of Transport, Emission Factor Toolkit (Version 4.2.2), 2 November 2010 [Online] Available at http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html#eft [Accessed on 02/04/2012]

A data capture rate of 90% or greater was achieved for most diffusion tube sites, although three sites required annualisation according to the procedure in the technical guidance. The data capture rate achieved by the automatic monitoring site was 95% for NO_2 and 92% for PM_{10}.

All diffusion tube data have been adjusted using a locally derived bias adjustment factor from Perth & Kinross Council's other automatic monitoring stations - the derived factor from the Crieff co-location study was not considered reliable - our approach mirrors that taken by the Council in their Updating and Screening Assessment. Full details of the bias adjustment calculation are provided in Perth & Kinross Council's 2012 Updating and Screening Assessment. The calculation yielded a bias adjustment factor of 0.92 which was used to correct all diffusion tube data in the study area.

The NO_2 measurements are taken at a variety of heights, and some are not reflective of relevant exposure as the closest residential properties are at first floor level. That said, the diffusion tube sites are typically located at a few metres height, so the concentrations are broadly reflective of exposure in the canyons that make up the model domain.

PM_{10} is monitored at a single location at James Square which has good data capture for 2011. It was decided not to exclude any data from the period, during which there were known PM_{10} regional episodes (parts of March and April). This decision was taken so as to preserve a high data capture rate, but also because there is no way to tell how much data should be discounted due to the regional episodes.

Table 4.1 NO_2 Monitoring data collected in Crieff 2011

Location	Data Capture 2011 %	Data with less than 9 months has been annualised (Y/N)	Annual mean concentration (Diffusion tube bias Adjustment factor = 0.92) 2011 (μgm^{-3})
Crieff real time monitor	95	N/A	34
7 West High Street	100	N/A	**50**
39 High Street	92	N/A	39
62 High Street	100	N/A	31
9 East High Street	100	N/A	**41**
19 West High Street	83	N/A	**41**
43 High Street	100	N/A	35
10 West High Street	58	Y	**47**
9 Comrie Street	66	Y	25

The NO_2 monitoring shows that there are areas along the A85 that exceed the annual mean objective and at the worst locations the exceedances are quite large. The exceedance areas are not characterised by especially high traffic volumes, but emissions coupled with the street canyon street configuration leads to quite high concentrations.

Table 4.2 PM_{10} Monitoring data collected in Crieff 2011

Location	Data Capture 2011 %	Annual mean concentration (Diffusion tube bias Adjustment factor = 0.92) 2011 (μgm^{-3})
Crieff real time monitor	92	19

The annual mean PM_{10} measurements from James Square are in excess of the Scottish objective but well within the 40 μgm^{-3} rest of UK objective. There is evidence of a regional pollution episode in the spring of 2011 but it is not possible to take the contribution from this out of the measurements in a robust manner. In any case, the effect on the annual mean of discounting data during this period would probably only reduce the annual mean by small amount, and there would almost certainly still be reasonably large modelled exceedances in the street canyons in Crieff.

5 Modelling

5.1 Modelling Methodology and Parameters

Annual mean concentrations of NO_2 and PM_{10} for 2011 have been modelled within the study area using ADMS Roads (version 3.1).

The model was verified and the outputs were adjusted by comparing the modelled predictions for road NO_x and road PM_{10} with local monitoring results. In this case, the modelled results were compared to the results gathered by the nine diffusion tube sites and the single automatic monitoring site.

The street canyon module within ADMS was used to model NO_2 concentrations within identified street canyons. This module models building downwash and resultant recirculation of pollutants within a street canyon.

Concentrations of NO_2 and PM_{10} were modelled at a height of 1.5m and 4.0m, to reflect concentrations at a height at which they are inhaled, and at 4m to predict concentrations at relevant receptors located at first floor level.

Hourly sequential meteorological data for 2011 from the Strathallan meteorological site was used, located approximately 20km west south west of the study area. A wind rose of average wind speed and direction during 2011 is shown in Appendix 3.

A surface roughness of 1.0 m was used in the modelling and a limit for the Monin-Obukhov length of 10 m was applied to represent the small town.

The intelligent gridding option was used in ADMS-Roads, which provides spatially resolved concentrations along the roadside, with a wider grid spaced at approximately 30m being used to represent concentrations further away from the road. These predictions were added to ArcGIS 10 and values between grid points are derived using interpolation in the Spatial Analyst tool. This allows contour concentrations to be produced and added to the base map provided by Perth & Kinross Council. **It should be noted that the contour plots presented in this document should be considered an estimate of the spatial distribution of NO_2 and PM_{10}. The modelling and**

interpolation techniques used to produce the contours introduce some uncertainty but all efforts have been made to ensure this is minimised where possible.

5.1.1 Treatment of background concentrations

Background concentrations of NO_x and PM_{10} were derived from the Scottish Government background maps[3]. A csv file containing concentrations across Perth & Kinross Council was obtained and the appropriate 1 km^2 grid square was selected with the appropriate concentration for the assessment. In this case, a mapped NO_x background concentration of 8.2 µg m^{-3} and 11.6 µg m^{-3} for PM_{10} was used in this assessment. The background NO_x concentration, from experience, seems quite low given the concentrations that are being measured within the town centre, and so we would recommend commencing a background NO_2 diffusion tube in Crieff to support the forthcoming Further Assessment. For both NO_x and PM_{10} All "A" road contributions from within the grid square were removed in order to prevent double counting of emissions within the model.

5.1.2 Treatment of modelled NO_x road contribution

It is necessary to convert the modelled NO_x concentrations to NO_2 for comparison with the relevant objectives. The Defra NO_x/NO_2 model[4] was used to calculate NO_2 concentrations from the NO_x concentrations predicted by ADMS-Roads. The model requires input of the background NO_x, the modelled road contribution and the proportion of NO_x released as primary NO_2. For the purposes of this assessment we have assumed that 21.8% of NO_x is released as primary NO_2 - the value associated with the *"UK Traffic"* option in the model. Additionally, the NO_x/NO_2 model has also been used to convert the monitored NO_2 back to NO_x to allow comparison of modelled and monitored NO_x.

5.1.3 Treatment of modelled PM_{10} road contribution

After model verification and adjustment, all modelled road PM_{10} was simply added to the assumed background. It is worth noting that the road PM_{10} component does not include a contribution from resuspension of dust from road surfaces; all road PM_{10} is therefore assumed to derive from exhaust emissions and brake and tyre wear.

It should also be noted that there is quite high uncertainty in the PM_{10} predictions as the adjustment is based on a single monitoring site.

5.1.4 Validation of ADMS-Roads

In simple terms, validation of the model is the process by which the model outputs are tested against monitoring results at a range of locations and the model is judged to be suitable for use in specific applications.

CERC have carried out extensive validation of ADMS applications by comparing modelled results with standard field, laboratory and numerical data sets, participating in EU workshops on short range dispersion models, comparing data between UK M4 and M25

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[3] Scottish Backround Maps,Scottish Government [Online]
Available at http://www.scottishairquality.co.uk/maps.php?n_action=data [Accessed on 02/04/2012]

[4] NO_x to NO_2 calculator, Defra [Online]
Available at http://laqm.defra.gov.uk/tools-monitoring-data/no-calculator.html [Accessed on 02/04/2012]

motorway field monitoring data, carrying out inter-comparison studies alongside other modelling solutions such as DMRB and CALINE4, and carrying out comparison studies with monitoring data collected in cities throughout the UK using the extensive number of studies carried out on behalf of local authorities and DEFRA.

5.1.5 Verification of the model

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations. LAQM.TG(09) recommends making the adjustment to the road contribution only and not the background concentration these are superimposed onto. The approach outlined in Example 2 of LAQM.TG(09) has been used, and correction factors were calculated and applied to all modelled data.

The modelling was verified using ten monitoring sites within the study area - nine diffusion tubes for NO_2 and a single automatic site for NO_2 and PM_{10}. The comparison of monitored against modelled Road NOx revealed that the model under predicted and that the concentrations required adjustment by a factor of 2.43. This is a reasonably high correction factor given the circumstances and one reason for this might be that the mapped background NO_x is too low. The Road PM_{10} concentrations required a larger adjustment which is common when modelling this species, the adjustment factor in this instance was 3.84. After adjustment the model agrees quite well and the RMSE value for the NO_2 model is 2.8 µg m^{-3} - well within the recommended 4 µg m^{-3} outlined in the technical guidance.

Further information on the verification process is available in Appendix 3.

5.2 Modelling Results

5.2.1 Numerical

Table 5.1 on the following page shows the predicted modelled concentrations at each of the NO_2 monitoring points in the model domain. The model is deemed to have performed well if the root mean square error (RMSE) between the measured and modelled NO_2 concentrations is below 4 mg m^{-3} or 10% of the annual mean objective. As a result, this model has performed sufficiently well for the purposes of this Detailed Assessment with a calculated RMSE of 2.8 μgm^{-3}.

Table 5.1 Modelled/measured NO_2 concentrations in model domain after adjustment

Site	Adjusted Modelled NO_2 Road NO_x adjustment= 2.43	Measured	Difference (%)
Crieff_auto	33.8	34	-0.6
19 West High Street	**44.9**	**41**	9.5
43 High Street	36.2	35	3.3
10/12 West High Street	**42.5**	**47**	-9.7
9 Comrie St	25.3	25	1.2
7 West High Street	**49.4**	**50**	-1.3
39 High Street	**41.9**	39	7.4
Highland Trading Company	26.0	31	-16.1
9 East High Street	**41.1**	**41**	0.2
		NO_2 Root Mean Square Error (μgm^{-3})	**2.8**

The model results for NO_2 indicate that exceedances of the annual mean NO_2 objective are present at five of the monitoring locations.

Table 5.2 Modelled/measured PM_{10} concentrations in model domain after adjustment

Site	Adjusted Modelled PM_{10} Road NO_x adjustment= 2.43	Measured	Difference (%)
Crieff_auto	19	19	0

As there is only a single monitoring location for PM_{10} the adjustment process brings the modelled value to perfect agreement with the measurement. The obtained value is higher than the Scottish annual mean PM_{10} objective although this is not a point with relevant exposure - it would be expected that concentrations within the canyons would be higher due to limited dispersion that occurs there, and this has been borne out in the modelling. It is not possible to calculate the error in the model for PM_{10} based on a single monitoring location.

5.2.2 Contour plots

NO_2 and PM_{10} concentrations were modelled at two heights, 1.5m and 4m. Figures 5.2 and 5.3 show contour plots with annual mean NO2 concentrations along the A85 in Crieff at the two specified heights during 2011. Figures 5.4 and 5.5 show contour plots with the predicted annual mean PM10 concentrations during 2011. The contour plots have been prepared using the Inverse Distance Weighting function in the Spatial Analyst extension of ArcGIS 10.

Black dots in the plots below denote residential properties. It can clearly be seen that several residential properties lie within the exceedance areas for both NO_2 and PM_{10} at 1.5m and 4.0m height. The exceedance area for PM_{10} is larger than that for NO_2.

It has been confirmed by the monitoring and subsequent modelling that the 40 mg m-3 annual average objective for NO_2 is likely to have been exceeded during 2011 at locations with relevant exposure. The 18 μgm^{-3} Scottish annual mean PM_{10} objective has also been exceeded at locations with relevant exposure.

Figure 5.2 Modelled Annual Average NO_2 Concentrations (μgm^{-3}) at 1.5m

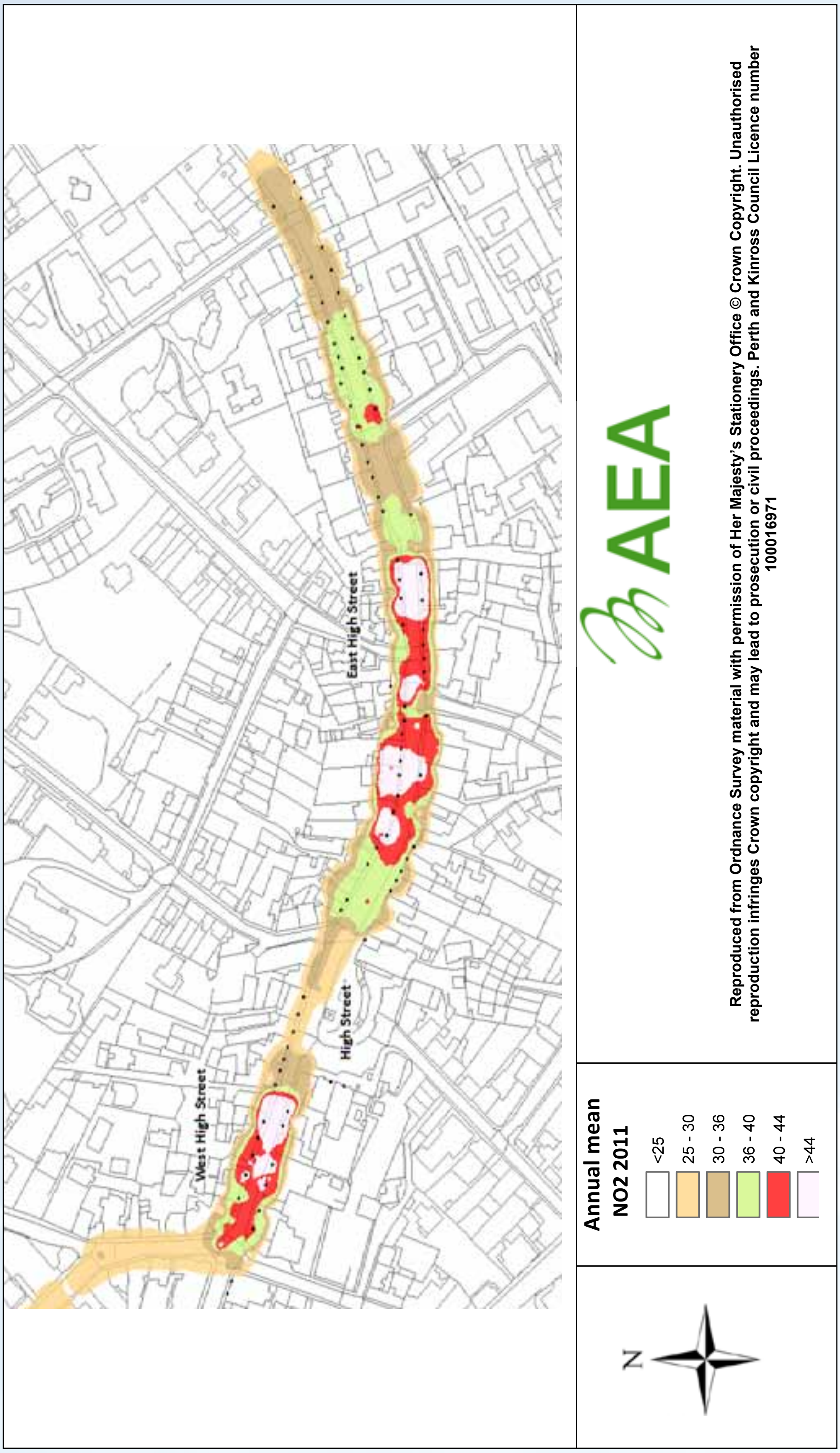


Figure 5.3 Modelled Annual Average NO_2 Concentrations (μgm^{-3}) at 4m

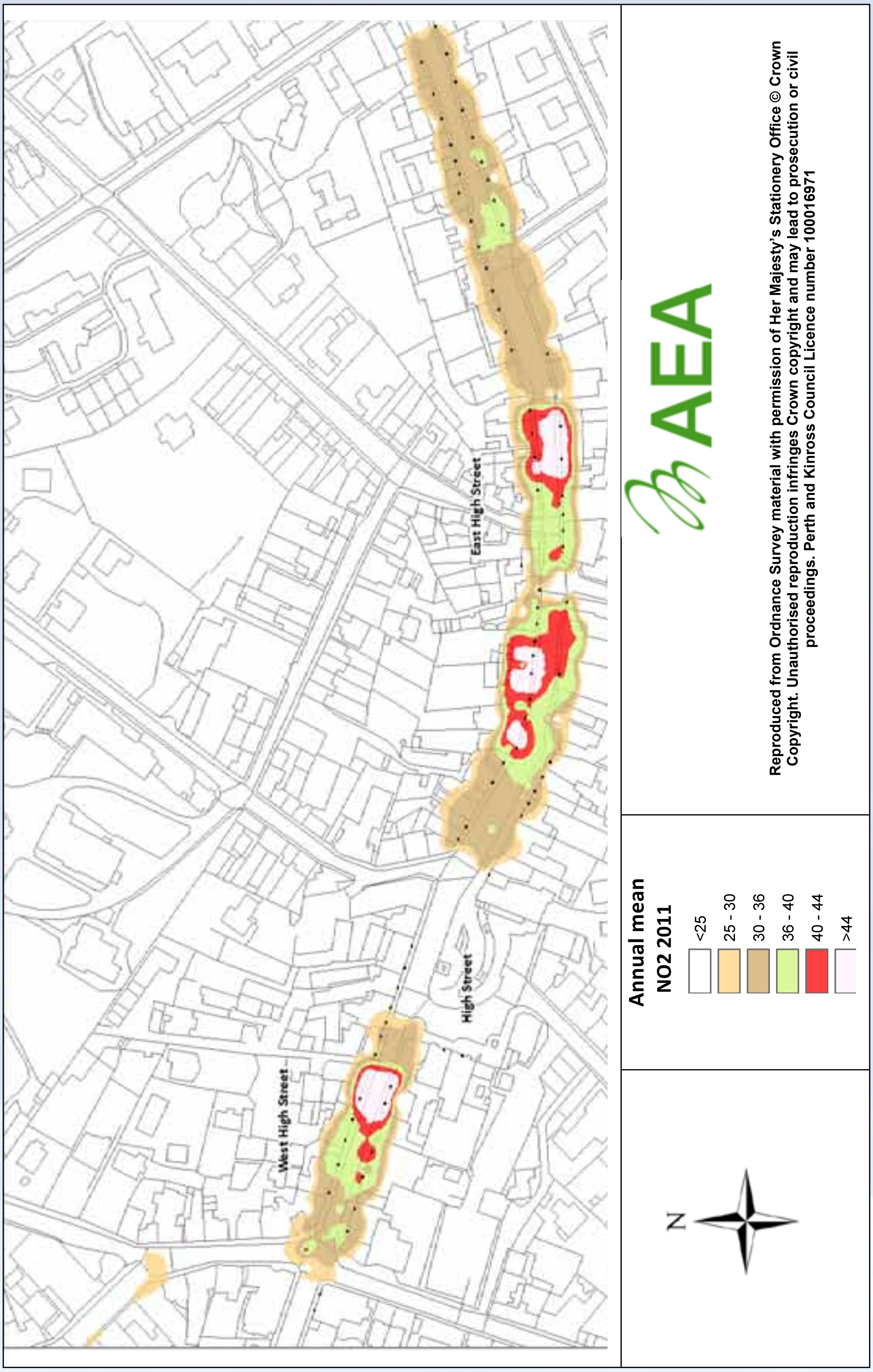


Figure 5.4 Modelled Annual Average PM_{10} Concentrations (μgm^{-3}) at 1.5m

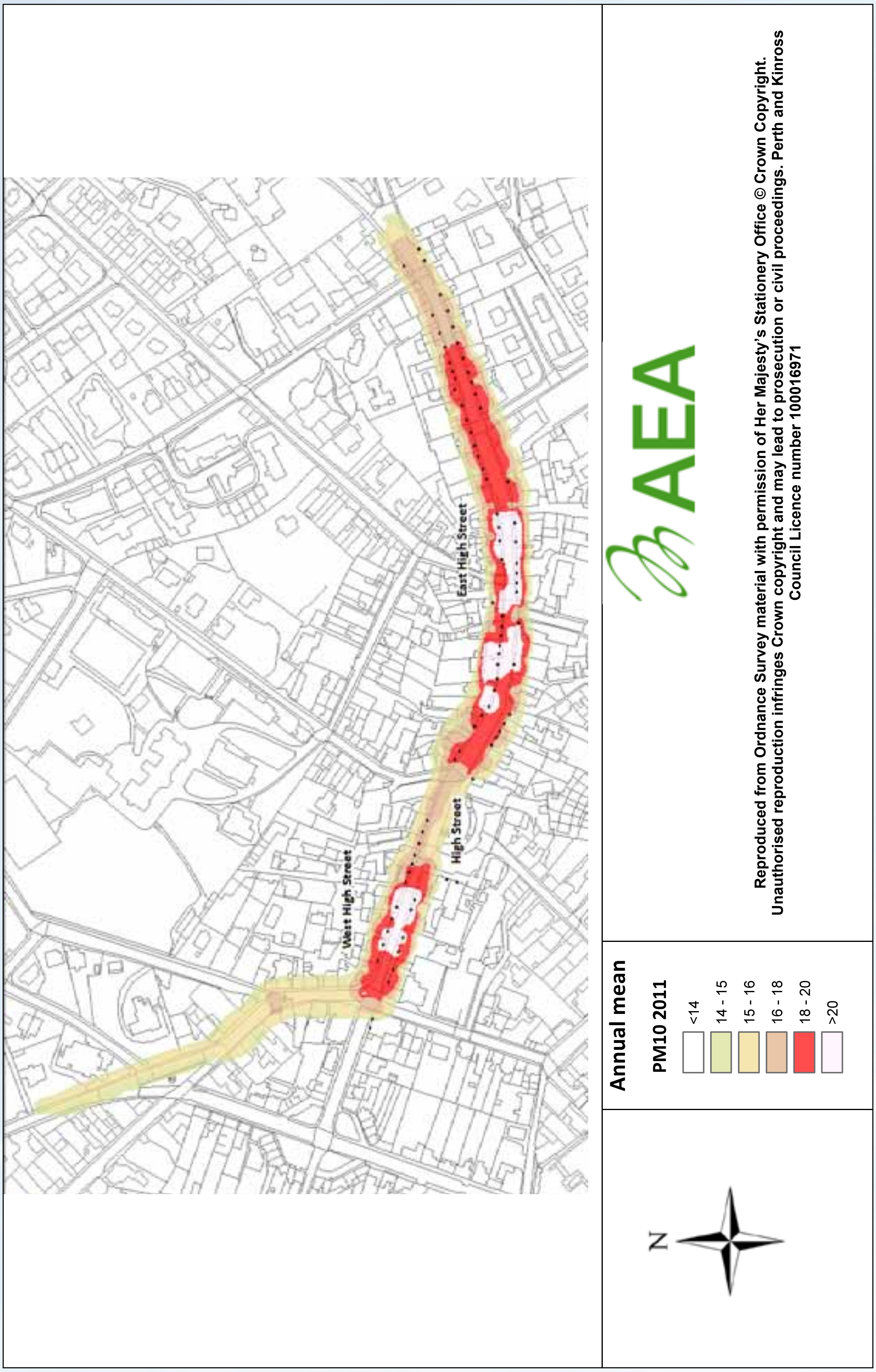
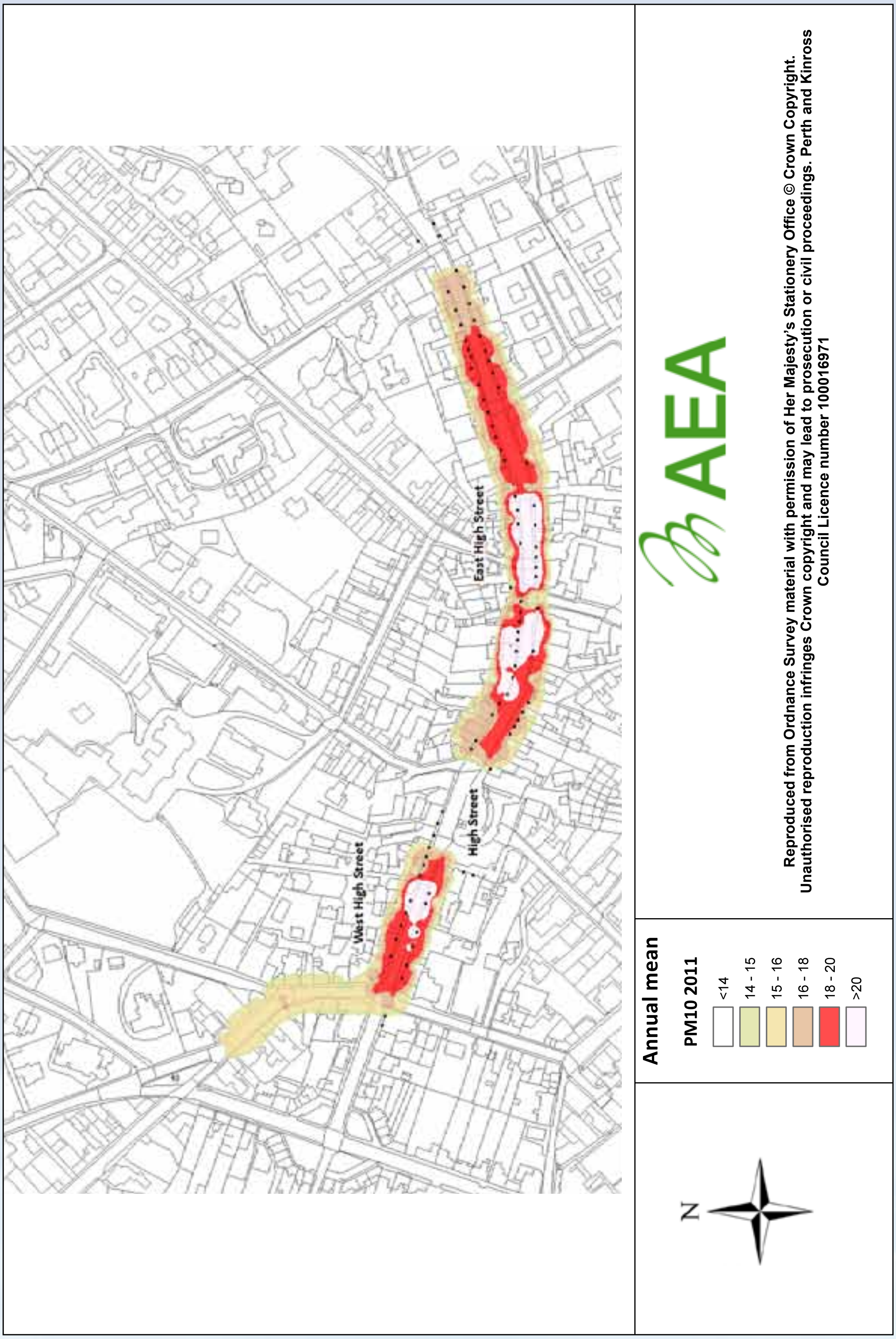


Figure 5.5 Modelled Annual Average PM_{10} Concentrations (μgm^{-3}) at 4m



5.2.3 Recommended Air Quality Management Area

The review of monitoring data and subsequent modelling of NO_2 concentrations in the area of West High Street, High Street and East High Street, Crieff has indicated that the annual mean objectives for both NO_2 and PM_{10} have been exceeded in the area of the West High Street and East High Street during 2011. High Street appears to comply with the objectives although any AQMA declaration would sensibly include this area for completeness.

Perth & Kinross Council should consider declaring an AQMA for both the NO_2 and PM_{10} annual mean objectives. The areas of the AQMA should be such that it safely encompasses all locations of exceedance described.

6 Summary and Conclusion

This report is a Detailed Assessment which investigates the magnitude and spatial extent of exceedances of the NO_2 and PM_{10} annual mean objectives along the A85 in Crieff, Perth and Kinross.

The study concludes that exceedances of the NO_2 annual mean objective of 40 μgm^{-3} occurred at locations with relevant exposure in 2011. The exceedances are in quite small areas along East High Street and West High Street.

The study also concludes that exceedances of the Scottish PM_{10} annual mean objective of 18 μgm^{-3} occurred at locations with relevant exposure in 2011. The exceedance areas for PM_{10} are slightly larger, but are still confined to short stretches of East High Street and West High Street. It should be noted that there are no predicted exceedances of the UK annual mean PM_{10} objective.

Therefore, in light of this Detailed Assessment, it is recommended that Perth & Kinross Council should consider declaring an AQMA for the NO_2 and PM_{10} annual mean objectives in the areas of the East High Street and West High Street.

After declaration Perth & Kinross Council should undertake a Further Assessment within 12 months for both pollutants in this area, and take the opportunity to minimise uncertainty in the modelling by:

- ***undertaking traffic counts and fleet characterisation along the A85 through Crieff;***
- ***undertaking queuing surveys along the A85 through Crieff;***
- ***conducting a background monitoring campaign at a suitable urban background location in Crieff.***

Appendices

Appendix 1: Traffic Data 2011

Appendix 2: Strathallan 2011 Wind Rose

Appendix 3: Model Verification

Appendix 4: Diffusion Tube Bias Adjustment Factors

Appendix 1 – Traffic Data 2011

Traffic Flows and Compositions

Table A1.1 summarises the Annual Average Daily Flows (AADF) of traffic and fleet compositions used within the model. The High Street, West High Street and East High Street traffic flows were calculated from the Transport Scotland automatic traffic counting site located to the east of Crieff. The traffic flows for Comrie Street were calculated from the Transport Scotland site to the West of Crieff.

Table A1.1 Annual Average Daily Flows

Street	2011 AADF	% cars	% light goods vehicles	% buses	% HGV	% motorcycle	Speed (kph)
West High Street	6284	81.5	13.4	0.8	3.9	0.4	15-30
High Street	6284	81.5	13.4	0.8	3.9	0.4	15-30
East High Street	6284	81.5	13.4	0.8	3.9	0.4	15-30
Comrie Street	3482	79.4	13.0	1.2	5.9	0.5	20-30

Queuing Traffic

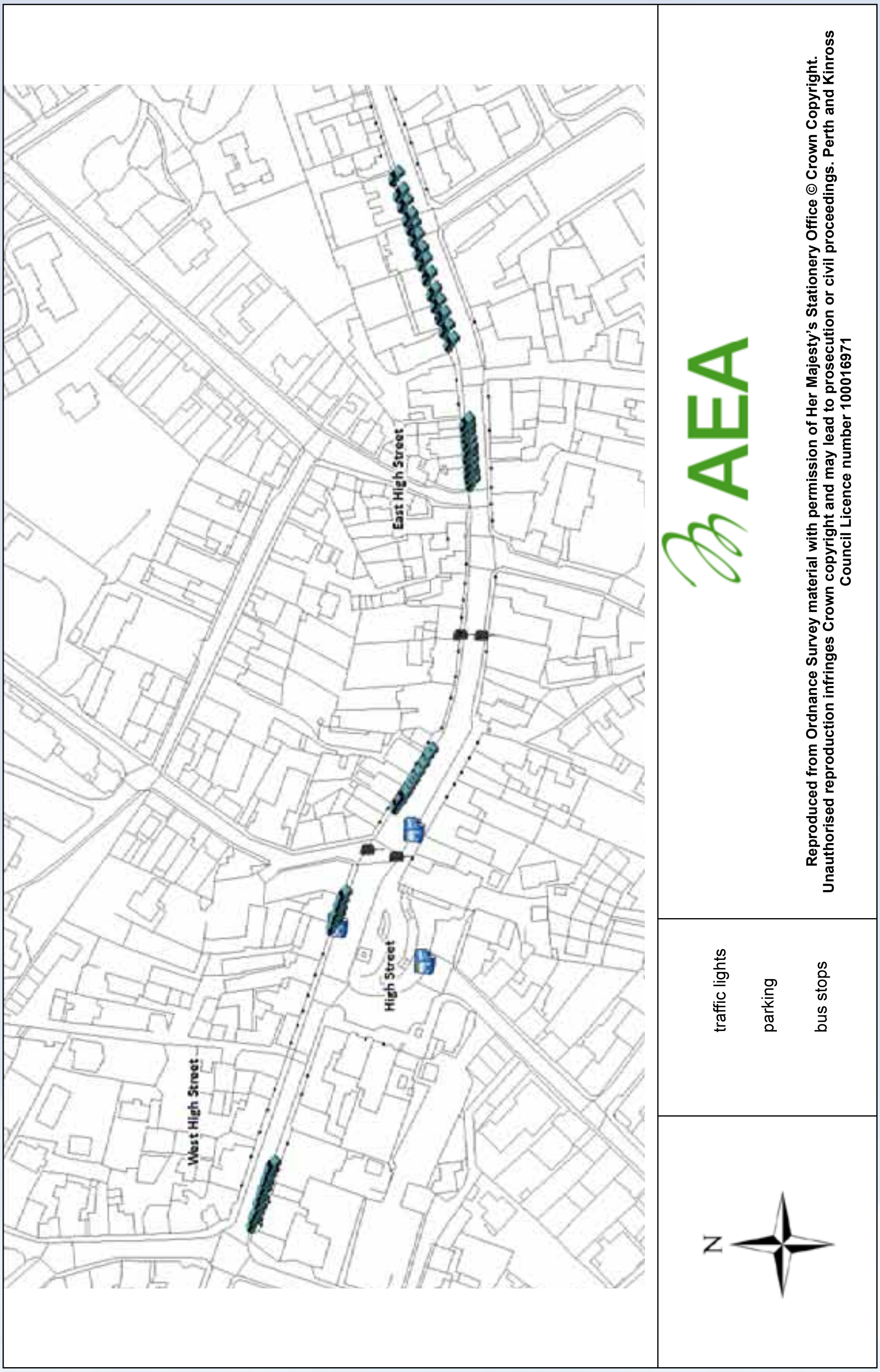
CERC note[5] 60 was used for estimating emissions from queuing traffic, which defines a representative AADF for queuing traffic to be 30,000 at 5 km h^{-1}, assuming an average vehicle length of 4m. The emissions from this AADF figure with the traffic composition of the corresponding road were then input into the Emission Factor Toolkit to calculate and emission rate. The emission rates were then used within the dispersion model as a separate line emissions of pre-defined length representing each queue. A maximum of 3 hours of queuing was assumed at the worst locations, spread throughout the 9.00 am to 5.00 pm working day.

Bus Stops, Parking Areas and Traffic Lights

Perth & Kinross Council provided advice as to the location of these in the study area. The diagram below shows the location of bus stops, parking area and traffic lights. These all represent barriers to the free flow of traffic in Crieff and therefore the average speed on the A85 as it passes through the town is thought to be significantly reduced.

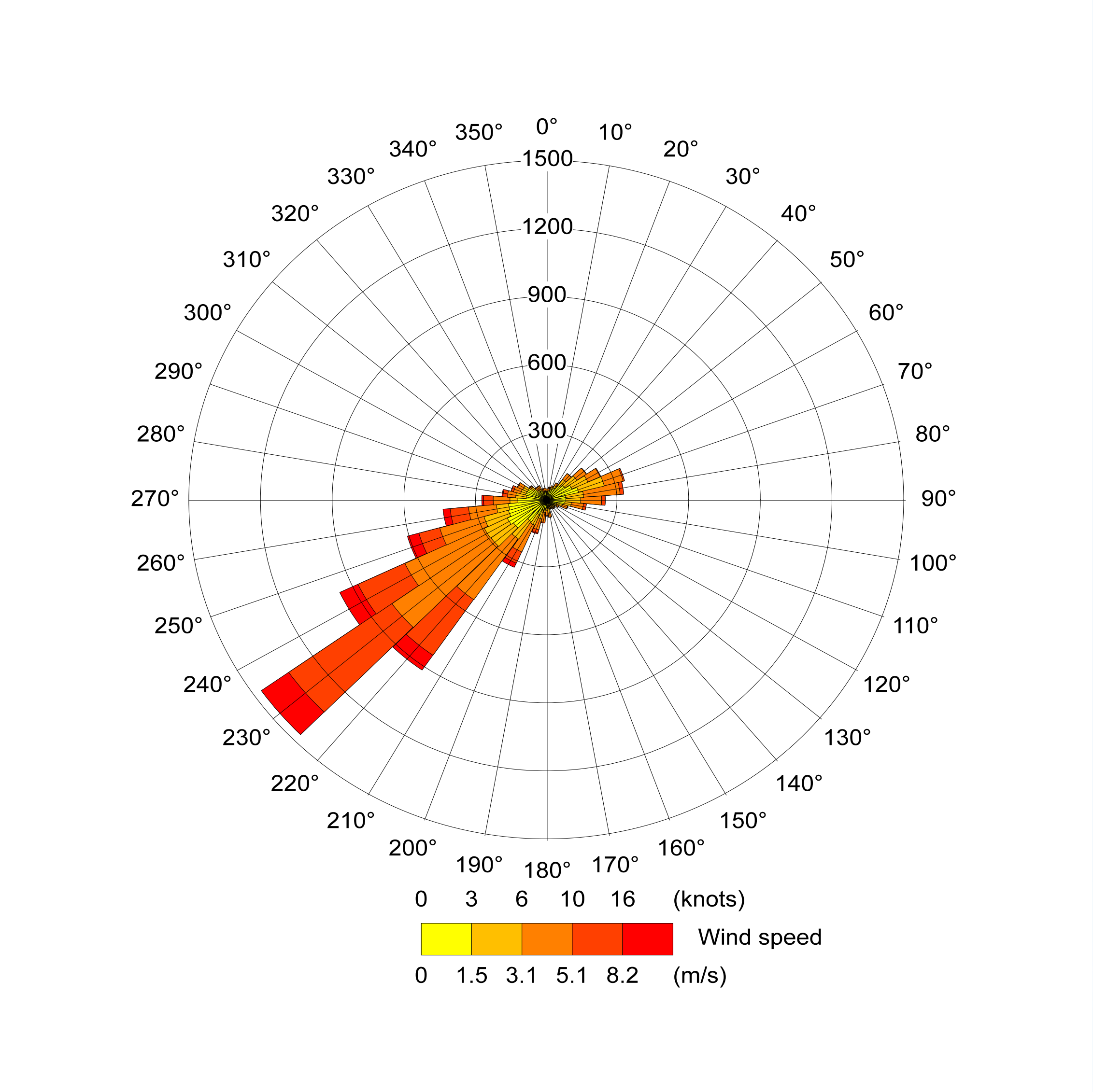
[5] Cambridge Environmental Research Consultants Ltd, Modelling Queuing Traffic – note 60, 20 August 2004

Figure A1.1 Bus Stops and Pedestrian Crossings within the Model Domain



Appendix 2 – Strathallan 2011 Wind Rose

Figure A2.1 Wind Rose of Wind Speed and Direction from Strathallen – 2011

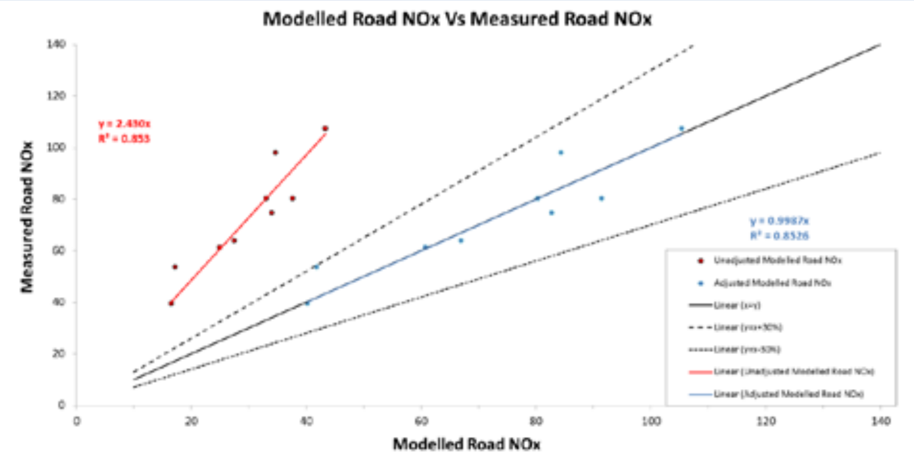


Appendix 3 – Model Verification

NO_x/NO_2

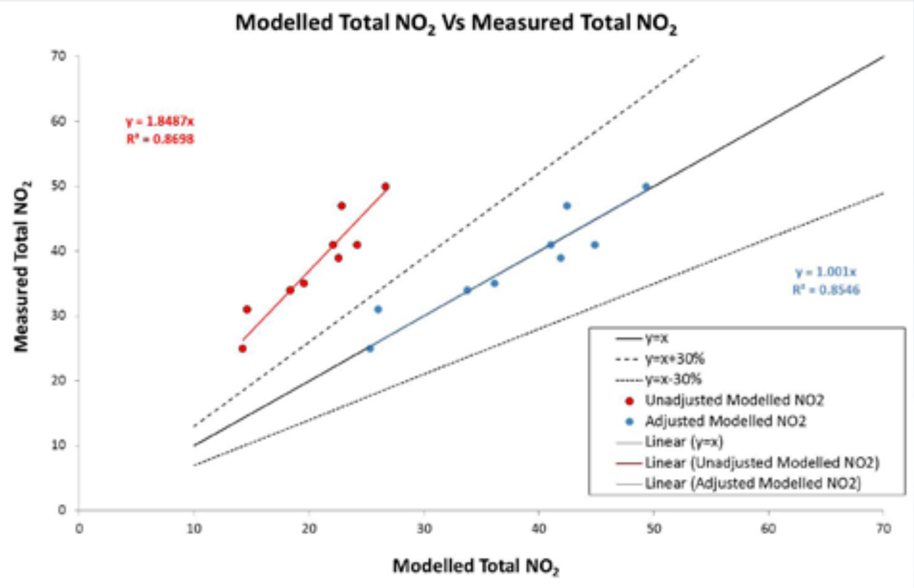
The model has been run to predict annual mean RoadNO_x concentrations during 2011 at the automatic and diffusion tube sites in the study area. The modelled NO_2 has then been calculated by using the output of RoadNO_x (the total NO_x originating from road traffic), the background NO_x from the Scottish background maps, and the 2010 version of the Defra NO_x/NO_2 calculator. In this case, it was found that the model under predicted the Road NO_x component by a factor of 2.43 - the adjustment factor is based on the correlation coefficient in figure A3.1 below.

Figure A3.1 Comparison of modelled Road NOx Vs Measured Road NOx



After adjustment the model agrees well with the NO_2 monitoring. The agreement is shown in figure A3.2 below. The RMSE of the model is 2.8 mg m^{-3} which is well within the recommended value of 4 mg m^{-3} from the Technical Guidance.

Figure A3.2 Comparison of modelled Road NOx Vs Measured Road NOx



PM_{10}

Model verification and adjustment for PM_{10} has been carried out by comparing the predicted concentration of PM_{10} at the automatic monitoring station with the modelled value at the same location. The availability of a single monitoring location for checking model performance introduces some uncertainty into the predictions away from the monitoring station.

When the assumed background was subtracted from the measured value, and this was compared with the modelled Road PM_{10} value, the model was found to under predict quite substantially. An adjustment factor of 3.84 was derived and this was applied to all modelled Road PM_{10} concentrations. It should be noted that all reasonable steps were taken to minimise uncertainty in the modelling and the reason for the large PM_{10} adjustment factor are not knows. When modelling two pollutants, any changes to the traffic inputs in the EfT will affect both pollutant emission outputs- to a certain extent the PM_{10} model is therefore constrained by the NO_2 model. It is impossible to change one without changing the other as their emission factors are co-dependent.

Derivation of the adjustment factor is shown in Table A3.1 below.

Table A3.1 PM_{10} adjustment factor derivation

Measured PM_{10}	Background	Measured minus background	Modelled	Measured/ Modelled
19.0	11.56	7.44	1.94	3.84

Appendix 4 – Diffusion Tube Bias Adjustment Factors

The information below is taken from Perth & Kinross Council's 2012 Updating and Screening Assessment. We have used the same bias corrected diffusion tube data as that presented in the Council's report:

> *"Diffusion tube monitoring has been undertaken at 44 locations within the Perth AQMA, and at 14 further locations within the Perth & Kinross Council area. The tubes are analysed by Dundee Scientific Services using a 20% TEA in water preparation method. Data capture at all of the sites was high, with at least eleven months data at all sites. The Bias adjustment for Tayside Scientific Services from the national database found at: http://laqm.defra.gov.uk/documents/Diffusion_Tube_Bias_Factors_v04_11_v6.xls was 0.78."*

Factor from Local Co-location Studies

> *"Collocation studies have been carried out at all three of the automatic monitors in Perth and Kinross, where diffusion tubes have been exposed in triplicate and the measured concentrations compared with the monthly results from the automatic monitor. The precision and accuracy tool found at http://www.airquality.co.uk/laqm/tools was used to determine bias factors for each of the automatic monitors."*

Checking Precision and Accuracy of Triplicate Tubes

AEA Energy & Environment
From the AEA group

Period	Start Date dd/mm/yyyy	End Date dd/mm/yyyy	Tube 1 μgm^{-3}	Tube 2 μgm^{-3}	Tube 3 μgm^{-3}	Triplicate Mean	Standard Deviation	Coefficient of Variation (CV)	95% CI of mean	Automatic Method: Period Mean	Automatic Method: Data Capture (% DC)	Data Quality Check: Tubes Precision Check	Data Quality Check: Automatic Monitor Data
1	01/01/2011	31/01/2011	54.1	53	52.5	53	0.8	2	2.0	47	99	Good	Good
2	01/02/2011	28/02/2011	38.1	36.8	38.6	38	0.9	2	2.3	34	100	Good	Good
3	01/03/2011	31/03/2011	30.1	32.3	32.4	32	1.3	4	3.2	31	100	Good	Good
4	01/04/2011	30/04/2011	27.2	24.6	26.5	26	1.3	5	3.3	22	100	Good	Good
5	01/05/2011	31/05/2011	19.4	20.8	19.8	20	0.7	4	1.8	18	100	Good	Good
6	01/06/2011	30/06/2011	27.1	26.2	27.1	27	0.5	2	1.3	20	44	Good	or Data Captu
7	01/07/2011	31/07/2011	23.5	22.1	22.3	23	0.8	3	1.9	21	86	Good	Good
8	01/08/2011	31/08/2011	22.2	22.9	21.9	22	0.5	2	1.3	20	100	Good	Good
9	01/09/2011	30/09/2011		23.8	25	24	0.8	3	7.6	20	99	Good	Good
10	01/10/2011	31/10/2011	27.3	23.7	25.7	26	1.8	7	4.5	22	98	Good	Good
11	01/11/2011	30/11/2011	30.2	33.4	28.3	31	2.6	8	6.4	28	100	Good	Good
12	01/12/2011	31/12/2011	25.2	27.4	25.7	26	1.2	4	2.9	33	99	Good	Good
13													

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

Overall survey --> Good precision | Good Overall DC

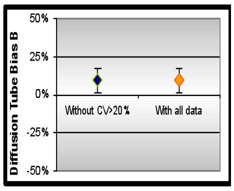
Site Name/ ID: High St

Precision 12 out of 12 periods have a CV smaller than 20%

(Check average CV & DC from Accuracy calculations)

Accuracy (with 95% confidence interval)
without periods with CV larger than 20%
Bias calculated using 11 periods of data
Bias factor A 0.92 (0.86 - 0.99)
Bias B 8% (1% - 16%)
Diffusion Tubes Mean: 29 μgm^{-3}
Mean CV (Precision): 4
Automatic Mean: 27 μgm^{-3}
Data Capture for periods used: 98%
Adjusted Tubes Mean: 27 (25 - 29) μgm^{-3}

Accuracy (with 95% confidence interval)
WITH ALL DATA
Bias calculated using 11 periods of data
Bias factor A 0.92 (0.86 - 0.99)
Bias B 8% (1% - 16%)
Diffusion Tubes Mean: 29 μgm^{-3}
Mean CV (Precision): 4
Automatic Mean: 27 μgm^{-3}
Data Capture for periods used: 98%
Adjusted Tubes Mean: 27 (25 - 29) μgm^{-3}



Jaume Targa, for AEA
Version 04 - February 2011

Checking Precision and Accuracy of Triplicate Tubes

AEA Energy & Environment
From the AEA group

Period	Start Date dd/mm/yyyy	End Date dd/mm/yyyy	Tube 1 μgm^{-3}	Tube 2 μgm^{-3}	Tube 3 μgm^{-3}	Triplicate Mean	Standard Deviation	Coefficient of Variation (CV)	95% CI of mean	Automatic Method: Period Mean	Automatic Method: Data Capture (% DC)	Data Quality Check: Tubes Precision Check	Data Quality Check: Automatic Monitor Data
1	01/01/2011	31/01/2011	79.4	86.2	84.5	83	3.5	4	8.8	75	100	Good	Good
2	01/02/2011	28/02/2011	70.6	66.2	70.1	69	2.4	3	6.0	64	100	Good	Good
3	01/03/2011	31/03/2011	66.3	63.4	70.1	67	3.4	5	8.3	62	100	Good	Good
4	01/04/2011	30/04/2011	65.3	62.7	58.8	62	3.3	5	8.1	55	100	Good	Good
5	01/05/2011	31/05/2011	51.2	55.8	57.4	55	3.2	6	8.0	48	100	Good	Good
6	01/06/2011	30/06/2011	58.8	60.9	58.9	60	1.2	2	2.9	49	96	Good	Good
7	01/07/2011	31/07/2011	49.6	53.8	51	51	2.1	4	5.3	40	100	Good	Good
8	01/08/2011	31/08/2011	55.2	57.6	53.4	55	2.1	4	5.2	44	100	Good	Good
9	01/09/2011	30/09/2011	60		62.2	61	1.6	3	14.0	49	85	Good	Good
10	01/10/2011	31/10/2011	62.3	65.6	63.8	64	1.7	3	4.1	53	98	Good	Good
11	01/11/2011	30/11/2011	61.8	66.9	67.6	65	3.2	5	7.9	62	100	Good	Good
12	01/12/2011	31/12/2011	51.9	58.3	55.6	55	3.2	6	8.0	79	100	Good	Good
13													

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

Overall survey --> Good precision | Good Overall DC

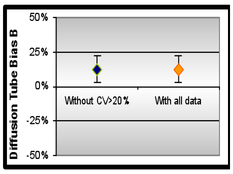
Site Name/ ID: Atholl St

Precision 12 out of 12 periods have a CV smaller than 20%

(Check average CV & DC from Accuracy calculations)

Accuracy (with 95% confidence interval)
without periods with CV larger than 20%
Bias calculated using 12 periods of data
Bias factor A 0.91 (0.83 - 1)
Bias B 10% (0% - 20%)
Diffusion Tubes Mean: 62 μgm^{-3}
Mean CV (Precision): 4
Automatic Mean: 57 μgm^{-3}
Data Capture for periods used: 98%
Adjusted Tubes Mean: 57 (52 - 62) μgm^{-3}

Accuracy (with 95% confidence interval)
WITH ALL DATA
Bias calculated using 12 periods of data
Bias factor A 0.91 (0.83 - 1)
Bias B 10% (0% - 20%)
Diffusion Tubes Mean: 62 μgm^{-3}
Mean CV (Precision): 4
Automatic Mean: 57 μgm^{-3}
Data Capture for periods used: 98%
Adjusted Tubes Mean: 57 (52 - 62) μgm^{-3}



Jaume Targa, for AEA
Version 04 - February 2011

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(PKC Design Team - 2013329)