OTTERPOOL PARK

Environmental Statement Appendix 6.2: Air Quality Model Verification

MARCH 2022

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TABLES

FIGURES

1 Model Verification

The comparison of modelled concentrations with local monitored concentrations is a process termed 'verification'. Model verification identifies any discrepancies between modelled and measured concentrations, which can arise for a range of reasons. The following are examples of potential causes of such discrepancies:

- estimates of background pollutant concentrations;
- meteorological data uncertainties;
- traffic data uncertainties;
- emission factor uncertainties;
- model input parameters, such as 'roughness length'; and
- overall limitations of the ability of the dispersion model to model dispersion in a complex urban environment.

The verification process involves a review of the modelled pollutant concentrations against corresponding monitoring data to determine how well the air quality model has performed. Depending on the outcome it may be considered that the model has performed adequately and that there is no need to adjust any of the modelled results.

Alternatively the model may perform poorly against the monitoring data (acceptable limits of model verification performance are set out in Defra's LAQM TG.16), as a result there is a need to check all the input data to ensure that it is reasonable and accurately represented in the air quality modelling process. Where all input data, such as traffic data, emissions rates and background concentrations have been checked and considered reasonable, then the modelled results may require adjustment to best align them with the monitoring data. This may be either be a single verification adjustment factor to be applied to the modelled concentrations across the study area or a range of different adjustment factors to account for different situations within the study area.

2 Residual Uncertainty & Model Performance

Residual uncertainty may remain after systematic error or 'overall model accuracy' has been accounted for in the final predictions. Residual uncertainty may be considered synonymous with the 'residual inaccuracies' of the model predictions, i.e. how wide the scatter or residual variability of the predicted values compare with the monitored 'true value', once systematic error has been allowed for. The quantification of final model accuracy provides an estimate of how the final predictions may deviate from the 'true' (monitored) values at the same location over the same period. It must though be recognised that some of the residual uncertainty will be down to uncertainties in the monitored values. This uncertainty is greater for monitoring using diffusion tubes than for automatic monitors.

Suitable local monitoring data for the purpose of verification is available for concentrations of NO_2 at the locations shown in Table 2. This monitoring data has been used to validate the dispersion model prediction and obtain adjustment factors which can be applied to predictions of pollutant concentrations in the base and future years.

An evaluation of model performance has been undertaken to establish confidence in model results. LAQM.TG(16) (Defra, 2016) identifies a number of statistical procedures that are appropriate to evaluate model performance and assess the uncertainty. The statistical parameters used in this assessment are:

- root mean square error (RMSE);
- fractional bias (FB); and
- correlation coefficient (CC).

A brief for explanation of each statistic is provided in Table 1, and further details can be found in LAQM.TG(16) Box 1.17.

Table 1: Statistical Parameters used to estimate model performance

Statistical Parameter	Comments	Ideal value
RMSE	RMSE is used to define the average error or uncertainty of the model. The units of RMSE are the same as the quantities compared. If the RMSE values are higher than 25% of the objective being assessed, it is recommended that the model inputs and verification should be revisited in order to make improvements. For example, if the model predictions are for the annual mean NO_2 objective of 40 µg/m3, if an RMSE of 10 µg/m^3 or above is determined for a model it is advised to revisit the model parameters and model verification. Ideally an RMSE within 10% of the air quality objective would be derived, which equates to ±4 µg/m^3 for the annual mean NO_2 objective.	0.01
Fractional Bias	It is used to identify if the model shows a systematic tendency to over or under predict. FB values vary between +2 and -2 and have an ideal value of zero. Negative values suggest a model over-prediction and positive values suggest a model under-prediction.	0.00
Correlation Coefficient	It is used to measure the linear relationship between predicted and observed data. A value of zero means no relationship and a value of 1 means absolute relationship. This statistic can be particularly useful when comparing a large number of model and observed data points.	1.00

These parameters estimate how the model results agree or diverge from the observations. These calculations have been carried out prior to, and after, adjustment and provide information on the improvement of the model predictions as a result of the application of the verification adjustment factors.

3 Arcadis Air Quality Monitoring

Arcadis undertook air quality monitoring in the vicinity of the proposed Development between April and October of 2017. The diffusion tubes were supplied by Staffordshire Highways Laboratory. The monitoring locations were selected as there were only five F&HDC monitoring sites located along the roads within 5km of the application site which are likely to be affected by the proposed Development.

Due to the inherent bias associated with passive NO_2 diffusion tubes, it was necessary to determine a bias adjustment factor which was applied to the raw diffusion tube results. Three diffusion tubes were co-located at the Maidstone Rural automatic monitor for the duration of the monitoring survey in accordance with the advice in LAQM.TG(16).

Table 2: Summary of Bias Adjustment at Maidstone Rural Automatic Monitor 04/04/2017-04/10/2017

Site	Type	Average NO_2 concentration (4th April 2017 to 4th October 2017)	Data Capture (%)	Bias Adjustment Factor
Maidstone Rural	Automatic Monitor	9.3	99	**0.71**
	Triplicate set of Diffusion tubes co-located on automatic monitor	13.1	100	

The results from the automatic monitoring site were compared to those results measured in the same location by the three diffusion tubes to derive a local bias adjustment factor. A summary is presented in Table 2. The local bias adjustment factor was found to be 0.71. The factor suggests that the diffusion tubes were systematically over-reading ambient concentrations of NO_2. This locally derived factor was applied to the monitoring dataset in accordance with LAQM. (TG(16)) which recommends that a local factor is more representative for surveys less than nine months in duration as it captures the adjustment over a matched time period whereas using the national annual factor would not.

Table 3: Summary of Site-specific and average annualisation Factors

Site	Annual Mean 2018	Period Mean 2017	Ratio
Maidstone Rural	11.1	9.15	1.21
Sevenoaks - Greatness Park	15.4	13.7	1.12
Rochester Stoke	13.0	11.1	1.17
Canterbury	12.0	11.9	1.01
		Average Ratio	**1.13**

As the duration of the survey was not a full year in duration and was undertaken in 2017, the data needed to be annualised in order to be representative of 2018 annual mean concentrations and concordant with the 2018 traffic base year. This was undertaken following the guidance detailed in box 7.9 of LAQM.(TG(16)). The Annualisation factor was calculated to be 1.13 as demonstrated in Table 3. This factor was applied to the bias adjusted short-term monitored concentrations. The raw, bias adjusted and annualised monitoring data is presented in Table 4.

Table 4 - Summary of raw and factored NO_2 concentrations at dedicated Arcadis monitoring sites

Site ID	X	Y	Raw Annual Mean NO2 (µg/m³) Concentration April 2017 – October 2017	Data Capture	Bias Adjusted and Annualised to 2018 annual mean NO_2 (µg/m³)
O1	613638	136970	26.7	100%	21.4
O2	612805	136835	15.3	100%	12.3
O3	612680	136185	26.0	100%	20.8
O4	612475	135827	16.2	100%	12.9
O5	610636	137872	24.0	33%	19.2
O6	611833	134980	15.4	100%	12.3
O7	612239	135341	21.0	83%	16.8
O8	611283	136671	27.4	83%	21.9
O9	610702	137675	31.8	83%	25.5
O10	610794	137453	12.6	83%	10.1
O11	610932	136835	26.8	100%	21.5
O12	610978	135615	18.0	100%	14.4
O13	611833	134980	19.2	100%	15.3
O14	612068	135514	12.6	100%	10.1
O15	612887	137513	30.4	67%	24.3
Background Tube	609262	136590	11.5	100%	9.2

4 Air Quality Monitoring Data

The air quality monitoring data collected as part of this assessment and detailed in the baseline section was reviewed to determine the suitability of each of the monitoring locations for inclusion into the model verification process.

The traffic base year was defined as 2018, therefore monitoring data representative of 2018 was acquired in order inform the model verification process. Monitoring data was collated from two local authorities (Ashford and Folkestone and Hythe DC), Highways England and from the dedicated Arcadis air quality monitoring survey. The following criteria was used to determine the suitability of the collected monitoring data for inclusion into the verification exercise;

- within 50m of a road within the air quality study area;
- monitoring from diffusion tubes for 2018 was used in preference to other years
- automatic monitoring data was used where there was greater than 90% data capture;
- monitoring sites were discounted where there was less than 75% data capture in 2018 and poor data capture in other years;
- monitoring was excluded from verification if major sources were missing from the traffic model that may influence monitored concentrations but could not be included in the air quality modelling (such as large car parks, industrial stacks in close proximity etc.); and
- sites where the location of the monitoring could not be confirmed to a satisfactory standard were omitted from the verification.

5 Verification Methodology

The verification method following the process detailed in LAQM.TG(16). The initial verification was undertaken by comparing the modelled versus monitored Road NO_x. Road NO_x measured at the diffusion tubes was calculated using a custom version of the latest Defra NO_x to NO_2 calculator (v81), because diffusion tubes only measure NO_2 and do not directly measure NO_x.

Concentrations of road NO_x recorded at automatic monitors were calculated by subtracting background concentrations of NO_x (acquired from Defra background maps) from the total NO_x recorded at the automatic site.

Following the removal of the monitoring locations with low data capture and those locations where road sources were not fully represented in the traffic data, a total of 21 diffusion tube and automatic monitoring sites were used in the verification. A description of the sites is presented in Table 5.

Table 5: Collated Monitoring Site Information

Site ID	X	Y	Data Owner	Monitoring Method	2018 Annual mean NO_2 concentration ($\mu g/m^3$)
DT3	609964	135279	Folkestone and Hythe DC	Diffusion Tube	12.0
DT6	614552	134012	Folkestone and Hythe DC	Diffusion Tube	23.2
DT8	612694	136190	Folkestone and Hythe DC	Diffusion Tube	21.3
DT9	621248	137352	Folkestone and Hythe DC	Diffusion Tube	28.8
AS15	603393	142073	Ashford BC	Diffusion Tube	30.5
AS40	603229	142795	Ashford BC	Diffusion Tube	16.3
AS44	603800	141792	Ashford BC	Diffusion Tube	18.9
AS46	603311	142192	Ashford BC	Diffusion Tube	24.1
AS47	604583	140961	Ashford BC	Diffusion Tube	14.4
AS48	604733	140878	Ashford BC	Diffusion Tube	13.8
O1	613638	136970	Arcadis	Diffusion Tube	21.4
O2	612805	136835	Arcadis	Diffusion Tube	12.3
O3	612680	136185	Arcadis	Diffusion Tube	20.8
O4	612475	135827	Arcadis	Diffusion Tube	12.9
O6	611833	134980	Arcadis	Diffusion Tube	12.3
O7	612239	135341	Arcadis	Diffusion Tube	16.8
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Site ID	X	Y	Data Owner	Monitoring Method	2018 Annual mean NO_2 concentration ($\mu g/m^3$)
O9	610702	137675	Arcadis	Diffusion Tube	25.5
O11	610794	137453	Arcadis	Diffusion Tube	21.5
O12	610932	136835	Arcadis	Diffusion Tube	14.4
O13	610978	135615	Arcadis	Diffusion Tube	15.3

For each monitoring site, the relevant 1x1km 2018 background concentrations for NO_x and NO_2 were acquired by using the 2018 reference year Defra background maps (issued Aug 2020) which were adjusted by a monitoring based adjustment factor to ensure that the modelled maps did not under-predict when compared to observed backgrounds.

The NO_2 to NOx tool was used to calculate the total of road NOx at each diffusion tube monitoring site. At those automatic sites which measured NOx, the road NOx component was calculated by subtracting the background NOx from the total NOx concentration. Table 6 summarises the background NOx/NO_2 concentrations, raw (i.e. no adjustment) modelled and monitored road NOx concentrations and raw modelled and monitored total NO_2 +-concentrations.

Table 6: Unadjusted Modelled Results vs Actual Monitored Results 2018 (Total NO_2 & Road NO_x)

Tube ID	Background NO_2 (µg/m³)	Monitored NO_2 (µg/m³)	Modelled Total NO_2 (µg/m³)	Monitored V Modelled Total NO_2 % Difference	Monitored Road NO_x (µg/m³)	Modelled Road NO_x (µg/m³)	Monitored v Modelled Road NO_x % Difference
DT3	9.4	12.0	12.9	-11.6	4.6	2.1	-1.19
DT6	10.0	23.2	17.8	-45.2	25.0	4.9	80.50
DT8	10.6	21.3	18.8	-36.9	20.1	5.1	74.43
DT9	13.2	28.8	27.6	-36.6	30.3	9.4	68.89
AS15	13.4	30.5	25.7	-26.4	33.4	17.0	49.10
AS40	13.4	16.3	20.1	12.3	5.3	9.0	-71.35
AS44	13.9	19.7	20.0	-6.8	10.9	8.3	23.28
AS46	13.4	25.6	25.7	-12.3	23.3	17.0	26.96
AS47	11.8	14.4	16.9	8.0	4.7	6.9	-45.15
AS48	11.8	13.8	18.0	18.3	3.6	8.3	-129.48
O1	10.5	21.4	24.1	-28.5	20.4	8.7	57.22
O2	10.6	12.3	13.5	-5.7	3.0	1.8	41.78
O3	10.6	20.8	23.2	-28.0	19.2	8.1	58.09
O4	10.3	12.9	14.9	-8.4	4.9	2.9	40.70
O6	9.5	12.3	12.6	-14.2	5.0	1.9	63.22
O7	10.3	16.8	15.3	-28.9	12.2	3.1	74.45
O8	10.3	21.9	18.8	-39.6	21.9	5.4	75.56

Tube ID	Background NO_2 (µg/m³)	Monitored NO_2 (µg/m³)	Modelled Total NO_2 (µg/m³)	Monitored V Modelled Total NO_2 % Difference	Monitored Road NO_x (µg/m³)	Modelled Road NO_x (µg/m³)	Monitored v Modelled Road NO_x % Difference
O9	10.5	25.5	27.0	-35.9	28.7	10.8	62.40
O11	10.5	21.5	21.4	-33.5	20.8	7.0	66.38
O12	9.9	14.4	16.1	-16.5	8.2	3.8	53.46
O13	9.8	15.3	14.1	-26.6	10.2	2.6	74.17

The modelled versus monitored road NOx component concentrations were plotted on a scatter graph as presented on Figure 1.

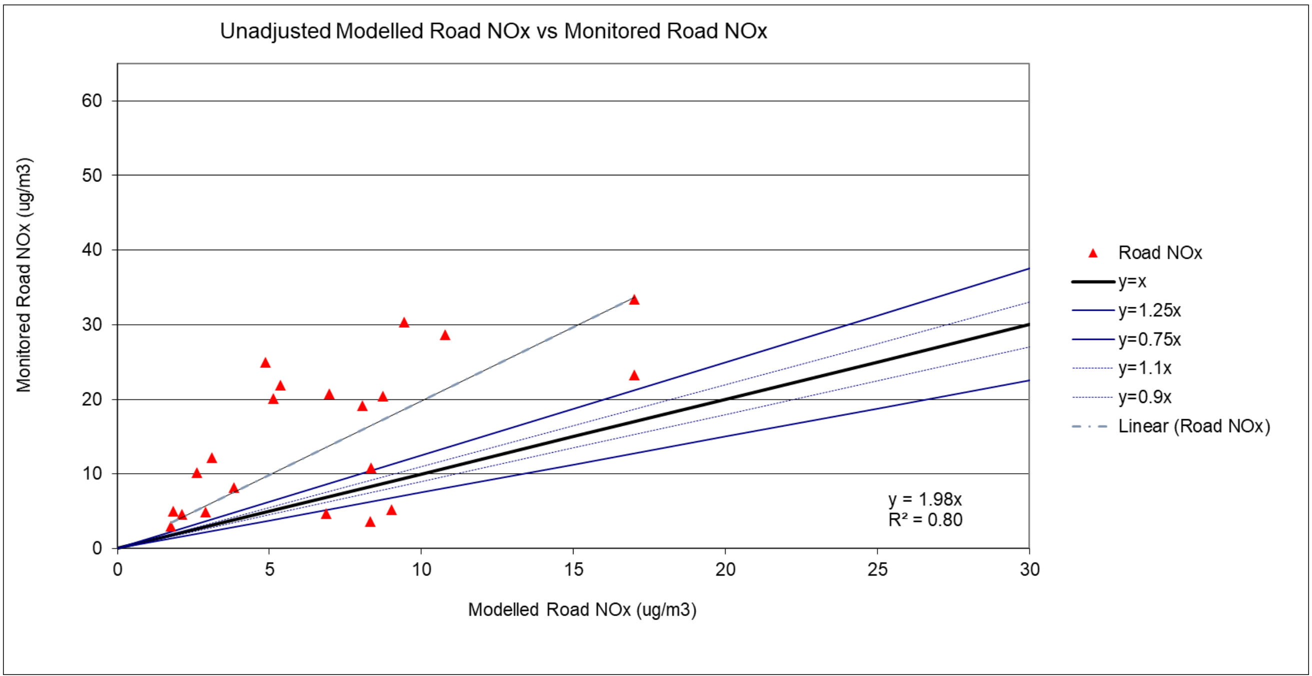

Figure 1: Scatterplot of Unadjusted Modelled Road NOx vs Monitored Road NOx

Figure 1 illustrates that the modelled concentrations systematically under-predict the road component of NOx in relation to the monitored concentrations. However, there is significant scatter in the data. To examine whether this scatter could be due to some systematic feature, such as the type of road or geographic area, a number of verification tests were carried out:

- Overall Factor – one single verification factor for all receptors.
- Detailed Verification - Splitting the model into two verification zones following review of the modelled versus monitoring (including splitting specific Sections of the road network into different zones).

Following a review of the various verification options it was decided that a detailed split of geographically defined verification zones gave the best level of performance. The road NOx verification factors for each of the modelled zones are presented in Table 7.

Table 7: Road NOx Verification Factors per Model Verification Zone

Verification Zone Description	Road NO_X Verification Factor	Number of Monitoring sites used	Number of Receptors in zone
1. Ashford	1.38	6	39
2. Otterpool and Folkestone	2.96	15	295

When the verification factors in Table 4 were applied to the raw modelled results, total annual mean NO_2 concentrations at 95% of the modelled sites were within 25% of monitored NO_2 concentrations as summarised in Figure 3, as opposed to 57% of the sites when no adjustment was applied (Figure 2).

Figure 3 demonstrates that once adjusted for road NOx, total modelled NO_2 concentrations are closer to monitored total NO_2 concentrations, than the unadjusted total modelled NO_2 in Figure 2.

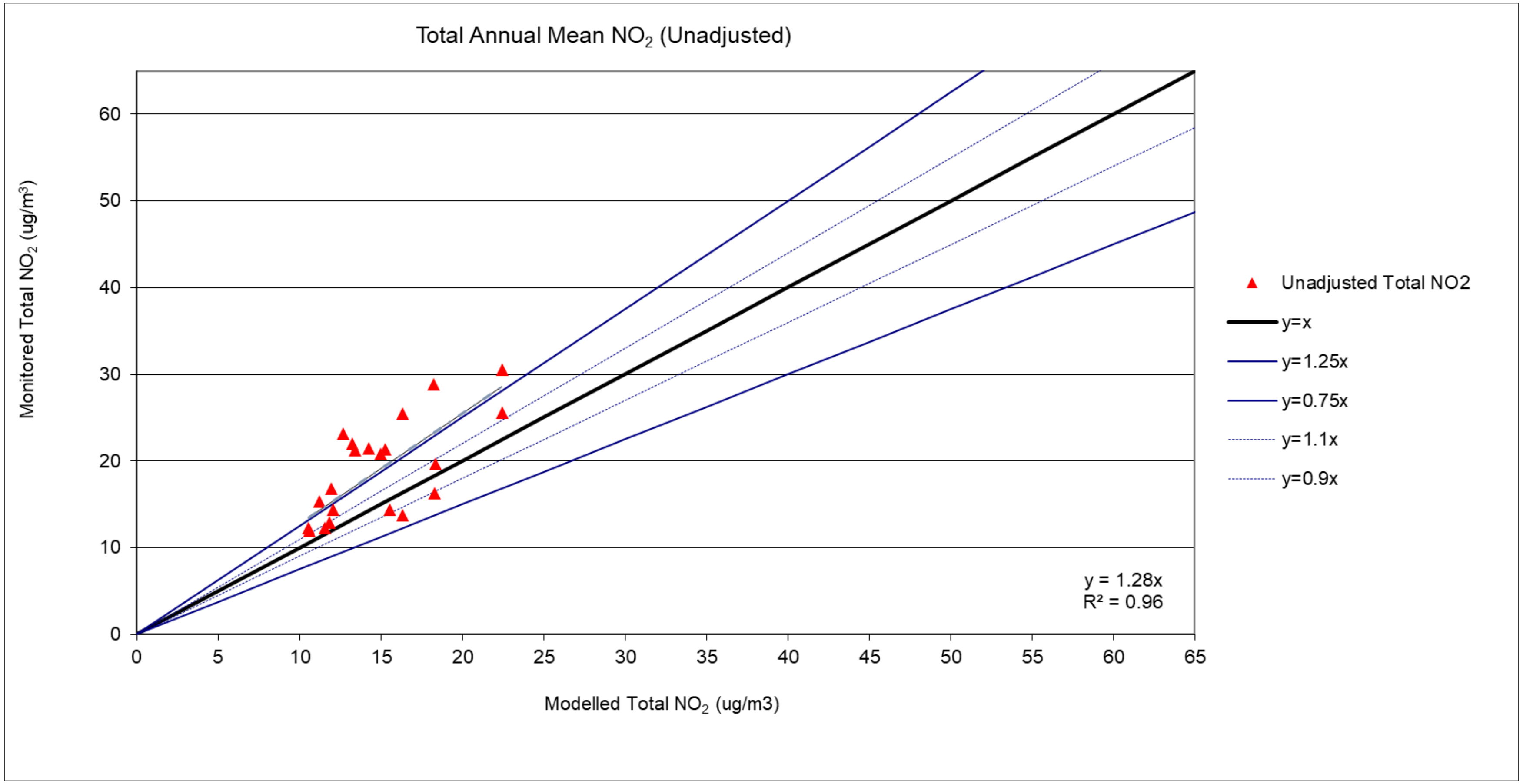

Figure 2: Scatterplot of unadjusted Total NO_2 vs Monitored Total NO_2

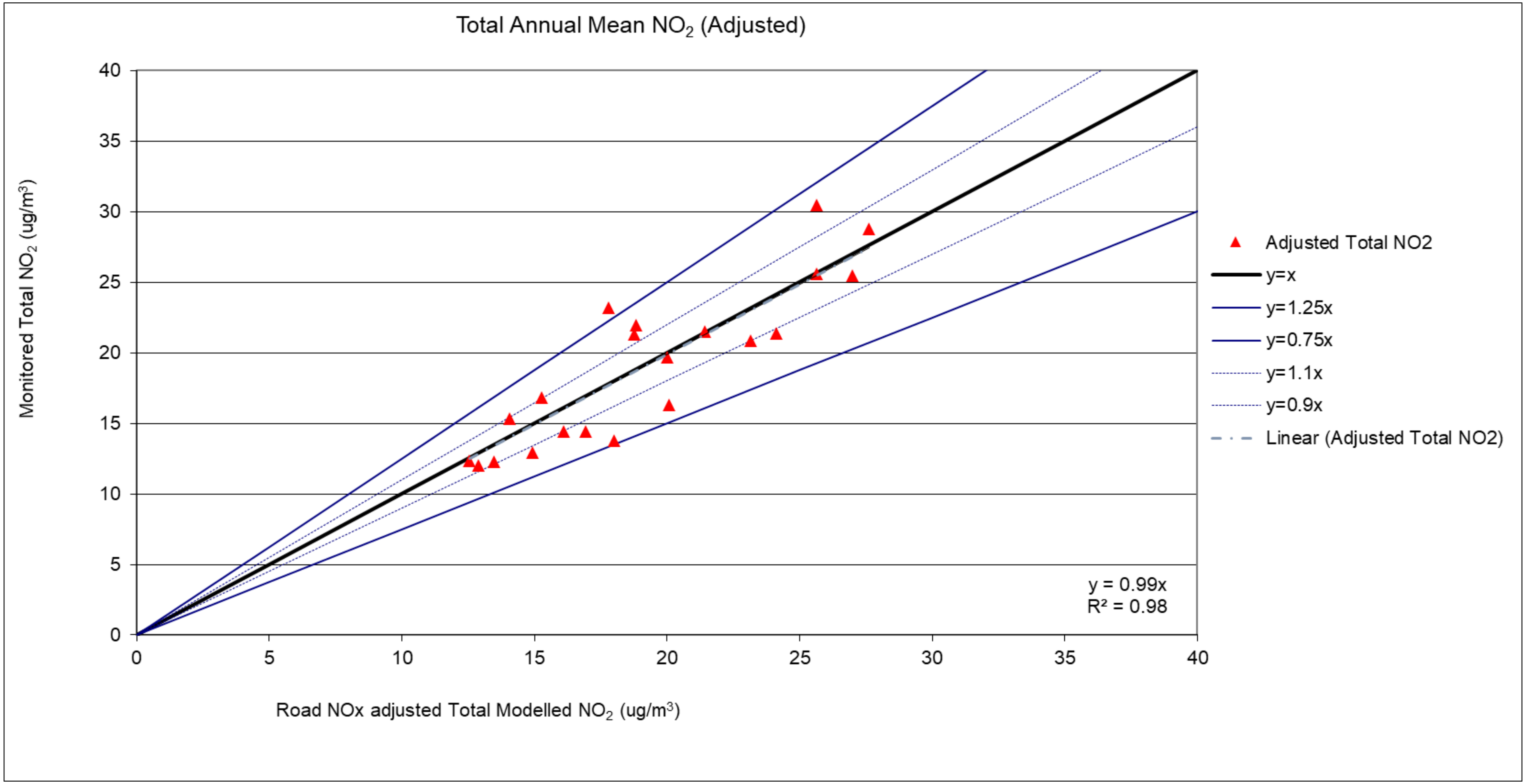

Figure 3: Scatterplot of Road NOx adjusted Modelled Total NO_2 vs Monitored NO_2

Table 8: Model Performance Statistics

Parameter	No Adjustment	Road NOx Contribution Adjustment
Root Mean Square Error (RMSE)	4.67	2.55
Fractional Bias	0.2	0.0
Correlation Coefficient	0.69	0.89

Table 8 summarises the model performance statistics which show that the uncertainty in the predictions of the total NO_2 using the unadjusted model would have been large, as the RMSE is 4.67 µg/m^3. Additionally, the model had a tendency to under-predict actual concentrations because the fractional bias is greater than zero. When road NO_x is adjusted by applying the geographical verification factors for the two zones, the RMSE is reduced from 4.67 µg/m3 to 2.55 µg/m3. The model doesn't systematically under or over predict actual concentrations once adjusted because the fractional bias is zero. The adjusted model thus provides a much improved model performance.

The road NOx adjustment factors were also applied to modelled road contribution PM10/$PM_{2.5}$ concentrations in the absence of sufficient PM_{10}/$PM_{2.5}$ monitoring data.

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