Calibrating Defra's 2018-based Background NOx and NO_2 Maps against 2022 Measurements

Experts in air quality management & assessment

Prepared by: Dr Kate Wilkins

Approved by: Dr Ben Marner

Version 1: 31/07/2023

Introduction

When using roadside[1] measurements to verify local-scale modelling, it is important that the local background concentration is predicted as accurately as possible for the year in which the verification is based. If the modelled background is too high, the local road component will be under-estimated[2]. Conversely if the modelled background is too low, the local road component will be over-estimated. This may then have significant implications for any future-year projections or impact assessments.

Defra has predicted background NOx and NO_2 concentration predictions for 2022[3]. Currently, these are included in its 2018-based maps. This means that they have been verified against measurements made in 2018, with the 2022 values being projected from this 2018 baseline.

This note compares Defra's (2018-based) background mapped NOx and NO_2 concentration predictions for 2022 against 2022 annual mean measured background concentrations at automatic monitoring sites with more than 75% data capture in the Automatic Urban and Rural Network (AURN), Scottish Air Quality Network (SAQN), Welsh Air Quality Network (WAQN), Air Quality England (AQE) network and King's College London (KCL) network. It follows the approach taken by AQC previously when calibrating the background maps for use in impact assessments using measurements from earlier years[4].

At the time that this note was produced, 2022 was the most recent full calendar year of available measurements. Factors for the years 2020 and 2021 were not calculated because of the impact of the Covid-19 pandemic on national travel patterns and traffic-related NOx and NO_2 concentrations.

Derivation of Factors

The mapped NOx values in 2022 were initially compared to those measured at the 98 suitable background sites with more than 75% data capture, with individual factors derived for each site plotted to identify any geographical patterns in the data. Two sites were then removed as outliers[5].

Initial investigation showed, as has been observed in previous AQC notes in this series[4], a clear delineation between the performance of the background maps inside London, and across the rest of the UK. The data for sites outside London were thus examined separately from those within London.

1 Or other near-source measurements.

2 This is because the local road increment of concentrations is typically taken to be the total roadside measurement minus the local background.

3 These maps cover the whole country on a 1x1 km grid and are published for each year from 2018 until 2030, and can be downloaded from https://uk-air.defra.gov.uk/data/laqm-background-home.

4 https://www.aqconsultants.co.uk/resources.

5 Burnham Beeches and Iver Heath Junior School were removed from the data set due to the background NO_2 concentrations being significantly underpredicted. Neither site measured NOx concentrations.

Sites Outside London

Figure 1 compares the 2022 predictions for background annual mean NOx against concurrent measurements (left plot). While there is clear scatter, overall bias is just 3% on average. Given that these predictions were forecast from a 2018 base year, the absence of significant overall bias is encouraging. The right plot in Figure 1 shows the same comparison for NO_2 with an even better overall fit, with the maps under-predicting by 1% on average. It is not felt that there is sufficient basis to apply any adjustment to the predictions for 2022 outside of London, and nor is there any need to apply an overall adjustment for bias in 2022.

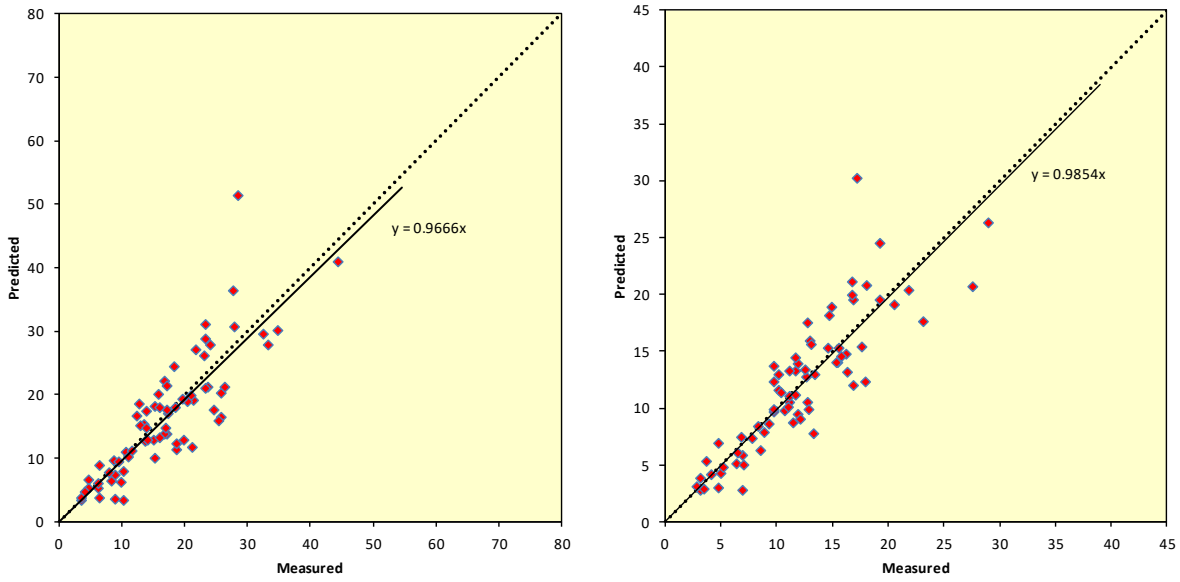

Figure 1: Predicted Mapped versus Measured Concentrations at Background Sites in the UK (Outside London) in 2022: NOx (Left) and NO_2 (Right)

Sites Inside London

Within London, the mapped background predictions tend to over-predict concentrations on average, but there appears to be appreciable spatial variability. Figure 2 shows the spatial distribution of the measured concentrations divided by the co-located mapped values. In the centre of London, the mapped concentrations are more than double the measurements, while toward the edges of London the maps are similar to, and in some cases under-predict, the measurements.

One feature which might have caused the observed differences is the Ultra Low Emission Zone (ULEZ). This was expanded in October 2021 from the area shown in purple in Figure 2 to the area shown in blue. The area shown in green in Figure 2 is the original Low Emission zone (LEZ). Given that the ULEZ expanded to the area shown in blue before the start of the monitoring year covered in this report, the original (purple) ULEZ boundary is unlikely to have driven the observed spatial patterns. However, it remains the case that in the centre of London, within the area of the original ULEZ, the 2018-based predictions performed quite differently in 2022 than they did elsewhere. The

three zones delineated in Figure 2 have thus been used as the basis for deriving average factors to adjust the maps for 2022[6], noting the relatively high degree of uncertainty in this approach.

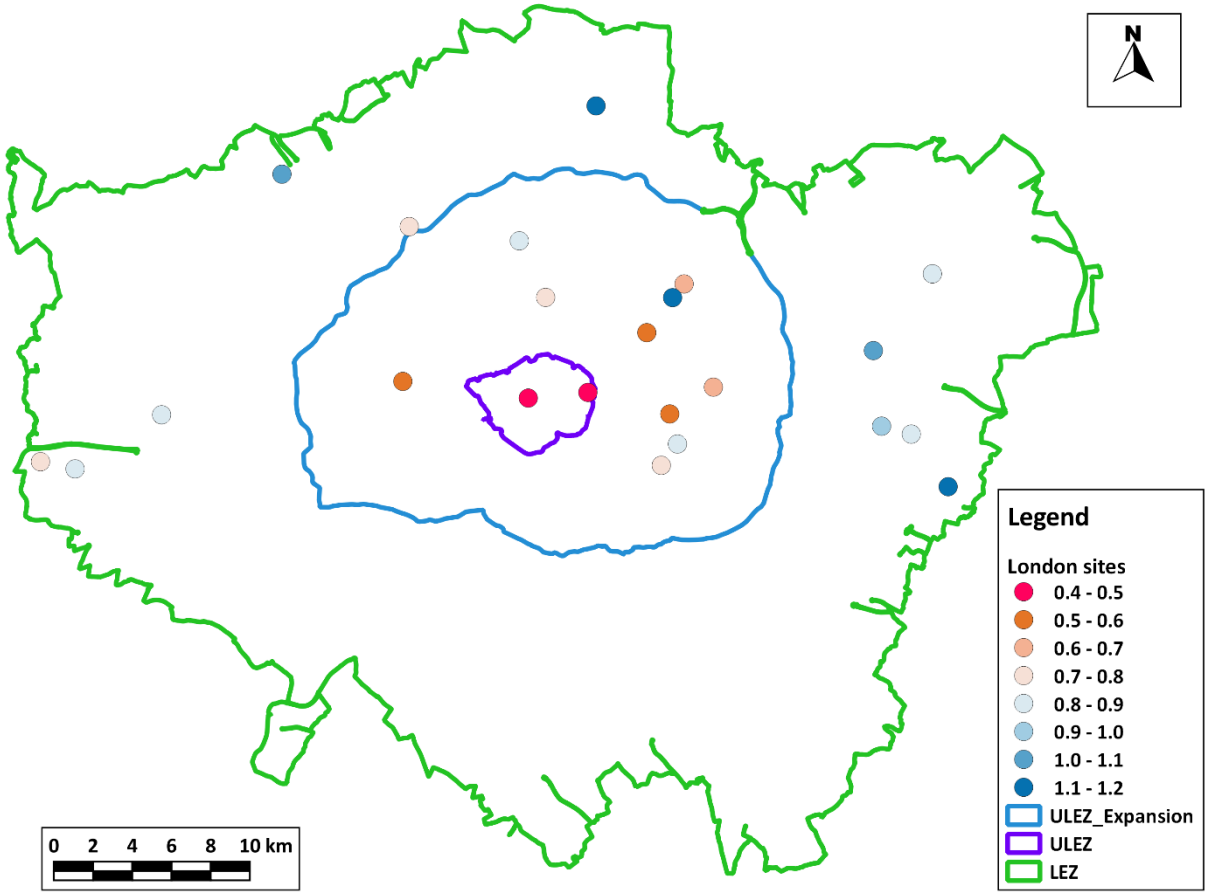

Figure 2: Mapped / Measured Annual Mean NOx in 2022 in London

Figure 3 (left plot) compares the mapped background NOx concentrations against the measurements for sites outside of the 2021-expanded ULEZ. It shows that the maps over-predict background NOx concentrations by 11% on average. The factor for calibrating Defra's background maps for 2022-based assessments at sites within London but outside of the 2021-expanded ULEZ is thus **0.8906** (i.e. 1/1.1129 = 0.8906). Figure 3 (right plot) shows the same comparison for NO_2; there is a 12% over-prediction in the maps. The calibration factor is thus **0.8962** (i.e. 1/1.1158 = 0.8962).

Figure 4 shows the comparison for sites within the 2021-expanded ULEZ but outside of the central area (original ULEZ). The maps over-predict background NOx concentrations by 38% on average for NOx (left plot), and 30% for NO_2 (right plot). The factor for calibrating Defra's background maps

[6] The traditional categories of Outer, Inner and Central London defined in the London Atmospheric Emissions Inventories follow borough boundaries and do not, therefore, ideally reflect the geography of London. For example, Central London extends outside of the 2021-Expanded ULEZ while much of Outer London is within this 2021-Expanded ULEZ. They have not, therefore, been used here.

in the 2021 ULEZ for NOx for 2022 is thus **0.7243** (i.e. 1/1.3806 = 0.7243), and for NO_2 the factor is **0.7664** (i.e. 1/1.3048 = 0.7664).

Figure 5 shows the two sites in the very central area. Here, the maps over-predicted background concentrations by 121% on average for NOx, and 66% for NO_2. The factor for calibrating Defra's background maps in the area of the original ULEZ for NOx is thus **0.4519** (i.e. 1/2.2127 = 0.4519), and for NO_2 the factor is **0.6025** (i.e. 1/1.6597 = 0.6025).

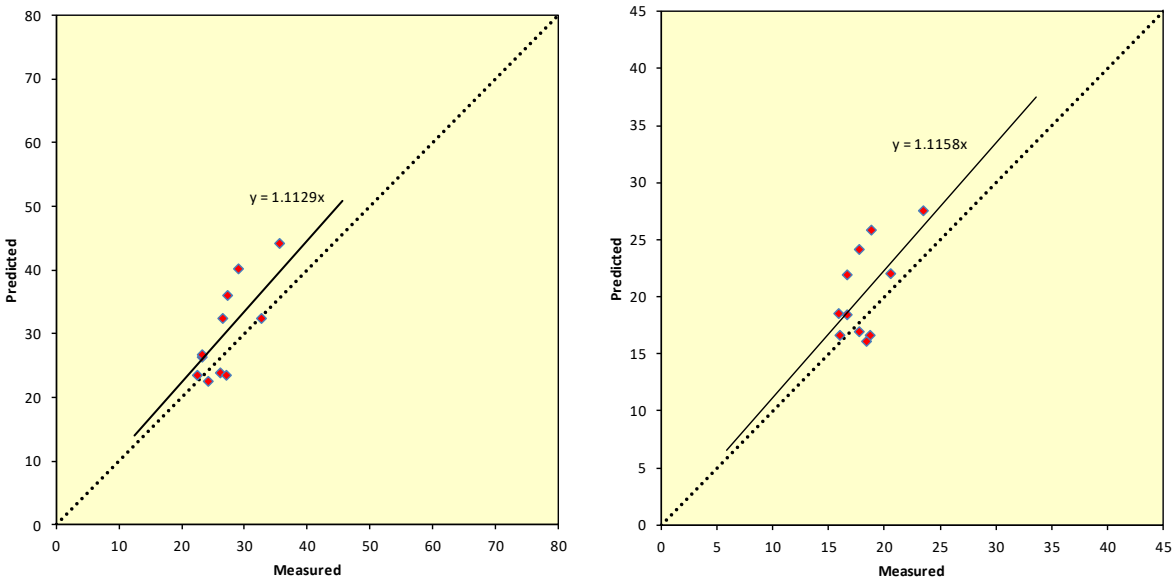

Figure 3: Predicted Mapped versus Measured Concentrations at Background Sites in the LEZ (Outside the 2021 ULEZ) in 2022: NOx (Left) and NO_2 (Right)

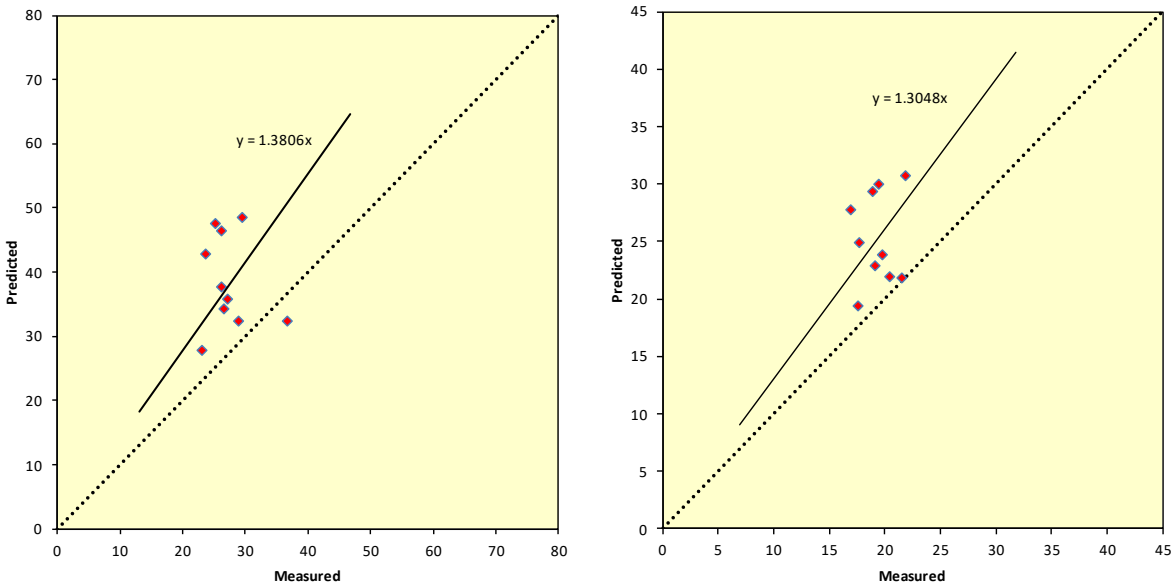

Figure 4: Predicted Mapped versus Measured Concentrations at Background Sites in the 2021 ULEZ (Outside the Central ULEZ) in 2022: NOx (Left) and NO_2 (Right)

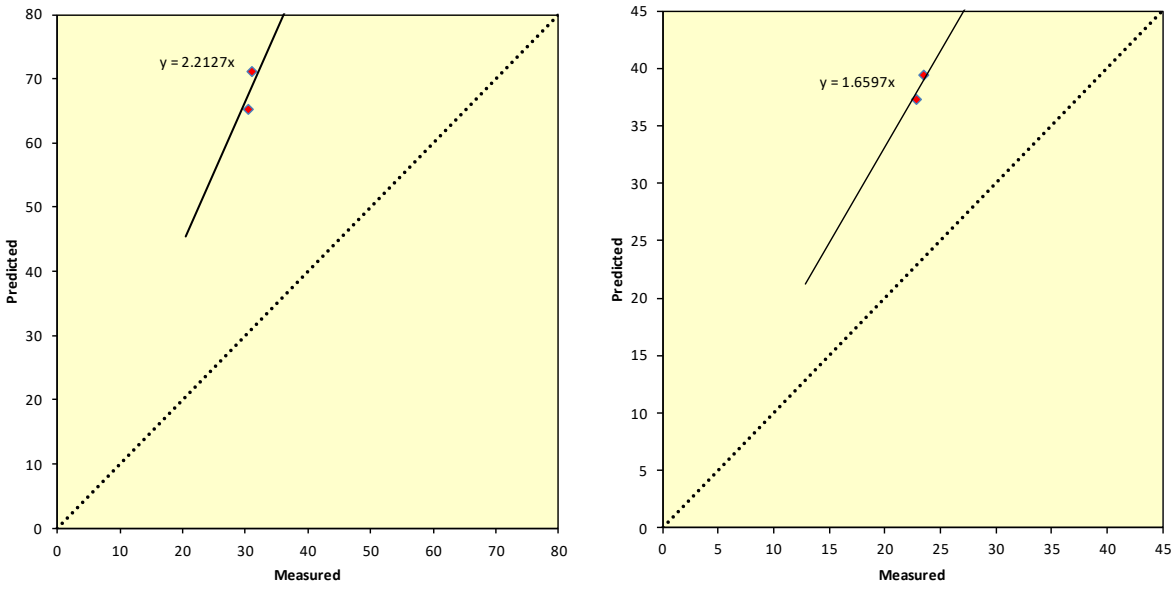

Figure 5: Predicted Mapped versus Measured Concentrations at Background Sites in the Central ULEZ in 2022: NOx (Left) and NO_2 (Right)

Conclusions

The NOx and NO_2 adjustment factors to be applied to Defra's 2018-based mapped concentrations when using 2022 as a base year are set out in Table 1. Mapped concentrations for the base year and each future year should simply be multiplied by the relevant factor.

Table 1: Factors to be Applied to Total Background Concentrations for 2022

Location	2022 Concentration Factors	
	NOx	NO_2
Centre of London (original ULEZ boundary)	0.4519	0.6025
Within the 2021-expanded London ULEZ but outside of the original ULEZ	0.7243	0.7664
Rest of London	0.8906	0.8962
Rest of the UK	No adjustment required	No adjustment required

Given the apparent spatial variability in the performance of the background maps, particular care should be taken close to boundaries where the factors change. It is also important to consider local factors which might ideally be informed by local background measurements, as long as the monitors are appropriately sited.

It is reasonable to expect that the future further expansion of the ULEZ in 2023 will cause additional spatial differences to emerge. These will not impact on model verification based on 2022 measurements but may affect future-year concentrations. It is not within the scope of this note to predict the effects of the future ULEZ expansion on air quality but ensuring that 2022-based model verifications are as accurate as possible will benefit future-year assessments.