Appendix A16.1: Air Quality Annexes

1 Introduction

1.1.1 This air quality technical appendix supports Chapter 16 (Air Quality) and includes the following annexes:

- Annex A Project Specific Air Quality Monitoring Results;
- Annex B Model Verification Project Specific Air Quality Monitoring Results;
- Annex C Detailed Assessment Results LAQM.TG(16) Approach – Sensitive Receptors; and
- Annex D Detailed Assessment Results – Designated Sites.

2 Annex A – Project Specific Air Quality Monitoring Results

2.1.1 A six-month monitoring programme using diffusion tubes was undertaken between February 2015 to August 2015 at 25 selected locations for the A9 southern section projects (referred to as Project 02 to Project 05 in Chapter 1 (Introduction) of the Environmental Statement (ES)). The details of monitoring sites for the proposed scheme (those numbered 7-10) are presented in Table 1 and are highlighted in grey. The locations of these monitoring sites within the study area are shown on Figure A16.1.

Table 1: Proposed scheme specific monitoring location details

Name	Description	X(m)	Y(m)	Height (cm)	A9 Dualling Project Number	Type
1	Give way sign at junction before bridge	301794	742051	230	P2	Background
2	Bus stop on A9 SB c/way	301716	742296	280	P2	Kerbside
3	Bus stop on A9 NB c/way	301627	742283	290	P2	Kerbside
4	Wooden telegraph pole across from bins	300056	749192	260	P3	Background
5	Parking sign preceding lay-by 28	299718	749202	160	P3	Roadside
6	Give way sign at junction with A9	299468	749766	230	P3	Roadside
7	Parking sign preceding lay-by 39	294309	757006	240	P4	Roadside
8	Silver pole near average speed camera adjacent to SB c/way	294307	757028	270	P4	Roadside
9	Lamppost next to national speed limit signs	293933	757525	290	P4	Background
10	Lamppost	293888	757643	360	P4	Background
11	No stopping sign A9 SB c/way	291761	762837	175	P5	Roadside
12	Bridge inspection stairwell railing	291608	763070	90	P5	Roadside
13	Fence post preceding lay-by 44	290595	763746	210	P5	Roadside
14	Hazard road sign	289259	764207	260	P5	Roadside
15	Passing place	289188	764082	240	P5	Background
16	Road sign A9 SB c/way Killiecrankie turn off	288916	764293	130	P5	Roadside
17	Parking sign preceding lay-by 46	288882	764285	160	P5	Roadside
18	Parking sign preceding lay-by 49	286952	764924	160	P5	Roadside
19	Parking sign preceding lay-by 51	285565	765243	160	P5	Roadside
20	Maintenance bay behind safety barrier	283906	765683	240	P5	Roadside
21	No stopping sign A9 SB c/way	283067	765516	160	P5	Kerbside
22	Metal pole near wooden telegraph pole	280540	765883	460	P5	Roadside
23	Wooden telegraph pole beside petrol station price sign	280489	765759	310	P5	Roadside
24	No parking sign in deceleration lane	280474	765910	190	P5	Roadside
25	Give way sign junction Calvine to A9 NB c/way	280149	765947	160	P5	Roadside

2.1.2 The six months of monitoring data collected are presented in Table 2. Those sites within the study area are highlighted in grey. As in Table 1, the other monitoring sites relate to the other southern sections of the A9 dualling programme.

Table 2: Average measured NO_2 concentration (µg/m^3) for the six monitoring periods

Site	A9 Proposed Scheme Location	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
1	P2	6.7	5.8	4.5	2.9	4.9	4.8
2	P2	35.1	30.4	26.9	25.8	28.6	28.3
3	P2	46.3	47.1	38.8	34.1	44.0	45.2
4	P3	6.6	5.1	3.6	3.3	4.1	3.9
5	P3	-	29.5	25.3	20.3	26.2	29.5
6	P3	-	18.6	13.8	14.2	16.8	17.7
7	P4	26.6	27.5	22.4	22.2	29.5	31.2
8	P4	22.9	19.7	14.4	14.3	14.3	16.8
9	P4	13.4	10.5	6.7	5.0	7.7	5.3
10	P4	11.2	9.0	5.7	3.5	5.4	8.2
11	P5	-	30.2	30.9	30.8	36.1	34.1
12	P5	-	19.6	16.6	16.3	19.2	20.3
13	P5	-	25.5	24.5	23.6	20.8	27.9
14	P5	12.9	11.5	9.3	7.7	7.7	8.6
15	P5	8.6	6.9	5.5	3.9	4.2	4.0
16	P5	28.1	24.8	22.7	21.3	24.2	27.5
17	P5	20.7	19.9	15.9	16.5	15.8	19.6
18	P5	25.8	24.4	22.5	18.6	21.6	27.7
19	P5	33.4	32.3	27.2	26.7	28.0	32.7
20	P5	23.2	21.1	15.3	15.1	14.1	15.3
21	P5	29.3	25.5	19.6	19.3	19.5	25.1
22	P5	22.4	20.3	14.5	16.2	15.4	16.9
23	P5	9.2	9.3	6.7	4.1	5.0	5.8
24	P5	29.4	28.3	21.3	23.5	24.2	28.9
25	P5	28.0	30.5	23.7	23.1	24.7	27.4

2.1.3 To address diffusion tube monitoring results for systematic over/underestimation, a bias adjustment factor is applied. The 2015 national bias factor (0.88) was used for the purposes of this assessment. The 2015 national bias factor was the bias adjustment factor determined from Local Authority co-location studies throughout the UK and has been collated by Defra's LAQM Helpdesk1.

2.1.4 As the Baseline Year is 2015 and the monitoring campaign took place in 2015 for a period of 6 months rather than the full year, the monitoring campaign results had to be adjusted to be able to represent the 2015 annual mean NO_2 concentrations at each of the locations sampled. This adjustment allowed a comparison to be made between monitoring data and Air Quality Objectives (AQO) on an annual mean basis. The calculation of the annualisation/seasonal adjustment factor is shown below in Table A3 in accordance with LAQM.TG(16) Box A3.2 (Defra, 2016).

[1] http://laqm.defra.gov.uk/documents/Database_Diffusion_Tube_Bias_Factors_v09_16-Final.xls

Table 3: Annualisation / seasonal adjustment

NO_2 concentration (µg/m^3)	Falkirk Grangemouth MC Monitoring Station	Grangemouth Moray Monitoring Station	Average
Period 1	17.2	11.2	
Period 2	21.9	15.8	
Period 3	17.5	15.0	
Period 4	10.3	8.0	
Period 5	12.1	11.9	
Period 6	10.8	10.5	
Average Period Mean (A)	15.8	12.2	
2015 Annual Mean (B)	18.5	14.9	
Annual Mean/Period Mean ratio (A/B)	1.17	1.22	1.19

2.1.5 The estimated annual mean NO_2 concentrations for Baseline Year 2015 are presented in Table 4. Those sites within the study area are highlighted in grey and referenced as 7-10. Other monitoring sites relate to the other southern sections of the A9 dualling programme.

Table 4: Estimated 2015 annual mean NO_2 concentrations

Site	A9 Proposed Scheme Location	6 Month Period Mean (µg/m^3)	Data Capture (100% = 6 months)	Annualisation / Seasonal Adjustment Ratio	Bias Adjustment Ratio	Estimated 2015 Annual Mean (µg/m^3)
1	P2	4.9	100	1.19	0.88	5.2
2	P2	29.2	100	1.19	0.88	30.7
3	P2	42.6	100	1.19	0.88	**44.7**
4	P3	4.5	100	1.19	0.88	4.7
5	P3	26.2	83	1.19	0.88	27.4
6	P3	16.2	83	1.19	0.88	17.0
7	P4	26.5	100	1.19	0.88	27.9
8	P4	17.1	100	1.19	0.88	17.9
9	P4	8.1	100	1.19	0.88	8.5
10	P4	7.1	100	1.19	0.88	7.5
11	P5	32.4	83	1.19	0.88	33.9
12	P5	18.4	83	1.19	0.88	19.2
13	P5	24.5	83	1.19	0.88	25.6
14	P5	9.6	100	1.19	0.88	10.1
15	P5	5.5	100	1.19	0.88	5.8
16	P5	24.8	100	1.19	0.88	26.0
17	P5	18.1	100	1.19	0.88	19.0
18	P5	23.4	100	1.19	0.88	24.6
19	P5	30.1	100	1.19	0.88	31.6
20	P5	17.4	100	1.19	0.88	18.2
21	P5	23.0	100	1.19	0.88	24.2
22	P5	17.6	100	1.19	0.88	18.5
23	P5	6.7	100	1.19	0.88	7.0
24	P5	25.9	100	1.19	0.88	27.2
25	P5	26.2	100	1.19	0.88	27.6
Exceedences are highlighted in **Bold** and **Underline**						

3 Annex B - Model Verification Project Specific Air Quality Monitoring Results

3.1.1 An evaluation of model performance has been undertaken to establish confidence in model results. LAQM.TG(16) identifies several 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).

3.1.2 A brief explanation of each statistic is provided in Table 5 and further details can be found in LAQM.TG(16) Box A3.7 (Defra, 2016).

Table 5: Model performance statistics

Statistical Parameter	Comments	Ideal Value
RMSE	RMSE is used to define the average error or uncertainty of the model. 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 model predictions are of an annual mean NO_2 objective of 40µg/m^3 and the RMSE is 10µg/m^3 or above, 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 4µg/m^3 for the annual mean NO_2 objective.	0.01
FB	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 has an ideal value of zero. Negative values suggest a model over-prediction and positive values suggest a model under-prediction.	0.00
CC	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

3.1.3 These parameters estimate how the model results agree or diverge from observations.

3.1.4 These calculations have been carried out prior to, and after, model adjustment and provide information on the improvement of the model predictions as a result of the application of the adjustment factor.

Model Verification Methodology

3.1.5 The verification process involves a review of the annual mean modelled pollutant concentrations against corresponding monitoring data to determine how closely the air quality model corresponds. The acceptable limits of model verification are set out in LAQM.TG(16). Depending on the outcome it may be considered that there is no need to adjust any of the modelled results (LAQM.TG(16)).

3.1.6 Alternatively, the model may not correlate against the monitoring data. There is then a need to check all the input data to ensure that it is reasonable and accurately represented in the air quality modelling process.

3.1.7 Where all input data, such as traffic data, emissions rates, and background concentrations have been checked and considered reasonable, then the model requires adjustment to best align with the monitoring data. This may either be a single adjustment factor to be applied to the modelled concentrations across the study area, or a range of different adjustment factors to account for different zones in the study area e.g. motorways, local roads. Suitable monitoring locations were selected and used in the verification process, considering the site types, position of the diffusion tubes and representation of local air quality environment.

3.1.8 The non-adjusted modelled versus monitored NO_2 concentrations are presented in Table 6.

Table 6: Non-adjusted modelled vs monitored NO_2

Monitor ID	X(m)	Y(m)	A9 Proposed Scheme Location	Monitored Annual Mean NO_2 (µg/m³)	Non Adjusted Modelled Annual Mean NO_2 (µg/m³)	Monitored versus Modelled (% Difference)
8	294307	757028	P4	17.9	14.5	-19.4%
12	291608	763070	P5	19.2	12.3	-35.9%
20	283906	765683	P5	18.2	10.8	-40.7%
22	280540	765883	P5	18.5	10.8	-41.8%

3.1.9 The initial comparison between the predicted concentrations and monitoring data illustrates that the model tends to under predict NO_2 concentrations over the modelled area.

3.1.10 Model adjustment was undertaken in accordance with LAQM.TG(16). A line-of-best-fit using linear regression was plot through the monitored and modelled source contribution of NO_x from Roads (Road-NO_x). The slope of the line-of-best-fit was 1.865 and this value was used to adjust modelled concentrations. The adjusted modelled concentrations versus monitored NO_2 concentrations are presented in Table 7. Modelled Road-NO_x concentrations predicted at sensitive receptors in the base and opening year scenarios were multiplied by the adjustment factor (1.865) to account for the under-prediction of Road NO_x by the model.

Table 7: Adjusted modelled vs monitored NO_2

Monitor ID	X(m)	Y(m)	A9 Proposed Scheme Location	Monitored Annual Mean NO_2 (µg/m³)	Adjusted Modelled Annual Mean NO_2 (µg/m³)	Monitored versus Modelled (% Difference)
8	294307	757028	P4	17.9	15.0	17.9%
12	291608	763070	P5	19.2	15.2	-0.6%
20	283906	765683	P5	18.2	12.6	-9.5%
22	280540	765883	P6	18.5	12.6	-11.2%

3.1.11 The summary results and model performance statistics defined in LAQM.TG(16) are provided in Table 8.

Table 8: Model performance statistics

	No Adjustment	NO_x Roads Adjustment
Adjustment Factor	-	**1.865**
Correlation Co-efficient	-0.294	-0.150
RMSE	**6.609**	**2.100**
Fractional Bias	0.418	0.010
Within +10%	0	0
Within -10%	0	2
Within +-10%	**0**	**2**

	No Adjustment	NO_x Roads Adjustment
Within +10 to 25%	0	1
Within -10 to 25%	1	1
Within +-10 to 25%	**1**	**2**
Over +25%	0	0
Under -25%	3	0
Greater +- 25%	**3**	**0**
Within +- 25%	**1**	**4**

3.1.12 A comparison of the performance of the annual mean modelled concentrations from the air quality model against the annual mean monitoring data was undertaken. The results show that all of the four modelled concentrations are within +/-25% of monitored concentrations. The model performance statistics show that the uncertainty in the predictions of adjusted total annual mean NO_2 was good as the RMSE is less than 4µg/m^3 (10%) for the study area.

4 Annex C – Detailed Assessment Results LAQM.TG(16) Approach – Sensitive Receptors

4.1.1 The detailed results of annual mean NO_2 concentrations at sensitive receptors following the LAQM.TG(16) approach are presented in Table 9.

Table 9: Annual mean NO_2 concentrations - (LAQM.TG(16) approach)

Receptor	Base 2015 (µg/m^3)	DM 2026 (µg/m^3)	DS 2026 (µg/m^3)	Change (µg/m^3)
1	3.6	2.2	2.3	0.1
2	4.1	2.4	2.5	0.1
3	7.0	3.6	3.7	0.1
4	5.2	2.8	2.7	-0.1
5	6.8	3.6	4.1	0.4
6	3.5	2.2	2.3	0.1
7	6.4	3.4	3.3	-0.1
8	3.2	2.2	2.9	0.7
9	8.4	4.0	4.8	0.7
10	7.0	3.8	3.9	0.2
11	4.7	2.6	3.0	0.4
12	10.0	4.4	5.0	0.6
13	5.5	2.9	4.8	1.9
14	11.5	5.1	3.2	-1.9
15	8.9	4.2	9.6	5.4
16	6.2	3.1	3.5	0.4
17	7.2	3.5	4.1	0.6

5 Annex D – Detailed Assessment Results - Designated Sites

5.1.1 The detailed results of annual mean NO_x concentrations at designated sites in the 2015 Baseline, Do-Minimum (DM) (2026) and Do-Something (DS) (2026) scenarios are presented in Table 10 for the Pass of Killiecrankie SSSI.

Table 10: Annual mean NO_x concentrations

Receptor (Transect and Distance (m) from kerb)	X(m)	Y(m)	2015 Base (µg/m^3)	2026 DM (µg/m^3)	2026 DS (µg/m^3)	Change (DS-DM) (µg/m^3)
Pass_69	291528	761284	11.5	7.4	8.6	1.24

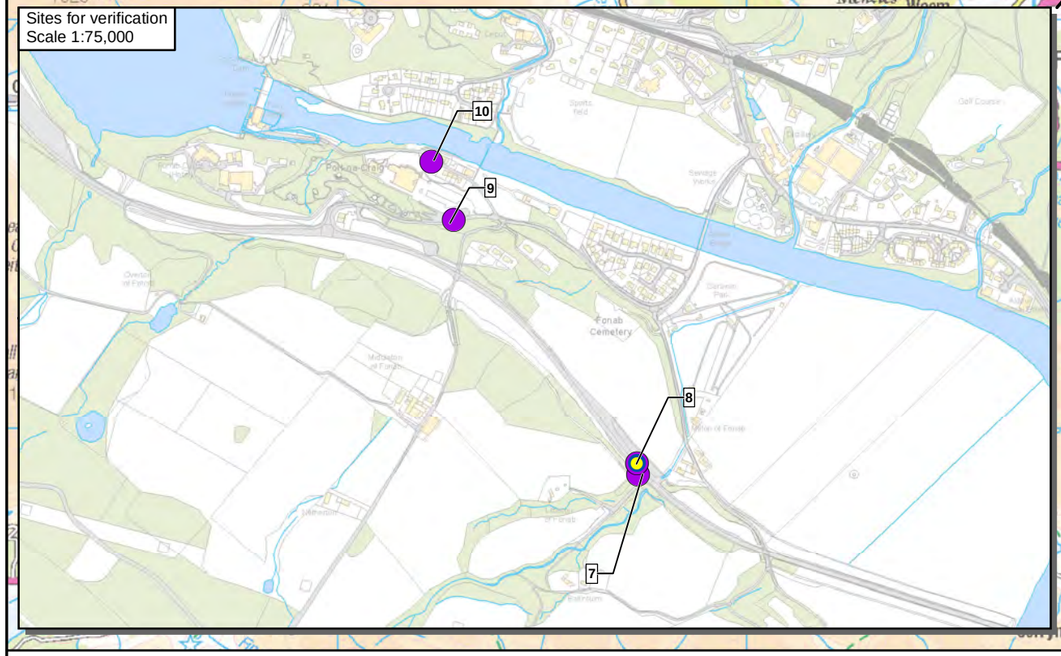
Receptor (Transect and Distance (m) from kerb)	X(m)	Y(m)	2015 Base (µg/m³)	2026 DM (µg/m³)	2026 DS (µg/m³)	Change (DS-DM) (µg/m³)
Pass_100	291499	761292	7.7	4.9	5.4	0.55
Pass_150	291451	761305	4.9	3.0	3.2	0.13
Pass_200	291402	761318	4.2	2.6	2.6	0.05

Figure A16.1

Legend

- Project extents
- Air quality monitoring sites for Pitlochry to Killiecrankie
- Air quality monitoring sites
- Air quality monitoring sites for verification

Sites for verification
Scale 1:75,000



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0	DEC 2017	ES Publication	EM	CS	MC	AJG

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Drawing title

Environmental Statement
Air Quality Monitoring Sites and Monitoring Sites Used for Verification Process

Sheet 1 of 1

Drawing Status	FINAL
Scale	1:150,000 @ A3 — DO NOT SCALE
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