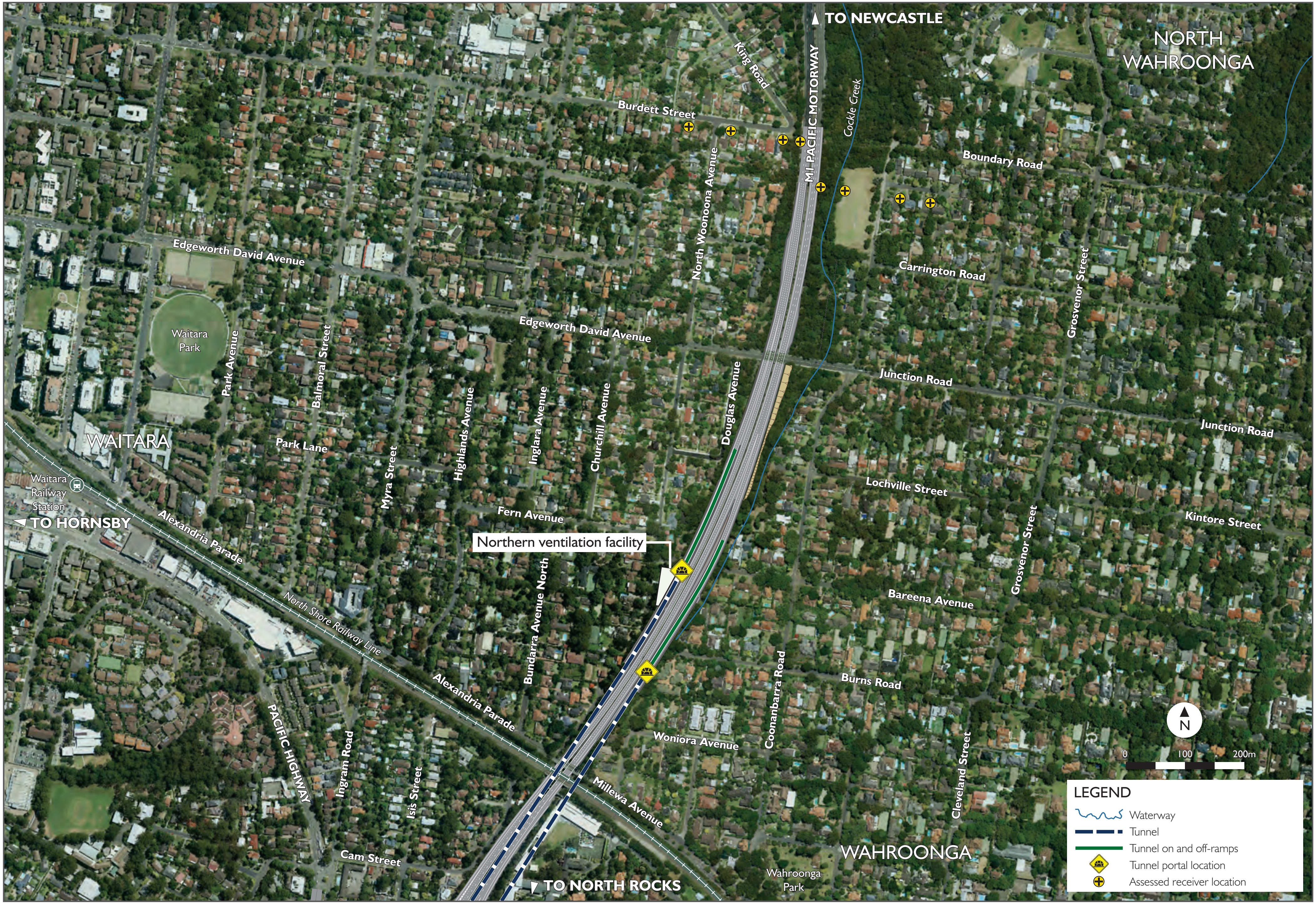

Figure 2-20 Northern assessment transects

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Figure 2-21 Central assessment transects

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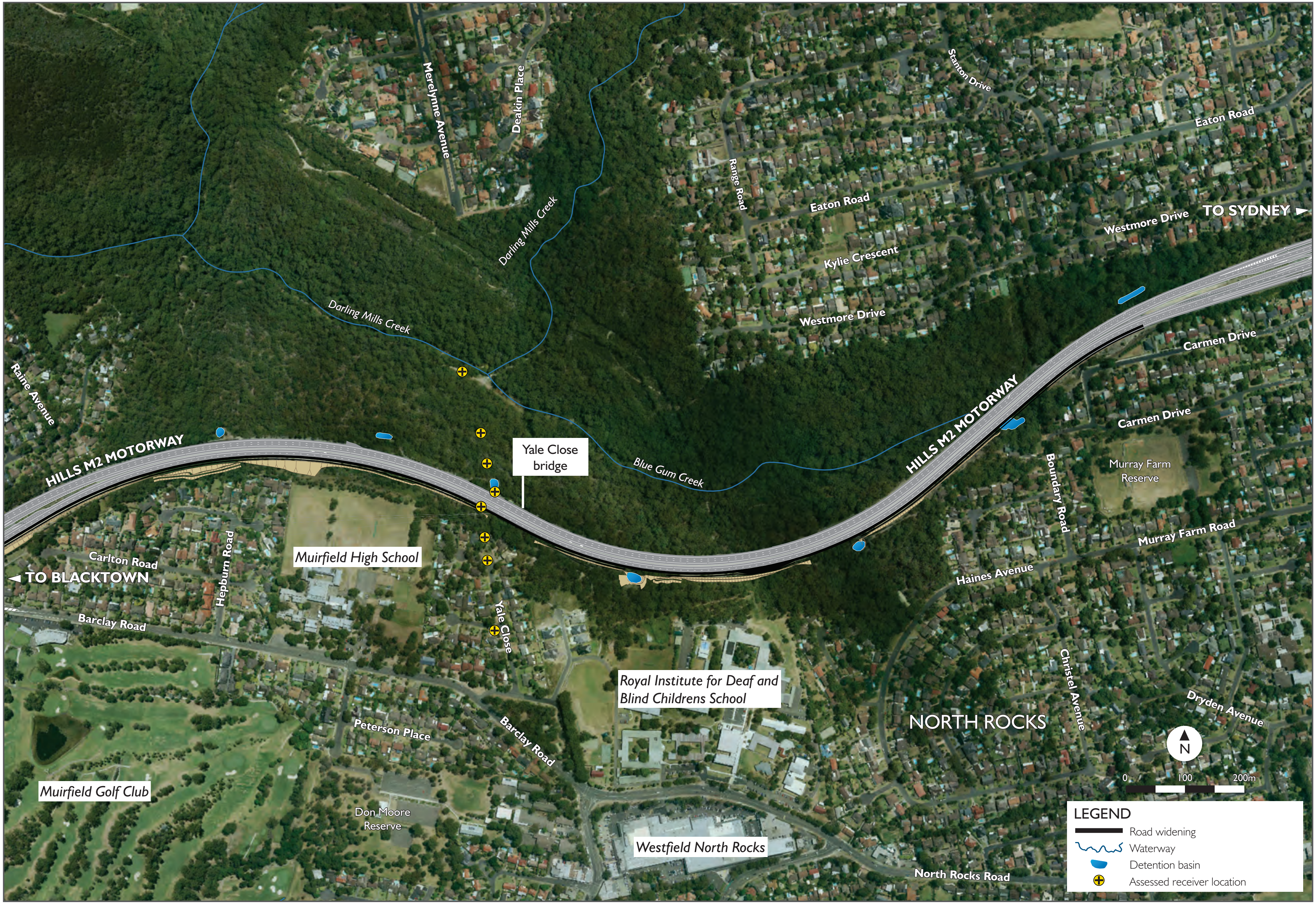

Figure 2-22 Southern assessment transects

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NO_2 data comparison

Figure 2-23, **Figure 2-24** and **Figure 2-25** show the predicted surface road air quality contributions for the northern, central and southern transects, respectively. The figures show CAL3QHCR outputs under forecast traffic volumes at each transect (in 2019) for the 'without project' and the 'with project' scenarios.

With the exception of the northern transect (**Figure 2-23**), changes in air quality reflect expected changes from the 'without project' and the 'with project' scenarios based on analysis of changes in traffic:

- For the central transect, total traffic volumes are forecast to decrease and heavy vehicle volumes are forecast to decrease. **Figure 2-24** shows a reduction in surface road emissions from the 'without project' to the 'with project scenarios.
- For the southern transect, total traffic volumes are forecast to increase but heavy vehicles volumes are forecast to decrease (in 2019). **Figure 2-25** shows that taking these two changes into account, there is minimal overall change between the 'without project' and the 'with project' scenarios.

In the case of the northern transect, total vehicle volumes and heavy vehicle volumes are forecast to increase. On this basis, surface road emissions are anticipated to increase at this location from the 'without project' to the 'with project scenario. However, **Figure 2-23** shows minimal difference between the scenarios and less than would be expected based on forecast increases in traffic.

Further investigation of this issue indicates that the unexpected results for surface road emissions at the northern transect are the result of interference from other road links in the area. That is, the unexpected result is a modelling artefact with the results presented in **Figure 2-23** not purely representing predictions for the M1 Pacific Motorway, but also reflecting the effects of other roads in the area. It is relevant to note that the CAL3QHCR includes a road link around 100 to 150 metres to the south east of the northern transect. Winds from the south east towards the northern transect are likely to have contributed emissions from that road link to the northern transect results. Based on meteorological data used in the air quality impact assessment for the project, winds around the northern ventilation outlet (close to the northern transect) show a predominance of winds from the east (from north-northeast to south-southeast), particularly during the summer.

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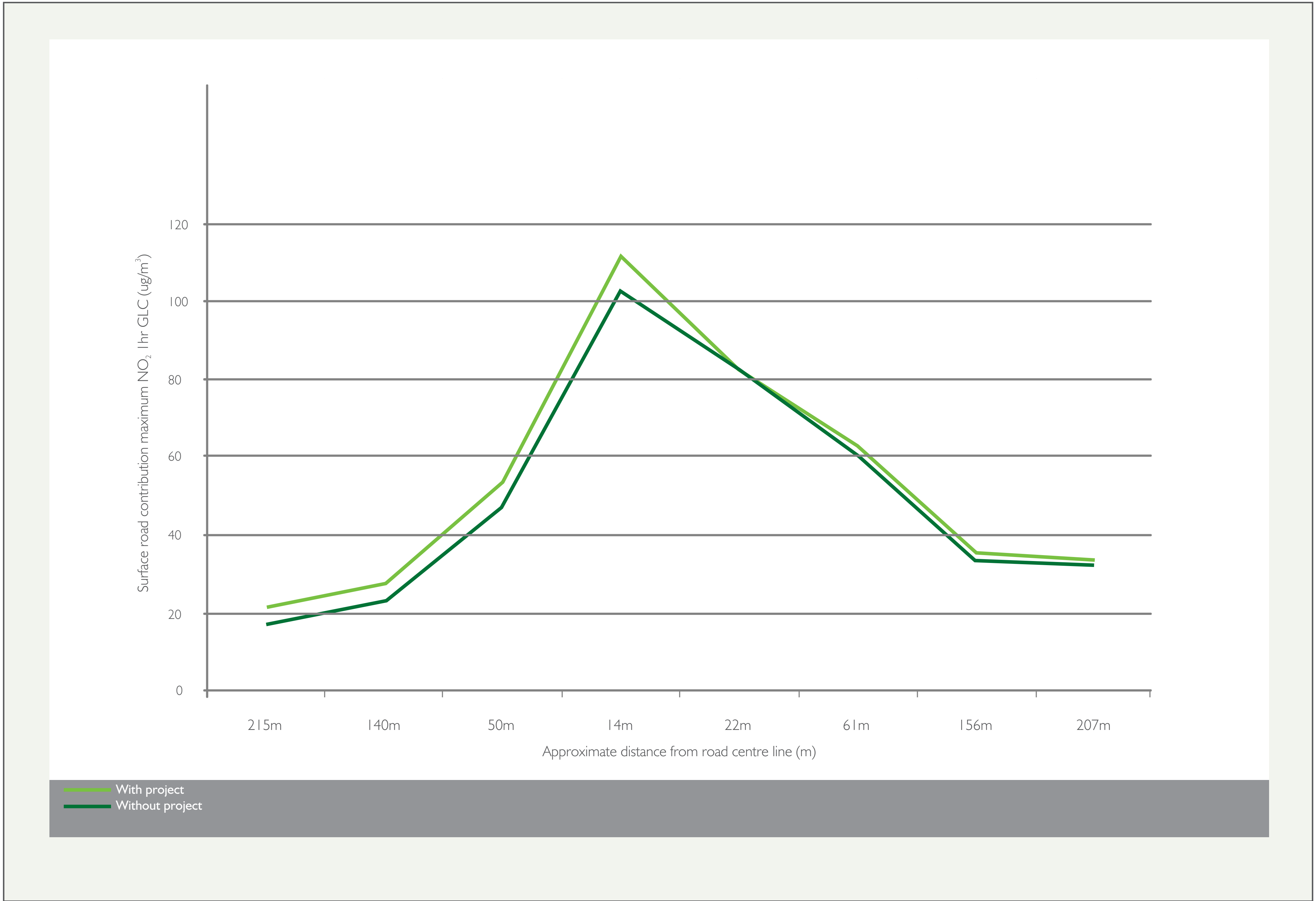

Figure 2-23 Transect 1 (northern) maximum NO_2 receptor results

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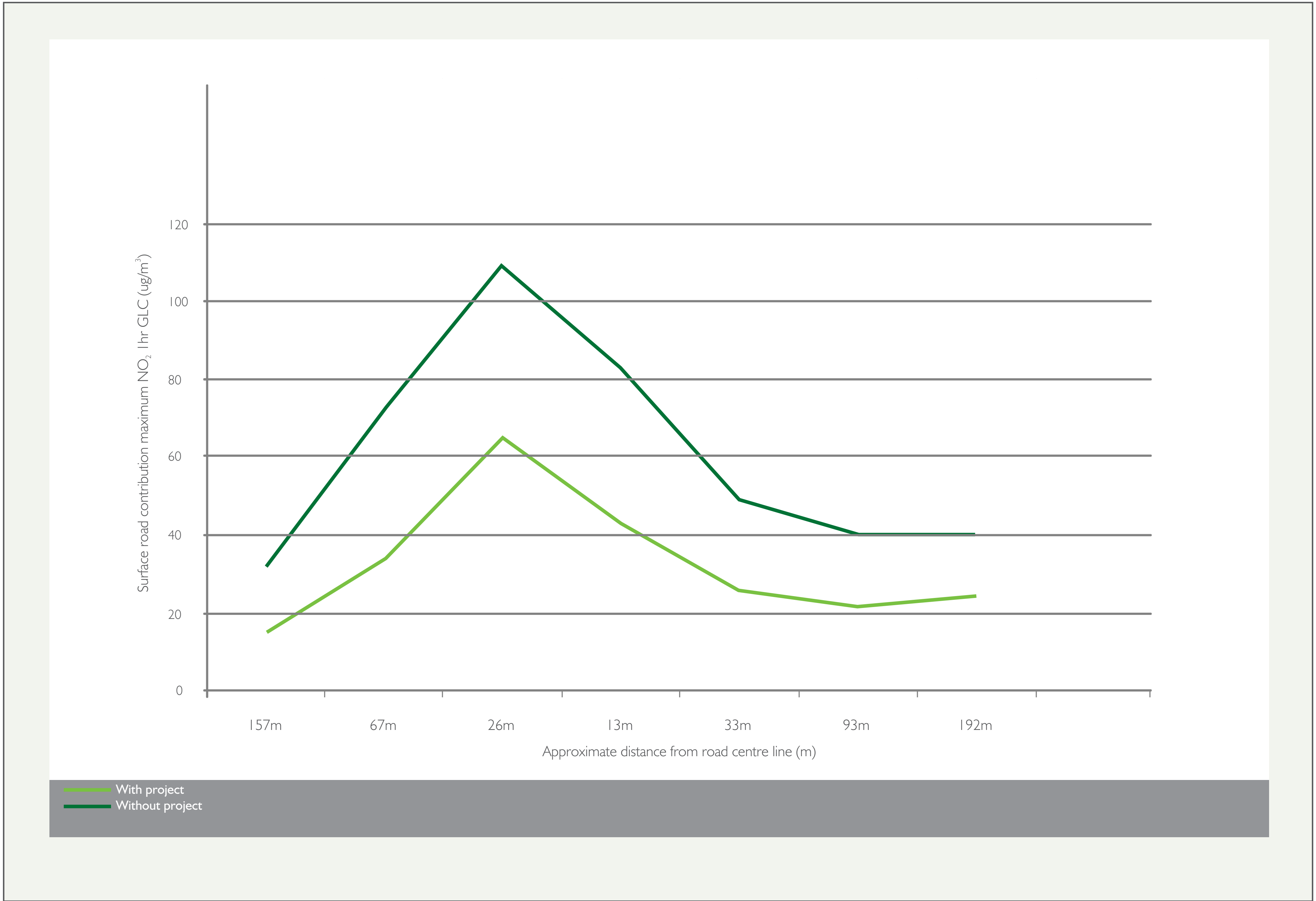

Figure 2-24 Transect 2 (middle) maximum NO_2 receptor results

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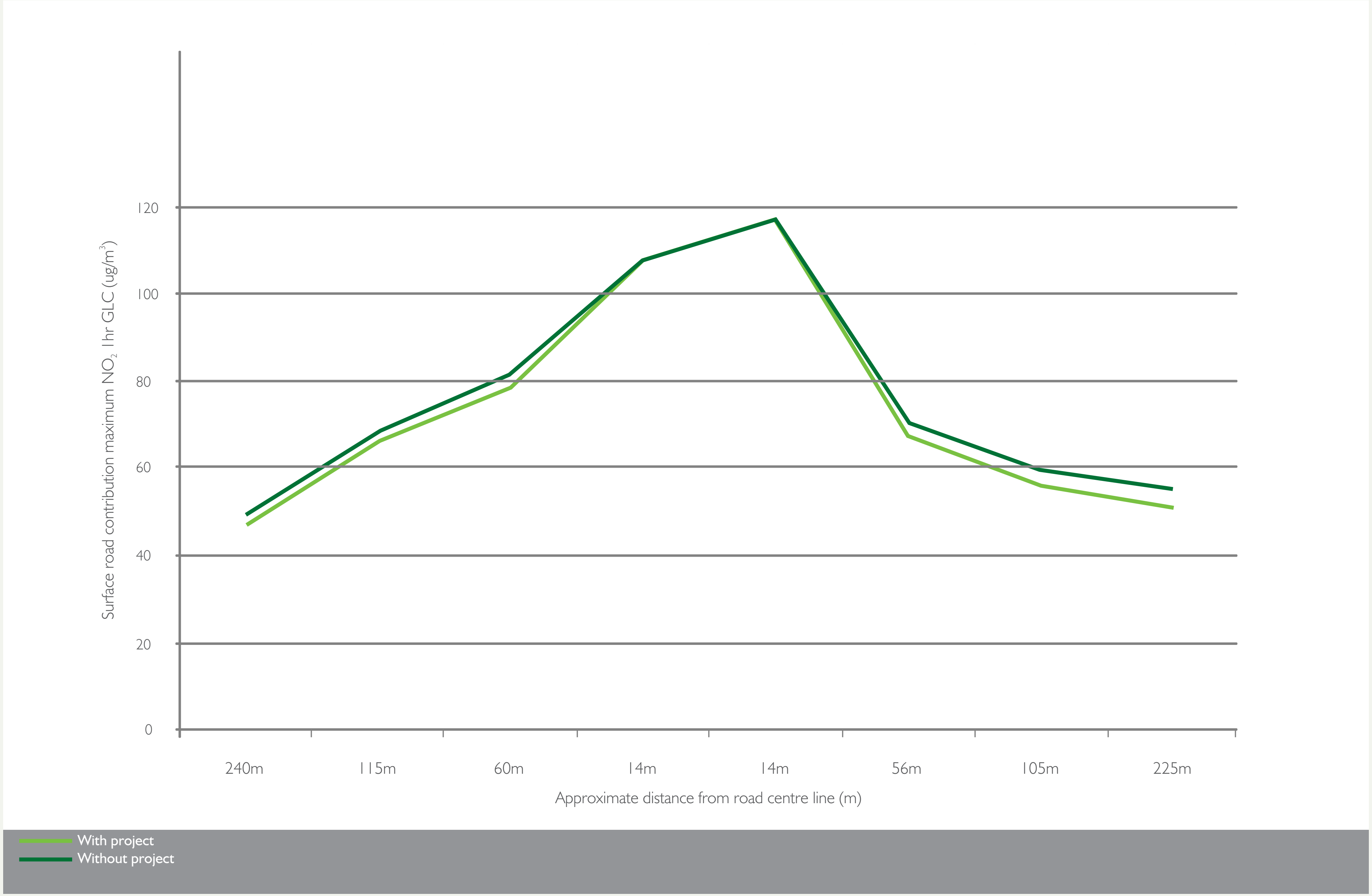

Figure 2-25 Transect 3 (southern) maximum NO_2 receptor results

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The outputs from the CAL3QHCR modelling shown in the preceding figures have been used to calculated project contributions, background contributions and cumulative concentrations at each transect and receiver location. The project methodology and the alternative methodology have been applied, as detailed earlier in this section.

Table 2-67, **Table 2-68** and **Table 2-69** show the background contribution, the project contribution and the cumulative concentration of NO_2 for selected receiver locations calculated using the project methodology and the alternative methodology.

It should be noted that the minimum and maximum background and project contributions provided in the tables cannot be added to calculate the cumulative pollutant concentrations. This is because the cumulative concentrations have been calculated contemporaneously – that is, the background and project contributions have been paired in time. The maximum background concentrations did not occur at the same time as the maximum project contributions occurred, so the maximum cumulative concentration does not represent the maximum project contribution summed with the maximum background concentration. The same issue is present for the minimum data but, as the minimum project contributions are 0 $\mu g/m^3$ at some receivers, the issue is not as apparent. With the average data, the background and project averages have been calculated and, as such, have no temporal association. The background and project averages can therefore be added together to determine cumulative concentrations.

Concentrations of NO_2 have been calculated from total nitrogen oxide concentrations using the ozone limiting method (refer to **Section 2.14.2**) and results are therefore affected by ambient concentrations of ozone.

Comparing the project methodology and the alternative methodology, the tables show that:

- The project methodology results in background NO_2 contributions that are equal to or higher than the background NO_2 contributions calculated using the alternative methodology. Where the project methodology results in the background contribution being higher than the alternative methodology, this indicates that the CAL3QHCR surface road modelling results are higher than the ambient monitoring data (Lindfield/ Prospect data set) at the relevant receiver location.
- The project methodology results in project NO_2 contributions that are higher than the minimum and average project contributions calculated using the alternative methodology. In the case of the maximum project NO_2 contributions, the project methodology and the alternative methodology show almost identical results at the southern and central transects. There are differences with the two methodologies evident in the results at the northern transect, with the alternative methodology producing slightly higher concentrations close to the road and the project methodology producing slightly higher concentrations further away from the road.
- The project methodology results in cumulative NO_2 concentrations that are higher than the minimum and average project contributions calculated using the alternative methodology. In the case of maximum cumulative concentrations the two methodologies produce identical results away from the road, while the project methodology produces higher cumulative concentrations for receivers close to the road.

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Table 2-67 Background contribution of NO_2 (one hour average) for selected receivers (µg/m³)

Project methodology – the maximum of OEH monitoring data or CAL3QHCR surface road model output (2019 and 2029 surface traffic)
Alternative methodology – OEH monitoring data

		Southern transect							
		240m	115m	60m	14m	14 m	56 m	105 m	225 m
Minimum value	Project methodology	1.9	1.9	1.9	1.9	1.9	0.9	0.9	0.9
	Alternative methodology	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Average valve	Project methodology	22.4	23.5	25.4	33.6	33.4	24.5	23.1	22.3
	Alternative methodology	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
Maximum value	Project methodology	99.6	99.6	99.6	108.1	117.9	99.6	99.6	99.6
	Alternative methodology	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6

		Central transect						
		157 m	67 m	26 m	13m	33 m	93 m	192 m
Minimum value	Project methodology	1.9	1.9	1.9	0.9	0.9	0.9	0.9
	Alternative methodology	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Average valve	Project methodology	22.0	22.3	24.1	23.5	22.3	22.0	22.0
	Alternative methodology	22.0	22.0	22.0	22.0	22.0	22.0	22.0
Maximum value	Project methodology	99.6	99.6	99.6	99.6	99.6	99.6	99.6
	Alternative methodology	99.6	99.6	99.6	99.6	99.6	99.6	99.6

		Northern transect							
		215 m	140 m	50 m	14 m	22 m	61 m	156 m	207 m
Minimum value	Project methodology	1.9	1.9	1.9	1.9	0.9	0.9	0.9	0.9
	Alternative methodology	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Average valve	Project methodology	22.0	22.1	23.3	29.1	25.6	22.9	22.2	22.1
	Alternative methodology	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0

Maximum value	Project methodology	99.6	99.6	99.6	112.0	99.6	99.6	99.6	99.6
	Alternative methodology	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6

Table 2-68 Project contribution of NO_2 (one hour average) for selected receivers (µg/m^3)

Project methodology – contributions from the project's ventilation outlets only

Alternative methodology – contributions from the project's ventilation outlets plus the change in surface road contributions (difference between the 'with project' and 'without project' scenarios

		Southern transect							
		240m	115m	60m	14m	14 m	56 m	105 m	225 m
Minimum value	Project methodology	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Alternative methodology	-2.9	-3.5	-3.7	-4.6	-5.1	-5.4	-4.9	-4.8
Average valve	Project methodology	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Alternative methodology	-0.2	-0.2	-0.3	-0.2	-0.3	-0.2	-0.2	-0.1
Maximum value	Project methodology	6.1	4.2	4.8	5.1	5.0	5.0	5.0	5.2
	Alternative methodology	3.9	4.2	4.8	5.1	5.0	4.9	5.0	5.2

		Central transect						
		157 m	67 m	26 m	13m	33 m	93 m	192 m
Minimum value	Project methodology	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Alternative methodology	-17.3	-38.5	-53.0	-44.1	-26.4	-19.0	-19.3
Average valve	Project methodology	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Alternative methodology	-1.3	-2.5	-4.1	-5.1	-3.9	-2.3	-1.5
Maximum value	Project methodology	16.6	14.9	13.4	11.6	10.6	10.7	10.5
	Alternative methodology	16.4	13.8	13.4	11.6	10.6	10.7	10.5

		Northern transect							
		215 m	140 m	50 m	14 m	22 m	61 m	156 m	207 m
Minimum value	Project methodology	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Alternative methodology	-3.5	-3.7	-3.9	0.0	0.0	0.0	-0.5	-1.0
Average valve	Project methodology	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Alternative methodology	0.5	0.61	0.9	2.2	1.1	0.83	0.6	0.6

Maximum value	Project methodology	23.4	24.9	25.2	24.7	23.9	24.7	21.8	27.4
	Alternative methodology	23.0	23.8	25.5	31.5	27.2	26.4	22.0	27.3

Table 2-69 Cumulative concentration of NO_2 (one hour average) for selected receivers ($\mu g/m^3$)

Project methodology – project contribution added to background contribution

Alternative methodology – project contribution added to background contribution

	Southern transect								
		240m	115m	60m	14m	14 m	56 m	105 m	225 m
Minimum value	Project methodology	1.9	1.9	1.9	1.9	1.9	0.9	0.9	0.9
	Alternative methodology	0.5	0.2	-0.1	-0.7	-1.7	-0.4	-0.1	0.0
Average valve	Project methodology	22.4	23.6	25.4	33.6	33.4	24.5	23.2	22.4
	Alternative methodology	21.8	21.7	21.7	21.8	21.7	21.7	21.8	21.8
Maximum value	Project methodology	99.6	99.6	99.6	108.1	119.2	99.6	99.6	99.6
	Alternative methodology	99.6	99.6	99.6	98.8	99.6	98.8	99.1	99.3

	Central transect							
		157 m	67 m	26 m	13m	33 m	93 m	192 m
Minimum value	Project methodology	1.9	1.9	1.9	0.9	0.9	0.9	0.9
	Alternative methodology	-11.9	-25.4	-38.7	-32.8	-18.1	-15.2	-15.5
Average valve	Project methodology	22.1	22.4	24.2	23.6	22.4	22.1	22.1
	Alternative methodology	20.7	19.5	17.8	16.8	18.1	19.6	20.4
Maximum value	Project methodology	99.6	99.6	99.6	99.6	99.6	99.6	99.6
	Alternative methodology	99.6	99.6	98.4	88.3	91.1	95.7	97.0

	Northern transect								
		215 m	140 m	50 m	14 m	22 m	61 m	156 m	207 m
Minimum value	Project methodology	1.9	1.9	1.9	1.9	0.9	0.9	0.9	0.9
	Alternative methodology	0.7	0.6	0.6	0.9	1.1	0.9	0.9	0.9
Average valve	Project methodology	22.5	22.6	23.7	29.5	25.9	23.3	22.6	22.5
	Alternative methodology	22.5	22.6	22.9	24.2	23.1	22.8	22.5	22.5

Maximum value	Project methodology	99.6	99.6	99.6	112.0	99.6	99.6	99.6	99.6
	Alternative methodology	99.6	99.6	99.6	100.0	99.7	99.6	99.6	99.6

PM_{10} data comparison

Figure 2-26, **Figure 2-27** and **Figure 2-28** show the predicted surface road air quality contributions for the northern, central and southern transects, respectively. The figures show CAL3QHCR outputs under forecast traffic volumes at each transect (in 2019) for the 'without project' and the 'with project' scenarios.

With the exception of the northern transect (**Figure 2-26**), changes in air quality reflect expected changes from the 'without project' and the 'with project' scenarios based on analysis of changes in traffic:

- For the central transect, total traffic volumes are forecast to decrease and heavy vehicle volumes are forecast to decrease. **Figure 2-27** shows a reduction in surface road emissions from the 'without project' to the 'with project scenarios.
- For the southern transect, total traffic volumes are forecast to increase but heavy vehicles volumes are forecast to decrease (in 2019). **Figure 2-28** shows that taking these two changes into account, there is minimal overall change between the 'without project' and the 'with project' scenarios.

Although **Figure 2-26** shows an increase in surface road emissions from the 'without project' to the 'with project' scenarios, the increase is not as great as may be anticipated based on forecast increases in traffic volumes (in 2019). Analysis of the CAL2QHCR model indicates that a similar influence from nearby road links is affected model results at the northern transect as discussed in relation to NO_2. The key difference, and the reason for there being a more pronounced difference in 'without project' and 'with project' scenarios for PM_{10} when compared with NO_2, is the effect of the ozone limiting method (for calculation of NO_2 concentrations). Application of the ozone limiting method tends to 'buffer' changes in total oxides of nitrogen based on the availability of ozone.

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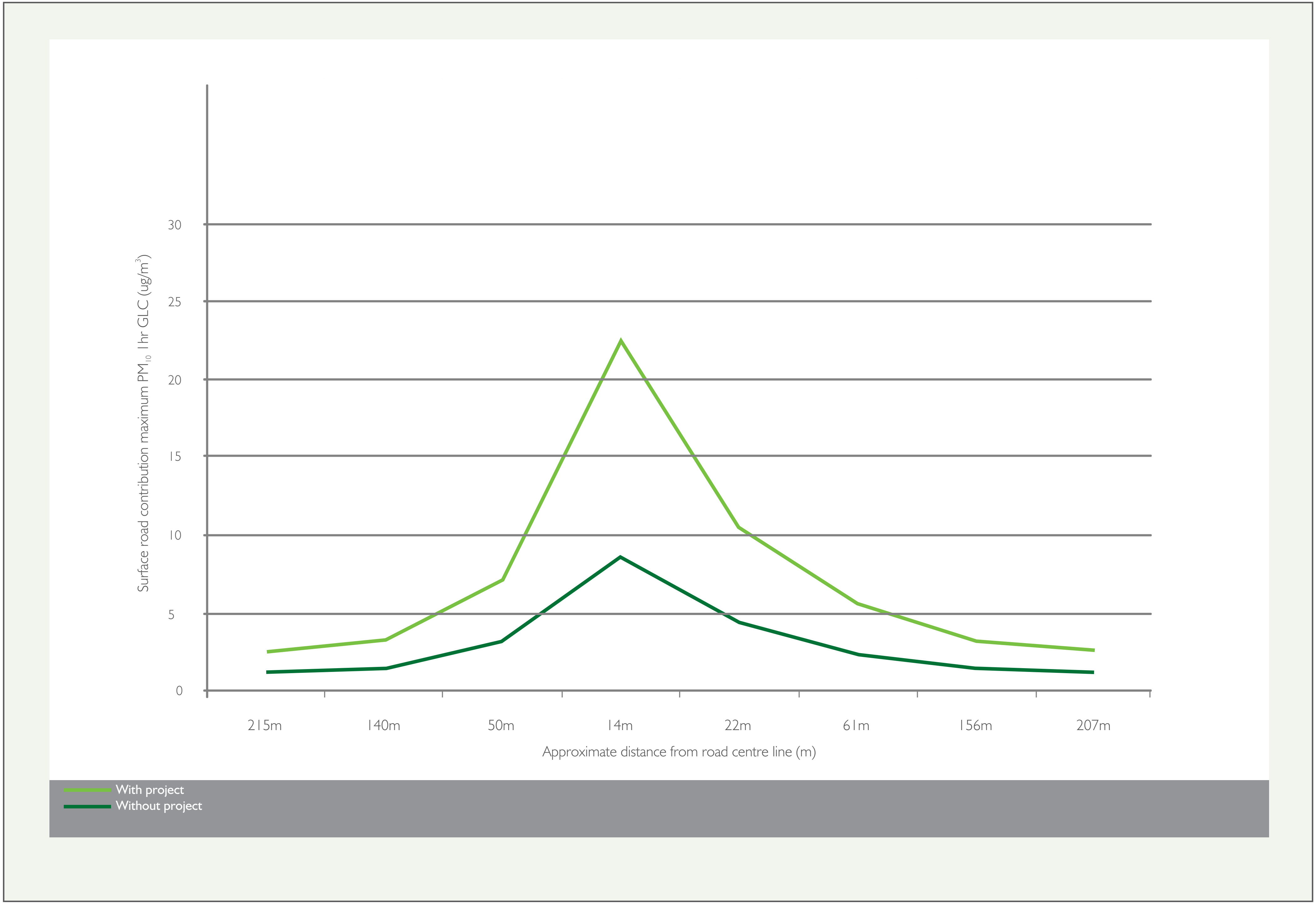

Figure 2-26 Transect 1 (northern) maximum PM_{10} receptor results

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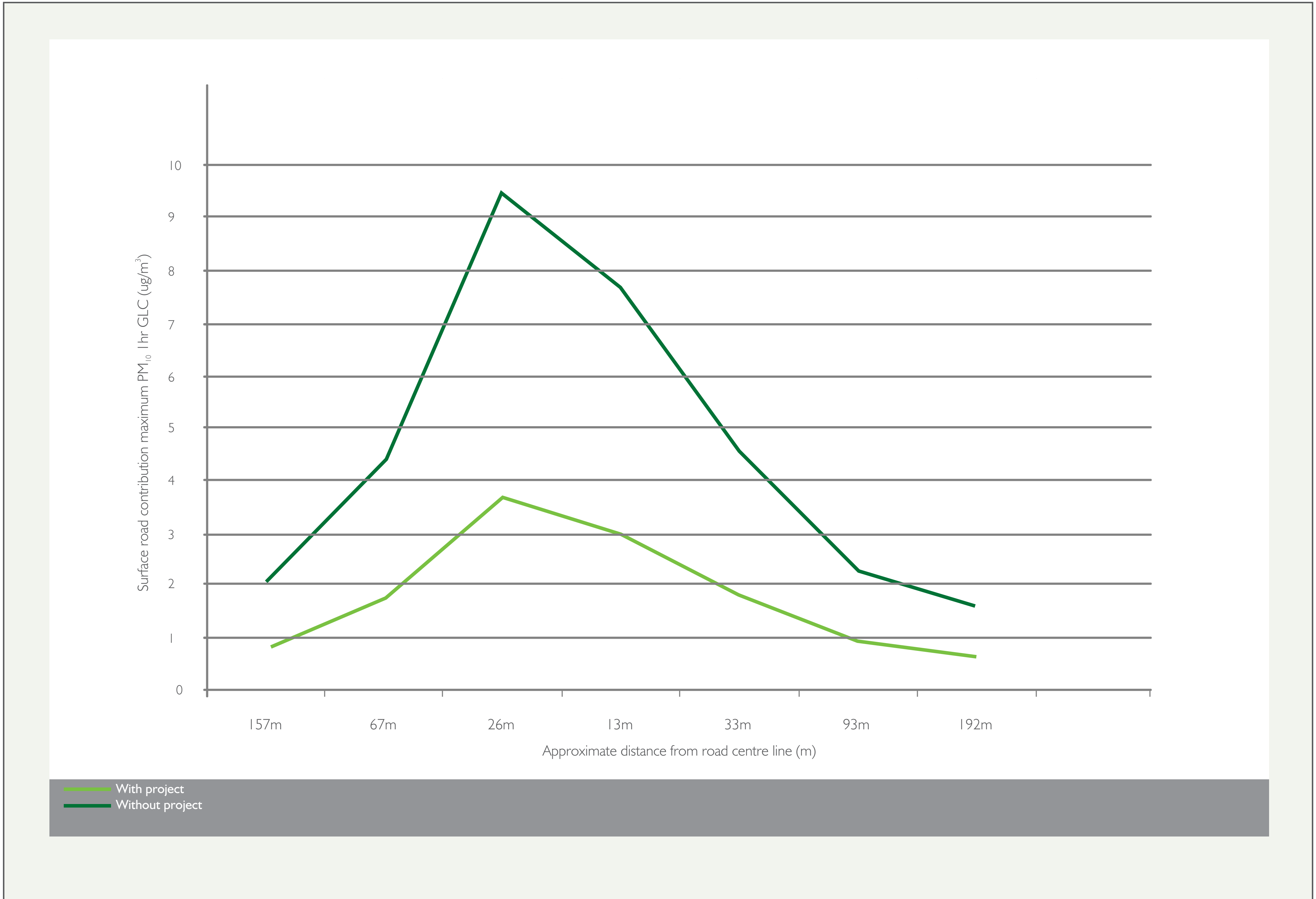

Figure 2-27 Transect 2 (middle) maximum PM_{10} receptor results

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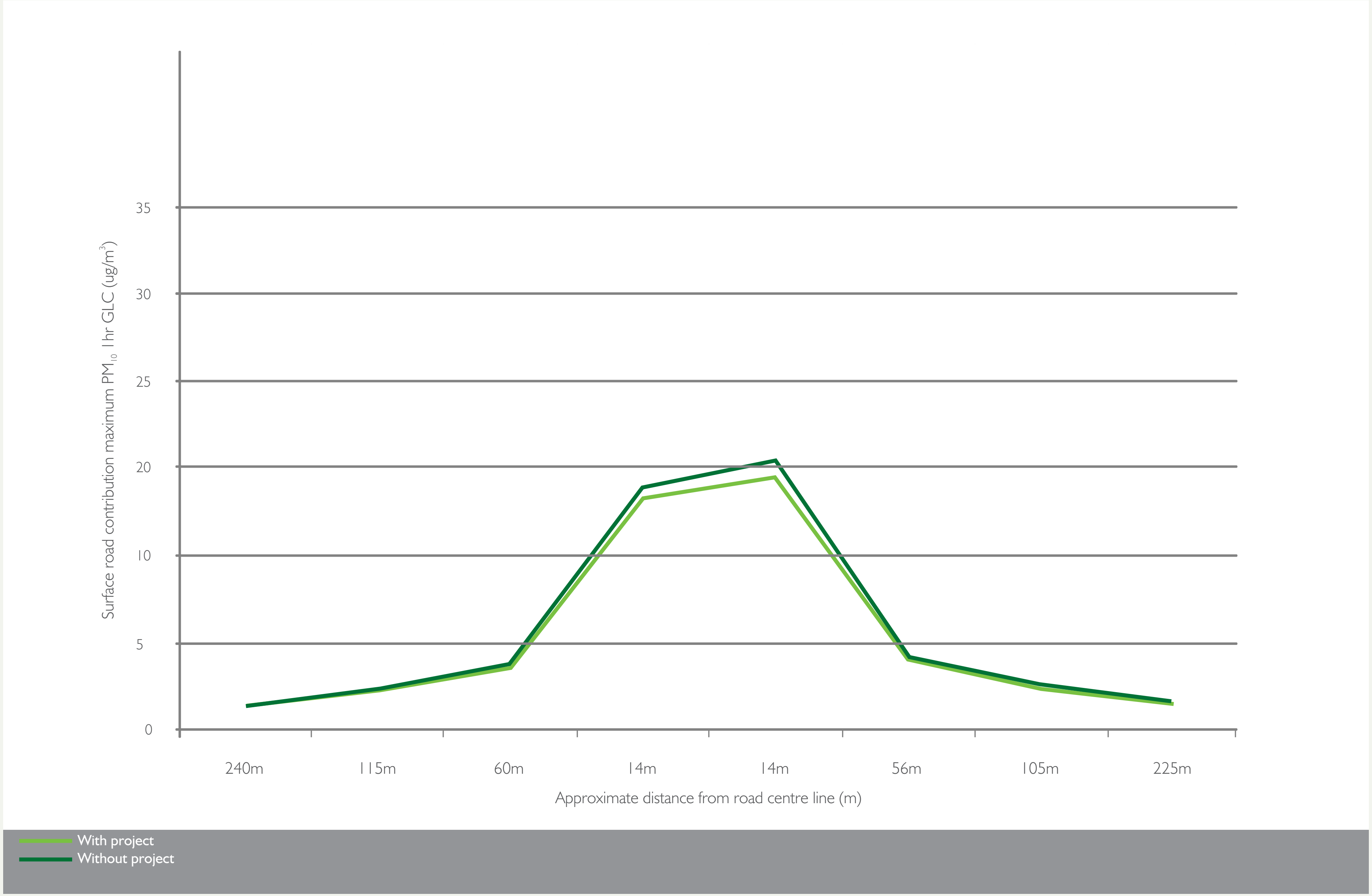

Figure 2-28 Transect 3 (southern) maximum PM_{10} receptor results

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The outputs from the CAL3QHCR modelling shown in the preceding figures have been used to calculated project contributions, background contributions and cumulative concentrations at each transect and receiver location. The project methodology and the alternative methodology have been applied, as detailed earlier in this section.

Table 2-70, **Table 2-71** and **Table 2-72** show the background contribution, the project contribution and the cumulative concentration of PM_{10} for selected receiver locations calculated using the project methodology and the alternative methodology.

As noted earlier in relation to NO_2 concentrations, background and project contributions provided in the tables cannot be added to calculate the cumulative pollutant concentrations. This is because the cumulative concentrations have been calculated contemporaneously.

Comparing the project methodology and the alternative methodology, the tables show that:

- The project methodology and the alternative methodology result in identical background PM_{10} contribution values. This is because in the case of the project methodology, the ambient monitoring data (from OEH monitoring stations) is higher than then CAL3QHCR surface road model outputs for PM_{10} at each of the receiver locations that were assessed.
- The project methodology results in project PM_{10} contributions that are higher than the minimum and average project contributions calculated using the alternative methodology. In the case of the maximum project PM_{10} contributions, the project methodology and the alternative methodology show almost identical results at the southern and central transects. There are differences with the two methodologies evident in the results at the northern transect, with the alternative methodology producing higher concentrations close to the road and the project methodology producing similar or slightly higher concentrations further away from the road.
- The project methodology results in cumulative PM_{10} concentrations that are higher than the minimum and average project contributions calculated using the alternative methodology. In the case of maximum cumulative concentrations the two methodologies produce similar results, with differences of no more than a few µg/m^3.

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Table 2-70 Background contribution of PM_{10} (24 hour average) for selected receivers (µg/m^3)

Project methodology – the maximum of OEH monitoring data or CAL3QHCR surface road model output (2019 and 2029 surface traffic)
Alternative methodology – OEH monitoring data

Southern transect		240m	115m	60m	14m	14 m	56 m	105 m	225 m
Minimum value	Project methodology	6.3	6.3	6.3	6.7	6.3	6.3	6.3	6.3
	Alternative methodology	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Average valve	Project methodology	21.2	21.2	21.2	21.3	21.2	21.2	21.2	21.2
	Alternative methodology	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
Maximum value	Project methodology	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6
	Alternative methodology	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6

Central transect		157 m	67 m	26 m	13m	33 m	93 m	192 m
Minimum value	Project methodology	6.3	6.3	6.3	6.3	6.3	6.3	6.3
	Alternative methodology	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Average valve	Project methodology	21.2	21.2	21.2	21.2	21.2	21.2	21.2
	Alternative methodology	21.2	21.2	21.2	21.2	21.2	21.2	21.2
Maximum value	Project methodology	221.6	221.6	221.6	221.6	221.6	221.6	221.6
	Alternative methodology	221.6	221.6	221.6	221.6	221.6	221.6	221.6

Northern transect		215 m	140 m	50 m	14 m	22 m	61 m	156 m	207 m
Minimum value	Project methodology	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
	Alternative methodology	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Average	Project methodology	21.2	21.2	21.2	21.4	21.2	21.2	21.2	21.2

valve	Alternative methodology	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
Maximum value	Project methodology	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6
	Alternative methodology	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6

Table 2-71 Project contribution of PM_{10} (24 hour average) for selected receivers (µg/m³)

Project methodology – contributions from the project's ventilation outlets only

Alternative methodology – contributions from the project's ventilation outlets plus the change in surface road contributions (difference between the 'with project' and 'without project' scenarios

		Southern transect							
		240m	115m	60m	14m	14 m	56 m	105 m	225 m
Minimum value	Project methodology	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Alternative methodology	-0.12	-0.15	-0.24	-0.81	-1.10	-0.32	-0.26	-0.21
Average valve	Project methodology	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Alternative methodology	-0.04	-0.07	-0.11	-0.41	-0.46	-0.09	-0.06	-0.04
Maximum value	Project methodology	0.06	0.06	0.06	0.07	0.06	0.06	0.07	0.08
	Alternative methodology	0.00	0.00	0.00	-0.09	-0.13	0.00	0.00	0.01

		Central transect						
		157 m	67 m	26 m	13m	33 m	93 m	192 m
Minimum value	Project methodology	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Alternative methodology	-1.22	-2.69	-5.73	-4.61	-2.74	-1.37	-0.87
Average valve	Project methodology	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Alternative methodology	-0.31	-0.66	-1.81	-2.18	-1.23	-0.64	-0.42
Maximum value	Project methodology	0.09	0.09	0.08	0.07	0.07	0.08	0.08
	Alternative methodology	0.02	0.00	0.00	0.00	0.00	0.00	0.00

		Northern transect							
		215 m	140 m	50 m	14 m	22 m	61 m	156 m	207 m
Minimum value	Project methodology	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Alternative methodology	-1.02	-1.40	-3.13	-8.24	-4.34	-2.23	-1.29	-1.09
Average	Project methodology	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.03

valve	Alternative methodology	0.29	0.40	0.95	2.38	-0.43	-0.19	-0.09	-0.07
Maximum value	Project methodology	0.31	0.29	0.50	0.50	0.39	0.24	0.35	0.39
	Alternative methodology	2.39	3.20	6.98	19.91	8.85	4.14	2.87	2.34

Table 2-72 Cumulative concentration of PM_{10} (24 hour average) for selected receivers (µg/m^3)

Project methodology – project contribution added to background contribution
Alternative methodology – project contribution added to background contribution

		Southern transect							
		240m	115m	60m	14m	14 m	56 m	105 m	225 m
Minimum value	Project methodology	6.3	6.3	6.3	6.7	6.3	6.3	6.3	6.3
	Alternative methodology	6.2	6.2	6.1	5.8	5.8	6.3	6.3	6.3
Average valve	Project methodology	21.2	21.2	21.2	21.3	21.3	21.2	21.2	21.2
	Alternative methodology	21.1	21.1	21.1	20.8	20.7	21.1	21.1	21.1
Maximum value	Project methodology	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6
	Alternative methodology	221.5	221.4	221.3	220.8	221.2	221.5	221.6	221.6

		Central transect						
		157 m	67 m	26 m	13m	33 m	93 m	192 m
Minimum value	Project methodology	6.3	6.3	6.3	6.3	6.3	6.3	6.3
	Alternative methodology	5.3	4.4	2.0	3.3	4.6	5.6	6.0
Average valve	Project methodology	21.2	21.2	21.2	21.2	21.2	21.2	21.2
	Alternative methodology	20.9	20.5	19.4	19.0	19.9	20.5	20.8
Maximum value	Project methodology	221.6	221.6	221.6	221.6	221.6	221.6	221.6
	Alternative methodology	221.5	221.5	220.8	217.4	219.4	220.5	220.8

		Northern transect							
		215 m	140 m	50 m	14 m	22 m	61 m	156 m	207 m
Minimum value	Project methodology	6.4	6.4	6.4	6.3	6.3	6.3	6.3	6.3
	Alternative methodology	5.8	5.5	4.4	-1.7	3.4	5.0	5.7	5.9
Average	Project methodology	21.2	21.2	21.2	21.4	21.2	21.2	21.2	21.2

valve	Alternative methodology	21.5	21.6	22.1	23.6	20.7	21.0	21.1	21.1
Maximum value	Project methodology	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.7
	Alternative methodology	222.4	222.8	224.3	222.5	217.3	219.4	220.4	220.6

Comparison of the methodologies

This comparison of the project methodology and the alternative methodology shows that:

- The alternative methodology and the project methodology result in similar cumulative NO_2 concentrations in areas away from the influence of surface roads. Close to surface roads, however, the project methodology results in higher cumulative NO_2 concentrations.
- The project methodology and the alternative methodology result in similar cumulative PM_{10} concentrations, both close to and away from surface roads. Based on the receiver locations assessed, the difference between the two methodologies is no more than around 3 $\mu g/m^3$ (and typically much less).
- The alternative methodology provides for a more comprehensive and transparent account of all air quality changes resulting from implementation of the project – both positive and negative. The alternative methodology is also more likely to better reflect the expected air quality benefits of the project. In contrast, the project methodology is more focused on identifying and quantifying potential adverse air quality outcomes (rather than benefits), particularly those associated with the operation of the project's ventilation outlets.
- One drawback of the alternative methodology may be that air quality improvements may mask adverse air quality outcomes in some areas. While this may be more representative of the likely cumulative outcome in practice, it is not desirable if the principal focus of the air quality impact assessment is to clearly and conservatively identify adverse impacts.

In interpreting air quality modelling results for the project, it is important to note that the project contributions that have been reported are focused on emissions from the project's ventilation outlets. The project will also result in changes to surface road emissions, and for the purpose of assessing the NorthConnex project, these changes have been taken into account as part of the background contribution component of the air quality calculations.

2.14.2 Atmospheric reactions – oxides of nitrogen

This section outlines:

- The approach taken to estimate the atmospheric conversion of nitrogen oxides (NO_x) to NO_2 after emission from the project's ventilation outlets.
- An analysis of the conservatism in the approach taken.
- Further consideration of the ratio of NO_2 to NO_x in emissions from vehicles.

Approach taken to the estimation of NO_2 formation in the atmosphere

In the atmosphere, nitrogen oxide (NO) is oxidised to nitrogen dioxide (NO_2) in the presence of ozone (O_3). The mechanics of this reaction in the atmosphere can be complex, but there are several methods to estimate the extent of conversion of NO to NO_2, with varying levels of conservatism.

The Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (DEC, 2005) endorses three methods for estimating the generation of the NO_2 (from the simplest approach to the more detailed approach):

- Method 1 – assume 100% conversion of NO to NO_2.
- Method 2 – assume that conversion of NO to NO_2 is limited by the ambient concentration of ozone (the ozone limiting method).
- Method – assume that conversion of NO to NO_2 is represented by the empirical equation developed by Janssen et al (1988).

If methods other than those above are proposed to be applied to an air quality impact assessment, the proposed method must be first discussed and agreed with the Environment Protection Authority.

Based on the loads of nitrogen oxides likely to be emitted from the project (as a major component of vehicle emissions), Method 1 is considered likely to unreasonably overestimate the ground level NO_2 concentrations attributable to the project. Method 1 is only typically used for minor sources of nitrogen oxides where only a simplistic assessment is required to demonstrate compliance with ambient air quality criteria. The NorthConnex project is not such a project.

Method 3 involves the application of an empirical relationship developed by Janssen et al (1988). This empirical relationship is based on distance from the source, ozone concentration, wind speed and season. It was developed for the conversion of NO to NO2 in plumes emitted from power stations. Power stations typically have tall emission sources (typically greater than 50 metres in height), and, subsequently, pollutants travel long distances downwind (tens of kilometres). As the air quality impact assessment for the NorthConnex project considered ventilation outlets 15 metres in height, and receivers within metres of emission sources, the Janssen et al empirical relationship is not considered appropriate.

Method 2, which involves the application of the ozone limiting method has been applied to the project to determine the extent of formation of NO_2 from nitrogen oxides emitted from the project. The ozone limiting methods applies the following equation:

$$[NO_2]_{\text{project increment}} = 0.1[NO_x]_{\text{prediction}} + \text{MIN}\{0.9[NO_x]_{\text{prediction}} \text{ or } (46/48)[O_3]_{\text{background}}\}$$

Where:

$[NO_2]_{\text{project increment}}$ is the project contribution to ambient NO_2 concentrations at ground level.

$[NO_x]_{\text{prediction}}$ is the predicted concentration of NO_x from the project at ground level.

$[O_3]_{\text{background}}$ is the background concentration of ozone.

A Level 2 (contemporaneous) assessment has been conducted using the ozone limiting method which:

- Combined the predicted ground level concentration of total nitrogen oxides (NOx) in each modelled hour with the background (ambient) ozone concentration for the same hour using the equation above.
- Added the resultant ground level concentration of NO_2 from the project to the background (ambient) concentration of NO_2 for the relevant hour (to obtain a total cumulative NO_2 concentration).

As part of this approach, the project contribution of nitrogen oxides ($[NO_2]_{project\ increment}$) has been taken as the contribution from the project's ventilation outlets only (refer to **Section 2.14.1** in relation to the treatment of project and background contributions). The background concentration of nitrogen dioxide added to the contribution from the project's ventilation outlets has been taken as the higher of the ambient air quality data or the outputs from the CAL3QHCR model (for major surface road contributions) as detailed in **Section 2.14.1**.

Conservatism in the ozone limiting method

The ozone limiting method endorsed in the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (DEC, 2005) was taken from the US Environmental Protection Agency ozone limiting method, originally developed by Cole and Summerhays (1979) and Tikvart (1996). The method assumes that all the available ozone in the atmosphere will react with NO in the plume until either all the O_3 or all the NO is used up. The approach is known to be conservative. Some of the reasons for its conservatism are listed below:

- The ozone limiting method assumes that the atmospheric reaction is instant, whereas in reality the reaction takes place over a number of hours.
- The actual reactions of NO to NO_2 occur in proportion to the moles of each reactant rather than in proportion to the concentration assumed by the ozone limiting method. At constant volume, one part per million of a gas is proportional to one mole of a gas. This assumption is not valid in the open atmosphere, as there is a virtually unlimited amount of O_3 available for reaction. As plumes expand downwind, more O_3 is available for reaction, and even lower concentrations of O_3 can react with NO in the plume.
- The ozone limiting method is further complicated as some of the NO_x is already converted to NO_2 upstream in the plume before it reaches the receiver.
- Studies have shown that the NO_x emission rates are extremely important with respect to the rate of conversion to NO_2. The size of the plume is not affected by the NO_x emission rate, which means that there is the same amount of O_3 available for chemical conversion regardless of the NO_x emission rate. Larger NO_x emission rates lead to lower predicted ratios of NO_2/NO_x. Maximum impacts that occur at receivers located further away have high predicted NO_2/NO_x ratios. Further emissions emitted into stable (narrow) plumes will have less conversion to NO_2 compared to those emissions emitted into less stable (wider) plumes. The ozone limiting method does not take the NO_x emission rate or plume size into consideration.
- The ozone limiting method can only be used on one plume at a time. The US Environmental Protection Agency states that the ozone limiting should be used with a 'plume-by-plume' approach. This is a significant limitation to a facility with many different plumes. The ozone limiting will therefore be very conservative for near field NO_2 impacts for large multi plume sources. The ozone limiting may not be conservative for single plumes downwind, where low concentrations of O_3 can still react with the plume.

The ozone limiting is expected to be conservative during daylight hours when the photochemical equilibrium reverses the oxidation of NO by O_3. It is also expected to be conservative during stable and night conditions when both NO_2 and O_3 are removed by reaction with vegetation and other surfaces.

Ratio of NO_2 to NO_x in vehicle emissions

The ozone limiting method equation as outlined above assumes that 10 per cent of nitrogen oxides (NO_x) are present as nitrogen dioxide (NO_2). This means that there is an inherent assumption in the ozone limiting method equation as stated that the ratio of NO_2 to NO_x at the point of emission (in this case, at the vehicle exhaust) will be 10 per cent.

In its submission in response to the environmental impact statement, the Environment Protection Authority noted that the total New South Wales fleet average NO_2 emission fraction ranges between 15 per cent and 17 per cent of total NOx. The Environment Protection Authority therefore suggested that a NO_2 to NO_x ratio of 16 per cent would be more appropriate (rather than the 10 per cent assumed in the ozone limiting method equation outlined above).

Implications for ambient air quality

Based on advice from the Environment Protection Authority, the ozone limiting method equation has been amended to reflect a 16 per cent NO2 to NOx ratio of 16 per cent as follows:

$$[NO_2]_{project\ increment} = 0.16[NO_x]_{prediction} + MIN\{0.84[NO_x]_{prediction} \text{ or } (46/48)[O_3]_{background}\}$$

A sensitivity analysis has been conducted to determine the potential effect of the amended ozone limiting method equation (as corrected above) on predicted ground level concentrations of NO2. Ground level concentrations of NO2 have been calculated for a series of NOx and O3 concentrations (up to around the NO2 one hour average criterion of 246 µg/m3) using the ozone limiting method equation for both 10 per cent NO_2:NO_x and 16 per cent NO_2:NO_x at the point of discharge. These calculations are summarised in **Table 2-73**. Shaded cells indicate situations in which O_3 concentration is the limiting factor for NO_2 generation.

For context, background O_3 concentrations applied to the air quality impact assessment are broadly summarised in **Section 2.11** and include:

- Maximum concentrations around 200 µg/m^3 to 250 µg/m^3.
- 95th percentile concentrations around 70 µg/m^3 to 90 µg/m^3.
- Average concentrations around 30 µg/m^3 to 35 µg/m^3.

Table 2-73 Comparison of ozone limiting method equation calculations

Total NO_x concentration (one hour) ($\mu g/m^3$)		Ozone concentration (one hour) ($\mu g/m^3$)					
		0	50	100	150	200	250
		Amended ozone limiting method equation (16% NO_2)					
	50	8.0	50	50	50	50	50
	100	16.0	63.9	100	100	100	100
	150	24.0	71.9	119.8	150	150	150
	200	32.0	79.9	127.8	175.8	200	200
	250	40.0	87.9	135.8	183.8	231.7	250
		Original ozone limiting method equation (10% NO_2)					
	50	5.0	50	50	50	50	50
	100	10.0	57.9	100	100	100	100
	150	15.0	62.9	110.8	150	150	150
	200	20.0	67.9	115.8	163.8	200	200
	250	25.0	72.9	120.8	168.8	216.7	250

Comparing the calculations presented in **Table 2-73**, the percentage change in predicted ground level NO_2 concentrations has been determined, as summarised in **Table 2-74**. The percentage values shown indicate the extent to which a 16 per cent NO_2:NO_x ratio exceeds a 10 per cent NO_2:NO_x ratio in terms of ground level NO_2 concentrations. The table indicates that:

- For situations where the NO_x concentration is limiting, rather than the O_3 concentration, there would be no difference in the air quality assessment outcomes for NO_2 based on differences in the ozone limiting method equation.
- The maximum difference resulting from amendment of the ozone limiting method equation is 60 per cent. This would occur when no O_3 is present which, although it may occur, is unlikely. Differences approaching 60 per cent would occur at low O_3 concentrations. However, under these conditions total NO_2 concentrations at ground level would be low (as indicated in **Table 2-74**) and would be dominated by the contribution of NO_2 at the point of discharge, rather than NO_2 generated through atmospheric conversion.
- Based on the air dispersion modelling present in the environmental impact statement, the project is expected to typically contribute peak ground level concentrations around 50 $\mu g/m^3$ to 150 $\mu g/m^3$. With most background air quality data indicating typical O_3 concentrations up to 100 $\mu g/m^3$, the net effect of the amended ozone limiting method equation is expected to be around 10 to 15 per cent (as a change in ground level concentration).

Table 2-74 Percentage difference between ozone limiting method equations

		Ozone concentration (one hour) (µg/m^3)					
		0	50	100	150	200	250
Total NO_x concentration (one hour) (µg/m^3)	50	60.0%	0%	0%	0%	0%	0%
	100	60.0%	10.4%	0%	0%	0%	0%
	150	60.0%	14.3%	8.1%	0%	0%	0%
	200	60.0%	17.8%	10.4%	7.3%	0%	0%
	250	60.0%	20.6%	12.4%	8.9%	6.9%	0%

As part of the further air quality impact assessment conducted for the submissions and preferred infrastructure report (to assess an increase in height of the northern and southern ventilation outlets by five metres), the ozone limiting method equation has been updated to reflect a NO_2 to NO_x ratio in vehicle emissions of 16 per cent.

Implications for in-tunnel air quality

The issue of in-tunnel concentrations of NO_2 is complex, noting that NO_2 concentrations within a road tunnel are a function of traffic volumes and vehicle/ fuel mix, vehicle emissions (as NO_x and as NO_2) and background pollutant levels drawn into the tunnel, the extent of dilution provided by background air, ventilation flow rates and in-tunnel air residence times, and the amount of ozone present. The significance of each of these factors will depend on the specific context of the road tunnel under consideration. However, broad observations about the proportions of NO_x and NO_2 in typical emissions from an entire vehicle fleet therefore do not necessarily reflect or approximate conditions that may be experience within a road tunnel.

When considering NO_2 concentrations within the NorthConnex project tunnels, and particularly the percentage of NO_x present as NO_2, it is important to take into account:

- The design of the tunnel ventilation system, including ventilation design criteria.
- Factors affecting the NO_x:NO_2 ratio.
- Historical data on NO_x:NO_2 ratios in other Australian and international road tunnels.
- Management of in-tunnel air quality.

<u>Tunnel ventilation design</u>

The project's ventilation system has been designed to meet specified design criteria under a range of average traffic speeds and tunnel operational scenarios. These ventilation design criteria are discussed in **Section 2.5**. As is typically the case with engineering design, a reasonable level of design conservatism has been applied to provide additional operational capacity if required.

The design of the project's ventilation system has been based on, among other things, guidance published by the Permanent International Association of Road Congresses (2012), which has been developed from extensive international experience in road tunnel design and operation. The guidance published by the Permanent International Association of Road

Congresses is inherently conservative to ensure a robust approach to the design of road tunnel ventilation systems. The data relied on as part of the design of the project's ventilation system has used emission factors relevant to the Australian vehicle fleet (including for CO, NO_x and opacity) and takes into account vehicle types (passenger vehicles, light duty vehicles and heavy goods vehicles) as well as fuel type (petrol and diesel).

The total rate of NO_x emissions generated by the combined fleet composition expected to travel through the project has been calculated for forecast traffic volumes and for a worst case traffic scenario (design analysis A) over a diurnal cycle. This includes peak traffic periods for the northbound and southbound main alignment tunnels, which would correlate with peak in-tunnel vehicle emissions.

Consistent with the advice published by the Permanent International Association of Road Congresses (2012), the calculation of in-tunnel air quality has assumed that 10 per cent of NOx within the project tunnels would be present as NO_2. Calculated NO_2 concentrations within the main alignment tunnels have been used to appropriately design the project's ventilation system, including sizing of ventilation fans, to achieve the ventilation design criteria summarised in **Section 2.5** under all conditions. The limiting design factor in this case is the maximum traffic design capacity of the main alignment tunnels, should it be achieved in the future (as distinct from forecast traffic volumes). This approach means that the project's ventilation system would have additional capacity to manage in-tunnel air quality above what would ordinarily be required for forecast traffic volumes.

Factors affecting the NO_x:NO_2 ratio

The ratio of NO_2:NO_x varies based on a range of factors, predominately the percentage of diesel vehicles within a road tunnel, the length of the tunnel, and operation of the ventilation system.

Heavy goods vehicles generate significantly higher NO_2 emissions as a proportion of total NOx, and will often be higher than 10 per cent. In comparison, petrol fuelled passenger vehicles generate considerably less NO_2 as a proportion of NO_x. Short tunnels generally experience higher ratios of NO_2:NO_x.

The Permanent International Association of Road Congresses (2012) states that:

> 'While in previous years NOx from combustion processes contained mostly NO (90 to 95% of the NOx), the implementation of diesel vehicle exhaust gas after-treatment systems (oxygenation catalyst, DPF1, SCR2 systems) tend to significantly increase the primary emitted NO2 percentages.
>
> In many European road tunnels, NO2 can be around 20 to 30% of NOx concentrations, which strongly depends on the share of diesel vehicles with exhaust gas after-treatment systems in the vehicle fleet and on the residence time of the NOx in the tunnel air.'

Although the percentage of diesel passenger vehicles in New South Wales is rising, the percentage of diesel vehicles forecast to use the Northconnex project is considerably lower than experienced in international road tunnels, particularly those in Europe. Taking this into account, the assumption of 10 per cent NO_2:NO_x is considered to be reasonable and sufficient for the design of the project's ventilation system, including sizing ventilation fans and maximum capacity, to accommodate a worst case traffic scenario. In doing so, additional capacity has been provided if required under forecast traffic scenarios.

Historical NOx:NO2 ratio data

Two studies have looked at the NO_2:NO_x ratios in Australian tunnels. One study, conducted by Holmes Air Science on the M5 East Motorway in 2004 showed values for the NO_2:NO_x ratio in that tunnel of around five to six per cent. The second study, conducted on the Lane Cove Tunnel, found a median NO_2:NO_x ratio of around seven per cent.

Several other studies have been conducted on international road tunnels. **Table 2-75** summarises the findings of these studies in relation to NO2:NOx ratios. It is important to note that the majority of these road tunnels do no actively and directly monitor in-tunnel concentrations of NO_2.

Table 2-75 supports the selection of a NO_2:NO_x ratio of 10 per cent as appropriate for design of the project's ventilation system under worst case traffic conditions.

Table 2-75 Reported NO_2:NO_x ratios in international road tunnels (O'Gorman and Gehrke, 2014)

Tunnel	Reported NO_2:NO_x ratio	Source
La Croix Rousse, France (1.8 kilometres, bi-directional)	Average: 7.3% to 9.2 % Daily peak: 8.7% to 9.6% Ratios of 20% have been measured during low NO_x periods (off peak)	Permanent International Association of Road Congresses (2000)
Careybeckx, Netherlands (1.6 kilometre, twin tube)	Average: 5%	De Fre, Bruynseraede and Kretzshmer (1994)
Tate's Cairn, Hong Kong (4 kilometre, twin tube) Tai Lam (3.7 kilometre, twin tube)	Average: 6% Peaks in areas of high ozone: 20%	Yao et al (2005)
Hatfield, United Kingdom (1.1 kilometres, twin tube) Bell Common, United Kingdom (500 metres, twin tube)	Peak in areas of high ozone: 25% Near exit portals: 12% to 14%	Boulter, McCrae and Green (2007)
M5 East Motorway, Australia (4 kilometres, twin tube)	Average: 5% to 6%	National Health and Medical Research Council (2008)
Laerdal, Norway (24.5 kilometres, bi-directional) Fodnes, Norway (6.6 kilometres, bi-directional) Knappe, Norway (2.5 kilometres, twin tube)	Range: 10% to 30% Typical: 20%	Norwegian Public Roads Administration (2013)
Lane Cove Tunnel, Australia	Median: 7%	O'Gorman et al (2009)

Management of in-tunnel air quality

The actual ratio of NO_2:NO_x within the project tunnels is expected to fluctuate throughout the day. During off peak hours when traffic volumes are low and times when there is a higher percentage of heavy vehicles within the tunnels, the ratio of NO_2:NO_x may increase above 10 per cent. Although the ratio of NO_2:NO_x may increase during these periods, the total NOx load would be considerably lower than during peak traffic periods.

Under all circumstances, the NorthConnex tunnels would continue to operate within the stipulated design criteria for NO_2. Air quality within the tunnels would be continuously monitored and the ventilation rate would be adjusted in response to traffic flows and real-time measurements for NO_2 concentrations taken within the project tunnels. This would maintain a safe environment for the tunnel users.

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2.15 Operational impact assessment

As discussed in **Section 2.3** of this report, two key amendments have occurred that have affected the outcomes of the air quality impact as presented in the environmental impact statement:

- The height of the northern and southern ventilation outlets have been increased by five metres as a result of further consideration of feasible and reasonable measures that could be applied to the project to reduce in-tunnel and ambient exposures to vehicle emissions (refer to **Section 3.2** for this analysis). This amendment has been included in the preferred infrastructure report component of this document, provided in **Chapter 9**.
- Amendments have been made to four assumptions and inputs into the air quality impact assessment of the project. These amendments have been discussed in the relevant parts of this chapter and are summarised in **Table 2-76**.

Table 2-76 Changes to dispersion model inputs

Assumption or input	Change made to the assessment approach
Receiver grid spacing of 150 metres may be too coarse.	The receiver grid has been recalculated for the following refined spacings: • 25 metre spacing for an area of 500 metres by 500 metres centred on each ventilation outlet. • 50 metre spacing for an area of 1,000 metres by 1,000 metres centred on each ventilation outlet. • 100 metre spacing for an area of 4,000 metres by 4,000 metres centred on each ventilation outlet.
The 90 metre SRTM topographic data used to determine the receiver grid elevations may be too coarse or may not reflect local conditions.	The topographic data have been re-extracted using five metre resolution Land and Property Information (LPI) data. The elevations of the discrete receivers and the ventilation outlet locations have been identified using this revised data.
Vehicle fleet composition data was based on 2013 Australia Bureau of Statistics data. This may potentially underestimate the future percentage of diesel vehicles as sales trends show an increase in diesel passenger vehicles.	2008 and 2013 Australian Bureau of Statistics data have been used to extrapolate predicted fleet compositions for 2019 and 2029. The data have then been used when calculating vehicle emissions to inform the project's emissions inventory. The emission rates in the air quality dispersion model have been adjusted accordingly.
Ozone limiting method (OLM) equation does not reflect the ratio of NO_2:NO_x identified from the NSW vehicle fleet by the Environment Protection Authority.	The ozone limiting method calculation has been amended to reflect an initial NO_2:NO_x ratio of 16 per cent.

The results of further air quality modelling, taking into account the increase in ventilation outlet heights and the amended assumptions summarised in **Table 2-76** are detailed in **Section 2.15.1**.

2.15.1 Air quality modelling results (increased ventilation outlet height)

Table 2-77 summarises the outcomes of the revised air quality dispersion modelling, under forecast traffic volumes in 2019 and 2029, and for 'design analysis A' (the worst case traffic scenario). Modelling outputs are presented as project contributions (without the addition of background pollutant concentrations), for direct comparison with modelling outcomes for the original ventilation outlet heights (as presented in the environmental impact statement).

Table 2-78 presents the outcomes of the air quality modelling included in the environmental impact statement and compares them with the outcomes of the revised air quality dispersion modelling. As expected with an increase in ventilation outlet height, most ground level concentrations of emissions would decrease by a significant percentage (up to 60 per cent reduction in some cases), although it is recognised that the concentrations were originally very low and remain very low. However, counterintuitively, some peak ground level concentrations of emissions are predicted to increase, despite the increase in ventilation outlet heights. This would only occur for one hour in three years and is still within the applicable impact assessment criteria.

When compared to the concentrations presented in the environmental impact statement, the increase in ventilation outlet heights by five metres generally results in a decrease in ground level concentrations. For the forecast traffic volumes, these decreases are:

- Annual average PM_{10} and $PM_{2.5}$ concentrations, up to 60 per cent at the southern ventilation outlet and up to 41 per cent at the northern ventilation outlet.
- Annual average nitrogen dioxide concentrations, up to 31 per cent at the southern ventilation outlet and up to 55 per cent at the northern ventilation outlet.
- Eight hour maximum carbon monoxide concentrations, up to 48 per cent at the southern ventilation outlet and up to 16 per cent at the northern ventilation outlet.
- Total volatile organic compounds, up to 56 per cent at the southern ventilation outlet and up to 35 per cent at the northern ventilation outlet.
- Polycyclic aromatic hydrocarbons, up to 56 per cent at the southern ventilation outlet and up to 34 per cent at the northern ventilation outlet.

There is, however, an increase in some pollutants for some averaging periods. Based on a more detailed review of modelling outputs, these increases occur very rarely (around one event for the three years of modelling data). **Section 2.15.2** analyses the very rare meteorological events that lead to infrequent increases in ground level concentrations of pollutants, and demonstrates that these events do not represent typical meteorological conditions.

Table 2-77 Revised predicted air quality outcomes for project operation in 2019, 2029 and design analysis A (increased ventilation outlet heights)

Pollutant	Averaging period	Value	Predicted maximum project contributions (μg/m³)						Impact assessment criteria/ standards (μg/m³)
			With project – forecast traffic in 2019		With project – forecast traffic in 2029		Design analysis A		
			Northern ventilation outlet	Southern ventilation outlet	Northern ventilation outlet	Southern ventilation outlet	Northern ventilation outlet	Southern ventilation outlet	
PM_{10}	24 hour maximum	Peak project contribution	1.02	0.65	1.28	1.18	1.80	1.93	50
		% of criterion	2.0%	1.3%	2.6%	2.4%	3.6%	3.9%	-
	Annual average	Peak project contribution	0.05	0.05	0.08	0.06	0.12	0.11	30
		% of criterion	0.2%	0.2%	0.3%	0.2%	0.4%	0.4%	-
$PM_{2.5}$	24 hour maximum	Peak project contribution	0.96	0.62	1.20	1.13	1.70	1.82	25
		% of reporting standard	2.5%	4.8%	4.5%	6.8%	7.3%	2.5%	-
	Annual average	Peak project contribution	0.05	0.04	0.08	0.05	0.11	0.11	8
		% of reporting standard	0.6%	0.5%	1.0%	0.7%	1.4%	1.3%	-
NO_2	1 hour maximum	Peak project contribution	54.3	69.0	58.3	76.0	70.4	91.8	246
		% of criterion	22.1%	28.0%	23.7%	30.9%	28.6%	37.3%	-
	Annual average	Peak project contribution	0.6	0.8	0.8	1.3	1.3	1.8	62
		% of criterion	1.0%	1.3%	1.3%	2.0%	2.1%	2.9%	-
CO	1 hour maximum	Peak project contribution	181.8	48.4	217.5	57.9	172.0	114.5	100,000
		% of criterion	0.18%	0.05%	0.22%	0.06%	0.17%	0.11%	-

Pollutant	Averaging period	Value	Predicted maximum project contributions (μg/m³) With project – forecast traffic in 2019 Northern ventilation outlet	With project – forecast traffic in 2019 Southern ventilation outlet	With project – forecast traffic in 2029 Northern ventilation outlet	With project – forecast traffic in 2029 Southern ventilation outlet	Design analysis A Northern ventilation outlet	Design analysis A Southern ventilation outlet	Impact assessment criteria/ standards (μg/m³)
	8 hour maximum	Peak project contribution	36.0	17.2	45.5	31.5	59.0	51.5	30,000
		% of criterion	0.12%	0.06%	0.15%	0.10%	0.20%	0.17%	-
Total VOC	1 hour 99.9th percentile	Peak project contribution	2.6	1.7	3.5	2.3	5.4	4.2	29*
		% of criterion	9.1%	5.8%	12.2%	8.0%	18.5%	14.6%	-
PAHs	1 hour 99.9th percentile	Peak project contribution	0.0005	0.0003	0.0006	0.0004	0.0011	0.0008	0.4**
		% of criterion	0.12%	0.08%	0.15%	0.10%	0.27%	0.21%	-

* as benzo(a)pyrene ** as benzene

Table 2-78 Comparison of revised air quality modelling results against EIS modelling results

Pollutant	Averaging period	Design	Predicted maximum project contributions (µg/m³) With project – forecast traffic in 2019: Northern ventilation outlet	With project – forecast traffic in 2019: Southern ventilation outlet	With project – forecast traffic in 2029: Northern ventilation outlet	With project – forecast traffic in 2029: Southern ventilation outlet	Design analysis A: Northern ventilation outlet	Design analysis A: Southern ventilation outlet	Impact assessment criteria (µg/m³)
PM_{10}	24 hour maximum	+5 metre ventilation outlet	1.02*	0.65	1.28	1.18	1.80	1.93	50
		EIS predictions	0.95	1.39	1.37	2.14	2.23	3.13	
		% change	**7%***	**-53%**	**-7%**	**-45%**	**-19%**	**-38%**	
	Annual average	+5 metre ventilation outlet	0.05	0.05	0.08	0.06	0.12	0.11	30
		EIS predictions	0.09	0.11	0.11	0.13	0.17	0.26	
		% change	**-41%**	**-60%**	**-25%**	**-58%**	**-32%**	**-57%**	
$PM_{2.5}$	24 hour maximum	+5 metre ventilation outlet	0.96*	0.62	1.20	1.13	1.70	1.82	25
		EIS predictions	0.90	1.34	1.30	2.01	2.11	2.97	
		% change	**7%***	**-54%**	**-7%**	**-44%**	**-19%**	**-39%**	
	Annual average	+5 metre ventilation outlet	0.05	0.04	0.08	0.05	0.11	0.11	8
		EIS predictions	0.08	0.11	0.10	0.13	0.16	0.25	
		% change	**-41%**	**-60%**	**-25%**	**-59%**	**-31%**	**-57%**	
NO_2	1 hour maximum	+5 metre ventilation outlet	54.3	69.0**	58.3	76.0**	70.4	91.8	246
		EIS predictions	68.9	61.8	74.6	65.0	114.8	98.2	
		% change	**-21%**	**12%****	**-22%**	**17%****	**-39%**	**-7%**	

Pollutant	Averaging period	Design	Predicted maximum project contributions (μg/m³)						Impact assessment criteria (μg/m³)
			With project – forecast traffic in 2019		With project – forecast traffic in 2029		Design analysis A		
			Northern ventilation outlet	Southern ventilation outlet	Northern ventilation outlet	Southern ventilation outlet	Northern ventilation outlet	Southern ventilation outlet	
	Annual average	+5 metre ventilation outlet	0.6	0.8	0.8	1.3	1.3	1.8	62
		EIS predictions	1.4	1.2	1.7	1.4	2.5	2.4	
		% change	**-55%**	**-31%**	**-53%**	**-10%**	**-47%**	**-24%**	
CO	1 hour maximum	+5 metre ventilation outlet	181.8**	48.4	217.5**	57.9	172.0	114.5	100,000
		EIS predictions	86.6	70.1	107.4	90.3	179.3	166.7	
		% change	**110%****	**-31%**	**103%****	**-36%**	**-4%**	**-31%**	
	8 hour maximum	+5 metre ventilation outlet	36.0**	17.2	45.5	31.5	59.0	51.5	30,000
		EIS predictions	32.4	33.1	54.2	57.9	80.3	81.7	
		% change	**11%****	**-48%**	**-16%**	**-46%**	**-27%**	**-37%**	
Total VOC	1 hour 99.9th percentile	+5 metre ventilation outlet	2.63	1.67	3.53	2.33	5.35	4.24	29***
		EIS predictions	4.07	3.72	5.38	5.36	7.40	8.96	
		% change	**-35%**	**-55%**	**-35%**	**-56%**	**-28%**	**-53%**	
PAHs	1 hour 99.9th percentile	+5 metre ventilation outlet	0.0005	0.0003	0.0006	0.0004	0.0011	0.0008	0.4****
		EIS predictions	0.0007	0.0007	0.0009	0.0009	0.0015	0.0018	
		% change	**-34%**	**-54%**	**-31%**	**-56%**	**-28%**	**-53%**	

* Occurs 1 day in three years   ** Occurs 1 hour in three years   *** as benzo(a)pyrene   **** as benzene