Contour plots – all sources

The contour plots for maximum 24 hour average PM_{10} in the 2033-DM and 2033-DSC scenarios are given in **Figure 9-49** and **Figure 9-50**. The changes in maximum 24 hour PM_{10} are shown in **Figure 9-51**.

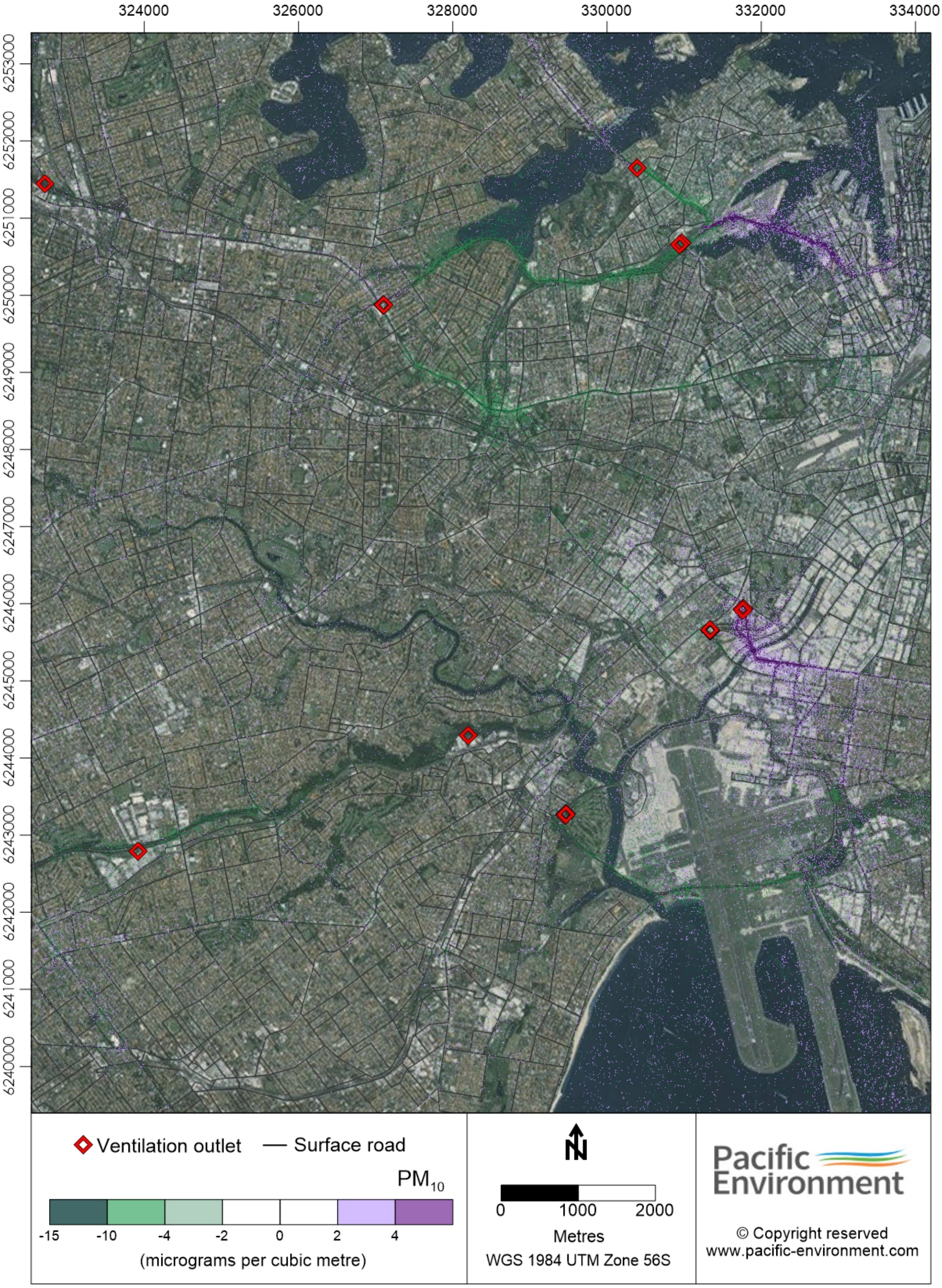

Figure 9-49 Contour plot of change in maximum 24 hour average PM_{10} concentration with the project (2023-DS)

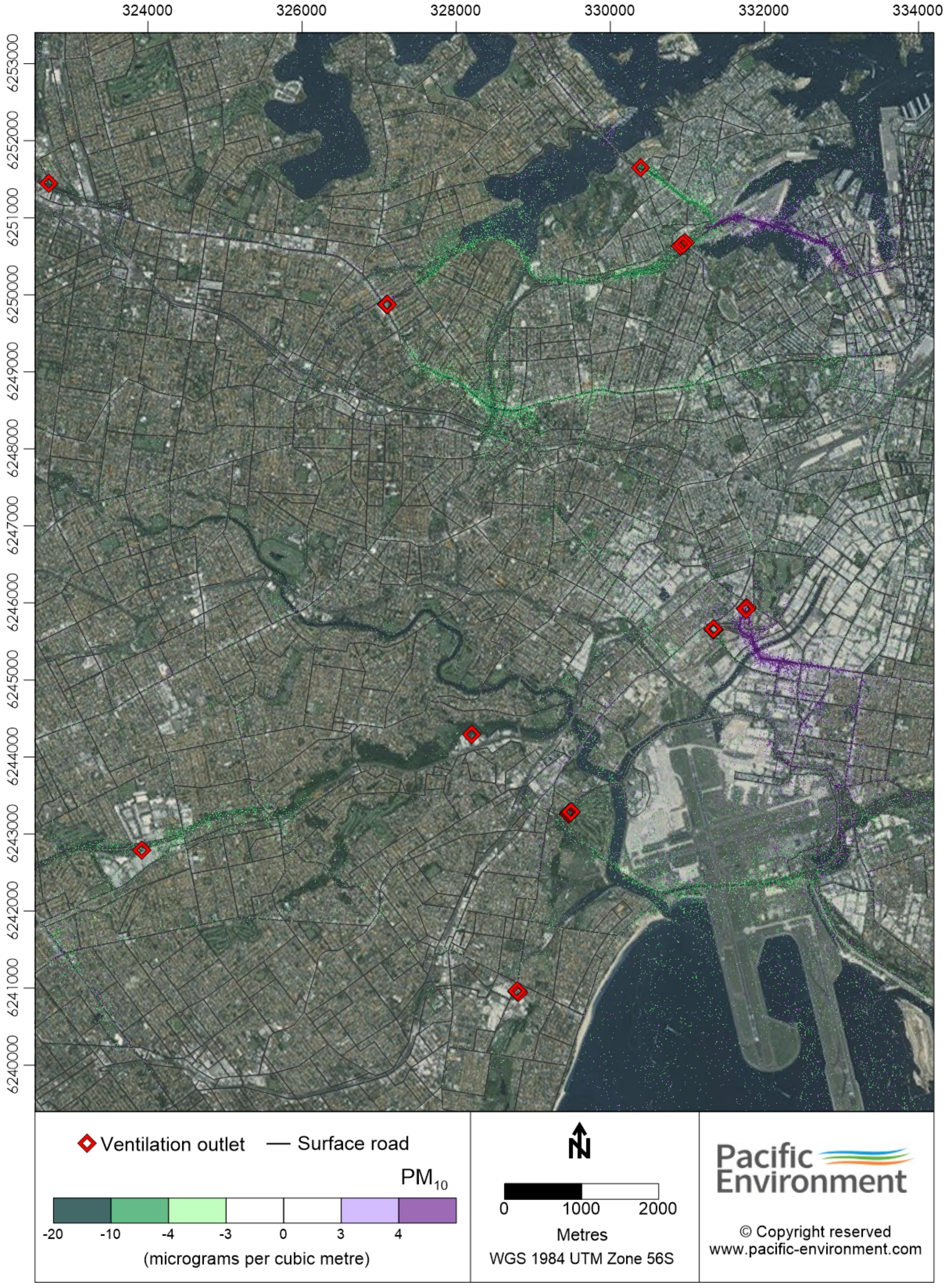

Figure 9-50 Contour plot of change in maximum 24 hour average PM_{10} concentration with the project (2033-DS)

$PM_{2.5}$ (annual mean)

Results for community receptors

Figure 9-51 presents the annual mean $PM_{2.5}$ concentrations at the community receptors. The results are based on an assumed background concentration of eight µg/m^3 (the AAQNEPM standard), and therefore the Figure shows exceedances at all receptors. Clearly, there would also be exceedances of the NSW target of seven µg/m^3. Internationally, there are no standards lower than eight µg/m^3 for annual mean $PM_{2.5}$. The next lowest is 12 µg/m^3 (California and Scotland). Any increases with the project were generally less than 0.2 µg/m^3; the largest increase (0.56 µg/m^{3t} receptor CR38, in the 2033-DS scenario) equated to seven per cent of the air quality criterion.

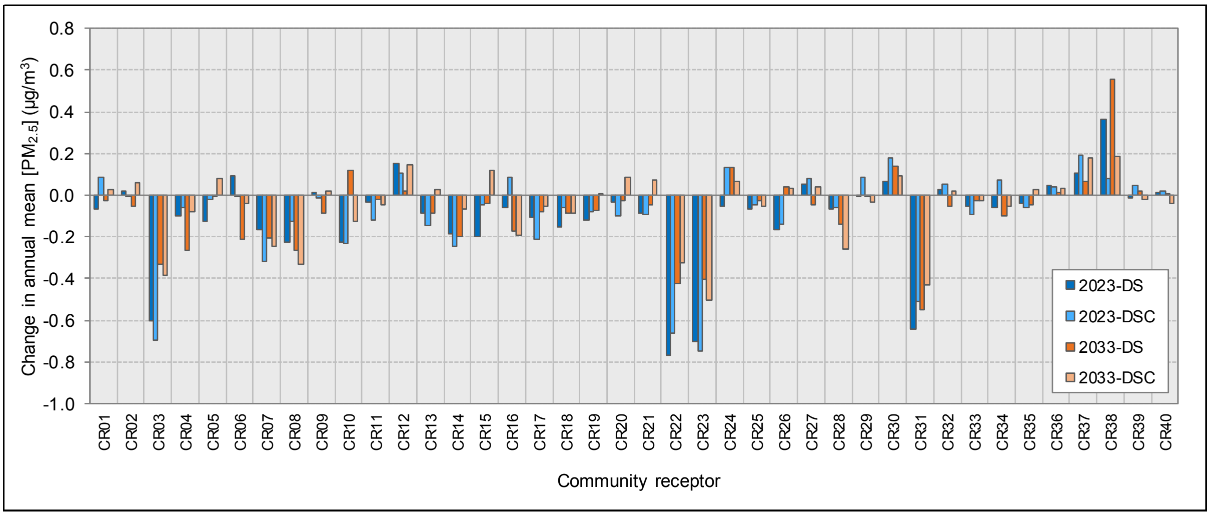

Figure 9-51 Change in annual mean $PM_{2.5}$ concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios, relative to corresponding Do Minimum scenarios)

Figure 9-52 shows that concentrations were again dominated by the background contribution. The surface road contribution was between 0.5 µg/m^3 and 2.7 µg/m^3. The largest contribution from tunnel ventilation outlets at any receptor was just 0.14 µg/m^3.

Figure 9-52 Source contributions to annual mean $PM_{2.5}$ concentration at community receptors (DS and DSC scenarios)

Results for RWR receptors

The ranked annual mean $PM_{2.5}$ concentrations at the RWR receptors in the with-project scenarios, are shown in **Figure 9-52**, including the contributions of surface roads and ventilation outlets. As the background concentration was taken to be the same as the NSW criterion of eight μg/m^3, the total concentration at all receptors was above this value. The highest concentration at any receptor was 14.2 μg/m^3 but, as with other pollutants and metrics, high values were only predicted for a small proportion of receptors and are unlikely to reflect real-world exposure situations. In the with-project scenarios, the largest surface road contribution at any receptor was 5.4 μg/m^3. The largest contribution from tunnel ventilation outlets in these scenarios was 0.17 μg/m^3.

The change in the annual mean $PM_{2.5}$ concentration at the RWR receptors in the with-project scenarios, are ranked in **Figure 9-53**. There was an increase in concentration at between 29 per cent and 37 per cent of the receptors, depending on the scenario. The largest predicted increase in concentration at any receptor as a result of the project was 2.3 μg/m^3, and the largest predicted decrease was also 2.3 μg/m^3. Where there was an increase, this was greater than 0.1 μg/m^3 at around 2–3 per cent of receptors.

The increase in annual mean $PM_{2.5}$ at sensitive receptors with the project ($\Delta PM_{2.5}$) is a key metric for assessing the risk to human health. For the M4-M5 Link project, the acceptable value of $\Delta PM_{2.5}$ was determined to be 1.8μg/m^3. Only one receptor (RWR-46456) had a predicted change in $PM_{2.5}$ above this value. However, this receptor is a commercial/industrial building that is very close to the indicative alignment of the proposed future Sydney Gateway, and would not represent a real-world exposure situation in the future. Given the proximity of these areas to Sydney Airport (runways and flight paths) it is considered unlikely that they would be rezoned for residential use and the increases in $PM_{2.5}$ are principally related to the Sydney Gateway project. Emissions to air related to the Sydney Gateway project have been estimated on the basis of provisional information in relation to roadway layout only. The maximum impacts predicted are on roadways/locations that may be within the future roadway alignments. The Sydney Gateway project would be subject to separate environmental assessment and approval, in which more detailed assessment of impacts in this area would be undertaken.

Contour plots – all sources

The contour plots for absolute annual mean $PM_{2.5}$ are given in **Figure 9-54** (2033-DM) and **Figure 9-55** (2033-DSC). The contour plot for the change in concentration associated with the project is shown in **Figure 9-55**.

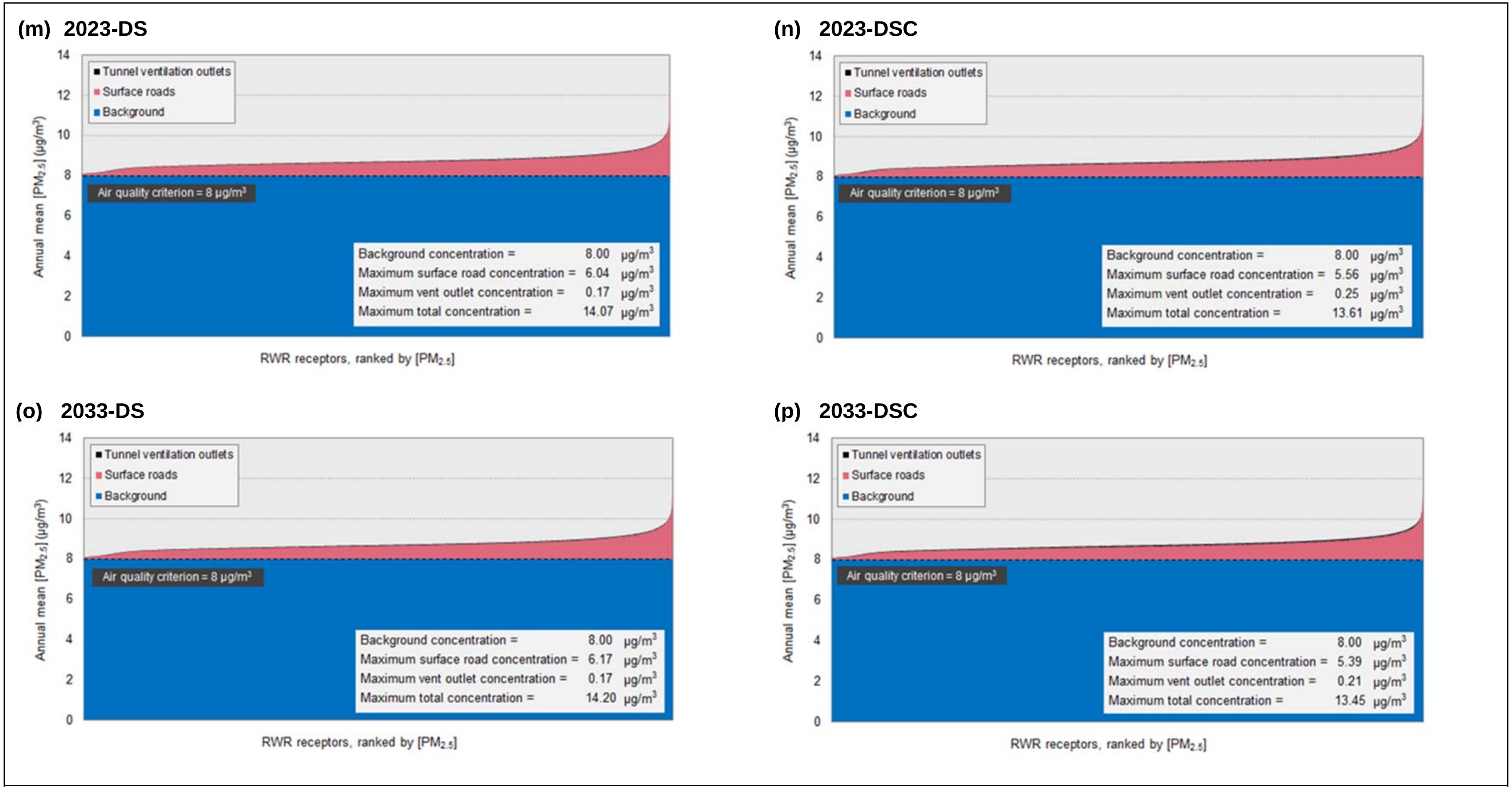

Figure 9-53 Source contributions to annual mean $PM_{2.5}$ concentration at RWR receptors (with-project and cumulative scenarios)

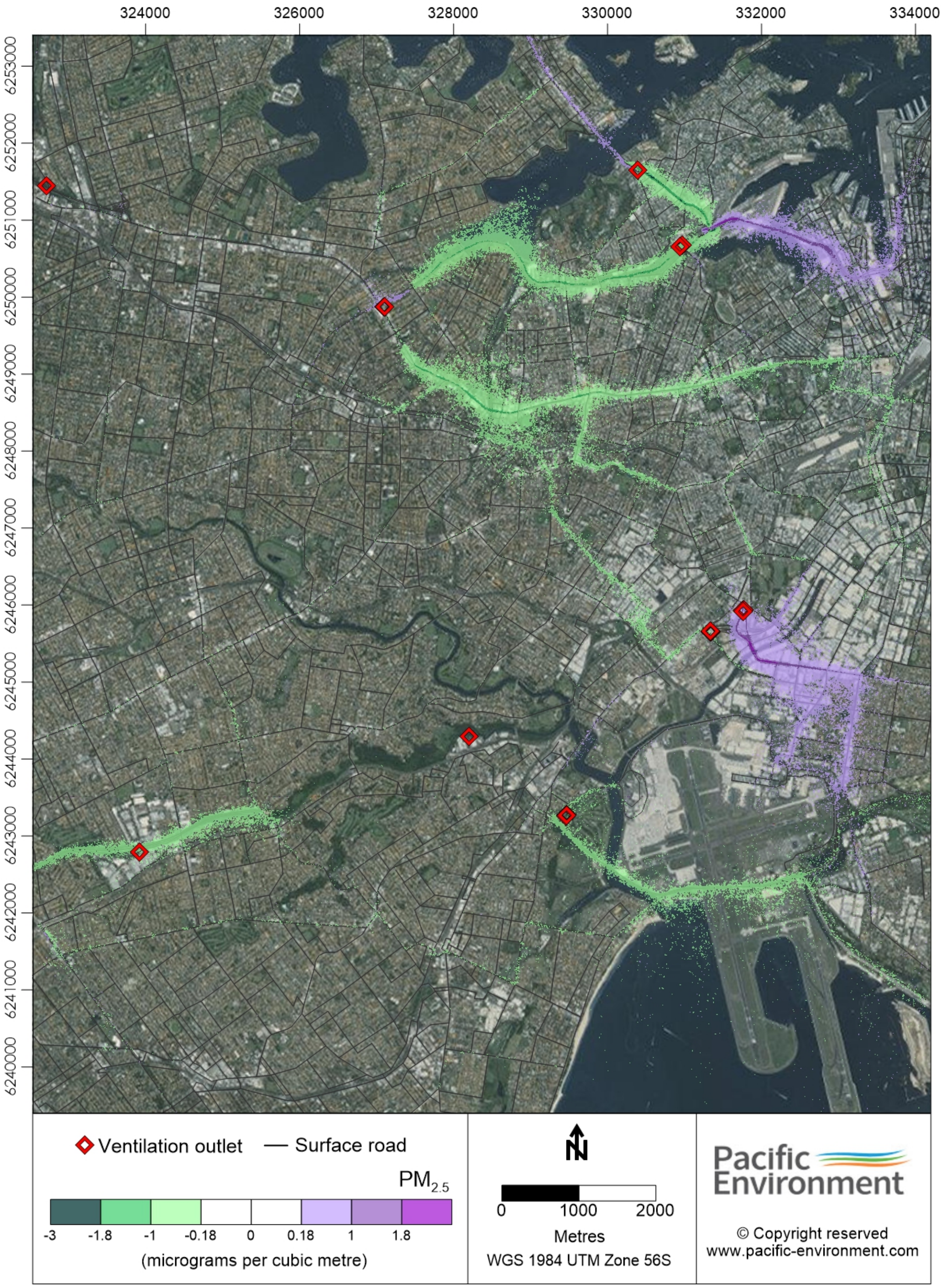

Figure 9-54 Contour plot of change in annual mean $PM_{2.5}$ concentration (2023-DS)

Figure 9-55 Contour plot of change in annual mean $PM_{2.5}$ concentration (2033-DS scenario)

$PM_{2.5}$ (maximum 24 hour mean)

Results for community receptors

The maximum 24 hour mean $PM_{2.5}$ concentrations at the community receptors with the project are presented in **Figure 9-56**. At all receptor locations, the maximum concentration was above the NSW impact assessment criterion of 25 µg/m^3, although exceedances were already predicted without the project. Internationally, there are no standards lower than 25 µg/m^3 for 24 hour $PM_{2.5}$, however, the AAQNEPM includes a long-term goal of 20 µg/m^3.

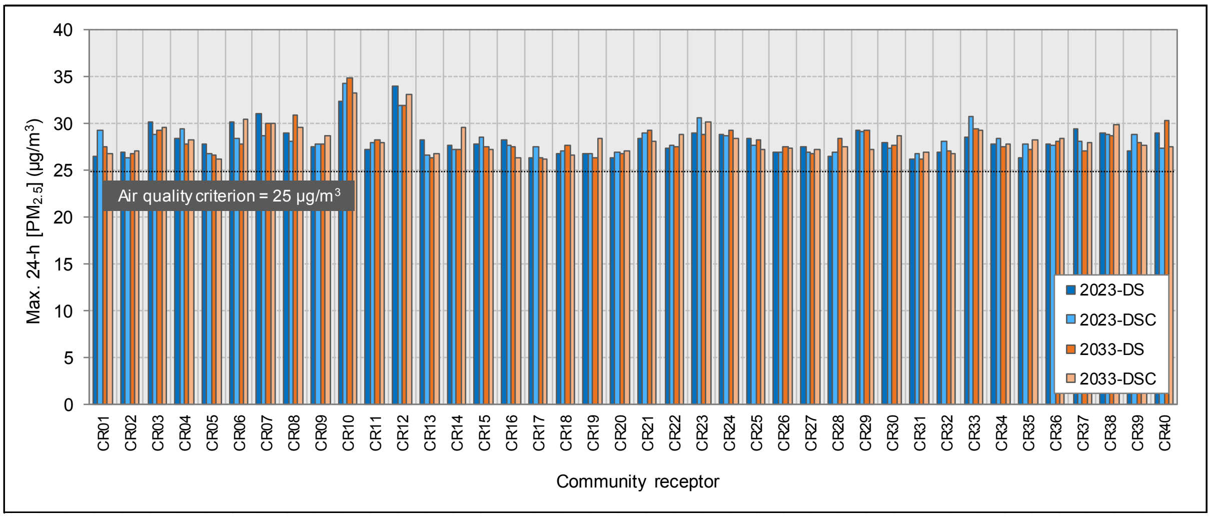

Figure 9-56 Maximum 24 hour $PM_{2.5}$ concentration at community receptors (DS and DSC scenarios)

Figure 9-57 presents the changes in maximum 24 hour $PM_{2.5}$ with the project at the community receptors. At the majority of receptors, there was a decrease in annual mean $PM_{2.5}$. Most of the increases with the project were less than 0.2 µg/m^3. The largest increase (2.9 µg/m^3 at receptor CR40, in the 2033-DSC scenario) equated to 11 per cent of the air quality criterion.

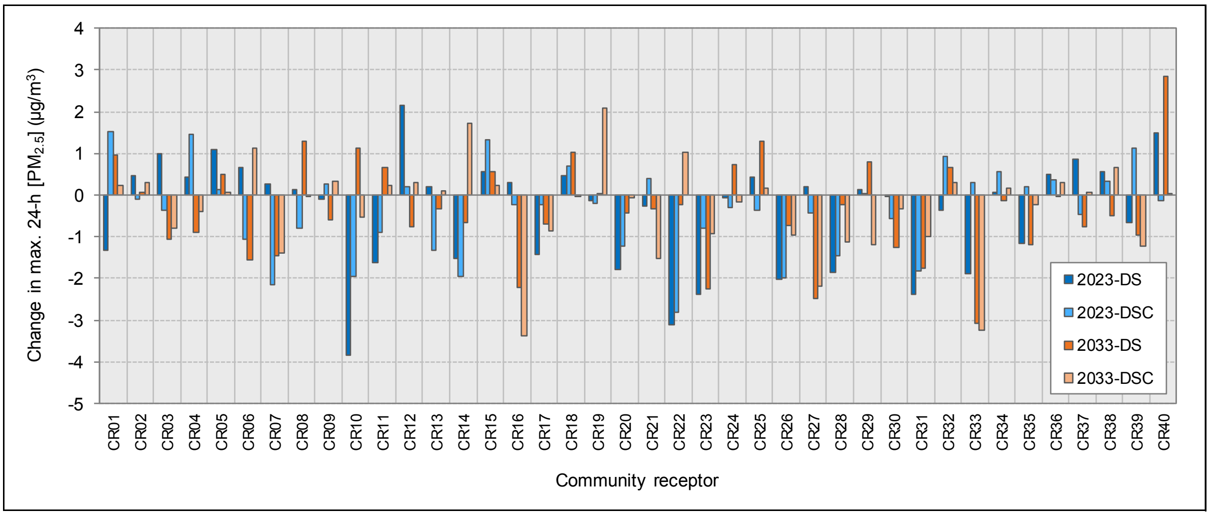

Figure 9-57 Change in maximum 24 hour $PM_{2.5}$ concentration at community receptors (DS and DSC scenarios), relative to corresponding DM scenarios

The combined road and ventilation outlet contributions to the maximum 24 hour $PM_{2.5}$ concentration at the community receptors were relatively small, as shown in The tunnel ventilation outlet contributions alone were negligible in all cases (<0.15 µg/m^3).

Figure 9-58 shows that the concentrations were again dominated by the background contribution. The surface road contribution was between 0.5 µg/m^3 and 2.7 µg/m^3. The largest contribution from tunnel ventilation outlets at any receptor was 0.14 µg/m^3.

Figure 9-58 Source contributions to maximum 24 hour mean $PM_{2.5}$ -concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios)

Results for RWR receptors

The ranked maximum 24 hour mean $PM_{2.5}$ concentrations at the RWR receptors in the with-project scenarios are shown in **Figure 9-59**. The concentration at all receptors was above the NSW impact assessment criterion of 25 µg/m^3. As with PM_{10}, the contributions of surface roads and ventilation outlets are not shown separately as these were not additive. The maximum contribution of tunnel outlets at any receptor with the project was 1.2 µg/m^3.

The changes in the maximum 24 hour mean $PM_{2.5}$ concentration at the RWR receptors in the with-project scenarios are ranked in **Figure 9-59**. There was an increase in concentration at between 36 per cent and 39 per cent of the receptors, depending on the scenario. The largest predicted increase in concentration at any receptor as a result of the project was 8.7 µg/m^3 (2023-DSC scenario), and the largest predicted decrease was 8.2 µg/m^3. For most of the receptors the change in concentration was small; where there was an increase in concentration, this was greater than 2.5 µg/m^3 at only 0.2 to 0.3 per cent of receptors.

Contour plots – all sources

The contour plots for maximum 24 hour $PM_{2.5}$ in the 2023-DS and 2033-DS scenarios are given in **Figure 9-60** and **Figure 9-61** respectively.

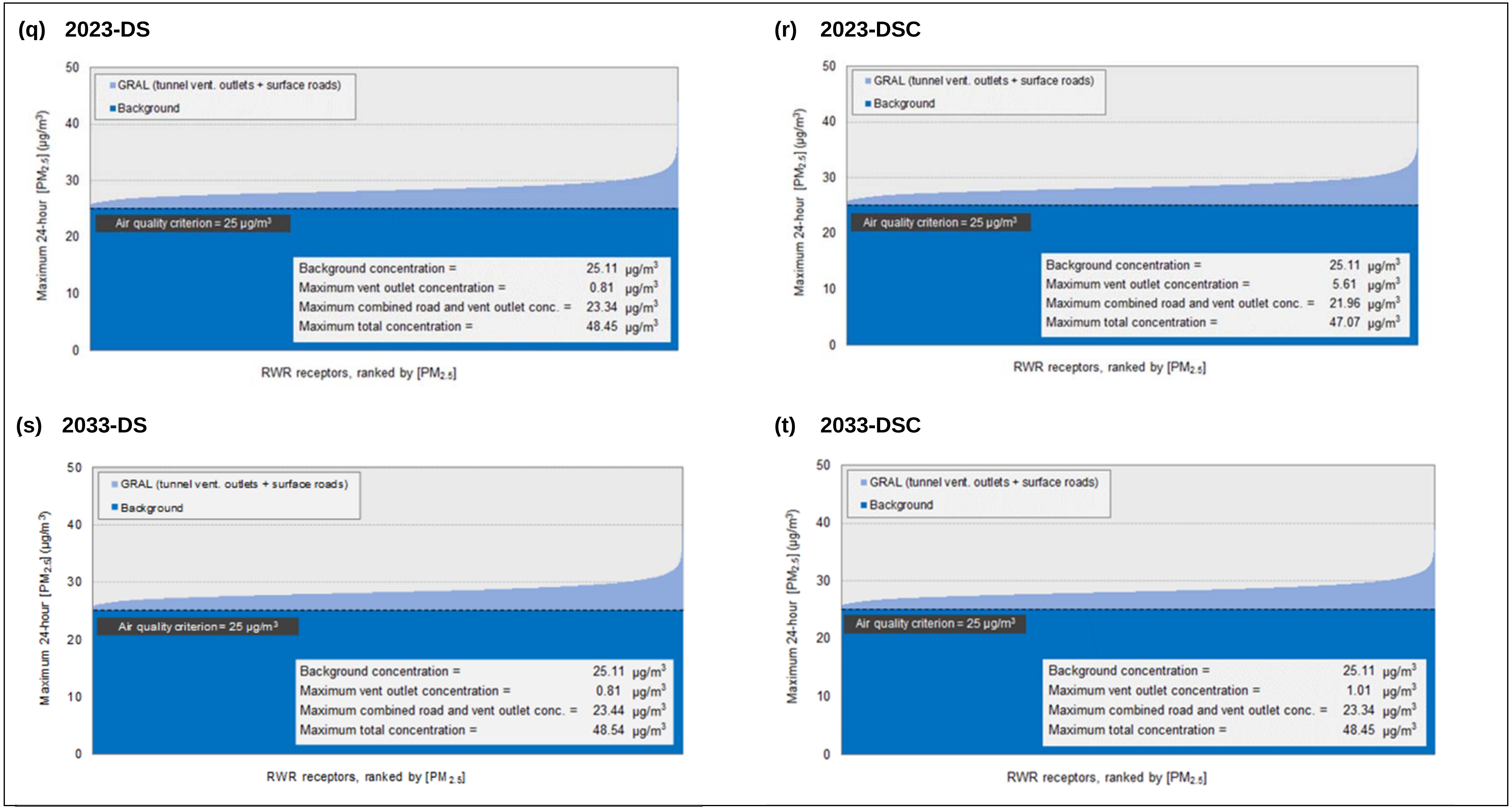

Figure 9-59 Source contributions to maximum 24 hour mean $PM_{2.5}$ concentration at RWR receptors (DS and DSC scenarios)

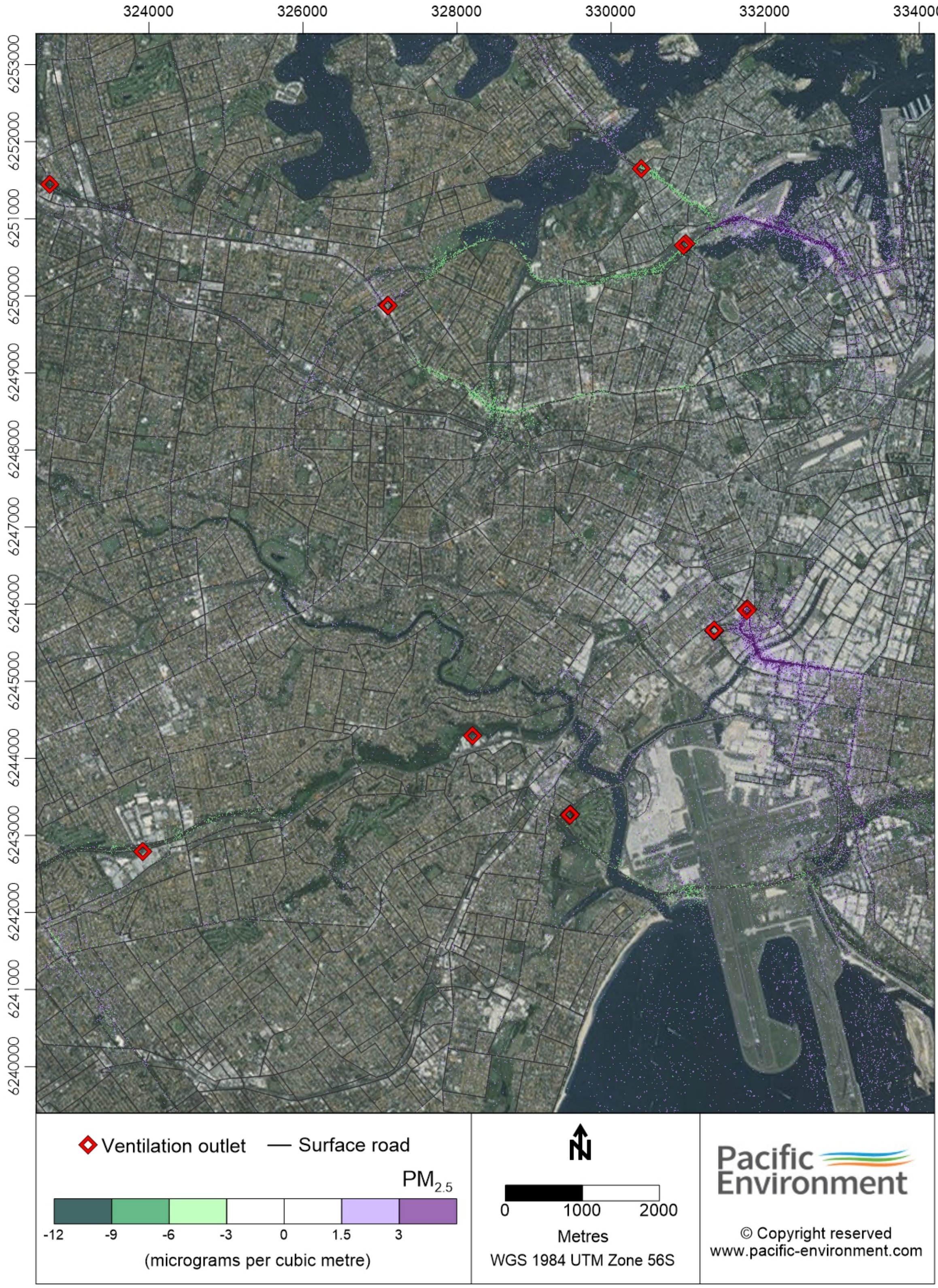

Figure 9-60 Contour plot of change in maximum 24 hour average $PM_{2.5}$ concentration in 2023-DS

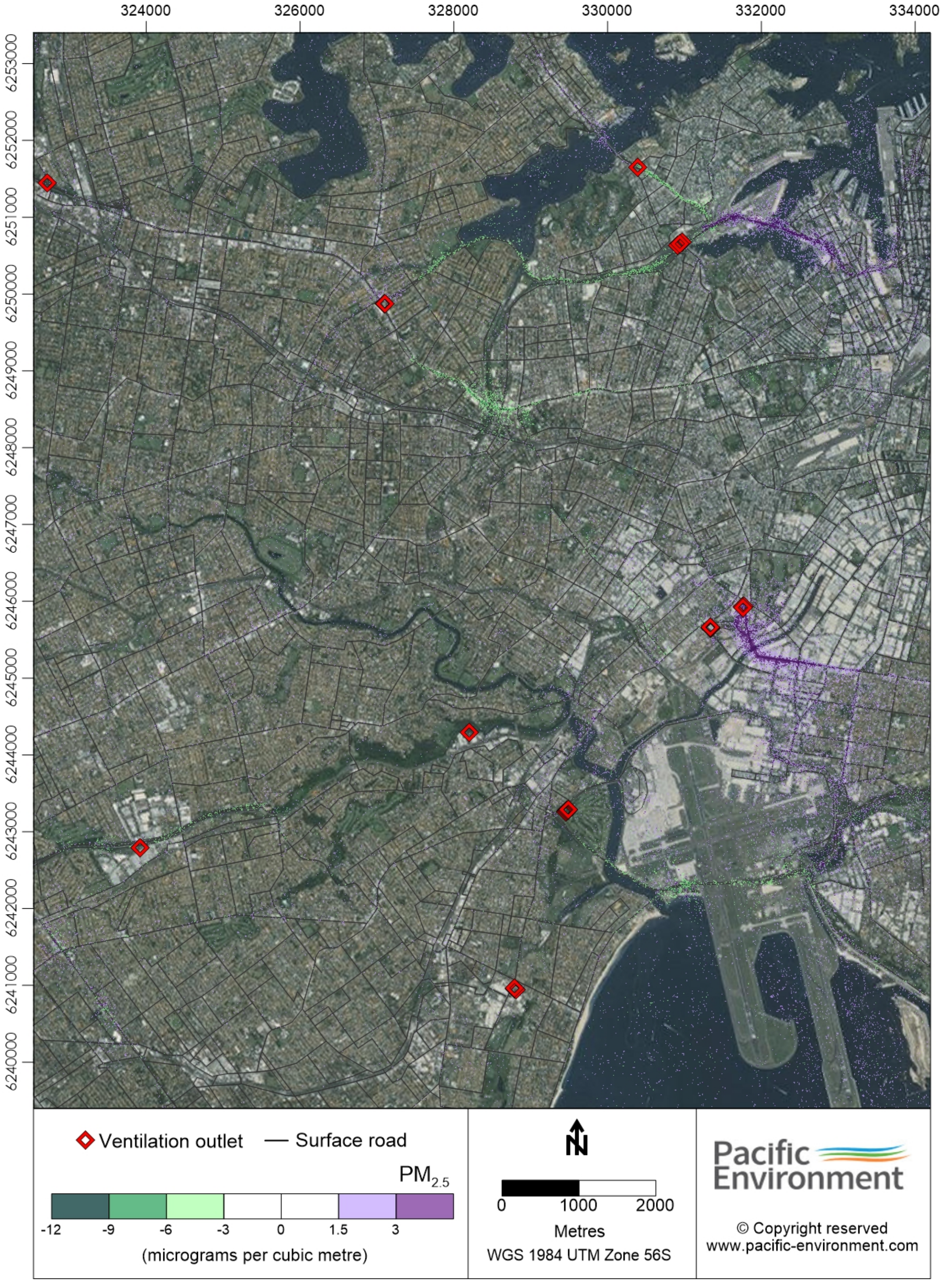

Figure 9-61 Contour plot of change in maximum 24 hour average $PM_{2.5}$ concentration in 2033-DS

Air toxics

Four air toxics – benzene, PAHs (as BaP), formaldehyde and 1,3-butadiene – were assessed. These compounds were taken to be representative of the much wider range of air toxics associated with motor vehicles, and they have commonly been used for assessment of road projects.

The changes in the maximum one hour benzene concentration at the community receptors as a result of the project are shown in **Figure 9-62**, where they are compared with the NSW impact assessment criterion from the NSW EPA Approved Methods. These changes took into account emissions from both surface roads and tunnel ventilation outlets. It can be seen from the Figure that there where there was an increase in the concentration, this was well below the assessment criterion. The changes in the maximum one hour BaP, formaldehyde and 1,3-butadiene concentration are presented in **Figure 9-63**, **Figure 9-64** and **Figure 9-65** respectively. For each compound, where there was an increase in the concentration, this was well below the NSW impact assessment criterion. The largest increases for the community receptors were also representative of the largest increases for the RWR receptors.

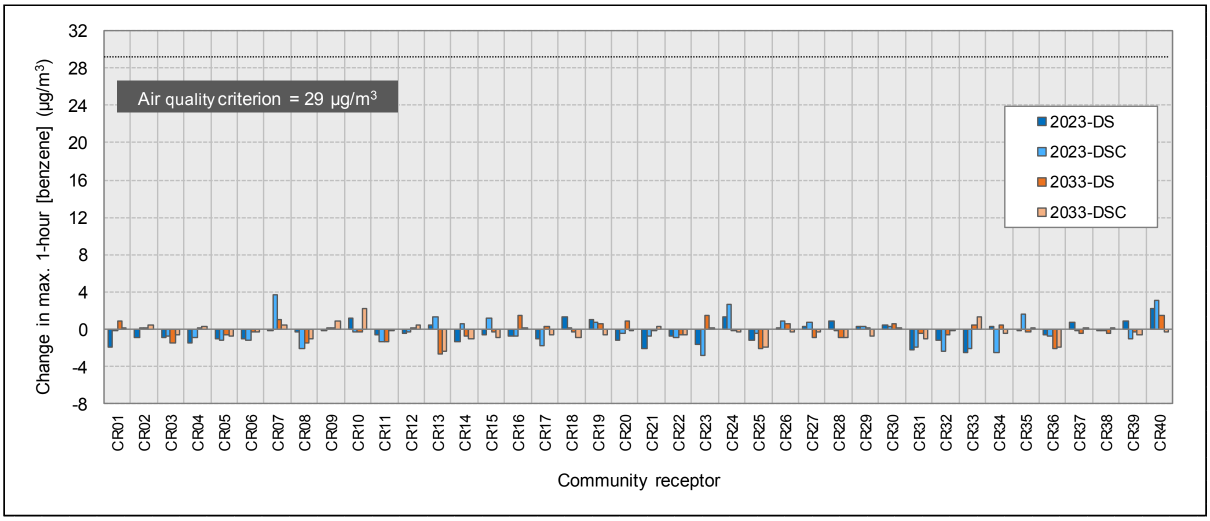

Figure 9-62 Change in maximum one hour mean benzene -concentration at community receptors (DS and DSC scenarios)

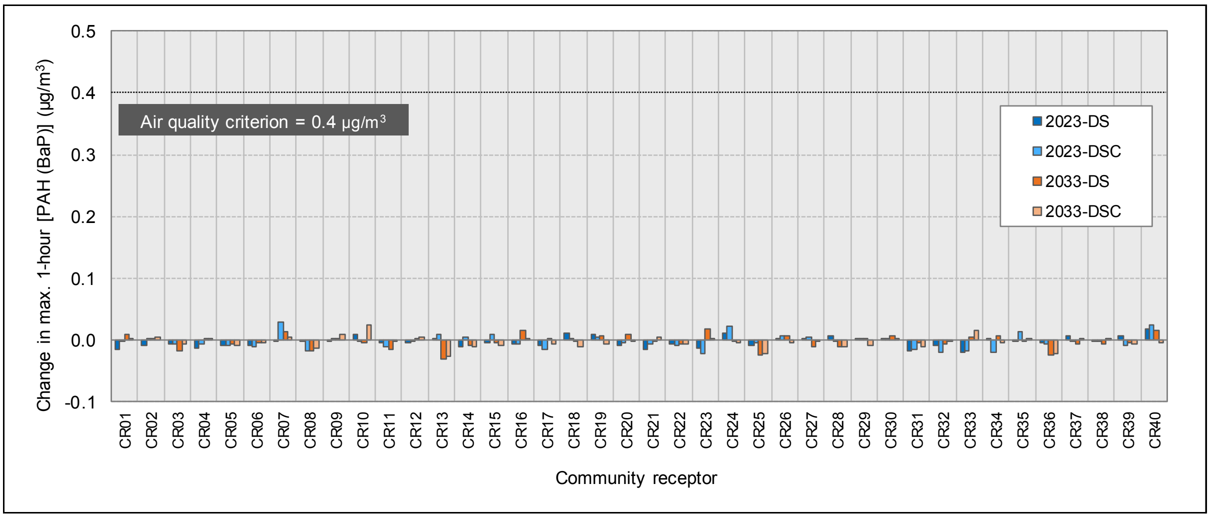

Figure 9-63 Change in maximum one hour mean BaP concentration at community receptors (DS and DSC scenarios)

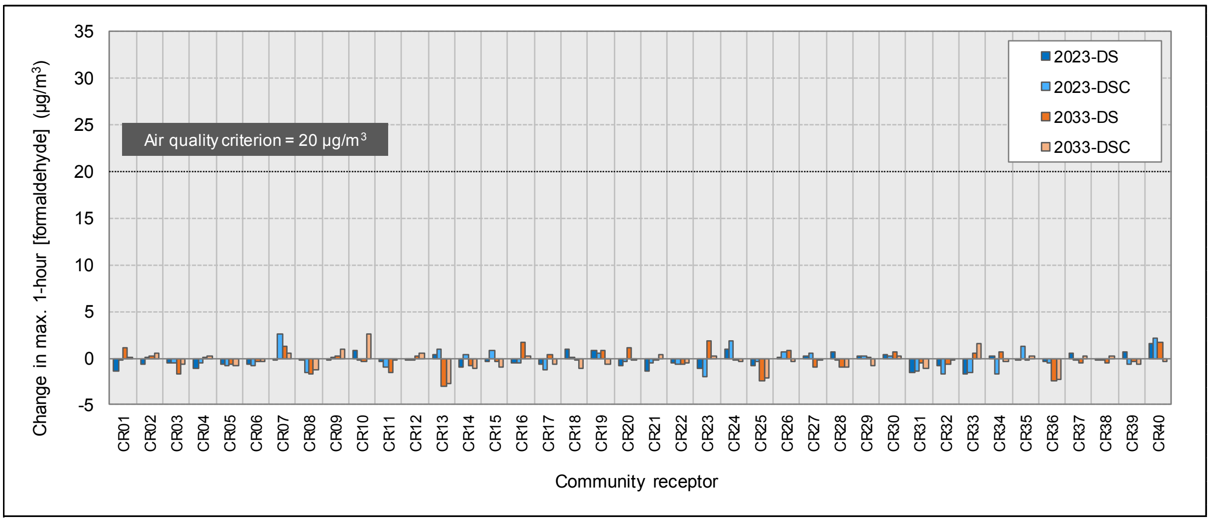

Figure 9-64 Change in maximum one hour mean formaldehyde concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios)

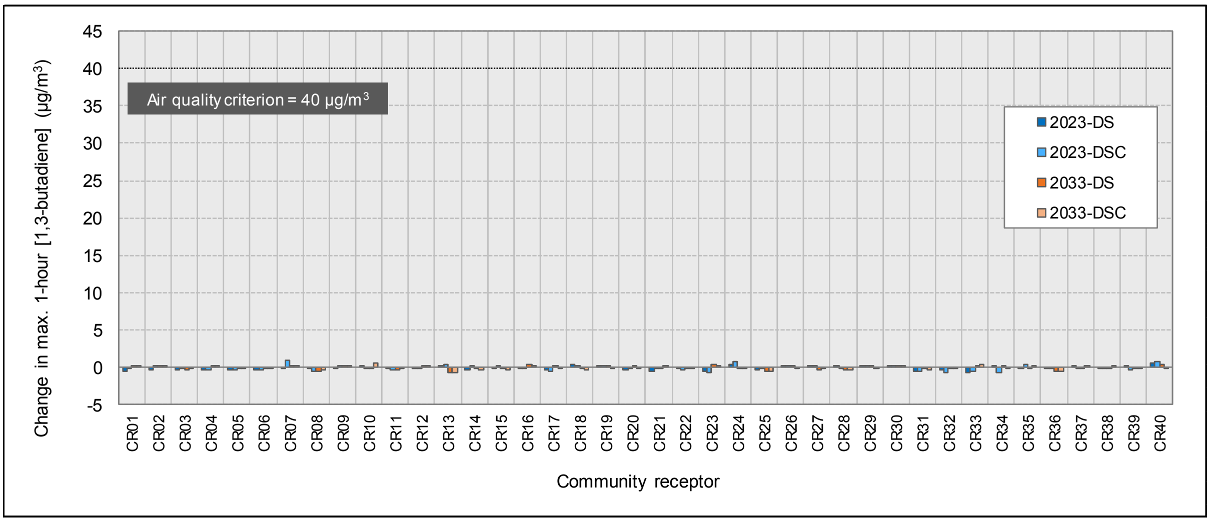

Figure 9-65 Change in maximum one hour mean 1,3-butadiene concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios)

9.7.4 Reasons for unrealistically high ground level concentrations at some RWR receptor locations

The predicted maximum one-hour NO_2 concentrations were very high at a small number of RWR locations. These elevated levels are not considered to be representative of exposure concentrations that would occur within the study area. This is due to the combined effect of the approach adopted for converting NOx to NO_2 (that overestimates short-term one-hour average concentrations), and the use of a contemporaneous assessment of background and project impacts. The contemporaneous approach assumes that the highest background concentrations may occur during the same hour as the maximum incremental change from the project. This results in a very high estimate of total NO_2 concentrations that is not expected to occur (refer to **Appendix I** (Technical working paper: Air quality) for more detailed discussion).

9.7.5 Results for expected traffic scenarios (elevated receptors)

Annual mean $PM_{2.5}$

Figure 9-66 and **Figure 9-67** present contour plots for the changes in annual mean $PM_{2.5}$ concentration in the 2033-DSC scenario, and for receptor heights of 10 metres and 30 metres respectively. These plots can be compared with the changes in ground level annual mean concentration for the same scenario. It should be noted that, for the 10 metre and 30 metre outputs, it was not necessarily the case that there were existing buildings at these heights at the receptor locations.

The reduced influence of surface roads at a receptor height of 10 metres compared with ground level can be seen in **Figure 9-66**. However, because the influence of surface roads in the Do Minimum case at 10 metres was also reduced, the distributions of changes in annual average $PM_{2.5}$ concentration at 10 metres and ground level were quite similar. For example, where there was an increase in annual mean $PM_{2.5}$ at the height of 10 metres, this was greater than 0.1 $\mu g/m^3$ for 2.9 per cent of receptors (compared with 3.2 per cent at ground level). However, the largest changes in concentration at 10 metres were smaller than those at ground level. The largest increase at the height of 10 metres for the RWR locations was 0.79 $\mu g/m^3$, which can be compared with the maximum increase for any ground level receptor in the 2033-DSC scenario of 2.3 $\mu g/m^3$.

Figure 9-67 show that the situation was quite different at a height of 30 metres. At this height the changes in annual mean $PM_{2.5}$ associated with surface roads are negligible at all locations, with the small increases closer to the ventilation outlets. The increase in $PM_{2.5}$ was greater than 1.8 $\mu g/m^3$ at a height of 30 metres at just one industrial location. However, the height of the existing building is 8.3 metres. The largest increases for residential locations at a height of 30 metres is between 1.41 and 1.43 $\mu g/m^3$ for a small group of locations close to the location of the M4-M5 Link ventilation facility at Campbell Road, St Peters. However, the height of the existing buildings at these locations is less than five metres. The results show that there would not be any significant impact on existing buildings however consideration would need to be given to detailed assessment of any future high rise buildings planned for these locations.

Maximum 24 hour $PM_{2.5}$

Figure 9-68 and **Figure 9-69** present the contour plots showing the changes in maximum 24 hour $PM_{2.5}$ concentration in the 2033-DSC scenario at receptor heights of 10 metres and 30 metres respectively. There are no existing buildings greater than 10 metres in height at the RWR receptor locations.

At a height of 10 metres, the maximum changes in concentration were slightly lower than at ground level but, as with the annual mean, the distributions of changes were quite similar. The largest increase in 24 hour $PM_{2.5}$ at the height of 10 metres for the RWR receptors was 6 $\mu g/m^3$, which can be compared with the maximum increase for any ground-level RWR receptor in the 2033-DSC scenario of 7.7 $\mu g/m^3$. Where there was an increase in $PM_{2.5}$ at the height of 10 metres, this was greater than 2.5 $\mu g/m^3$ (10 per cent of the assessment criterion) for 0.1 per cent of receptors locations (compared with 0.2 per cent at ground level).

At the height of 30 metres the largest increases in the maximum 24 hour $PM_{2.5}$ concentrations were again in the vicinity of the ventilation outlets, and these largest increases were greater than those at 10 metres and ground level. Again, there was a large increase of 36.6 $\mu g/m^3$ at one industrial location. There was predicted to be an increase in maximum 24 hour $PM_{2.5}$ of more than 2.5 $\mu g/m^3$ (10 per cent of the assessment criterion) at 86 (0.1 per cent) receptors. Of these, 67 were at residential locations, and of these 67, the ones with the largest increases were close to the location of the M4-M5 Link ventilation facility at St Peters. Again, the actual height of buildings at these locations was less than 10 metres so no actual exposures would occur at a height of 30 metres.

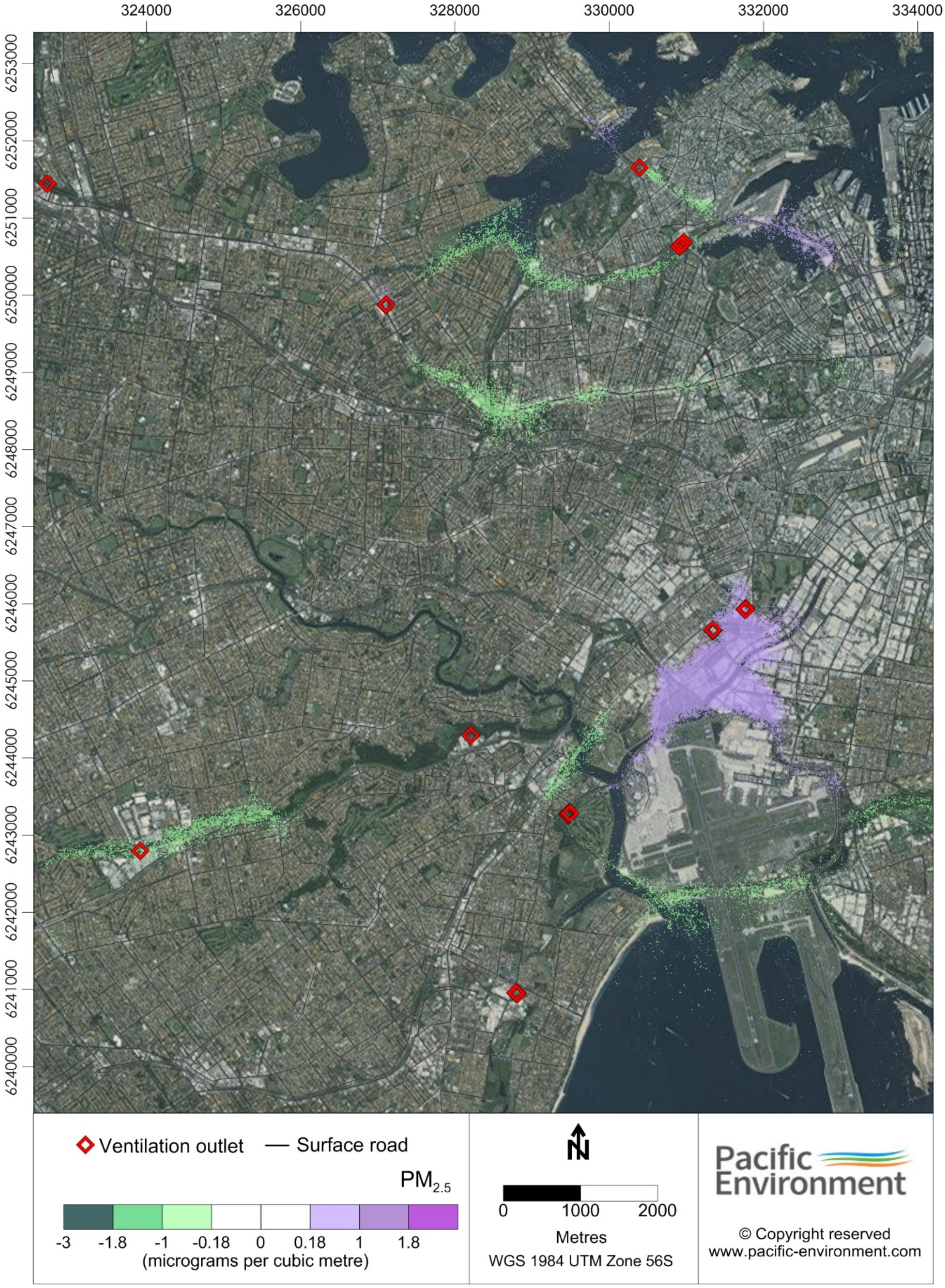

Figure 9-66 Contour plot of change in annual mean $PM_{2.5}$ concentration in 2033-DSC minus 2033-DM, 10 metre receptor height

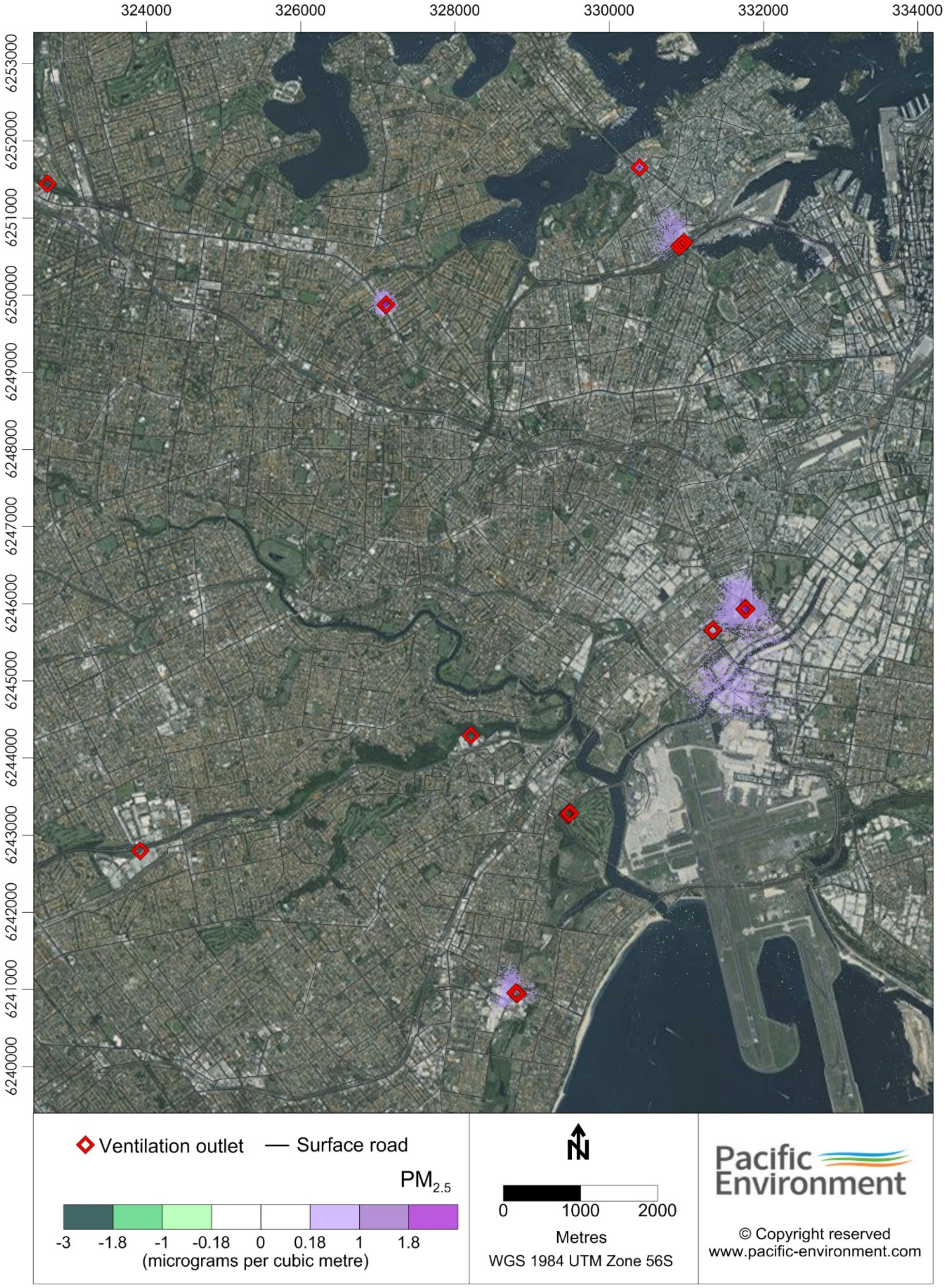

Figure 9-67 Contour plot of change in annual mean $PM_{2.5}$ concentration in the 2033-DSC minus 2033-DM, 30 metre receptor height

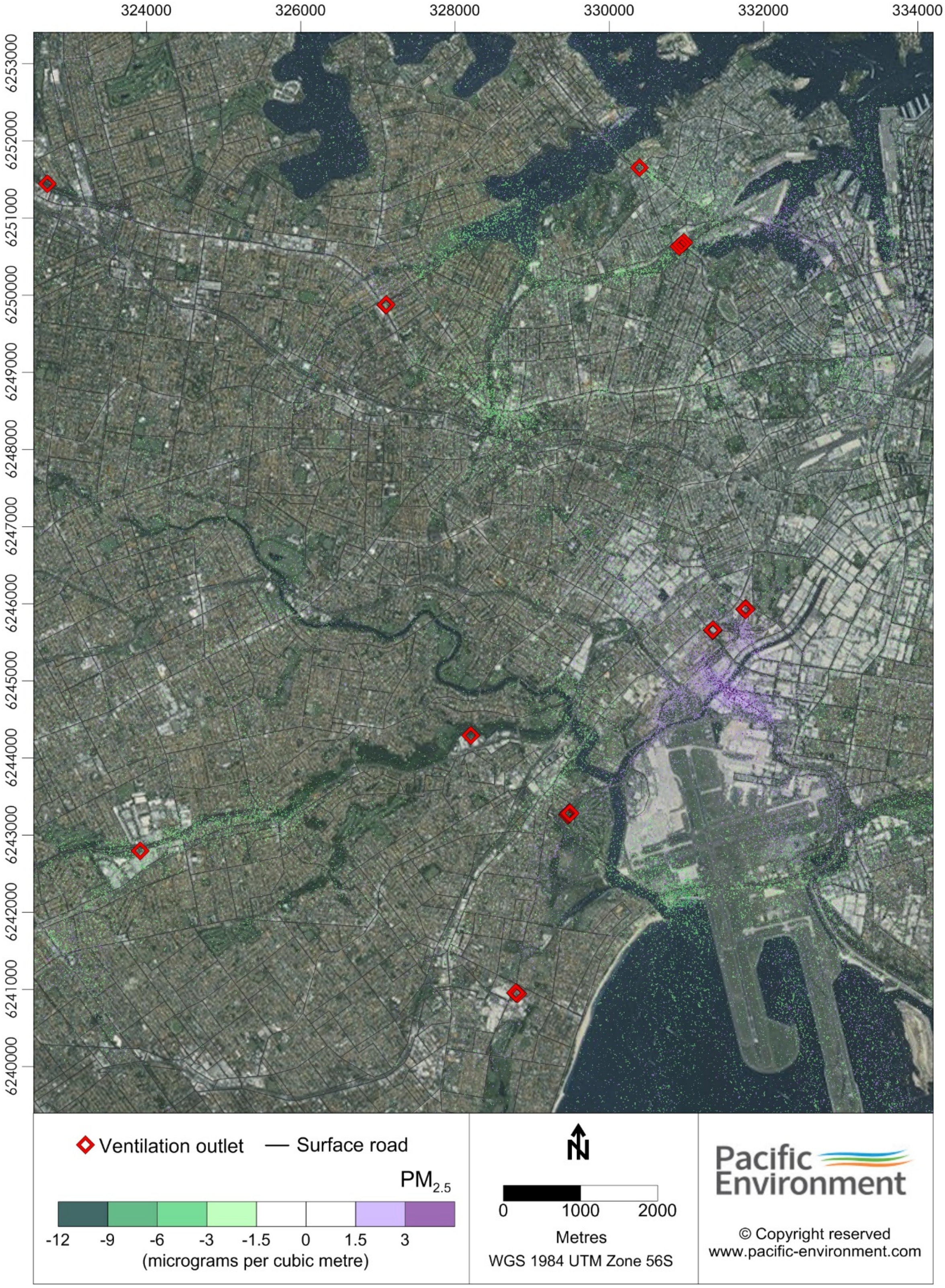

Figure 9-68 Contour plot for change in maximum 24 hour $PM_{2.5}$ concentration (2033-DSC minus 2033-DM, 10 metre receptor height)

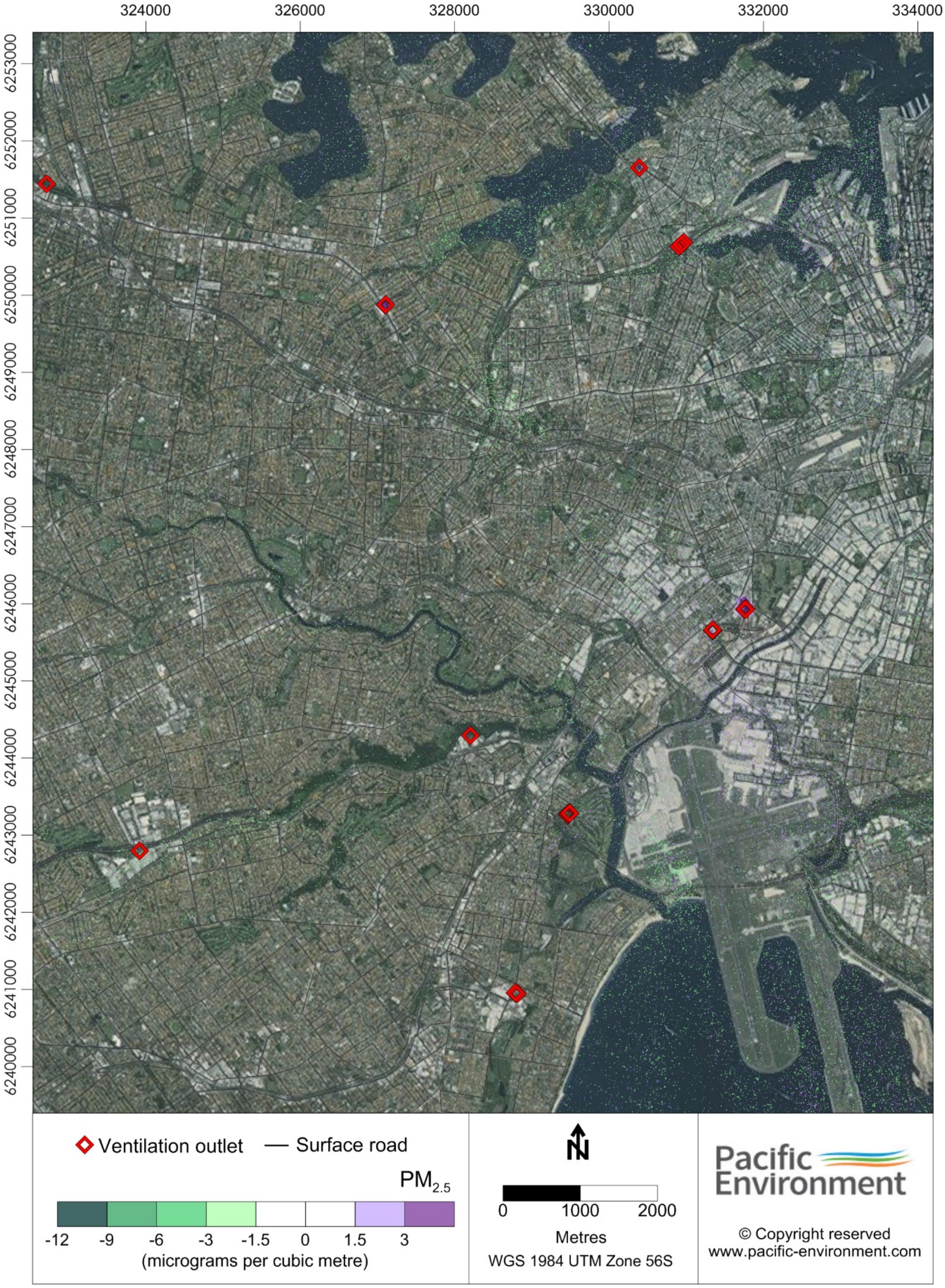

Figure 9-69 Contour plot for change in maximum 24 hour $PM_{2.5}$ concentration (2033-DSC minus 2033-DM, 30 metre receptor height)

Summary

The implications of the results for elevated receptors can be summarised as follows:

- For all receptor locations, the changes in $PM_{2.5}$ concentration at 10 metres are acceptable
- Future developments to the height of 10 metres should be possible at all locations in the study area. This assumes that the changes in $PM_{2.5}$ concentration for heights between ground level and 10 metres are also acceptable. This is a reasonable assumption because the influence of surface roads diminishes by 10 metres, so that the largest changes at 10 metres were smaller than the changes at ground level
- The predictions do not indicate the need for any restrictions on future developments to 30 metres height, except in the immediate vicinity of ventilation outlets, in particular at St Peters:
  - The ventilation outlets were predicted not to result in adverse air quality impacts at any existing receptors as there are no existing buildings 30 metres or higher located close to the proposed ventilation facilities at St Peters
  - Planning controls should be developed in the vicinity of St Peters to ensure future developments at heights 30 metres or higher are not adversely impacted by the ventilation outlets. Development of planning controls would need to be supported by detailed modelling addressing all relevant pollutants and averaging periods.

9.7.6 Results for regulatory worst case scenarios

The following sections highlight the results of these scenarios for the receptors with the largest impacts. As noted in the methodology, a more detailed approach was required for NO_2 than for the other pollutants. The objective of these scenarios was to demonstrate that compliance with the concentration limits for the tunnel ventilation outlets would deliver acceptable ambient air quality. The scenarios assessed emissions from the ventilation outlets only, with concentrations fixed at the limits. This represented the theoretical maximum changes in air quality for all potential traffic operations in the tunnel, including unconstrained and worst case traffic conditions from an emissions perspective, as well as vehicle breakdown situations.

Further detail of the regulatory worst case scenarios is in **Appendix I** (Technical working paper- Air Quality). The analysis was undertaken to assist regulatory authorities in assessing and determining potential ventilation outlet concentration limits that could be applied to the ventilation outlets through conditions of approval. Assuming that concentration limits are applied to the ventilation outlets, the results of the analysis would demonstrate the air quality performance of the project if it operates continuously at the limits. In reality, ventilation outlet concentrations would only occasionally approach the concentration limits under heavy traffic or incident conditions. Ventilation and traffic management would be used to avoid reaching concentration limits to avoid exceeding the limits. Experience in operating tunnels in Sydney shows that normal tunnel operations including congested traffic cases, are well below outlet limits.

CO and PM

The results for CO, PM_{10} and $PM_{2.5}$ in the regulatory worst case scenario (RWC-2033-DSC only) are given in **Table 9-27**. The table shows the maximum contribution of tunnel ventilation outlets at any of the RWR receptors in this scenario, as well as the maximum contribution at any residential receptor. For most of the pollutant metrics, the results were the same in both cases.

Table 9-27 Results of regulatory worst case assessment (RWR receptors) – CO and PM

Pollutant and period	Units	Maximum ventilation outlet contribution at any receptor					
		Regulatory worst case scenario (RWC-2033-DSC)		Expected traffic scenarios			
		All receptors	Residential receptors	2023-DS	2023-DSC	2033-DS	2033-DSC
CO (1 h)	(mg/m^3)	0.50	0.50	0.06	0.07	0.06	0.07
PM_{10} (annual)	($\mu g/m^3$)	1.01	1.01	0.24	0.37	0.24	0.30

Pollutant and period	Units	Maximum ventilation outlet contribution at any receptor					
		Regulatory worst case scenario (RWC-2033-DSC)		Expected traffic scenarios			
		All receptors	Residential receptors	2023-DS	2023-DSC	2033-DS	2033-DSC
PM_{10} (24 h)	(µg/m^3)	4.51	4.06	1.25	1.94	1.23	1.50
$PM_{2.5}$ (annual)[(a)]	(µg/m^3)	1.01	1.01	0.17	0.25	0.17	0.21
$PM_{2.5}$ (24 h)[(a)]	(µg/m^3)	4.51	4.06	0.81	1.23	0.81	1.01

Note:

(a) The same emission rates were used for PM_{10} and $PM_{2.5}$.

The concentrations in the regulatory worst case scenario were higher than those for the expected traffic scenarios in all cases, and the following points are noted for the former:

- The maximum one hour CO concentration was negligible, especially taking into account the fact that CO concentrations are well below the NSW impact assessment criterion. For example, the maximum one hour outlet contribution in the regulatory worst case scenario (0.50 mg/m^3) was a very small fraction of the criterion (30 mg/m^3). The maximum background one hour CO concentration (3.27 mg/m^3) was also well below the criterion. Exceedances of the criterion are therefore highly unlikely
- For PM_{10} the maximum contributions of the ventilation outlets are predicted to be small. For both the annual mean and maximum 24 hour metrics the outlet contributions were less than 10 per cent of the respective criteria
- The ventilation outlet contribution would be most important for $PM_{2.5}$, with the maximum contributions equating to 13 per cent and 18 per cent of the annual mean and 24 hour criteria respectively. Again, any exceedances of the criteria would be dominated by background concentrations.

NO_X and NO_2

The results of the more detailed assessment for NO_2 at the M4-M5 Link ventilation facilities are shown in **Appendix I** (Technical working paper: Air quality). The criterion was not exceeded in any of the project scenarios.

Total hydrocarbons and air toxics

The maximum outlet concentrations for the four specific air toxics considered in the regulatory worst-case assessment (scenario RWC-2033-DSC only) were determined using the THC predictions in conjunction with the speciation profiles stated in **Appendix I** (Technical working paper: Air quality). The results are given in **Table 9-28**. The Table shows the maximum contribution of tunnel ventilation outlets at any of the RWR receptors in this scenario (for most of the pollutant metrics these were residential receptors). The outlet contributions to the specific air toxics are well below the impact assessment criteria in the NSW EPA Approved Methods.

Table 9-28 Results of regulatory worst case assessment (RWR receptors) – air toxics (ventilation outlets only)

Pollutant and period	Units	Maximum ventilation outlet contribution at any receptor	
		Regulatory worst case scenario (RWC-2033-DSC)	Impact assessment criterion (µg/m^3)
THC (annual)	(µg/m^3)	3.65	-
THC (1 hour)	(µg/m^3)	55.29	-
Benzene (1 hour)	(µg/m^3)	2.20	29
PAH (BaP) (1 hour)	(µg/m^3)	0.016	0.4
Formaldehyde (1 hour)	(µg/m^3)	1.83	20
1,3-butadiene (1 hour)	(µg/m^3)	0.59	40

Table 9-29 shows that, even if the maximum outlet contribution is added to the maximum increase in concentration with the project (which implies some double counting), the results are still well below the impact assessment criteria.

Table 9-29 Results of regulatory worst case assessment (RWR receptors) – air toxics (ventilation outlets plus traffic)

Pollutant and period	Units	Maximum outlet contribution at any receptor	Maximum increase due to project (outlet + expected traffic)	Sum	Impact assessment criteria
THC (1 hour)	(μg/m^3)	55.29	-	-	-
Benzene (1 hour)	(μg/m^3)	2.20	3.08	5.28	*29*
PAH (BaP) (1 hour)	(μg/m^3)	0.016	0.035	0.051	*0.4*
Formaldehyde (1 hour)	(μg/m^3)	1.83	3.59	5.42	*20*
1,3-butadiene (1 hour)	(μg/m^3)	0.59	0.84	1.43	*40*

9.7.7 Sensitivity tests

In the EISs for the M4 East and New M5 projects, several sensitivity tests were conducted for various model inputs (Pacific Environment 2015). These included:

- The influence of ventilation outlet temperature
- The influence of ventilation outlet height
- The inclusion of buildings near tunnel ventilation outlets.

These tests were based upon a sub-area of the M4 East and New M5 GRAL domains of about two to three kilometres around the project ventilation outlets. Only the ventilation outlet contribution, and annual mean $PM_{2.5}$ and maximum 24 hour $PM_{2.5}$, were included in the tests. A sub-set of sensitive receptors was evaluated. The predicted concentrations were indicative, as the aim of the sensitivity tests was to assess the proportional sensitivity of the model to specific input parameters.

As the parameters for the tests from both the M4 East and New M5 projects were very similar to that for M4-M5 Link, the outcomes from those projects would also apply to the M4-M5 Link project.

The following sections present a summary of the tests.

Ventilation outlet temperature

The ventilation outlet temperatures for the M4 East and New M5 projects were around 25ºC. For this test, the effects of using outlet temperatures 10˚C below, and above, this value were modelled.

The results of the tests showed that the predicted concentrations for the ventilation outlets were higher for the lower temperature (by a factor of, on average, around 1.5). The predicted concentrations for both projects remained well below the standards for $PM_{2.5}$, and made up a very small proportion of the total combined results (for surface roads and ventilation outlets). Even with a significant change in ventilation outlet temperature, the total predicted concentration (roads and ventilation outlets) is unlikely to be significantly affected.

Ventilation outlet height

The height of the ventilation outlets for the M4 East and New M5 projects was around 30 metres. For this test, the effects of using outlet heights 10 metres below and above this value were modelled. The results for both projects were similar to those for the temperature sensitivity tests, with the lower outlet resulting in concentrations that were around 1.3 times greater, on average, than the higher outlet. Again, ventilation outlet height is unlikely to represent a large source of uncertainty in the overall predictions.

Buildings

The sensitivity of the inclusion of buildings to predicted concentrations was assessed in both the M4 East and New M5 projects. Modelling of the ventilation outlet was undertaken using inclusion and exclusion scenarios of the closest buildings.

The results showed that, when buildings were included, there was an average increase in concentrations associated with the ventilation outlet by a factor of about 1.3 to 1.5. Whilst these tests were not comprehensive, they indicated that the inclusion or exclusion of buildings is unlikely to represent a large source of uncertainty in the overall predictions. The total predicted concentrations, and the conclusions of the assessment, would not change significantly with the inclusion of buildings.

9.8 Regional air quality

The changes in the total emissions resulting from the project are shown in **Figure 9-70**, **Table 9-30** and **Table 9-31**.

These changes can be viewed as a proxy for the project's regional air quality impacts which, on the basis of the results, are likely to be negligible. For example:

- The increases in NO_X emissions for the assessed road network in a given year ranged from 71 to 174 tonnes per year. These values equate to a very small proportion (around 0.3 per cent) of anthropogenic NO_X emissions in the Sydney airshed in 2016 (around 53,700 tonnes)
- The increases in NOx in a given year are much smaller than the projected reductions in emissions between 2015 and 2033 (around 2,340 tonnes per year).

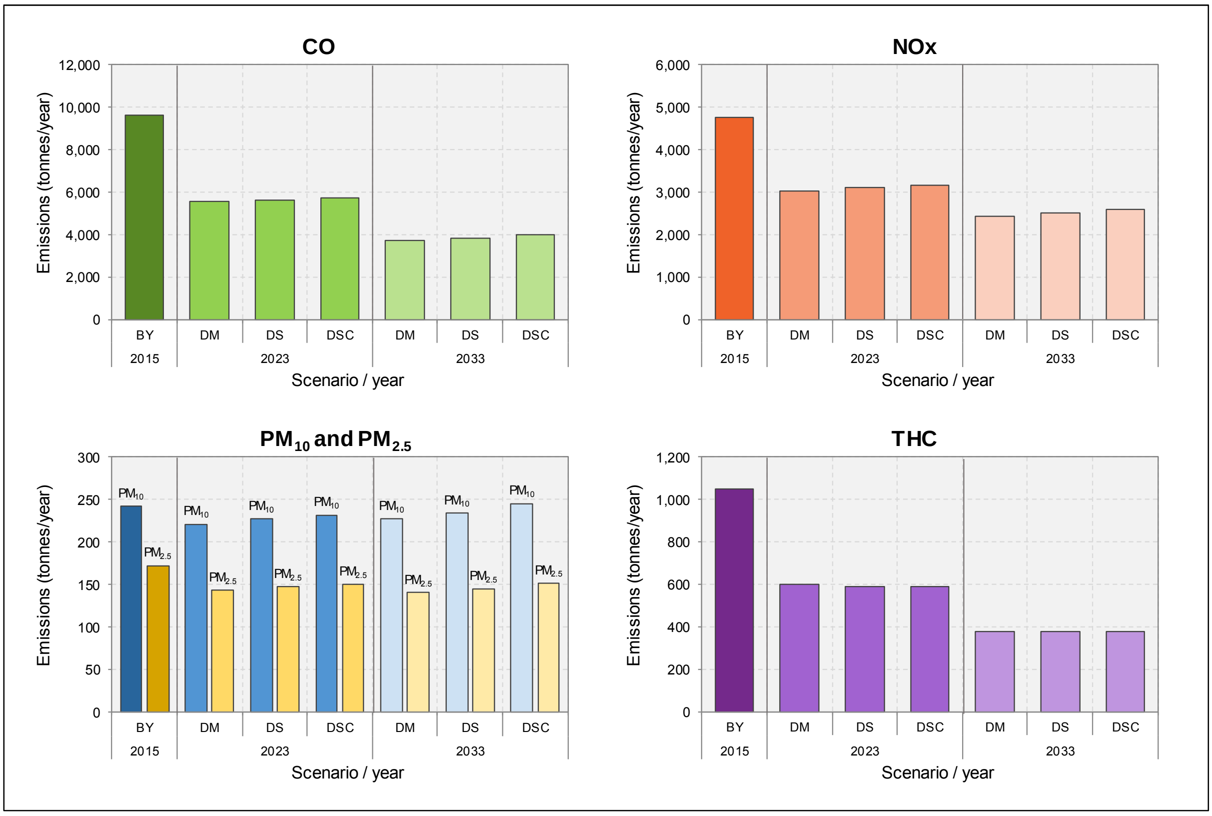

Figure 9-70 Total traffic emissions by pollutant in the WestConnex study area

Table 9-30 Total traffic emissions in the WestConnex study area

Scenario code	Scenario description	Total daily VKT[(a)] (million vehicle-km)	Total emissions (tonnes/year)				
			CO	NOx	PM_{10}	$PM_{2.5}$	THC
2015-BY	2015 – Base Year (existing conditions)	11.5	9,633	4,775	242	173	1,052
2023-DM	2023 – Do Minimum (no M4-M5 Link)	13.2	5,561	3,037	221	143	599
2023-DS	2023 – Do Something (with M4-M5 Link)	13.8	5,648	3,108	227	147	590
2023-DSC	2023 – Do Something Cumulative (with M4-M5 Link and some other projects)	14.3	5,737	3,164	232	150	589
2033-DM	2033 – Do Minimum (no M4-M5 Link)	14.5	3,719	2,434	227	140	380
2033-DS	2033 – Do Something (with M4-M5 Link)	15.2	3,837	2,506	234	145	376
2033-DSC	2033 – Do Something Cumulative (with M4-M5 Link and all other projects)	16.1	4,005	2,609	245	152	380

Note:

(a) VKT = vehicle kilometres travelled

Table 9-31 Absolute changes in total traffic emissions in the WestConnex study area

Scenario comparison	Change in total emissions (tonnes/year)				
	CO	NOx	PM_{10}	$PM_{2.5}$	THC
Underlying changes in emissions with time[(a)]					
2023-DM vs 2015-BY	-4,072	-1,738	-21	-30	-453
2033-DM vs 2015-BY	-5,914	-2,341	-15	-32	-672
Changes due to the project in a given year					
2023-DS vs 2023-DM	+87	+71	+6	+4	-9
2023-DSC vs 2023-DM	+176	+127	+11	+7	-10
2033-DS vs 2033-DM	+118	+72	+7	+4	-4
2033-DSC vs 2033-DM	+286	+174	+18	+11	-1

Note:

(a) The 2023-DM and 2033-DM scenarios include the M4-East and New M5 projects. The 2015-BY scenario does not.

The regional air quality impacts of a project can also be described in terms of its capacity to influence ozone production. NSW EPA has developed a *Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources* (ENVIRON 2011). Although this procedure does not relate specifically to road projects, it was applied here to give an indication of the likely significance of the project's effect on ozone concentrations in the broader Sydney region.

The first step in the procedure involved the classification of the region within which the project is to be located as either an ozone 'attainment' or 'non-attainment' area, based on measurements from OEH monitoring stations over the past five years and criteria specified in the procedure. Following this approach, the project was identified as being in an ozone non-attainment area.

The second step involved the evaluation of the change in emissions due to the project against thresholds for NO_X and VOCs. For both attainment and non-attainment areas the procedure gives an emission threshold for NO_X and VOCs (separately) of 90 tonnes per year for new sources, above which a detailed modelling assessment for ozone may be required. Some lower thresholds are also specified for modified sources and for the scale of ozone non-attainment.

The results in **Table 9-32** show that for the 2023-DSC and 2033-DSC scenarios, the increases in NOX emissions with the project (127 and 174 tonnes per year respectively) were above the 90 tonnes per year threshold. In such cases, the procedure specifies that a ‘Level 1’ assessment is to be undertaken using a screening tool provided by the NSW EPA[9]. The tool estimates the increases in one hour and four hour ground level ozone concentrations, based on an input of emissions of CO, NO_x and VOC (THC) in tonnes per day. For sources located within ozone non-attainment areas, the incremental increases in ozone concentration predicted by the tool are compared against a screening impact level (SIL) of 0.5 ppb, and against a maximum allowable increment of one ppb. In cases where the maximum ozone increment is below the SIL and/or below the relevant maximum allowable increment, further ozone impact assessment is not required, but a best management practice (BMP) determination should be undertaken for the source. The results from the tool, shown in **Appendix I** (Technical working paper: Air quality) show that the project increment is below the SIL.

Table 9-32 Results from ozone screening tool

Scenario	Change in emissions with the project (tonnes per day)			Incremental O_3 concentration (ppb)		SIL (ppb)
	CO	NOx	THC	Max. 1 hour	Max. 4 hour	
2023-DSC	+0.483	+0.349	-0.026	0.13	0.11	0.50
2033-DSC	+0.784	+0.478	-0.002	0.17	0.15	

Overall, it is concluded that the regional impacts of the project would be negligible, and undetectable in ambient air quality measurements at background locations.

9.9 Odour

For each of the RWR receptors, the change in the maximum one hour THC concentration as a result of the project was calculated. The largest change in the maximum one hour THC concentration across all receptors was then determined, and this was converted into an equivalent change for three of the odorous pollutants identified in the NSW EPA Approved Methods (toluene, xylenes, and acetaldehyde). These pollutants were taken to be representative of other odorous pollutants from motor vehicles.

The changes in the levels of three odorous pollutants as a result of the project, and the corresponding odour assessment criteria from the NSW EPA Approved Methods, are given in **Table 9-33**.

Table 9-33 Comparison of changes in odorous pollutant concentrations with criteria in NSW EPA Approved Methods (RWR receptors)

Scenario	Largest increase in maximum one hour THC concentration relative to Do Minimum scenario (μg/m^3)	Largest increase in maximum one hour concentration for specific compounds		
		Toluene (μg/m^3)	Xylenes (μg/m^3)	Acetaldehyde (μg/m^3)
2023-DS	141.0	10.8	8.9	2.0
2023-DSC	137.1	10.5	8.6	1.9
2033-DS	110.8	7.0	5.8	2.0
2033-DSC	98.9	6.3	5.2	1.8
Odour criterion (μg/m^3)		360	190	42

The change in the maximum one hour concentration of each pollutant was well below the corresponding odour assessment criterion in the NSW EPA Approved Methods.

[9] http://www.epa.nsw.gov.au/air/appmethods.htm.

9.9.1 Overview

The SEARs for the project require details of, and justification for, the air quality management measures that have been considered. This section of the report firstly reviews the measures that are available for improving tunnel-related air quality, and then describes their potential application in the context of the project. The measures have been categorised as follows:

- Tunnel design
- Ventilation design and control
- Air treatment systems
- Emission controls and other measures.

9.10 Environmental management measures

9.10.1 Construction impacts

Mitigation and management measures for potential ambient air quality impacts during construction are shown in **Table 9-34**. Most of these measures are routinely employed as 'standard practice' on construction sites.

It is acknowledged there is potential for crystalline silica emissions to occur during tunnel excavation due to the high temperatures caused at the excavation face. The potential for crystalline silica to be released is primarily relevant to occupational exposure, and would be managed in accordance with relevant NSW and Australian guidelines. The controls would effectively eliminate its discharge into the atmosphere. Safe work method statements would be developed as part of the project safety management system. In relation to non-occupational exposures the World Health Organization (WHO 2000a) states 'there are no known adverse health effects associated with the non-occupational exposures to quartz' (where quartz is crystalline silica).

A Construction Air Quality Management Plan (CAQMP) will be produced (as a sub-plan to the Construction Environmental Management Plan) to address the construction impacts of the M4-M5 Link project. The CAQMP will contain details of the site-specific mitigation measures to be applied. Additional guidance on the control of dust at construction sites in NSW is provided as part of the NSW EPA Local Government Air Quality Toolkit[10]. Detailed guidance is also available from the United Kingdom (GLA 2006) and the United States of America (Countess Environmental 2006). Dust control procedures will be included as part of the CAQMP.

Table 9-34 Mitigation for all sites: communication

	Mitigation measure	All scenarios 1 – 7
1	Communication, notification and complaints handling requirements regarding air quality matters will be managed through the Community Communication Strategy (CCS).	Highly recommended

Table 9-35 Mitigation for all sites: dust management

	Mitigation measure	All scenarios 1 – 7
2	A Construction Air Quality Management Plan will be developed and implemented to monitor and manage potential air quality impacts associated with the construction for the project. The Plan will be implemented for the duration of construction.	Highly recommended

[10] http://www.epa.nsw.gov.au/air/lgaqt.htm.

	Mitigation measure	All scenarios 1 – 7
Site management		
3	Regular communication to be carried out with sites in close proximity to ensure that measures are in place to manage cumulative dust impacts.	Highly recommended
Monitoring		
4	Regular site inspections will be conducted to monitor for potential dust issues. The site inspection, and issues arising, will be recorded.	Highly recommended
Preparing and maintaining the site		
5	Construction activities with the potential to generate dust will be modified or ceased during unfavourable weather conditions to reduce the potential for dust generation.	Highly recommended
6	Measures to reduce potential dust generation, such as the use of water carts, sprinklers, dust screens and surface treatments, will be implemented within project sites as required.	Highly recommended
7	Unsealed access roads within project sites will be maintained and managed to reduce dust generation.	Highly recommended
8	Where reasonable and feasible, appropriate control methods will be implemented to minimise dust emissions from the project site.	Highly recommended
9	Storage of materials that have the potential to result in dust generation will be minimised within project sites at all times.	Highly recommended
Operating vehicle/machinery and sustainable travel		
10	All construction vehicles and plant will be inspected regularly and maintained to ensure that they comply with relevant emission standards.	Highly recommended
11	Engine idling will be minimised when plant is stationary, and plant will be switched off when not in use to reduce emissions.	Highly recommended
12	The use of mains electricity will be favoured over diesel or petrol-powered generators where practicable to reduce site emissions.	Highly recommended
13	Haul roads will be treated with water carts and monitored during earthworks operations, ceasing works if necessary during high winds where dust controls are not effective.	Highly recommended
Construction		
14	Suitable dust suppression and/or collection techniques will be used during cutting, grinding or sawing activities likely to generate dust in close proximity to sensitive receivers.	Highly recommended
15	The potential for dust generation will be considered during the handling of loose materials. Equipment will be selected and handling protocols developed to minimise the potential for dust generation.	Highly recommended
16	All vehicles loads will be covered to prevent escape of loose materials during transport.	Highly recommended

Table 9-36 Mitigation specific to demolition

	Mitigation measure	Scenario						
		1	2	3	4	5	6	7
17	Demolition activities will be planned and carried out to minimise the potential for dust generation.	Desirable	Highly recommended			Desirable	Highly recommended	Desirable
18	Adequate dust suppression will be applied during all demolition works required to facilitate the project.	Desirable	Highly recommended					
19	All potentially hazardous material will be identified and removed from buildings in an appropriate manner prior to the commencement of demolition.	Desirable	Highly recommended					

Table 9-37 Mitigation specific to earthworks

	Mitigation measure	Scenario						
		1	2	3	4	5	6	7
20	Areas of soil exposed during construction will be minimised at all times to reduce the potential for dust generation.	Not required	Desirable		Highly recommended			
21	Exposed soils will be temporarily stabilised during weather conditions conducive to dust generation and prior to extended periods of inactivity to prevent dust generation.	Not required	Desirable		Highly recommended			
22	Exposed soils will be permanently stabilised as soon as practicable following disturbance to minimise the potential for ongoing dust generation.	Not required	Desirable		Highly recommended			

Table 9-38 Mitigation specific to construction

	Mitigation measure	Scenario 1	2	3	4	5	6	7
23	Ensure sand and other aggregates are stored in bunded areas and are not allowed to dry out, unless this is required for a particular process, in which case ensure that appropriate additional control measures are in place.	Highly recommended						
24	Ensure fine materials are stored and handled to minimise dust.	Desirable			Highly recommended			

Table 9-39 Mitigation specific to track-out of loose material onto roads

	Mitigation measure	All scenarios 1 – 7
25	Deposits of loose materials will be regularly removed from sealed surfaces within and adjacent to project sites to reduce dust generation.	Highly recommended
26	During establishment of project ancillary facilities, controls such as wheel washing systems and rumble grids will be installed at site exits to prevent deposition of loose material on sealed surfaces outside project sites to reduce potential dust generation.	Highly recommended

9.10.2 Operational impacts

The SEARs for the project require details of, and justification for, the air quality management measures that were considered for the project. This section reviews the environmental management measures that are available for improving tunnel-related air quality, and then describes their potential application in the context of the project. The measures are categorised as follows:

- Tunnel design
- Ventilation design and control
- Air treatment systems
- Emission controls and other measures.

Tunnel design

Tunnel infrastructure is designed in such a way that the generation of pollutant emissions by the traffic using the tunnel is minimised. The main considerations are minimising gradients and ensuring that lane capacity remains constant or increases from entry to exit point. Traffic management can also be used to improve traffic flows, which results in reduced overall emissions.

Ventilation design and control

There are several reasons why a tunnel needs to be ventilated. The main reasons are:

- Control of the internal environment. It must be safe and comfortable to drive through the tunnel. Vehicle emissions must be sufficiently diluted so as not to be hazardous during normal operation, or when traffic is moving slowly or stationary
- Protection of the external environment. Ventilation, and the dispersion of pollutants, is the most widely used method for minimising the impacts of tunnels on ambient air quality. Collecting emissions and venting them via elevated ventilation outlets is a very efficient way of dispersing pollutants. Studies show that the process of removing surface traffic from heavily trafficked roads and releasing the same amount of pollution from an elevated location results in substantially lower concentrations at sensitive receptors (PIARC 2008)

- Emergency situations. When a fire occurs in a tunnel, the ventilation system is able to control the heat and smoke in the tunnel so as to permit safe evacuation of occupants, and to provide the emergency services with a safe route to deal with the fire and to rescue any trapped or injured persons.

The ventilation system design options that were considered for the project are discussed in **Chapter 4** (Project development and alternatives) and the system adopted for the project is described in **Chapter 5** (Project description).

Air treatment systems

There are several air treatment options for mitigating the effects of tunnel operation on both in-tunnel and ambient air quality. Where in-tunnel treatment technologies have been applied to road tunnels, these technologies have focused on the management and treatment of PM. The most common of these is the electrostatic precipitator (ESP), and this is discussed in detail in **Appendix I** (Technical working paper: Air quality). Information is provided on the method of operation, the international experience with ESPs in tunnels, and the effectiveness of systems. Other techniques include filtering, denitrification and biofiltration, agglomeration and scrubbing. These are described in **Appendix I** (Technical working paper: Air quality).

Emission controls and other measures

Various operational measures are available to manage in-tunnel emissions and ambient air quality. These include the following:

- Traffic management. Traffic management will be employed by tunnel operators to control exposure to vehicle-derived air pollution. Measures can include (PIARC 2008):
  - Allowing only certain types of vehicle
  - Regulating time of use
  - Tolling (including differential tolling by vehicle type, emission standard, time of day, occupancy)
  - Reducing traffic throughput
  - Lowering the allowed traffic speed
- Incident detection. Early detection of incidents and queues is essential to enable tunnel operators and the highway authority to put effective traffic management in place. Monitoring via CCTV cameras is normally a vital part of the procedure for minimising congestion within tunnels and allowing timely operator response to changes in traffic flow
- Public information and advice. Traffic lights, barriers, variable message signs, radio broadcasts, public address systems (used in emergencies) and other measures can help to provide driver information and hence influence driver behaviour in tunnels
- Cleaning the tunnel regularly assists in reducing concentrations of small particles (PIARC 2008), as is common practice in Sydney tunnels.

Detailed design of the In-tunnel monitoring system will be undertaken during future project development phases and will include the following:

- NO_x, NO_2, CO and visibility. Monitoring of each pollutant will be undertaken throughout the tunnel. The locations of monitoring equipment will generally be at the beginning and end of each ventilation section. This would include, for example, monitors at each entry ramp, exit ramp, merge point and ventilation exhaust and supply point. The location of monitors will be governed by the need to meet the in-tunnel air quality criteria for all possible journeys through the tunnel system, especially for NO_2. This will require sufficient, appropriately placed monitors to calculate a journey average
- Velocity monitors will be placed in each tunnel ventilation section and at portal entry and exit points. The velocity monitors in combination with the air quality monitors will be used to modulate the ventilation within the tunnel to manage air quality and to ensure net air inflow at all tunnel portals.