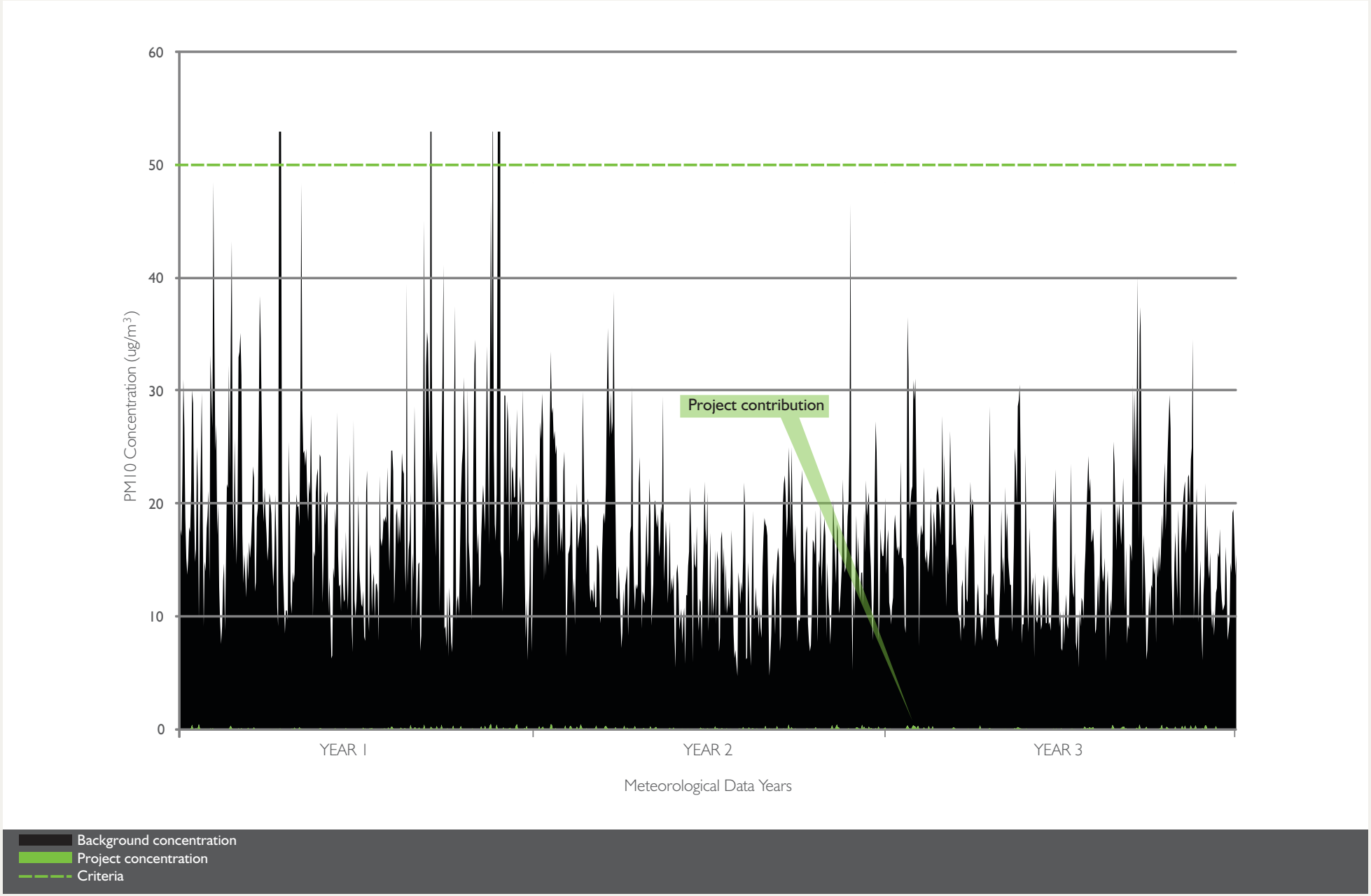

Figure 7-20 PM10 2019 24 hour average concentrations - northern ventilation facility

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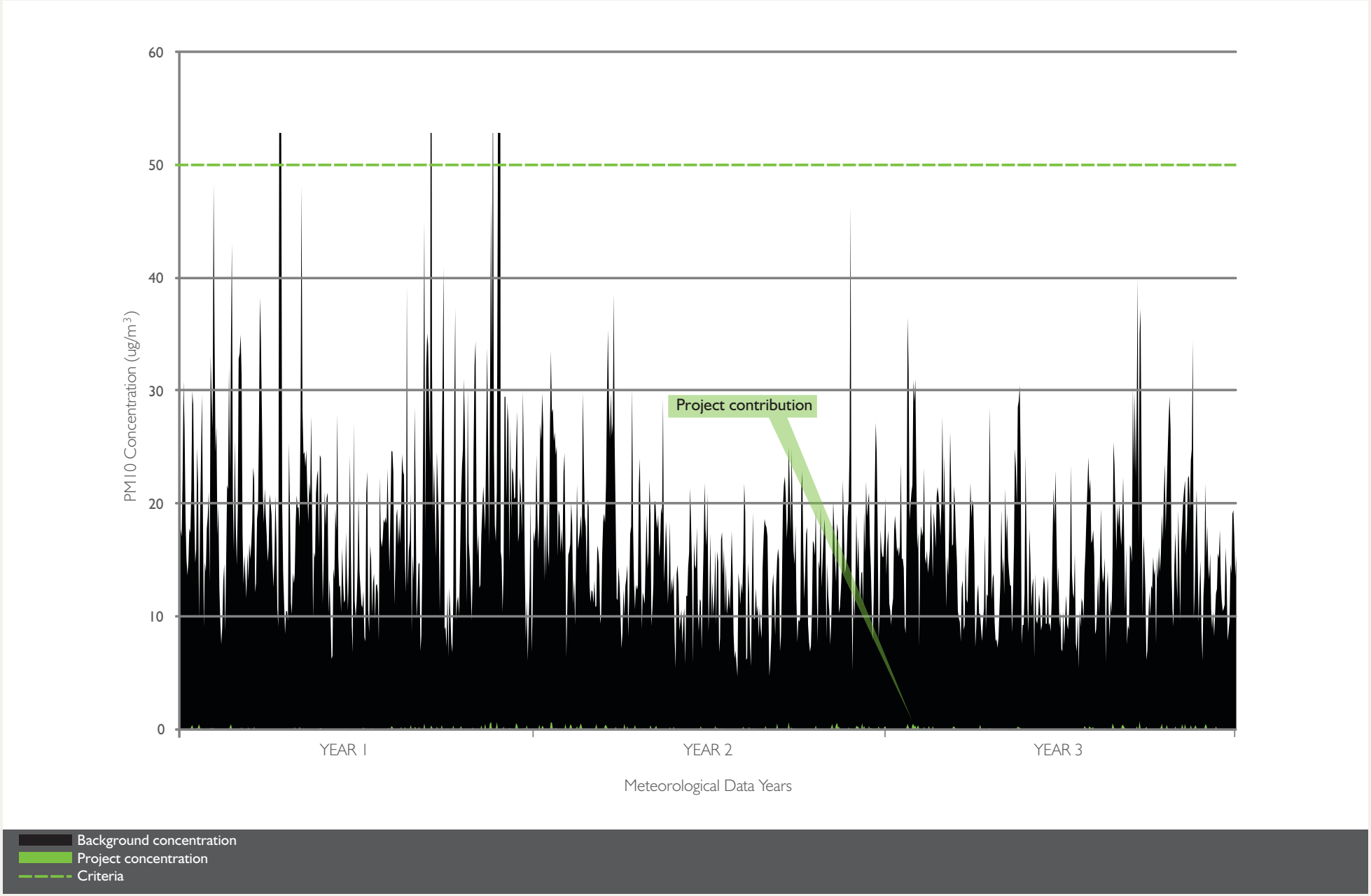

Figure 7-21 PM10 2029 24 hour average concentrations - northern ventilation facility

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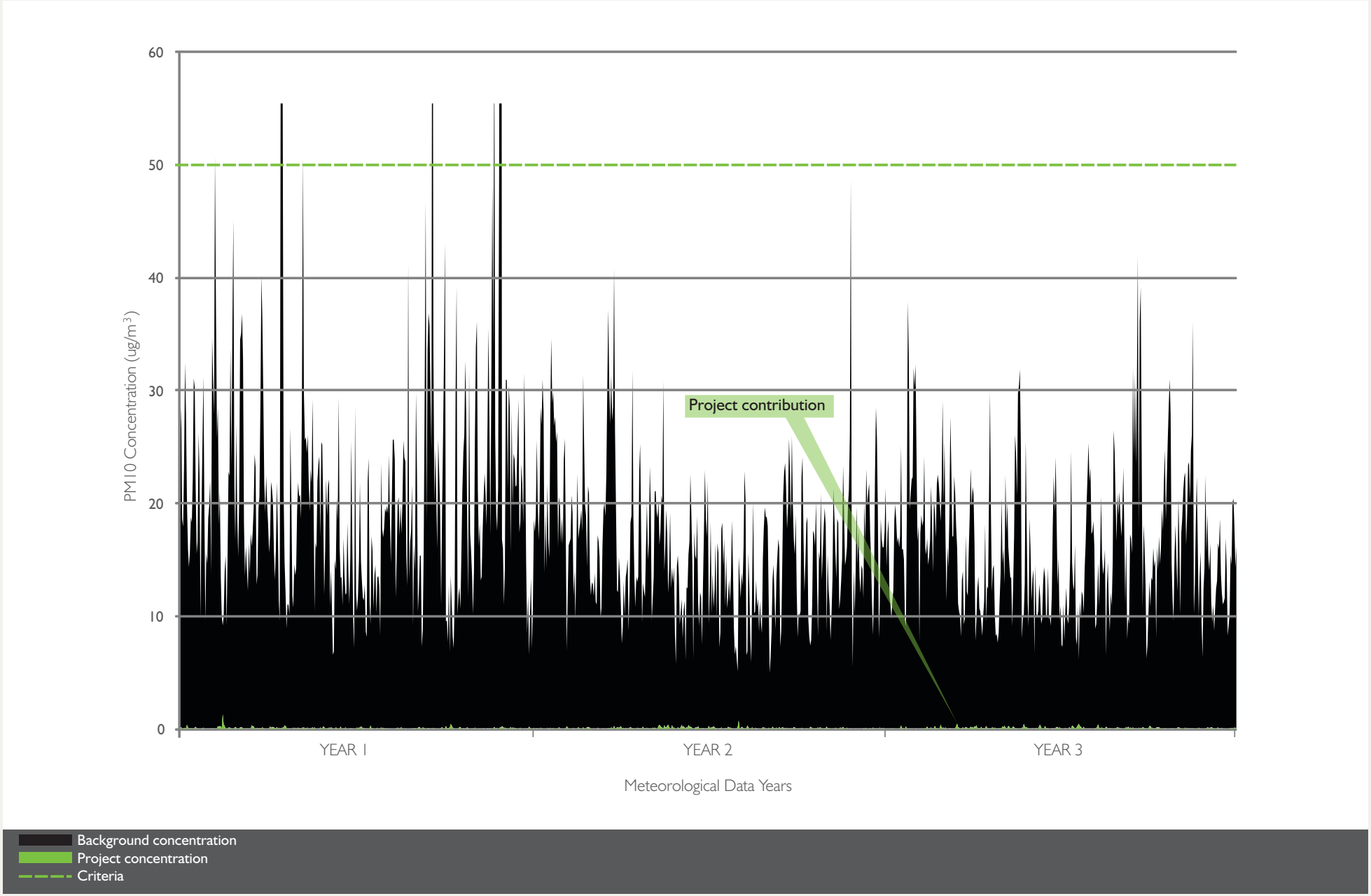

Figure 7-22 PM10 2019 24 hour average concentrations - southern ventilation facility

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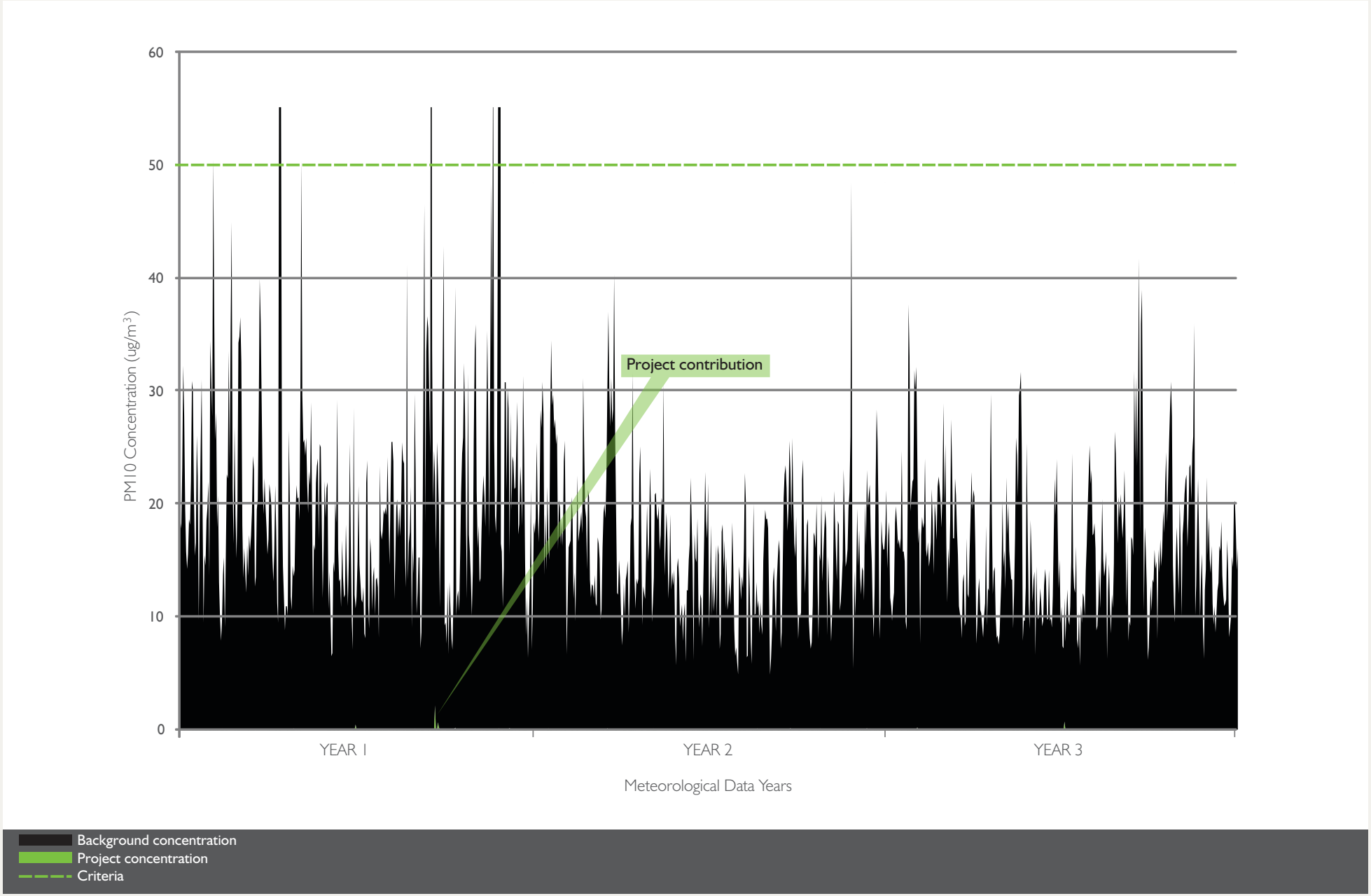

Figure 7-23 PM10 2029 24 hour average concentrations - southern ventilation facility

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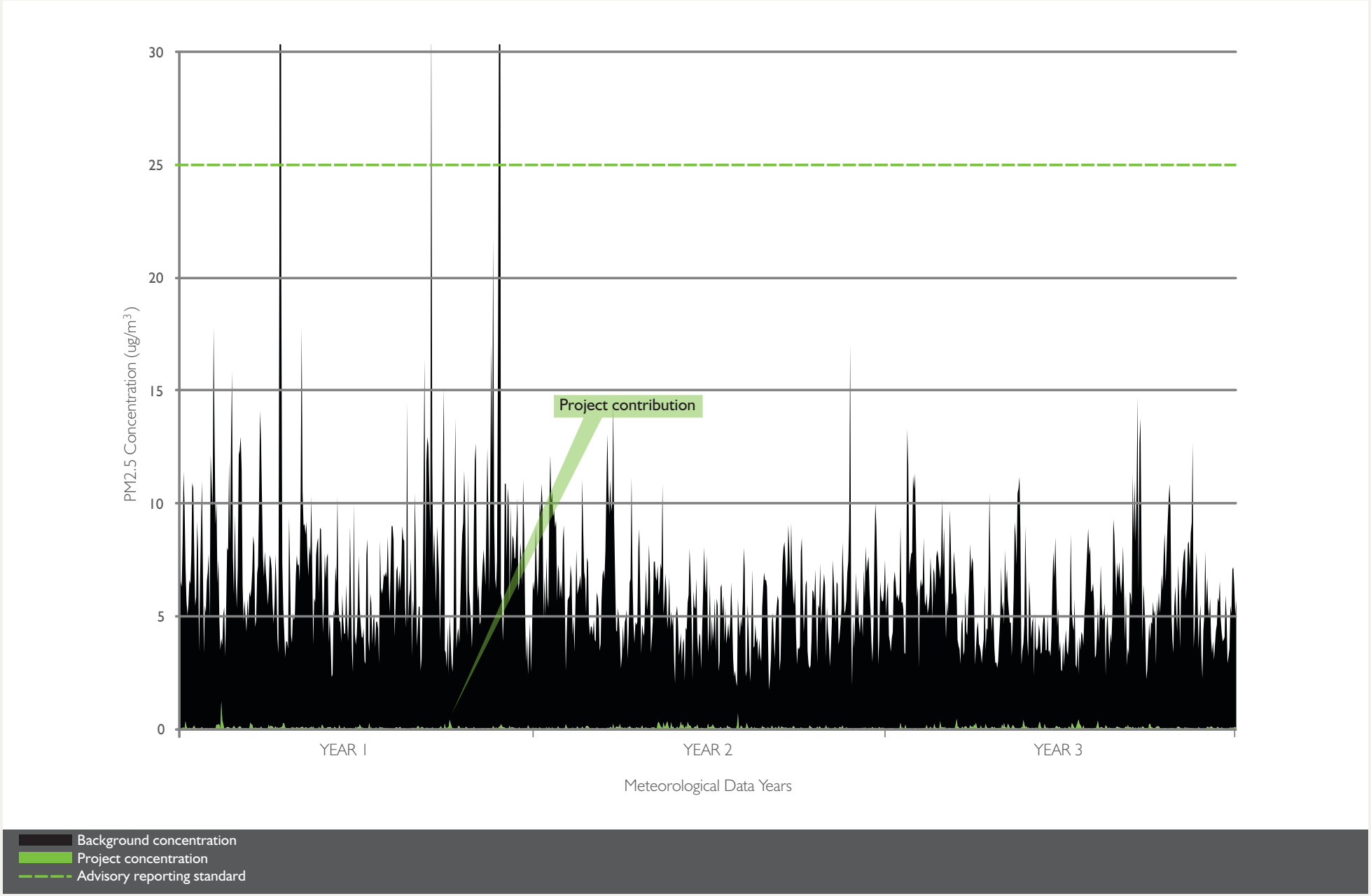

Figure 7-24 PM2.5 2019 24 hour average concentrations - northern ventilation facility

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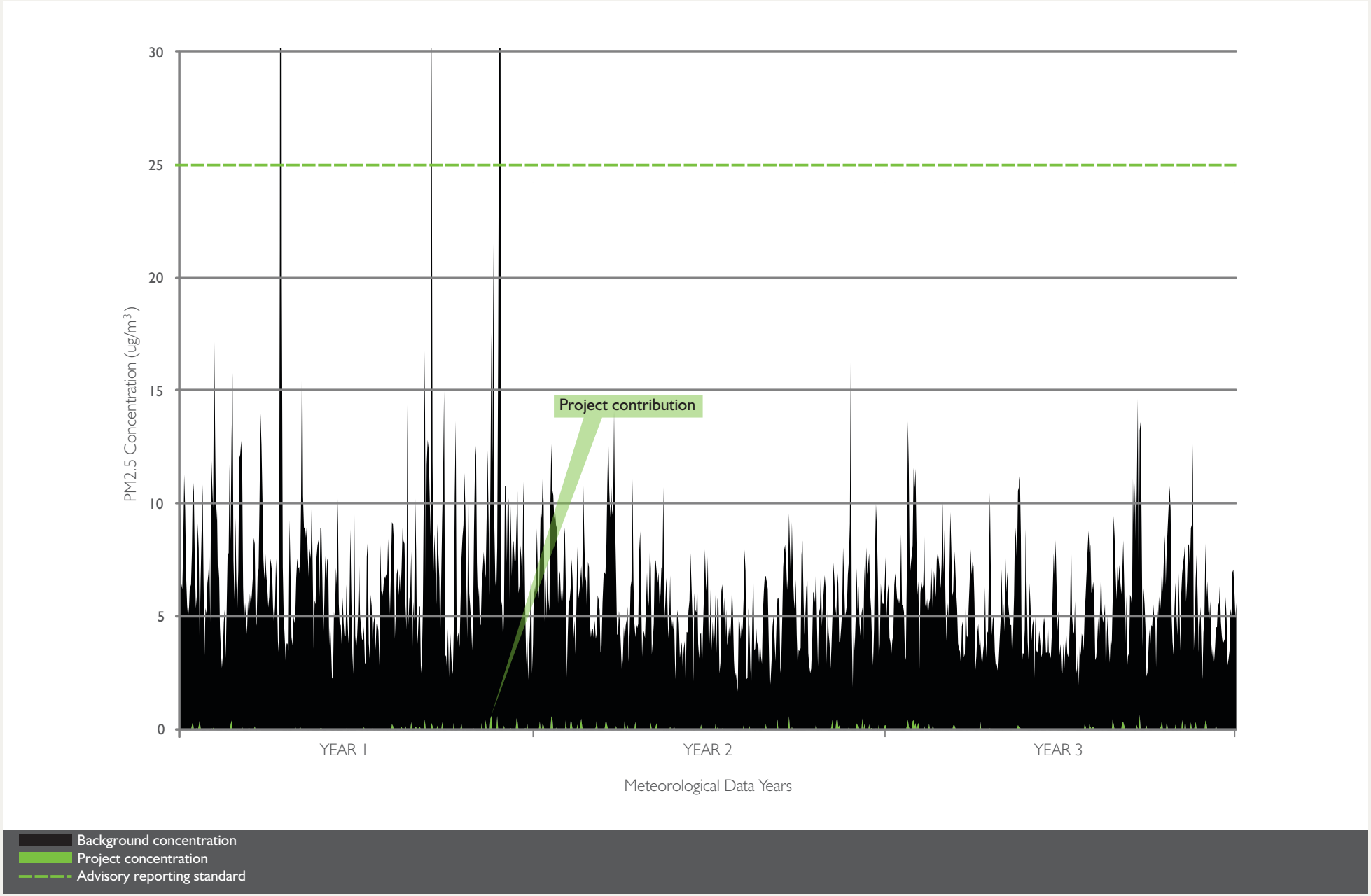

Figure 7-25 PM2.5 2029 24 hour average concentrations - northern ventilation facility

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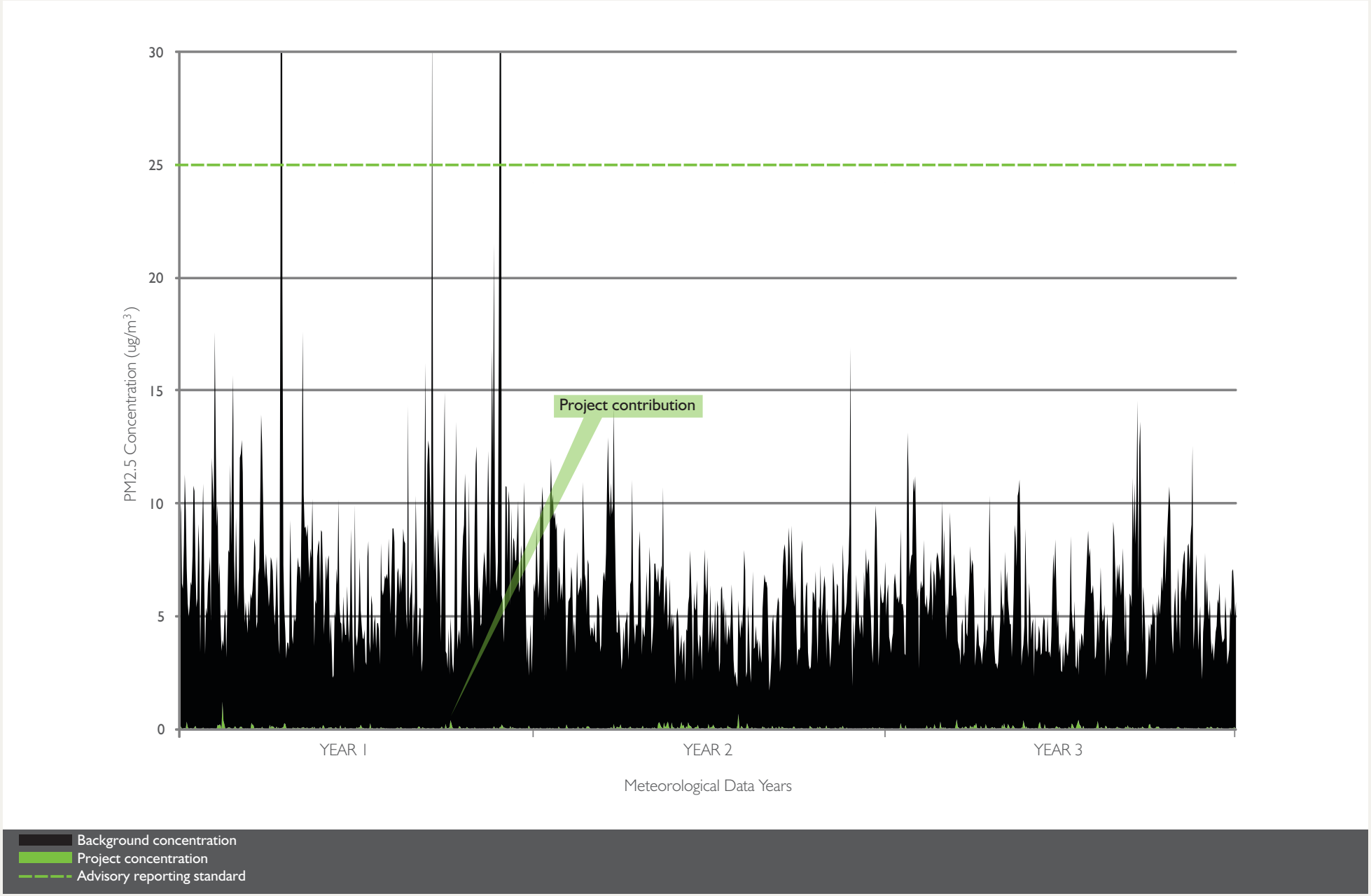

Figure 7-26 PM2.5 2019 24 hour average concentrations - southern ventilation facility

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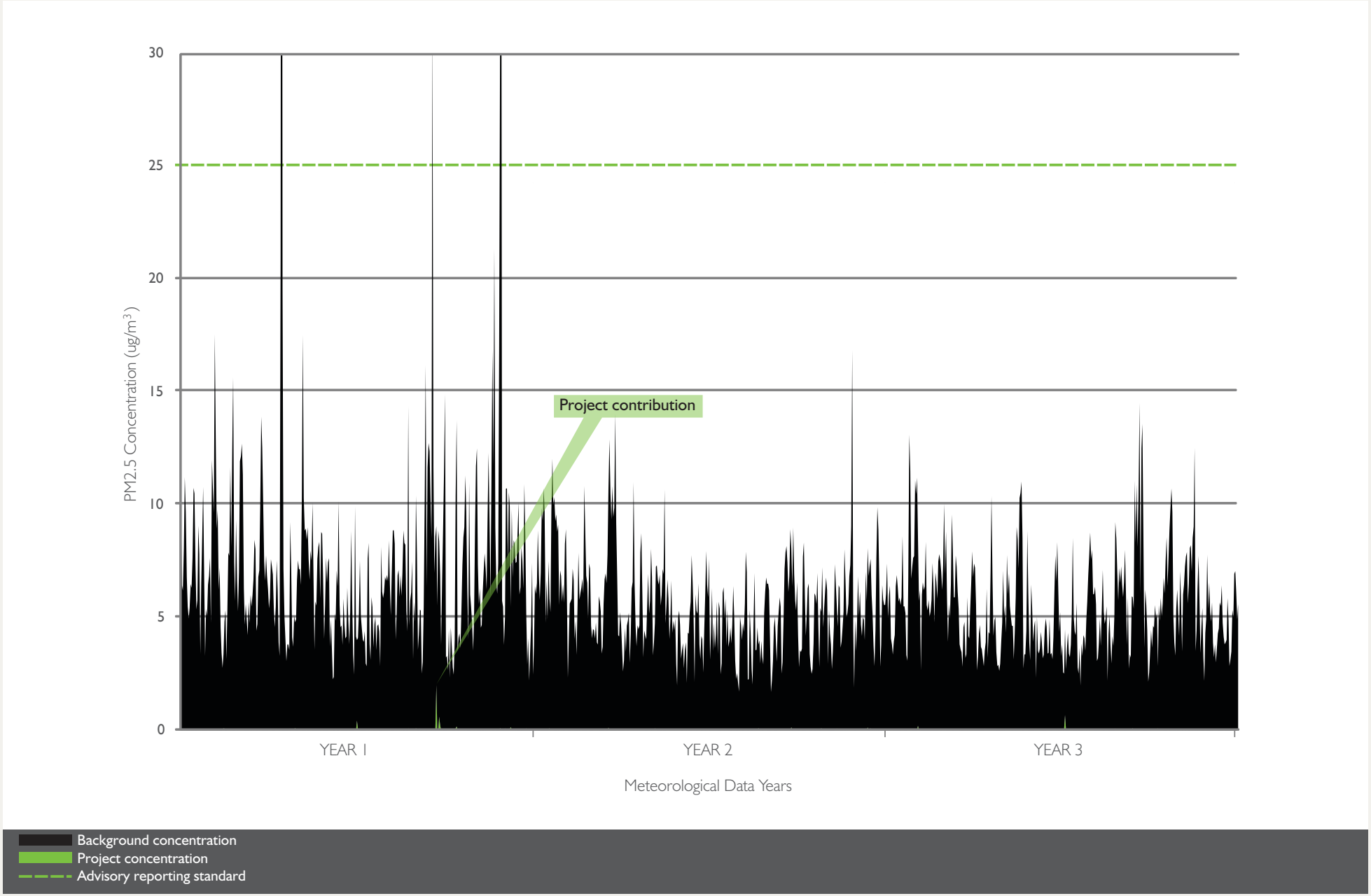

Figure 7-27 PM2.5 2029 24 hour average concentrations - southern ventilation facility

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Breakdown scenario

A semi-quantitative assessment has been undertaken to assess potential emissions associated with a 'breakdown scenario'.

The project has been designed and would be managed to minimise the potential for prolonged congestion within the tunnels, specifically:

- The height of the tunnel is 5.3 metres which is greater than other Sydney tunnels. This would reduce the likelihood of incidents involving over-height vehicles.
- An over height detection system, which would comprise of an electronic over height detector prior to the tunnel portals, vehicle presence detectors, and warning signs with lanterns that would activate upon detection of an over height vehicle.
- Provision of two vehicle cross passages, which would allow emergency response vehicles to bypass a congested tunnel.
- Wide shoulders to accommodate breakdowns and provide access by recovery and emergency vehicles.
- Ability for the in-take of air from tunnel support facilities along the alignment to bring in additional fresh air, if required.
- Tunnel barrier gates to prevent access in the event of a tunnel closure.
- CCTV and audible systems to detect and manage incidents.
- Monitoring of vehicle speeds and traffic management infrastructure to reduce or prevent vehicle access to the tunnels if congestion is experienced.

In the event of an incident, approaching traffic would be prevented from entering both the incident main alignment tunnel and the non-incident main alignment tunnel. Traffic flow and speeds would also be monitored, so that in the event that traffic flows start to fall below 40 kilometres per hour, upstream traffic management measures would be in place before traffic speeds fall below 20 kilometres per hour.

For the theoretical breakdown scenario, the tunnel would be completely blocked at one exit with cars continuing to enter the tunnel for ten minutes, after which the tunnel would be closed to inbound traffic. In this scenario, cars have been assumed to be idling continuously for 55 minutes with no engines turned off. This represents the anticipated time that it would take for emergency services to clear the accident. In reality, the measures described above would prevent the tunnel from becoming full of vehicles and drivers would be directed to turn off their engines.

Emission rates for the breakdown scenario for primary vehicle exhaust pollutants (carbon monoxide, oxides of nitrogen, and PM_{10}) are presented in **Table 7-98**. For comparison purposes the estimated emissions for the 'with project – forecast traffic flows' (northern ventilation outlet in 2029) are also presented (as these are the highest expected mass emission rates of the scenarios considered in this assessment). The numbers in brackets represent the breakdown scenario emission rates expressed as a percentage of the 'with project – forecast traffic flows' scenario (northern ventilation outlet in 2029).

Table 7-98 Comparison of predicted emission rates under the breakdown scenario against the 'with project – forecast traffic flows' scenario (northern ventilation outlet, 2029)

Pollutant	Emission rates (grams per second)	
	Breakdown scenario	With project – forecast traffic flows (northern ventilation outlet, 2029)
PM_{10}	0.3 (83%)	0.36
NO_X	4.0 (69%)	5.81
CO	3.6 (74%)	4.84

When compared to the 'with project – forecast traffic flows' scenario (northern ventilation outlet, 2029), the results in **Table 7-98** show that, during a breakdown scenario, emissions of carbon monoxide, oxides of nitrogen and PM_{10} are all lower.

Given the similarities between predicted emission rates under both scenarios, the contributions of these pollutants during a breakdown scenario would be comparable to those modelled for the 'with project – forecast traffic flows' scenario. The 'with project – forecast traffic flows' scenario has been demonstrated as complying with applicable air quality criteria (results of this scenario are presented in **Table 7-97**). Because the mass emission rates for the breakdown scenario are comparable to, but no greater than, the 'with project – forecast traffic flows' scenario, and the breakdown scenario would occur over a relatively short period, it is expected that the breakdown scenario would also comply with applicable air quality criteria.

Air quality along Pennant Hills Road – with and without project

Vehicles using the project in preference to Pennant Hills Road would avoid 21 sets of traffic lights, and would have an estimated travel time of around five to six minutes. This would offer significant travel time savings over the alternative of using Pennant Hills Road or if the project was not constructed (refer to **Section 7.1** Traffic and transport).

Air quality modelling has been carried out to assess the air quality along the Pennant Hills corridor:

- Based on expected traffic along Pennant Hills Road in 2019 and 2029 if the project were not implemented.
- Based on expected traffic along Pennant Hills Road in 2019 and 2029 with changes in traffic along that corridor as a result of the project.

The air quality modelling has taken into account traffic changes only (without contributions from the project's ventilation outlets) to demonstrate the traffic related air quality benefits of the project for receivers along Pennant Hills Road. For the purpose of comparison, the most affected receiver location(s) along Pennant Hills Road has been considered.

The 'without project' scenario assessed the expected future pollutant concentrations along the Pennant Hills Road corridor in the absence of the project. These results have been compared against surface road modelling results (without ventilation outlet contributions) for the 'with project – forecast traffic flows' along the Pennant Hills Road corridor, and are presented in **Table 7-99** for 2019 and **Table 7-100** for 2029.

The results demonstrate that the project would result in lower pollutant concentrations along Pennant Hills Road in 2019 and in 2029 for most pollutants. The key exception is carbon monoxide, which is expected to increase marginally. The carbon monoxide concentrations are orders of magnitude lower than the relevant criteria.

For both PM_{10} and $PM_{2.5}$, the operation of the tunnel has been calculated to:

- Decrease the maximum 24 hour average concentrations by around 27 per cent in 2019 and 38 per cent in 2029.
- Decrease the annual average concentrations by around 20 per cent in 2019 and 33 per cent in 2029.

Table 7-99 Comparison of maximum predicted pollutant concentrations for 'with project' scenario against 'without project' scenario (2019)

Pollutant	Averaging period	Maximum predicted concentrations for 2019 (µg/m^3)		Impact assessment criteria (µg/m^3)
		With project	Without project	
PM_{10}	24 hour	19.8	27.1	50
	Annual	10.6	13.3	30
$PM_{2.5}$	24 hour	18.8	**25.7**	25
	Annual	**10.1**	**12.6**	8
NO_2	1 hour	165	183	246
	Annual	39	45	62
CO	1 hour	575	583	30,000
	8 hour	414	406	10,000
Total VOCs	1 hour	**42.0**	**44.4**	29
PAHs	1 hour	0.005	0.0065	0.4

Note: bold text indicates predicted exceedences of the applicable impact assessment criteria

Table 7-100 Comparison of maximum predicted pollutant concentrations for 'with project' scenario against 'without project' scenario (2029)

Pollutant	Averaging period	Maximum predicted concentrations for 2029 (µg/m^3)		Impact assessment criteria (µg/m^3)
		With project	Without project	
PM_{10}	24 hour	20.4	32.8	50
	Annual	10.8	16.1	30
$PM_{2.5}$	24 hour	19.4	**31.2**	25
	Annual	**10.2**	**15.3**	8
NO_2	1 hour	167	207	246
	Annual	44	49	62
CO	1 hour	643	647	30,000
	8 hour	459	462	10,000
Total VOCs	1 hour	**45.9**	**49.3**	29
PAHs	1 hour	0.0053	0.0077	0.4

Note: bold text indicates predicted exceedences of the applicable impact assessment criteria

Project air quality benefits

The project is expected to improve traffic flows along Pennant Hills Road, which would improve air quality along the road corridor. Further, the capture and dispersion of emissions from the diverted traffic through ventilation outlets would improve dispersion of pollutants. To demonstrate this, and to illustrate the net positive impact of the project on air quality, modelled changes to background air quality as a result of the combined effects of the project ventilation outlets and the traffic changes along Pennant Hills Road have been mapped.

Figure 7-28 and **Figure 7-29** show the relative change in $PM_{2.5}$ concentrations along the Pennant Hills Road corridor, as a percentage of the 25 µg/m^3 (24-hour average) and 8 µg/m^3 (annual average) advisory reporting standards, respectively. The assessment found that:

- In the case of both 24-hour average and annual average $PM_{2.5}$ concentrations, the project's ventilation system and ventilation outlets would capture and effectively disperse emissions to very low levels in the surrounding environment. The peak impacts of the project would be around five to ten per cent (24-hour average) and one to five per cent (annual average) of the advisory reporting standards for $PM_{2.5}$. Both of these percentages are well within the normal variability in background $PM_{2.5}$ concentrations measured at existing regional monitoring stations managed by the Office of Environment and Heritage, and as recorded at monitoring stations established along the Pennant Hills Road corridor for the project.
- Significant reductions in 24-hour average $PM_{2.5}$ concentrations are expected along the Pennant Hills Road corridor (refer to **Figure 7-28**[1]). These improvements in air quality are expected to peak at up to 25 percent of the 25 µg/m^3 (24-hour average) advisory reporting standard for $PM_{2.5}$ within the Pennant Hills road reserve. Receivers along the road corridor are expected to benefit from around five to 20 per cent improvement in $PM_{2.5}$ concentrations (24-hour average) as a result of the project.

[1] Due to the scale of **Figure 7-28** and **Figure 7-29** it is only possible to clearly show changes of up to ten per cent.

- Significant reductions in annual average $PM_{2.5}$ concentrations are expected along the Pennant Hills Road corridor (refer to **Figure 7-29**[2]). These improvements in air quality are expected to peak at up to 40 percent of the 8 µg/m^3 (annual average) advisory reporting standard for $PM_{2.5}$ within the Pennant Hills road reserve. Receivers along the road corridor are expected to benefit from around five to 35 per cent improvement in $PM_{2.5}$ concentrations (annual average) as a result of the project.
- The project is expected to result in a net improvement in air quality, taking into account significant improvements in air quality along the Pennant Hills Road corridor balanced with less extensive, very low levels of impact around the northern and southern ventilation outlets.

The potential benefits of these net improvements in air quality for human health risks are assessed in more detail in **Section 7.4** (Human health).

[2] Due to the scale of **Figure 7-28** and **Figure 7-29** it is only possible to clearly show changes of up to ten per cent.

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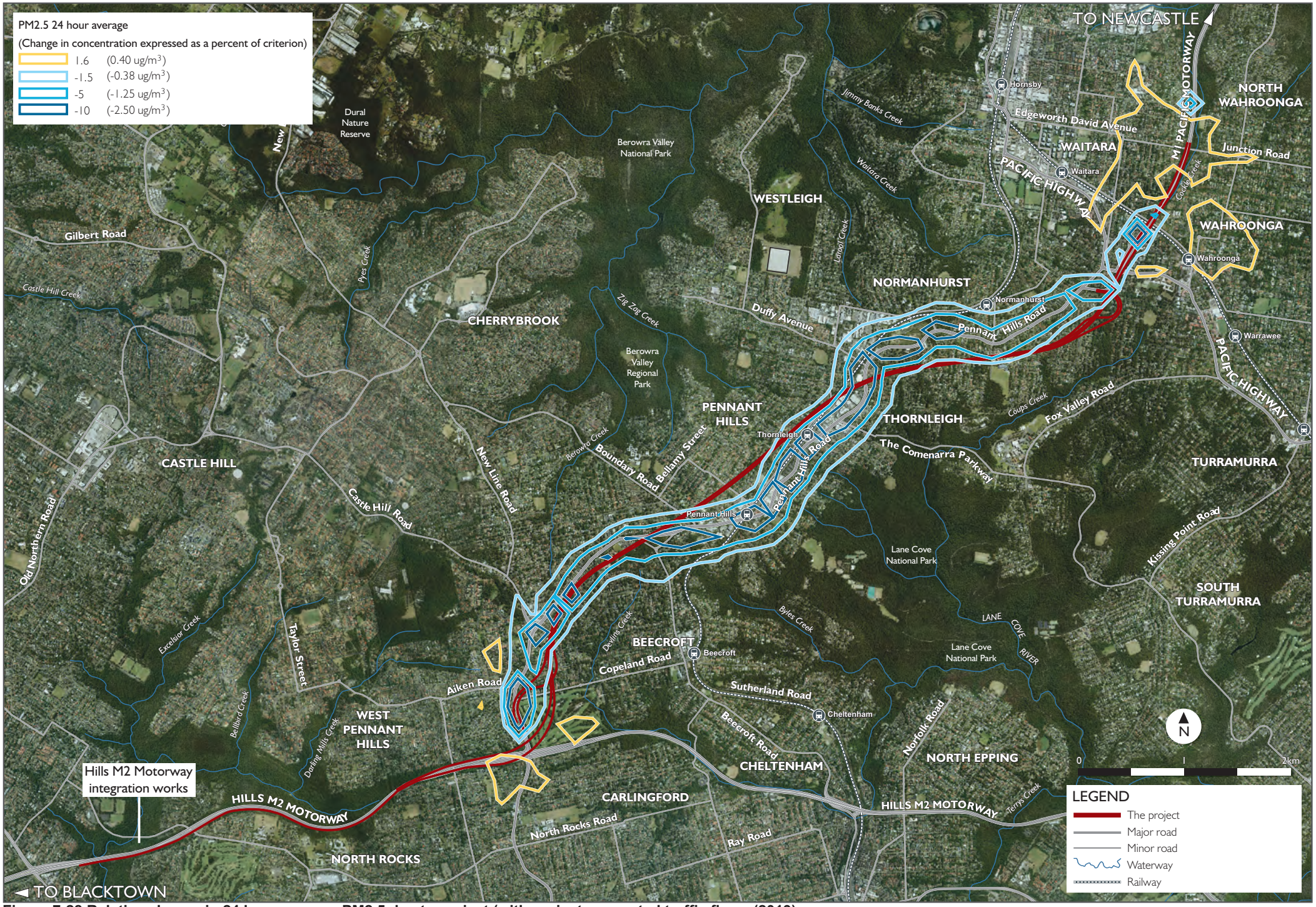

Figure 7-28 Relative change in 24 hour average PM2.5 due to project (with project - expected traffic flows (2019)

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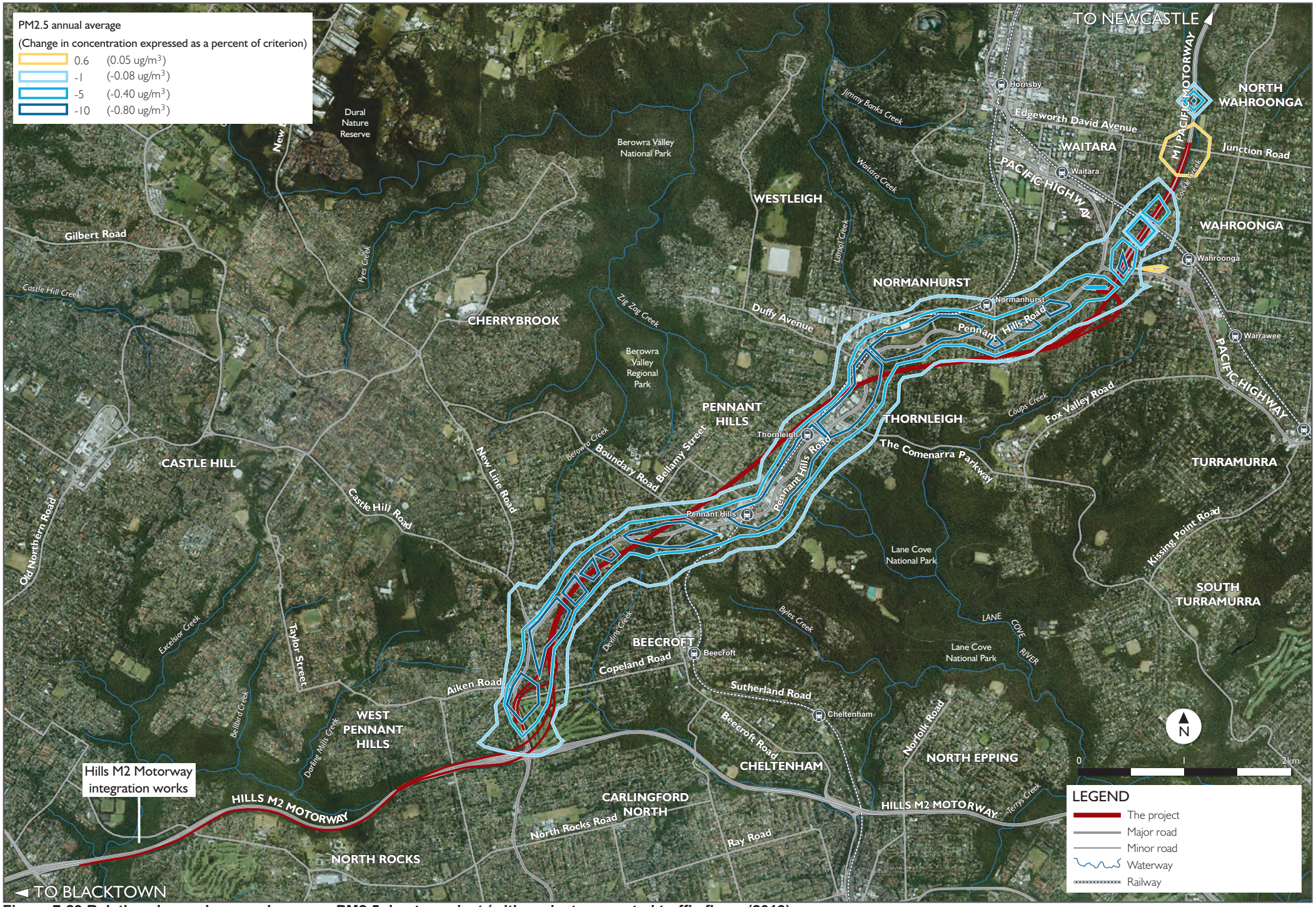

Figure 7-29 Relative change in annual average PM2.5 due to project (with project - expected traffic flows (2019)

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Project design analyses

For design analysis A, which assumes the maximum physical capacity of the main alignment tunnels is reached during peak hours, modelling and assessment indicates that:

- The peak project contribution of PM_{10} (24-hour average) is 3.1 µg/m^3, which around six per cent of the 50 µg/m^3 assessment criterion.
- The peak project contribution of PM_{10} (annual average) is 0.26 µg/m^3, which is less than one per cent of the 30 µg/m^3 assessment criterion.
- The peak project contribution of $PM_{2.5}$ (24-hour average) is 3.0 µg/m^3, which is around 12 per cent of the 25 µg/m^3 advisory reporting standard.
- The peak project contribution of $PM_{2.5}$ (annual average) is 0.25 µg/m^3, which is around three per cent of the 8 µg/m^3 advisory reporting standard.
- The peak project contribution of NO_2 (24-hour average) is 114.8 µg/m^3, which is around 47 per cent of the 246 µg/m^3 assessment criterion.
- The peak project contribution of NO_2 (annual average) is 2.5 µg/m^3, which is around four per cent of the 62 µg/m^3 assessment criterion.

Modelling and assessment of air quality impacts for design analysis B, which assumes constant and continuous emission of pollutants at their potential maximum concentrations indicates that:

- The peak project contribution of PM_{10} (24-hour average) is 4.2 µg/m^3, which is around eight per cent of the 50 µg/m^3 assessment criterion.
- The peak project contribution of PM_{10} (annual average) is 0.2 µg/m^3, which is less than one per cent of the 30 µg/m^3 assessment criterion.
- The peak project contribution of $PM_{2.5}$ (24-hour average) is 3.9 µg/m^3, which is around 16 per cent of the 25 µg/m^3 advisory reporting standard.
- The peak project contribution of $PM_{2.5}$ (annual average) is 0.18 µg/m^3, which is around two per cent of the 8 µg/m^3 advisory reporting standard.
- The peak project contribution of NO_2 (24-hour average) is 96.4 µg/m^3, which is around 40 per cent of the 246 µg/m^3 assessment criterion.
- The peak project contribution of NO_2 (annual average) is 2.1 µg/m^3, which is around three per cent of the 62 µg/m^3 assessment criterion.

The modelling results summarised above and presented in more detail in **Appendix G** for design analysis A and design analysis B demonstrate that the project design limits the potential contribution of the project to ambient air pollution. In all cases above, contributions from the project to the surrounding airshed are well below applicable air quality assessment criteria.

In-tunnel air quality

Forecast in-tunnel air quality

Concentrations of vehicle emissions have been estimated within the main alignment tunnels for expected traffic volumes in 2019 and in 2029. These calculations align with the scenarios assessed for external air quality impacts earlier in this section (refer to **Table 7-97**). The calculations have confirmed that the maximum concentration of vehicle emissions within the main alignment tunnels would occur:

- In the southbound main alignment tunnel during the morning peak (around 9 am) in 2019 and in 2029.
- In the northbound main alignment tunnel during the afternoon peak (around 6 pm) in 2019 and in 2029.

Table 7-101 presents a summary of forecast in-tunnel concentrations of pollutants at the end of each kilometre of each main alignment tunnel during the relevant peak hour. These calculations have been based on the PIARC emission factors and the emissions inventory developed for the purpose of air quality dispersion modelling for the project. As explained earlier in this section, the emissions inventory has relied on conservative PIARC emission factors that are developed to design and size road tunnel ventilation systems. The review of the emissions inventory conducted by Pacific Environment Limited has concluded that the emissions inventory is conservative and includes higher concentrations for most pollutants when compared with the emission factors published by the NSW Environment Protection Authority. This is especially the case for particulate matter (PM_{10} and $PM_{2.5}$) where the PIARC concentrations are in some cases more than twice as high as the concentrations predicted with the NSW Environment Protection Authority emissions factors. This conservatism gives confidence that in-tunnel air quality would be better than the calculations presented in **Table 7-99** suggest. Concentrations of particulate matter may be as little as half of the values listed in the table during operation of the project.

Based on expected traffic volumes, these in-tunnel concentrations are representative of free flowing traffic traveling at 80 kilometres per hour. For free flowing traffic traveling at 80 kilometres per hour, the total journey time through one of the main alignment tunnels would be less than seven minutes. The exposure profiles for a motorist under these conditions, as shown in **Table 7-101**, are well below the exposure standards set as design criteria for the project, which relate to a longer, 15-minute exposure period (refer to **Table 7-92**). The in-tunnel air quality data in **Table 7-101** also shows that:

- Concentrations of nitrogen dioxide expected within the main alignment tunnels are closer in magnitude to the exposure standards set as design criteria (refer to Table 7-92) than for other pollutants. This indicates that nitrogen dioxide is likely to be the limiting factor affecting the design and operation of the project's ventilation system. Provided that the design criteria for nitrogen dioxide are met, then other pollutants would also be below their respective design criteria.
- The conservative peak concentration of particulate matter at any point in the main alignment tunnels would occur in the northbound tunnel in 2029, around the offtake for the northern ventilation outlet (at 0.585 mg/m^3 as PM_{10}). Based on the correlation factor recommended by PIARC (2012), this concentration is equivalent to an extinction coefficient of 0.003 m^{-1}. This is well below the visibility standard set as a design criterion for the project (0.005 m^{-1}) and meets the definition of a 'clear air' tunnel (PIARC, 2012) (0.003 m^{-1} or less).

A preliminary ventilation design analysis for the project indicates that the in-tunnel air quality design criteria may be approached in the case of significant congestion within the main alignment tunnels. Significant congestion (average traffic speeds of 40 kilometres per hour or less) is not anticipated for normal operations based on the design capacity of the project and the forecast traffic volumes in 2019 and 2029. However, there is potential for traffic congestion to occur in the event of an incident or breakdown in the main alignment tunnels.

The potential for congested traffic conditions to occur would be actively managed to ensure that acceptable in-tunnel air quality is maintained for motorists. An initial review of the traffic conditions that would cause in-tunnel air quality to approach the design criteria (refer to **Table 7-95**) has been undertaken. The review identified that under the following conditions, the in-tunnel air quality would approach the design criteria:

- At an average speed of 20 kilometres per hour, around 2,800 passenger car units per hour.
- At an average speed of 30 kilometres per hour, around 3,400 passenger car units per hour.
- At an average speed of 40 kilometres per hour, around 3,700 passenger car units per hour.

These initial indicative traffic condition thresholds would be used to inform the further development of congested traffic management measures during detailed design of the project. Based on detailed design development, a framework would be established for the management of the project tunnels to ensure that significant congestion is effectively managed and that acceptable in-tunnel air quality is maintained. This framework would include:

- In-tunnel monitoring of carbon monoxide, nitrogen dioxide and / or visibility (extinction coefficient).
- Monitoring of traffic conditions and traffic speeds within the main alignment tunnels, and upstream and downstream of the project.
- Measures to limit and manage traffic entering the project tunnels in the event of significant congestion conditions that may lead to unacceptable in-tunnel air quality. This may include measures such as lane closures, rapid responses to incidents / breakdowns, and broader traffic network management.
- Operational requirements to ensure that operation of the project's ventilation system reflects traffic volumes and in-tunnel air quality requirements.
- Provision for the review of the management framework after a period of operation, once sufficient actual in-tunnel air quality and traffic data have been gathered.
- Contingency measures in the event of elevated, unexpected in-tunnel air quality (including measures to manage emergency situations).
- Provision for publication of relevant in-tunnel air quality performance data.
- Review of the performance of smoky vehicle regulation / enforcement and whether additional or amended measures may be required.

Table 7-101 Calculated in-tunnel air quality – main alignment tunnels during peak hours

Pollutant	Pollutant concentrations (mg/m^3) (peak hour) Approximate distance along main alignment tunnels 1 km	2 km	3 km	4 km	5 km	6 km	7 km	8 km	9 km
Southbound main alignment tunnel at 9 am (2019)									
CO	0.331	0.772	1.06	1.34	1.62	1.90	2.17	2.58	3.45
NO_2*	0.039	0.098	0.124	0.144	0.165	0.186	0.206	0.250	0.374
PM_{10}	0.039	0.084	0.122	0.158	0.193	0.229	0.265	0.307	0.377
$PM_{2.5}$	0.037	0.080	0.115	0.149	0.183	0.217	0.251	0.290	0.347
PAH	0.000006	0.00002	0.00002	0.00003	0.00003	0.00004	0.00004	0.00005	0.00006
VOC	0.033	0.079	0.109	0.136	0.164	0.192	0.219	0.260	0.346
Southbound main alignment tunnel at 9 am (2029)									
CO	0.411	0.956	1.32	1.67	2.01	2.35	2.70	3.20	4.29
NO_2*	0.043	0.108	0.136	0.159	0.182	0.204	0.277	0.276	0.411
PM_{10}	0.047	0.101	0.145	0.189	0.232	0.275	0.319	0.369	0.439
$PM_{2.5}$	0.046	0.095	0.137	0.178	0.219	0.260	0.301	0.348	0.414
PAH	0.000007	0.00002	0.00003	0.00003	0.00003	0.00004	0.00005	0.00005	0.00007
VOC	0.040	0.094	0.129	0.162	0.195	0.228	0.262	0.310	0.413
Northbound main alignment tunnel at 6 pm (2019)									
CO	0.156	0.911	1.76	2.62	3.47	4.32	5.12	5.59	6.26
NO_2*	0.005	0.110	0.231	0.352	0.473	0.594	0.707	0.771	0.860
PM_{10}	0.032	0.090	0.153	0.215	0.278	0.340	0.401	0.450	0.504
$PM_{2.5}$	0.030	0.085	0.144	0.203	0.263	0.322	0.379	0.425	0.477
PAH	0.000002	0.00002	0.00003	0.00005	0.00006	0.00008	0.00009	0.00010	0.0010
VOC	0.014	0.089	0.173	0.258	0.342	0.427	0.506	0.554	0.620
Northbound main alignment tunnel at 6 pm (2029)									
CO	0.195	1.13	2.19	3.25	4.31	5.37	6.35	6.94	7.76
NO_2*	0.005	0.119	0.250	0.381	0.512	0.643	0.765	0.834	0.932
PM_{10}	0.039	0.106	0.178	0.250	0.323	0.395	0.464	0.521	0.585
$PM_{2.5}$	0.037	0.100	0.169	0.237	0.305	0.373	0.439	0.497	0.553
PAH	0.000002	0.00002	0.00003	0.00005	0.00007	0.00008	0.00010	0.00011	0.00012
VOC	0.017	0.106	0.207	0.308	0.408	0.509	0.603	0.661	0.739

*Note: NO_2 has been assumed to be 10% of total nitrogen oxides, consistent with PIARC (2012)

Performance relative to other Sydney motorway tunnels

An important consideration that has informed the design development for the project has been the desire to learn from the experience with the M5 East Motorway tunnel and to avoid the historical in-tunnel 'haze' challenges of that project. Consultation conducted with the local community and stakeholders during the preparation of this environmental impact statement has reinforced that the history of the M5 East Motorway tunnel should not be repeated. Key design aspects of the NorthConnex project that have been developed in response to the historical experience with the M5 East motorway tunnels include:

- The main alignment tunnels would be wider and higher than the M5 East Motorway tunnels. These larger dimensions would assist in adequately ventilating the main alignment tunnels, particularly in the event of traffic congestion.
- The main alignment tunnels are flat along the majority of their length, with relatively short entry and exit ramps with low grades (less than 4%). In comparison, the M5 East Motorway tunnels include steep exit grades which contribute to slower heavy vehicle speeds, increased vehicle emissions and potential to exacerbate congested traffic conditions.
- The project's ventilation system would not recirculate air within or between the main alignment tunnels, as is the case with the M5 East Motorway tunnels. This would avoid circulating dirty air within the main alignment tunnels, with fresh air drawn in from the main alignment tunnel portals during normal operation, and potentially via the tunnel support facilities in the event of congested traffic conditions.
- The project has been designed to include motorway to motorway connections, which would allow free flowing traffic conditions and minimise the risk of vehicle queuing and congestion.

In order to provide a comparison between the current M5 East Motorway tunnels and predicted in-tunnel air quality for NorthConnex, monitored visibility data has been used as a proxy for in-tunnel particulate matter. PIARC (2012) provides a conversion factor between visibility (as an extinction coefficient) and particulate matter (as PM_{10}) concentrations. Visibility (haze) within the main M5 East Motorway tunnels is currently monitored at four locations:

- AQS301 – within the eastbound main alignment tunnel, prior to the offtake for the Turrella ventilation outlet.
- AQS302 – within the eastbound main alignment tunnel, prior to the tunnel crossover.
- AQS403 – within the westbound main alignment tunnel, prior to the offtake for the Turrella ventilation outlet.
- AQS404 – within the westbound main alignment tunnel, prior to the tunnel crossover.

Visibility monitoring data from these locations for the period from April 2013 to April 2014, inclusive, has been analysed to determine the typical and maximum visibility conditions within the M5 East Motorway tunnels. This analysis has included:

- Removing visibility data that are negative or null values, and data during periods of malfunction or incorrect function of the monitoring equipment.

- Conversion of monitored 15-minute average visibility data to hourly averages for direct comparison with in-tunnel air quality calculations for the NorthConnex project.
- Analysis of the M5 East Motorway visibility data to identify maximum and typical in-tunnel air quality conditions.

The in-tunnel visibility within the M5 East Motorway tunnels during the period April 2013 to April 2014 is significantly better than the recorded historical performance. For example:

- Ten years ago (2004), in-tunnel visibility monitoring data indicates that:
  - In the westbound tunnel, extinction coefficients exceeding 0.004 m^{-1} were recorded in most months, with occasional peaks above 0.005 m^{-1}. An extinction coefficient exceeding 0.006 m^{-1} was recorded on one day in November 2004.
  - In the eastbound tunnel, extinction coefficients frequently exceeded 0.004 m^{-1}, with most months recording several days with peaks in excess of 0.005 m^{-1}. Peaks were recorded above 0.006 m^{-1} in March 2004 and May 2004.
- Five year ago (2009), in-tunnel visibility monitoring data indicates that the performance of the M5 East Motorway tunnels had improved slightly from 2004. However, it was still common that peak extinction coefficients above 0.005 m^{-1} were recorded for several days in each month. In some months, including January 2009 and April 2009, extinction coefficients above 0.006 m^{-1} were also recorded.

Table 7-102 summarises the monitored in-tunnel visibility (as extinction coefficient) for the M5 East Motorway tunnels from April 2013 to April 2014. The monitoring data indicates that for most of the time, both of the M5 East Motorway tunnels now operate with good in-tunnel visibility, and as defined as 'clear air' tunnels by PIARC (2012) (0.003 m^{-1} or less). However, on some occasions (during congested traffic conditions) parts of both tunnels experience reduced visibility. This is particularly the case near the tunnel crossovers (monitoring locations AQS302 and AQS404). This is consistent with current driver experience in the M5 East Motorway tunnels.

A principal reason for the improvement in the in-tunnel air quality in the M5 East Motorway tunnels has been the attention given to smoky vehicles, and particularly the installation of smoky vehicle cameras. The tunnels currently experience reduced incidence of poor in-tunnel air quality, and less frequently experience 'hazy' in-tunnel conditions than has historically been the case.

Table 7-102 Monitored in-tunnel visibility – M5 East Motorway tunnels (April 2013-April 2014)

Monitoring Location	In-tunnel visibility (extinction coefficient) (m^{-1}, one-hour)			
	Maximum	99th percentile	90th percentile	50th percentile
AQS301	0.0035	0.0027	0.0019	0.0008
AQS302	0.0043	0.0032	0.0023	0.0014
AQS403	0.0015	0.0012	0.0009	0.0004
AQS404	0.0037	0.0025	0.0018	0.0009

For comparison purposes, the in-tunnel particulate concentrations (as PM_{10}) summarised in **Table 7-101** for the NorthConnex project have been converted to an extinction coefficient using the correlation factor recommended by PIARC (2012). The results are shown in **Table 7-103**. As indicated earlier in this section, particulate matter concentrations calculated within the project's main alignment tunnels are conservative and in some cases more than twice the concentration of particulate matter (PM_{10} and $PM_{2.5}$) that would be expected if the NSW Environment Protection Authority emission factors had been used. Because in-tunnel haze (visibility) is directly related to concentrations of particulate matter, the extinction coefficients summarised in **Table 7-103** based on PIARC emission factors are expected to overestimate in-tunnel haze by as much as a factor of two. For completeness, and to provide a more realistic estimate of likely in-tunnel visibility, extinction coefficients based on particulate concentrations derived from NSW Environment Protection Authority emissions factors have also been calculated and are presented in **Table 7-103**.

The calculated extinction coefficients in **Table 7-103** show that:

- Even when applying the conservative emission factors published by PIARC, the main alignment tunnels are expected to operate as 'clear air' tunnels (0.003 m^{-1} or less), as defined by PIARC (2012) under forecast traffic volumes, at all times of the day in 2019 and in 2029.
- Expected in-tunnel visibility, as calculated using NSW Environment Protection Authority emission factors, is likely to be significantly better than the conservative assessment based on PIARC emission factors. Using NSW Environment Protection Authority data from the NSW vehicle fleet, extinction coefficients are expected to be well under 0.002 m^{-1} for all assessed scenarios.

Table 7-103 Calculated in-tunnel visibility – main alignment tunnels during peak hours

Source	Extinction coefficient (m^{-1}) (peak hour) Approximate distance along main alignment tunnels								
	1 km	2 km	3 km	4 km	5 km	6 km	7 km	8 km	9 km
Southbound main alignment tunnel at 9 am (2019)									
PIARC	0.0002	0.0004	0.0006	0.0007	0.0009	0.0011	0.0012	0.0014	0.0018
EPA	0.0001	0.0003	0.0004	0.0006	0.0007	0.0009	0.0010	0.0012	0.0014
Southbound main alignment tunnel at 9 am (2029)									
PIARC	0.0002	0.0005	0.0007	0.0009	0.0011	0.0013	0.0015	0.0017	0.0021
EPA	0.0002	0.0003	0.0005	0.0006	0.0008	0.0009	0.0011	0.0012	0.0014
Northbound main alignment tunnel at 6 pm (2019)									
PIARC	0.0002	0.0004	0.0007	0.0010	0.0013	0.0016	0.0019	0.0021	0.0024
EPA	0.0001	0.0003	0.0005	0.0007	0.0009	0.0011	0.0013	0.0015	0.0017
Northbound main alignment tunnel at 6 pm (2029)									
PIARC	0.0001	0.0005	0.0008	0.0012	0.0015	0.0019	0.0022	0.0024	0.0027
EPA	0.0001	0.0003	0.0005	0.0006	0.0008	0.0009	0.0011	0.0012	0.0014

The predicted visibility performance of the NorthConnex project is shown relative to the current performance of the M5 East Motorway tunnels in **Figure 7-30**. The figure shows calculated visibility in the northbound main alignment tunnel in 2019 (PM peak hour) using both PIARC and NSW Environment Protection Authority emission factors relative to the monitored visibility in the M5 East Motorway tunnels (refer to **Table 7-102**). **Figure 7-30** shows that:

- During the PM peak hour in 2019, visibility along the entire length of the northbound main alignment tunnel is predicted to be better than the levels currently exceeded in the M5 East Motorway (AQS302) for 87 hours per year (99th percentile).
- Using NSW Environment Protection Authority emission factors, visibility along the entire length of the northbound main alignment tunnel is predicted to approach the levels currently exceeded in the M5 East Motorway (AQS302) for over 4,000 hours per year (50th percentile).

Particulate matter measured as $PM_{2.5}$ is recognised as an important concern for motorists and the general public, and is a key factor when assessing the human health implications of exposures to vehicle emissions (refer to **Section 7.4** (Human health) and **Appendix H**). Recent data relating to $PM_{2.5}$ concentrations in other motorway tunnels in Sydney includes:

- Investigations conducted by AMOG into the performance of the filtration trial at the M5 East Motorway, which recorded concentrations of $PM_{2.5}$ of around 0.350 µg/m^3.
- Recent in-stack air quality monitoring in the Marsden Street ventilation facility of the Lane Cove Tunnel, which recorded concentrations of $PM_{2.5}$ up to around 0.160 µg/m^3.

Figure 7-31 shows calculated in-tunnel concentrations of $PM_{2.5}$ for the northbound main alignment tunnel of the NorthConnex project, relative to recorded concentrations for the M5 East Motorway and the Lane Cove Tunnel. Concentrations are shown as a profile along the northbound main alignment tunnel in 2019 and in 2029, using both the PIARC and NSW Environment Protection Authority emission factors. **Figure 7-31** shows that:

- $PM_{2.5}$ concentrations (derived from PIARC emission factors) used for the design of the project's ventilation system and external air quality modelling and assessment are conservative. Concentrations of $PM_{2.5}$ calculated at the end of the northbound main alignment tunnel during the PM peak are around double the concentrations that would be expected based on NSW Environment Protection Authority emission factors.
- Expected $PM_{2.5}$ concentrations would be lower than recorded concentrations in the M5 East Motorway. Emission concentrations based on NSW Environment Protection Authority emission factors are lower than recorded by AMOG in the M5 East Motorway in January 2011 for the entire length of the northbound main alignment tunnel in both 2019 and 2029.
- The highest concentrations of $PM_{2.5}$ are expected in 2019. Emission concentrations based on NSW Environment Protection Authority emission factors are around 75 per cent lower in 2029 than in 2019. This reflects expected improvements in fuel standards and vehicle efficiencies over the coming decade.
- By 2029, in-tunnel air quality is expected to be approaching the current performance of the Lane Cove Tunnel. In 2029, peak $PM_{2.5}$ concentrations (around 200 mg/m^3) would be similar to peak emission concentrations measured in the Lane Cove Tunnel ventilation outlet (around 160 mg/m^3).

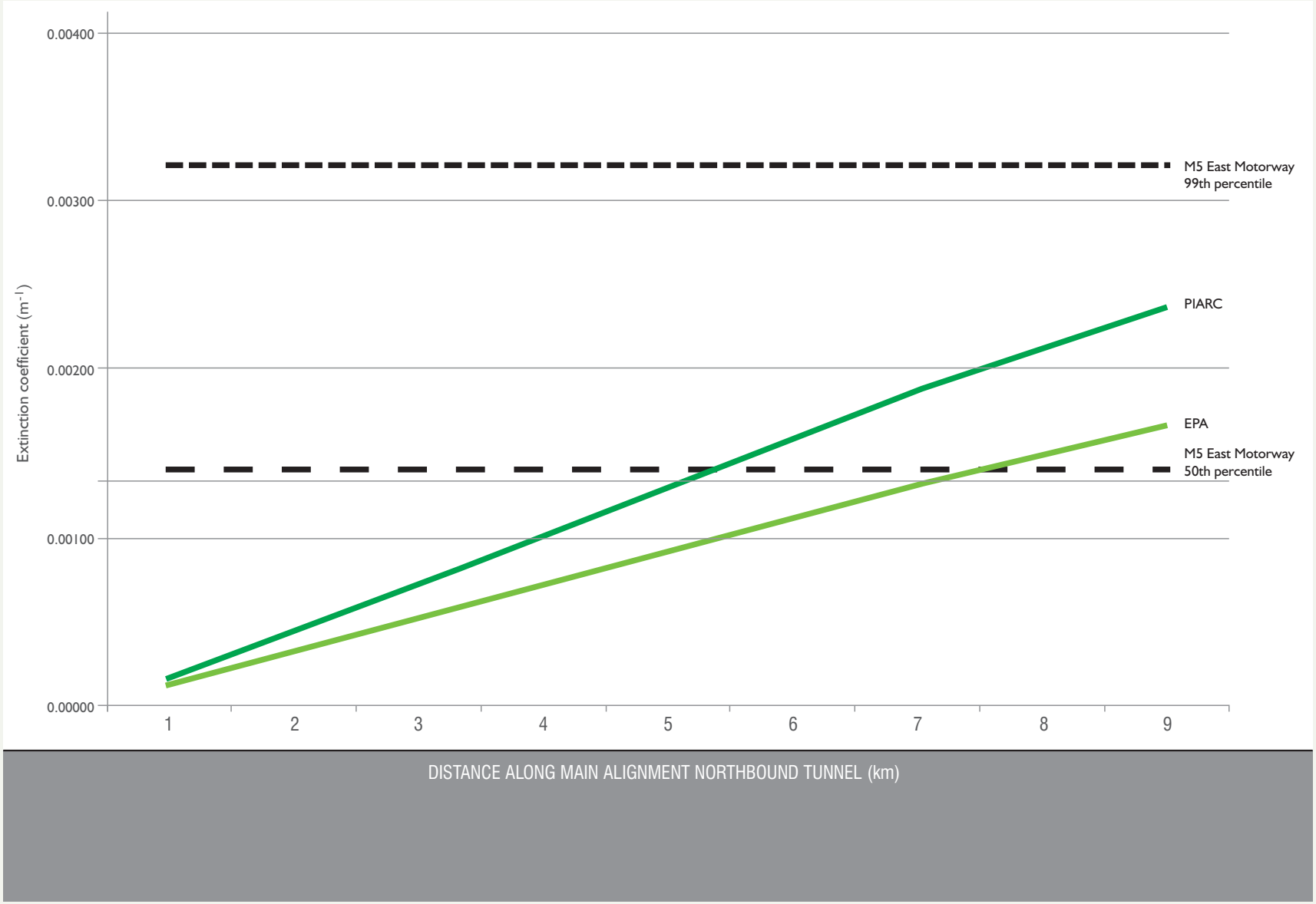

Figure 7-30 Visibility northbound tunnel 2019 PM peak hour

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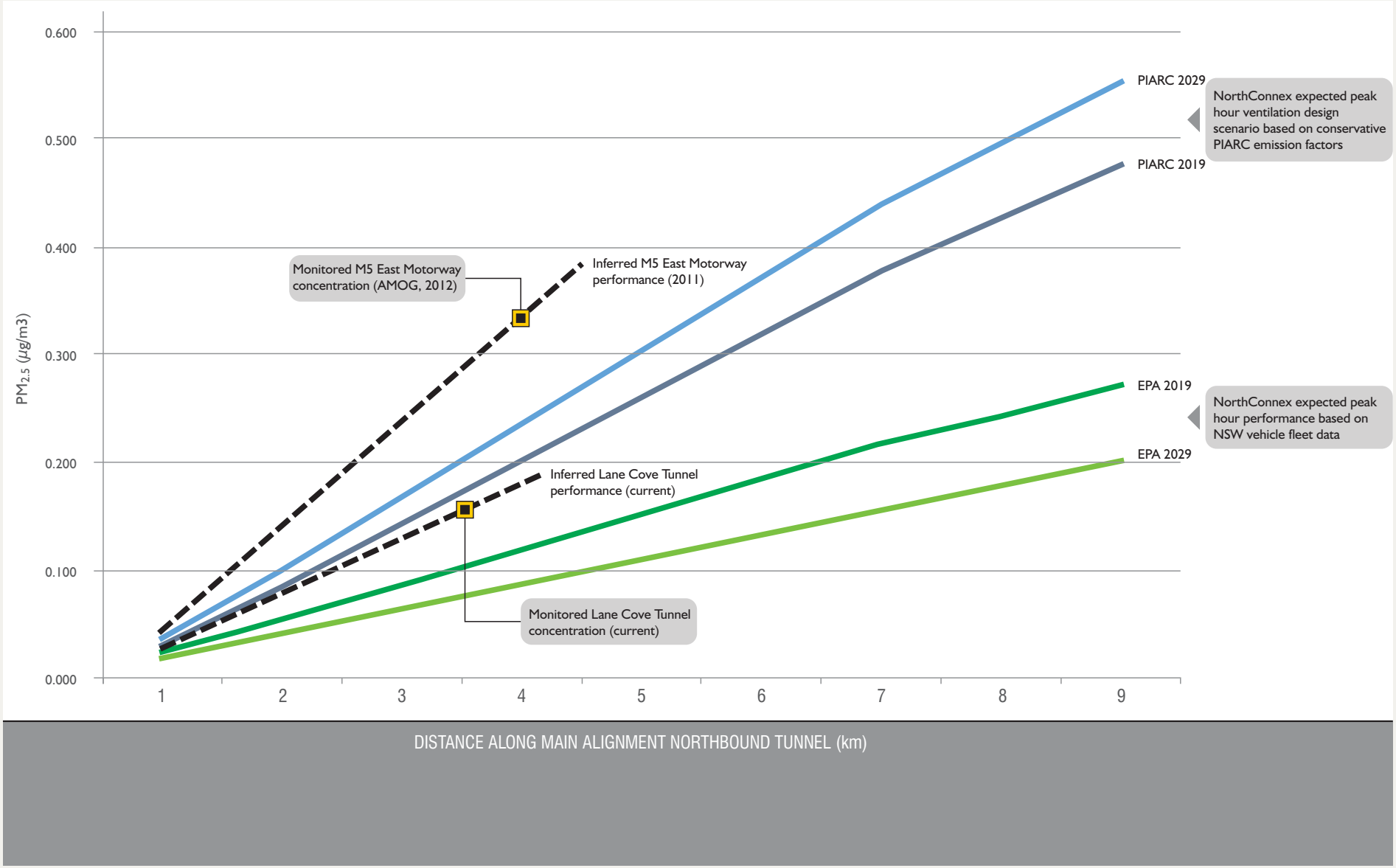

Figure 7-31 $PM_{2.5}$ Northbound tunnel PM peak hour

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Summary of operational air quality

The assessment of operational air quality has been conducted in accordance with the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (EPA, 2005).

The assessment considered a range of scenarios including the without project scenario, the forecast traffic flows in 2019 and 2029, and a breakdown scenario. The ventilation design of the tunnels was also tested by examining the maximum physical capacity of the main alignment tunnels. The assessment also included the incremental project contributions around the ventilation outlets as well the calculated air quality benefits along Pennant Hills Road.

The key findings of the operational air quality assessment are:

- The project would result in a net improvement in air quality, taking into account the significant improvements in air quality along Pennant Hills Road corridor and the less extensive, very low levels of impact around the northern and southern ventilation outlets.
- Along Pennant Hills Road, the project has been calculated to decrease the 24 hour average $PM_{2.5}$ and PM_{10} concentrations by around 38 per cent in 2029 and the annual average concentrations by around 33 per cent in 2029.
- In both 2019 and 2029 the project contribution to concentrations of air pollutants around the ventilation outlets are well below the relevant impact assessment criteria and the background levels.
- Project contribution of $PM_{2.5}$ would be less than two per cent of the annual average advisory reporting standard and a maximum of eight per cent of the 24-hour average reporting standard.
- Project contributions of PM_{10} would be less than one per cent of the annual average advisory reporting standard and less than five per cent of the 24-hour average advisory reporting standard.
- Project contributions of nitrogen dioxide would be less than three per cent of the annual average criteria and a maximum of 30 per cent of the one hour maximum criteria.
- Project contributions of carbon monoxide would be less than one percent of the one hour maximum criteria and the eight hour maximum criteria.
- Project contributions of volatile organic compounds would be less than twenty per cent of the applicable criteria.
- Project contributions of polycyclic aromatic hydrocarbons would be less than one per cent of the applicable criteria.
- Emissions rates during a breakdown scenario would be marginally less than the rates during the forecast traffic flows during 2029. As such, air quality during this scenario would also comply with applicable air quality criteria.
- The ventilation design of the project has been tested through consideration of the maximum physical capacity of the main alignment tunnels. In this case, the project contributions to the surrounding airshed are well below the applicable air quality assessment criteria.
- Design criteria have been set for in-tunnel air quality to reflect a modern, well designed road tunnel. The main alignment tunnels would operate as a ‘clear air tunnel’ (as defined by PIARC, 2012) during free flowing conditions.
- The in-tunnel air quality would be equivalent to or better than other road tunnels around the world.

Water treatment plant

An operational water treatment plant would be established at the motorway operations complex to treat groundwater inflow into the tunnels. Emissions to air associated with water treatment depend on the nature of the contamination of the water being treated and the treatment process. Primary air emissions associated with water treatment are odorous compounds, such as ammonia and volatile organic compounds, which are associated with aeration (primary treatment), aerobic digestion, sludge thickening, anaerobic digestion and sludge drying (NPI, 2011).

The nature of any odours would depend on the degree and type of any contamination present in the water. Management measures plan would be developed, as part of an Air Quality Management Plan, to address any odours should contamination be encountered and if odours arise. The plan would include identification of odours, identification of the extent to which the odours are detectable, and, if necessary, mitigation measures to reduce any odours affecting sensitive receivers. Such mitigation measures could include modifications to the operating process, or the installation of carbon filters to capture odorous compounds before they are emitted.

7.3.5 Environmental management measures

The ventilation system for the tunnel has been designed to result in negligible impacts to the surrounding airshed and appropriate air quality within the tunnels. The project would also provide air quality improvements along Pennant Hills Road, resulting in a net benefit to air quality from the project.

The potential for construction impacts such as dust has been minimised by the provision of acoustic sheds at the tunnelling support sites.

Environmental management measures relating to air quality during construction and operation are provided in **Table 7-104**.

Table 7-104 Environmental management measures – air quality

Impact	No.	Environmental management measure	Timing
Construction			
General	AQ1	Site inductions and ongoing toolbox talks would be provided to make construction works aware of air quality control practices and responsibilities.	Construction
	AQ2	Construction activities would be modified, reduced or controlled during high or unfavourable wind conditions if they would potentially increase off-site dust emissions.	Construction
	AQ3	Measures would be implemented to control dust emissions, such as the use of water carts, sprinklers, sprays and dust screens. The frequency of use would be modified in response to weather conditions.	Construction
	AQ4	Dust extraction and filtration systems would be installed for tunnel excavation works.	Construction
	AQ5	Should odour emissions arise from the groundwater treatment plant or stockpiles, a management plan would be developed to identify and implement appropriate mitigation measures.	Construction
	AQ6	Disturbed areas would be stabilised as soon as practicable to prevent or minimise windblown dust.	Construction
	AQ7	Cutting of materials such as concrete or bricks would be undertaken in a manner that minimises the generation of dust, such as the wetting of the cutting face.	Construction
	AQ8	Controls, such as rumble grids or wheel wash facilities, would be implemented to minimise the tracking of dirt onto public roads.	Construction
	AQ9	Hardstand areas and surrounding public roads would be cleaned, as required.	Construction
	AQ10	Speed limits would be posted and observed by all construction vehicles on the construction site.	Construction
	AQ11	Loaded haulage trucks would be covered at all times on public roads and on-site where there is a risk of release of dust or other materials.	Construction
	AQ12	Haul trucks, plant and equipment would be switched off when not in operation for periods of greater than 15 minutes.	Construction
	AQ13	Construction plant, vehicles and machinery would be maintained in good working order and in accordance with manufacturers' specifications.	Construction

Impact	No.	Environmental management measure	Timing
Monitoring	AQ14	A formal dust observation program would be implemented during construction, involving daily reviews of weather forecasts, observations of meteorological conditions and on site dust generation. This would inform mitigation measures or alterations to construction activities to be implemented during unfavourable weather conditions (such as dry weather and strong winds).	Construction
Operation			
In-tunnel air quality monitoring	OpAQ1	A management framework would be developed and implemented to ensure that significant congestion is effectively managed and that acceptable in-tunnel air quality is maintained. The framework would include: • In-tunnel monitoring of carbon monoxide, nitrogen dioxide and / or visibility (extinction coefficient). • Monitoring of traffic conditions and traffic speeds within the main alignment tunnels, and upstream and downstream of the project. • Measures to limit and manage traffic entering the project tunnels in the event of significant congestion conditions that may lead to unacceptable in-tunnel air quality. This may include measures such as lane closures, rapid responses to incidents / breakdowns, and broader traffic network management. • Operational requirements to ensure that operation of the project's ventilation system reflects traffic volumes and in-tunnel air quality requirements. • Provision for the review of the management framework after a period of operation, once sufficient actual in-tunnel air quality and traffic data have been gathered. • Contingency measures in the event of elevated, unexpected in-tunnel air quality (including measures to manage emergency situations). • Provision for publication of relevant in-tunnel air quality performance data. • Review of the performance of smoky vehicle regulation / enforcement and whether additional or amended measures may be required.	Operation
Local air quality monitoring	OpAQ2	Air quality in the vicinity of the project would be monitored for a specified time period following project opening. If pollutant concentrations contributed by the project are above predicted levels, additional feasible and reasonable mitigation measures would be considered to meet applicable predicted limits.	Operation